When the Highest Bidder Loses the Auction: Theory and Evidence from Public Procurement

Francesco Decarolis*

14th February 2010

Abstract

When bids do not represent binding commitments, the use of a first price sealed bid auction favors those bidders who are less penalized from reneging on their bids. These bidders are the most likely to win but also the most likely to default on their bid. In this paper I study two methods often used in public procurement to deal with this problem: (1) augmenting the first price auction with an ex-post verification of the responsiveness of the bids and (2) using an average bid auction in which the winner is the bidder whose bid is closest to the simple average of all the bids. The average bid auction is new to economics but has been proposed in civil engineering literature and adopted by several countries. I show that when penalties for defaulting are asymmetric across bidders and when their valuations are characterized by a predominant common component, the average bid auction is preferred over the standard first price by an auctioneer when the costs due to the winner's bankruptcy are high enough. Depending on the cost of the ex-post verification, the average bid auction can be dominated by the first price with screening. I use a new dataset of Italian public procurement auctions, run alternately using a form of the average bid auction or the augmented first price, to structurally estimate the bids' verification cost, the firms' mark up and the inefficiency generated by the average bid auctions.

JEL: L22, L74, D44, D82, H57.

*Department of Economics, University of Wisconsin - Madison. *E-mail address:* fdc@ssc.wisc.edu.

This paper is part of my PhD thesis at the University of Chicago. I would like to thank Ali Hortacsu, Roger Myerson, Philip Reny and Timothy Conley for their guidance. I also benefited from conversations with Marianne Bertrand, Jeremy Fox, Ken Hendricks, Gustavo Piga, Jesse Shapiro and Giancarlo Spagnolo and from comments of the participants at the seminars at the University of Chicago, Bank of Italy, EIEF Rome, Penn, NYU Stern, LSE, Harvard KSG, Toronto, UW Madison, PSU, Columbia, Stanford, Minnesota and at the conferences of the IIOC in Washington, ES in Pittsburgh, EEA in Milan and EARIE in Toulouse, NBER Market Design where I presented preliminary versions of this research. Financial support from the University of Chicago and the Bank of Italy is gratefully acknowledged.

1 Introduction

Most of the vast literature on auctions assumes that bids represent binding commitments for bidders. However, there are many real world situations in which the nature of the bid and the lack of effective enforcement mechanisms may give bidders the incentive to default. In these cases the literature has identified the limitations of competitive bidding. For instance, Spulber (1990) studies first price auctions for contracts where a bid consists of the bidder's obligation to perform a work at a certain predefined price. He shows that when the penalty for not completing the work is not high enough, the contractor may default if he incurs a cost overrun. Similarly, in Zheng (2001) a limited liability regulation limits the losses of a winner who chooses to default on his bid and go bankrupt. In a first price auction, if bidders have asymmetric budgets and share the same valuation for a good of uncertain value, then the equilibrium bidding function is decreasing in the size of the budget. Therefore, the most budget constrained bidder has the highest probability of winning and, also, of going bankrupt.[1] In Board (2008) bidders have limited liability and the auctioneer bears a cost from the winner's default. The auctioneer's preference between a first price and a second price auction are shown to depend on the cost of default. In this paper I follow this line of thought and analyze how the default risk limits the benefits of competitive bidding and how it influences the auctioneer's choice of auction formats.

In particular, this study is motivated by a policy change that occurred in Italy in 2006. This reform constrained the choice of the auction formats that Public Administrations (PAs) could use for the public procurement of contracts for works. In particular, for each contract the PAs could freely decide whether to award it through a first price auction (FP) or through an average bid auction (AB). Moreover, in the case of the first price auction the law required the PAs to screen the bids received to assess their reliability before awarding the contract. The contribution of this paper is to present an analysis, both theoretical and empirical, of the PAs' choice of auction format based on both the cost of default and the cost of screening bids. Moreover, this paper introduces a new dataset that is rather unique because it contains auctions run alternately using AB and FP.

A standard first price auction augmented with an ex post screening of bids is a fairly common mechanism. There are many instances in public procurement where auctioneers use this format to reduce the risk that an excessively high winning bid leads to a subsequent default on the part of the winner. Although less well known, another frequently used auction format is the average bid auction. According to the simplest version of this format, the bidder closest (from above or from below) to the average of the bids wins and pays his own price. This format has been proposed by Ioannou and Leu (1993) in engineering literature and is in use in several countries.[2] For instance, among the possible auction formats that the Florida Department of

[1] Rhodes-Kropf and Viswanathan (2005) extend this analysis by considering how different methods of financing bids affect the relationship between the wealth and bids of the bidders. In their study, both the wealth and the valuation are bidders' private information.

[2] Liu and Lai (2000) instead proposed a version of this auction in which the winner is the one offering the

Transportation (DoT) can use to procure its contracts there is the following form of average bid auction:[3]

"If five or more responsive bids are received, the Department will average the bids, excluding the highest and the lowest responsive bids. If three or four responsive bids are received, the Department will average all bids. Award of the Contract will be to the winner who submitted the responsive bid closest to the average of those bids" (Source: Florida DoT Award and Execution of the Contract, (Rev 2-7-97) (7-00), sub-article 3-2.1).

Intuitively an average bid auction does not appear to be an interesting mechanism for an auctioneer concerned with her revenues.[4] In fact, this format implies that the highest bid is automatically eliminated every time it is the lone highest bid. However, the main factor motivating my research is the seemingly puzzling evidence that this mechanism is widely used in very different countries. In Italy between 1998 and 2006 the average bid auction was the only mechanism that public administrations were allowed to use to procure contracts for works (the total annual value of these auctions was about 0.7% of GDP). In 2006 a legislative reform fostered by a ruling of the European Court of Justice allowed public administrations the freedom to choose alternatively between the average bid auction (AB) and the first price auction (FP).[5] To provide an explanation for why the vast majority of administrations continued to use the AB is one of the main goals of this paper.

Therefore, in Section 3 I extensively document the environment in which Italian PAs operate and argue that the default risk is a main concern. I focus my analysis on auctions for simple roadwork contracts held by municipalities and counties in the North of Italy and explain why a model based on the default risk may capture the salient features of this environment better than alternative models based, for instance, on the risk of corruption or on that of low quality of work. Therefore, in Section 4 I present this model and use it to show that for the auctioneer the choice of the auction format depends crucially on the cost of default and on the cost of screening. If the auctioneer is constrained to choose between a FP and an AB, each of which can be augmented by an ex post screening stage, only the AB with screening leads to systematically lower expected revenues than the FP with screening. On the contrary, the relative ranking of the three remaining formats (FP with and without screening and AB without screening) depends on the costs of defaults and of screening. In particular, when the cost of default is very high, a regular FP without screening is never the best format. When, instead, the cost of screening is very high, the FP with screening is never the best format. Therefore, the auctioneer's preference of AB can be rationalized in an environment with high costs of both default and screening. In addition to providing this rationalization, another contribution of my theoretical analysis is to

price "closest-from-below" to the average of all the prices offered. See Section 2 for a list of countries where forms of the average bid auction are used.

[3] I am grateful to Giancarlo Spagnolo for having signaled me this rule.

[4] Throughout the paper I will refer to the auctioneer as "she" and to the bidder as "he". Sometimes I will use Public Administration (PA) instead of auctioneer and firms instead of bidders.

[5] Bidders are informed through the official notice of the auction of which mecanism will be used.

provide a characterization of equilibrium bidding in the average bid auction and to show that this format is equivalent to a random allocation.

However, the main contribution of the paper consists in the empirical analysis conducted in Sections 6 and 7. This analysis tries to capture the essential features of my model of the auctioneer's choice and to provide a quantitative assessment of the effects of choosing AB instead of FP. The data used for this analysis are described in Section 5. They constitute a unique dataset put together for this study. I collected data on both bids and identities of all bidders bidding in public procurement auctions for road construction held by Italian counties and municipalities between 2005 and 2009. Moreover, I integrate these data with the dataset of the Italian Authority for Public Contracts containing ex post information on the execution of all the contracts auctioned between 2000 and 2007.

In Section 6 I use these data to conduct a reduced form analysis of the effects produced by the switch from AB to FP. My estimates indicate that, relative to AB auctions, FP auctions generate both a lower winning price in the auction phase and a higher incidence of renegotiations during the life of the contract. The effect of a switch from AB to FP is to increase the winning discount (i.e. the rebate bidders offer on the announced reserve price) by about 11 points (from an average of 12% to an average discount of 23%).[6] Switching to FP is also estimated to increase the extra payment renegotiated by the contractor by about 6% of the reserve price. However, both mechanism are effective to prevent defaults. I provide multiple evidence arguing that, in the case of the FP auctions, this is because the administrations that moved to FP always perform a careful ex post screening. Although this screening is effective, I also show evidence that it is costly. Therefore, this positive screening cost might explaining why only big PAs, that likely have a lower per-auction cost of screening, switched to FP.[7] Finally, the reduced form analysis shows the limits of a model based on competition and illustrates evidence of firms' collusion in AB. The presence of collusion makes a formal analysis of bidding in AB difficult but the empirical analysis is used to develop a "rule of thumb" approach to estimate the auctioneer's expectation of the winning bid in such auctions.

In addition to the reduced form analysis, in Section 7 I present results obtained through a structural estimation of the subsample of FP auctions. In particular, this estimation is performed using the modification of the Guerre, Perrigne and Voung (2000) procedure introduced to study unobserved heterogeneity by Krasnokutskaya (2004). I show that within the framework of unobserved heterogeneity, under certain assumptions, the reserve price can be used to identify the bidders' underlying cost distributions when the only other available information is the winning bid. This approach allows me to obtain estimates of the distributions of firms'

[6] This estimated increase in the winning discount goes up by 19 points when the sample is restricted to a very homogenous group of auctions for road construction works held by PAs in five regions in the North of Italy.

[7] A related, although not identical explantion, would be that small PAs that do not switch to FP are more inefficient. In a study on the purchasing of goods by Italian PAs, Bandiera, Prat and Valletti (2009) show that relevant ineffieicnsies are present. My analysis does not separately identify the roles of inefficiency and that of the cost of screening. Therefore my estimates of this cost may be biased upward.

costs. Therefore, I can use these estimates to answer relevant policy questions that the reduced form analysis by itself cannot address. For instance, I can show that there is a strong inefficiency associated with the use of AB auctions. The variance of the idiosyncratic component of firms' costs accounts for at least 39% of the total costs' variance. Therefore, a mechanism like the AB that randomizes the allocation among bidders is foregoing the benefits of selecting the most efficient firm. For the same reason, the firms' markups in the AB auctions are in the same order of magnitude, around 8%, of those in the FP auctions. Despite the auctioneer pays a higher price in the AB, this price goes to a firm that is generally not the most efficient. However, I argue that both subcontracting behavior and cartels's activity seem to mitigate the allocative inefficiency and rise winners' markups in AB. In terms of the auctioneer's cost, for every PA that in the past used AB, I am able to estimate a bound on the cost of screening that would rationalize the choice of AB. On average this cost is large, amounting to around 220,000 euros. Moreover, I find that the PAs are using a reserve price that is substantially above the optimal level.

Overall, my finding is that, for the market that I study, AB auctions generate both significant inefficiency in contract allocation and high costs of procurement. Thus, a transition toward first price auctions could produce improvements along these two dimensions, but only if the ex-post screening of bids is not too expensive. Therefore, the main policy implication that can be derived from this research is that large benefits can be obtained if, by reducing the cost of screening, more auctioneers can be induced to use FP auctions in which bids are binding commitments for the bidders. The analysis of the best method to achieve this result is left for future research but in the conclusions I discuss several possible options like the use of a system of surety bonds, of more stringent qualification requirements or of reputational mechanisms.

Literature: This paper contributes to the vast literature on first price auctions originating from the seminal works of Vickery (1961) and Myerson (1981). Within this literature it follows the branch that deals with the case of bidders that can default on their bid. To my knowledge the first paper in this literature was Spulber (1990). Waehrer (1995) is another early attempt to study the effects of bidders' default in second and first price auctions. Che and Kim (2009) is a recent generalization of the effects of adverse selection in auctions. My paper is particularly related to the studies in the literature that seek to link the nature of the awarding mechanism to ex post renegotiation, (Bajari et al., 2007 and Guash et al., 2007) and ex post bankruptcy (Rhodes-Kropf and Viswanathan, 2000 and 2005, Zheng, 2001 and Board, 2008).[8] Moreover, my result that AB auctions in equilibrium are equivalent to random allocation is related to the result of Chillemi and Mezzetti (2009) showing that the optimal mechanism is a random lottery when bidders can default and the auctioneer bears a high enough cost of default. Finally, my analysis is also related to Albano et al. (2006) and Wambach et al. (2006) which were, to my knowledge, the first papers in the economics literature to introduce the AB format and

[8]Since in my analysis I will focus on the case of bidders that receive a payment from the auctioneer to complete a work, I will not address the problem of how bids above budget are financed. For an analysis of how financing bids affects bidders behavior see Rhodes-Kropf and Viswanathan, 2000 and 2005 and Zheng, 2001.

to present examples of its (mis)functioning. As regards econometric methodology, I utilize some of the techniques that originated from the pioneering studies of Paarsch on the structural estimation of auctions (see Paarsch, 1992). In particular, I have used the adaptation made by Krasnokutskaya (2004) of the methodology of Guerre, Perrigne and Vuong (2000). Asker (2008) is a recent example of another paper using this methodology. Finally, I present a quantitative assessment of different auction formats on the auctioneer's revenues with regard to first price and average bid auctions. this is related to the similar results presented in Athey et al (2004) comparing first price sealed bid and open outcry auctions.

The outline of the paper is as follows: Section 2 presents cross country evidence about the average bid auctions. Section 3 documents the use of the AB in Italy and describes the policy change motivating our study. Section 4 presents the theoretical analysis, Section 5 the data, Section 6 the reduced form empirical analysis, Section 7 the structural analysis, and finally section 8 concludes the study.

2 Average Bid Auctions: Cross-Country Evidence

The awarding rule of the Florida DoT auctions reported in Section 1 is remarkably different from those usually seen in studies about auctions. If we follow the literature and define auctions in which the highest bidder wins as "standard" auctions, then the auctions in Florida are clearly not standard. Their departure from a standard auction is rather extreme since the awarding rule ensures that if there are more than two bidders and if the highest discount is unique, then this solo highest bidder will lose with probability equal to one. As is illustrated in the next section, the same is true with the Italian rule when there are more than four bidders. Given this intuitively unappealing property of the Florida and Italian auctions, we first check to see if these are isolated cases or if similar auctions exist elsewhere. A careful look at the institutional details of the rules of public procurement of various countries reveals that these two cases are not an anomaly. Table 1 illustrates this point.

Table 1: Rules for Identification & Elimination of Abnormal Bids

Automatic elimination	Only identification	No disclosed rules
Chile	Belgium	Canada
China	Brazil	USA (Most of the States)
Italy	Germany	
Japan	Portugal	
Peru	Romania	
Taiwan	Spain	
USA - Florida DoT	Turkey	
- NYS Proc.Ag.	UK	
(Switzerland)		

The countries in the left column of the table are those in which there are instances of the most severe departure from standard auctions.[9] There are rules in these countries that identify and automatically eliminate "abnormally" high tenders.[10] Generally this means that discounts greater than some threshold (often defined as a function of the average of the bids submitted) are automatically eliminated from the auction and the contract is awarded to the highest non eliminated bid. This often implies that the highest solo bidder instead of winning will be eliminated with probability one. For the countries in the middle column the identification of an abnormal tender does not mandate its automatic elimination. Generally, these countries run first price auctions augmented by an ex post screening stage in which further checks on the reliability of unusually high bids are undertaken before the contract can be awarded to such a bidder.[11] Even when there are no explicitly disclosed rules for detecting abnormal tenders, as is true of countries in the right column, usually the auctioneer can exclude bids that are so high as to jeopardize the correct execution of the job.[12]

Different awarding rules are used in each of the countries listed in the left column of Table 1. However, if we loosely define an average bid (AB) auction as a non-standard auction that employs a formal algorithm to endogenously (i.e. through the submitted bids) eliminate bids, then all these countries use AB auctions. A straightforward algorithm that awards the contract to the bidder closest to the average (regardless of whether from above or from below) exists in the codes of Taiwan and the Florida DoT.[13] More complicated functions of the average of all (or

[9] I classified countries according on the basis of the rules contained in their codes of public procurement for works, goods or services. In particular a country is in the left column if, in any of its codes, there is a rule allowing the use of an auction with automatic (i.e. using an algorithm based on the bids) elimination of abnormal tenders. It is in the middle if there is any rule allowing for the use of automatic identification of abnormal bids but no rule requiring their automatic elimination. Finally, countries in the right column are reported to have rules for the identification or elimination of the abnormal bids but the algorithm used to mark them is not disclosed.

[10] "Anomalously high tenders" is also an expression often used in the Codes of Procurement.

[11] An example of such procedure is the rule used in Brazil. In this country the public procurement agency (PPA) requests motivations to be provided whenever a supplier presents an offer to execute the contract that is 70% lower than the lowest of the following values: (1) the arithmetic average between tendering prices that are above 50% of the estimated price set by the PPA; (2) the estimated price set by the PPA. A different rule is that used by the Turkish PPA which requires explanations about an offer when it is below a value called "boundary value", obtained by multiplying a certain value K by the estimated cost of the contract. The K value, is calculated by the procurement agency as the ratio between the arithmetic average of the tenders (tenders 120% above or 40% below of the estimated cost are not taken into account) and the estimated cost. Any value of this ratio between 1.2 and 0.4 is matched by a corresponding K value tabled by the PPA.

[12] For example, Bajari, Houghton and Tadelis (2007) report that this is why 4 percent of the auctions in their database of the California DoT auctions for road construction are not awarded to the highest bidder. Hence, Caltrans auctions should not be seen as simple first price auctions but as "first price auctions plus ex post monitoring". The model of Bajari et al. (2007) accounts for this issue through an explicit penalty for those bids that depart excessively from the average of the bids.

[13] In Taiwan the rule is simply that the bid closest to the average of the submitted bids wins. In Florida one of the awarding rules the DoT can use is the one reported in the first section. Officers at the DoT reported that the rule was still valid in 2009 but was last used in 2001. Instead, the Procurement Services Group of

some of) the bids are used in other countries like Chile[14], China[15], Japan[16] and Peru[17]. The case of the Italian AB rule will be illustrated at length in the following section. According to this loose definition of AB auctions, a rule that eliminates the highest bid and awards the contract to the second highest bidder is an AB auction. The use of such a mechanism in Switzerland is reported by some studies.[18]

Therefore, it seems possible to conclude from this review of public procurement regulations that AB are not an isolated and negligible phenomenon. The next natural question is what determined the success of these formats. However, different countries may have different reasons for the use of AB and a detailed cross-country analysis of the determinants of this choice is beyond the scope of this paper. Instead, in the next section I will introduce the stylized facts concerning the policy change undertook by Italy in 2006: the switch from a compulsory use of AB to a voluntary choice between AB and FP. Within that context, I will form an argument to explain why Italian public administrations have preferred using the AB when the FP format was available.

3 Motivating Case: The Change from AB to FP in Italy

Between 2000 and 2006 in Italy roughly 75% of all the public procurement of contracts for works occurred through AB auctions. The total value of contracts procured through AB amounted to approximately €10 billion per year, roughly .7% of Italy's GDP in 2004.[19] With the exception of only a few regions, the awarding rule characterizing these AB auctions was the following:[20] if four or less bidders participated, then the winner was the bidder offering the highest discount.

the State of New York Executive Department uses a very complex form of AB for the procurement of liquid bituminous materials (tendering procedure 11/10/2004 commodity group 31501). Albano et al (2006) describe this procedure.

[14]In Chile the combinatorial auction used to procure school meals entails the use of an endogenous price floor such that those firms offering a price lower than the floor are automatically eliminated. The Chilean auction is analyzed in Epstein et al. (2002, 2004).

[15]In the Guangdong region in China, numerous variations of the simple average bid auctions have been experimented in the last years for the procurement of construction contracts. Zheng (2006) is a PhD thesis, in Chinese, that studies these auctions.

[16]In Japan several prefectures have recently started to use various forms of AB. For instance, the Nagano prefecture excludes those bidders offering a price-bid lower than the 80% of the five lowest price-bid.

[17]In Peru the Public Procurement Authority (PPA) used to first take the average of the bids submitted eliminating those bids that were 10% above or below this average. The average of the remaining bids was calculated again and the contract was awarded to the bidder whose bid was immediately below this second average. This rules was modified by Law 28267, Art 33 which only requires the automatic elimination of bids that are 10% above or 90% below the reference value stated by the auctioneer.

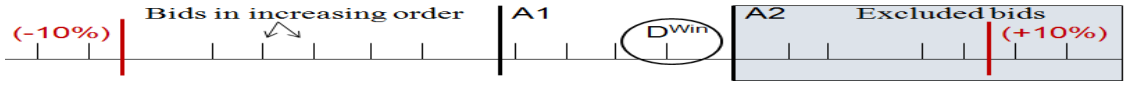
[18]However, we did not manage to find a Swiss public procurement code reporting this rule.

[19]See Decarolis, Giorgiantonio and Giovanniello (2010) for more details.

[20]See Art. 21 Law 109/94, later modified by Art 86 and 122 Law 163/06. The rule described in the text was in effect since 1998 in almost all of the country. Se Decarolis et al. (2010) for more details.

If, instead, five or more bidders participated, then the winner was determined as follows: (step1) disregard the top and bottom 10 percent (or the closest integer) of the bids; (step2) compute the average of the remaining bids, call it A1; (step3) compute the average difference between A1 and all the bids that are greater than A1 and then add it to A1, call A2 their sum; (step4) eliminate all the bids that are greater or equal to A2; (step5) the winning bidder is then the bidder with the highest bid among those not eliminated. The auction format was sealed bid and open to all qualified bidders, with bids expressed as discounts over the announced reserve price. The winner paid his own price. The figure below offers a graphical interpretations of the rule:

Figure 1: The Italian AB Rule

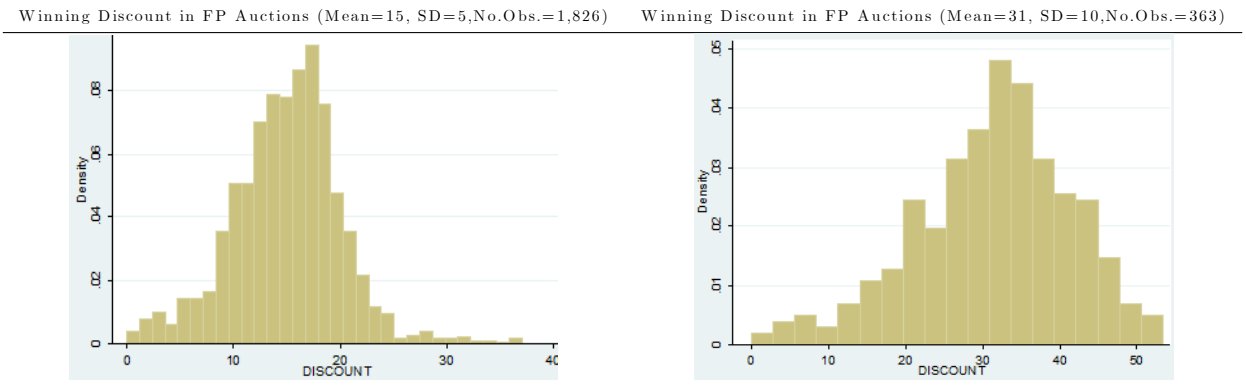


For almost all Italian public administrations (PAs), this mechanism was the compulsory procurement method for every work worth less than (approximately) €5 million, the "European Threshold" (ET). In the same period, first price auctions were also used but only for contracts above the ET. Hence, although numerically FP auctions accounted for only 9% of all contracts procured between 2000 and 2006, their value was about 45% of the total.

This system was recently modified by two policy changes, the first in 2006 and the second in 2008.[21] Starting in July 2006 all PAs became free to use the FP format also for auctions below the ET. The law simply required that for every auction the PAs announce in advance whether an AB or a FP is used. Moreover, the law required that the AB algorithm was used at FP auctions for the sole purpose of identifying the potentially abnormal bids. The law mandated that the PAs carefully screened abnormal bids to evaluate their reliability (i.e. whether it was reasonable to believe that the firm could perform the job at the promised price). Therefore, this FP auction augmented with an ex post screening phase is similar to those auctions in place in the countries listed in the central column of Table 1. The second policy change occurred on October 2008. In this occasion, the FP format became compulsory for every auction worth more than €1 million or for which less than ten bidders participated. For contracts above €1 million it remained possible for the PA to choose freely between AB and FP.

[21] Both policy changes occurred because Italy had to comply with requirements of the European Union.

Figure 2: Winning Discount Under AB & FP - IE Sample



We collected data for AB and FP auction held by local administrations (counties and municipalities) between November 2005 and December 2009. We call this dataset "Extended-IE Sample." Moreover, we call "IE sample" a subset of these data regarding only comparable, simple roadwork contracts procured by local administrations in five Northern regions (more details are found Section 5). Figure 2 illustrates the histograms of the winning discount in AB and (voluntarily chosen) FP auctions. The whole distribution under FP is right shifted and the average winning discount increases from 15 to 31% of the reserve price. For those administrations that after the 2008 reform used FP for contracts above €1 million but never use FP otherwise (we call them "forced FP users"), a similar effect holds: the average winning discount increases from 12 to 30% of the reserve price.

In light of this large cost saving at the time of the auction, it is rather surprising to find that most PAs decided not to switch to FP. By looking at PAs in the Extended-IE Sample we see that only PAs in the North moved to FP. Moreover, among the PAs in the North in the "IE sample", only 30 out of 481 administrations moved to FP. This behavior may seem at odds with the cost minimization objective that the law mandates and that budget constrained PAs should follow. Moreover, using the IE sample, we can see that these administrations appear to be much larger than those that continued to use AB. They are larger both in terms of the population they administer (reported in thousands) and in terms of their "experience" (i.e. the number of auctions for simple roadwork they held per year).

TABLE 2 Summary Statistics for the Auctioneers - IE Sample

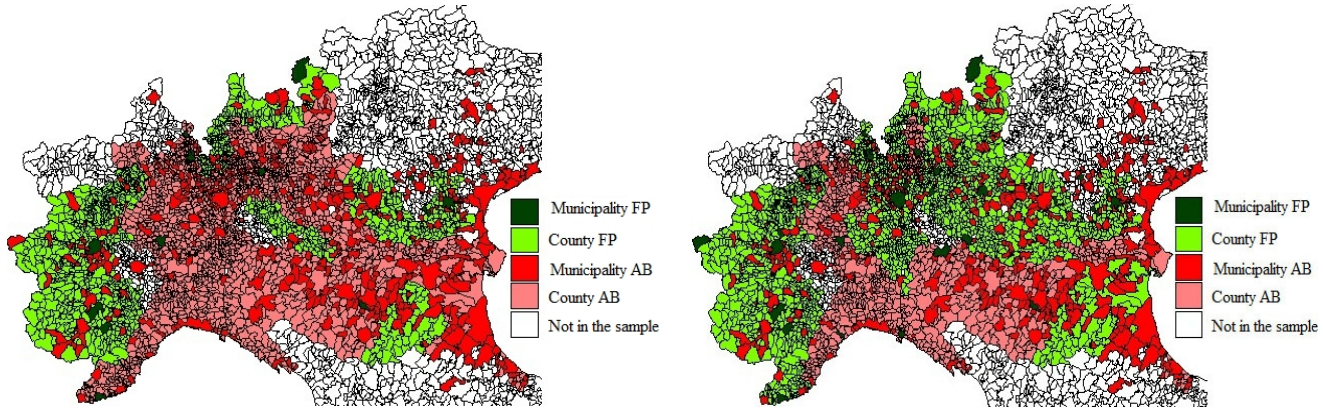
	Admin. Remained with AB				Admin. Moved to FP			
	Mean	SD	Median	Obs.	Mean	SD	Median	Obs.
Experience	2.43	3.70	1.11	451	10.68	10.94	6.44	30
Population	.50	2.22	.09	451	2.78	4.86	.3	30

The figures below illustrate the adoption of FP by counties and municipalities belonging to the IE sample. The plot on the left reports what PAs did when they could choose freely. The

one on the right pools all the data. The large prevalence of AB in the first period is evident. Moreover, these pictures should also convey the idea of how dispersed the public procurement process is in Italy: even the tiniest municipalities run procurement auctions by themselves.

Figure 3: Geographical Distribution of the Adoption of AB & FP

Voluntary Adoption of FP (Jul. 2006 - Sep. 2008) Overall Adoption of FP (Oct. 2008 - Dec. 2009)



The facts reported above illustrate a puzzle: why most local administrations use the AB auction although the FP seems to lead to systematically lower procurement costs? However, those facts also suggest a direction where to look for the answer: administrations of different size make different choices and, in particular, small administrations tend to stay away from the FP. The key element that our analysis adds to rationalize the administrations' behavior is the risk of the winner's default. In particular, the next section will introduce a model to explain why, if bidders can strategically default and if their default is costly "enough" for the auctioneer, administrations might rationally sort between an AB and an augmented FP with screening depending on their cost of performing the ex post screening.

However, before turning to the model, we shall discuss our main assumptions. First of all, it seems reasonable to assume that defaults are costly for administrations.[22] This cost likely includes all the expenses associated with running a second auction. Moreover, the likely presence of some relationship specific investments on the part of the auctioneer could cause her to be stuck in a classical "hold up", so that she would suffer a large loss if the winner were to interrupt the execution of the work.[23] Another assumption that should not be controversial is that the screening cost differs across administrations of different size. This is clear especially

[22] Evidence from European and US contracts is provided for instance in Ganuza (2007).

[23] The European Commission Enterprise & Industry (2002) report presents some evidence on the auctioneer's costs due to bidders failure to comply with their contractual obligations. A different and more general approach than the one that we follow here would be to look at the social welfare. This is the approach of Bajari and Lewis (2008) who consider an auctioneer that takes into account the welfare loss associated with delays in the execution of works.

if we think of it as a fixed cost. Since the law mandates that the screening process is done in house, part of the screening cost will be the cost of having a team of specialized engineers and lawyers in the PA that will perform such screening. Lawyers may be needed also because an eliminated firm may try to sue the PA. A large PA can amortize these costs over many auctions and have a lower cost per auction than a small PA running few auctions. In line with this interpretation of screening as a cost (at least in part) fixed, 28 out of the 30 PA that switched to FP never went back to AB. In sections 6 and 7 the magnitude of both the default and the screening costs is analyzed.

Therefore, the last key assumption that we need to discuss is the risk of default. In particular, we assume that bidders have an asymmetric cost of default and that, in certain circumstances, they will optimally default. For rational defaults to occur there must be some uncertainty in the cost. It seems, however, quite likely that bidders are uncertain about the final cost of the work ex ante and that during the prolonged time that it takes to complete the work, a cost overrun can occur. It may be more controversial that bidders have asymmetries in their costs of default such to make the default risk a first order concern for the auctioneer. The end of this section is devoted to illustrating why we think that this is the case and why alternative explanations are less appealing.

1) The Default Risk

In the literature, the risk of defaults is the main argument used by the proposers of the AB. The seminal papers in the civil engineering literature that suggested replacing FP with AB claimed the superiority of the second format because of the reduced default risk.[24] The European Commission (EC) endorsed this same view in a 2002 report.[25] This report also tries to explain why bidders in a FP may bid so high as to generate a risk of default. The argument is along the lines of the "gambling for resurrection" idea: a firm with a low cost of defaulting offers a very high discount on a contract of uncertain value with the intention of completing it only if ex post it will be profitable to do so. A variation of this story is that of a credit constrained firm in bad financial conditions that is either reluctant to lay off its employees or is in search of a contract in order to obtain a cash advance from its client or bank. In the economics literature the problem of strategic defaults is well known at least since Spulber (1990). In addition to acknowledging the problem, this literature has also proposed ways to solve it. For instance, Spulber (1990) suggests to protect the contract with adequate monetary penalties for the contractor's violations of his obligations. A similar effect is obtained by requiring bidders to provide a surety bond that serves as a guarantee for the auctioneer. Calveras et a. (2004) characterize the optimal surety bond. Therefore, the fact that there is not a system of surety bonds in Italy is an important indication for why we should focus on the

[24] See Ioannou and Leu (1993) and Liu and Lai (2000). Notice that the studies adopt the very restrictive assumption that bidders are not strategic: they do not react to changes of the awarding rules.

[25] See European Commission, "Prevention, Detection and Elimination of Abnormally Low Tenders in the European Construction Industry," 2002. The report suggests abandoning the FP format in favor of an awarding rule that eliminates the 20% of the highest bids and awarding the contract the highest remaining discount.

default risk. The introduction of such a system has been discussed in the Parliament several times[26] but it has been always rejected on the ground that distortions in the insurance or capital market would transmit to the bidding process. Therefore, in the market that we study there is only a system of letters of credit through which a minimum guarantee is enforced. Nevertheless, this guarantee is always partial and, in the AB auctions in our sample, the guarantee is around 20% of the reserve price.[27] This can be contrasted with the situation in the US where the Miller Act requires a 100% insurance coverage through a surety bond for every federal contract above $100,000. Moreover, while in the US the use of performance bonds ensures that the job will be completed (the surer will do so in case of the winner's default), in Italy auctioneers just receive a reimbursement. Furthermore, from interviews we had with PAs, it is often lamented that it is hard to obtain the due payment. Indeed, in terms of the efficiency of the judiciary system for the recovery of a credit, the 2009 "Doing Business" report of the World Bank ranks Italy 156th, right after Gabon, while the US is 6th.

The slow legal system also implies that an administration is unlikely to recover her damages by suing the contractor. Moreover, firms are generally liable at most up to their subscribed capital. In the Web Appendix we illustrate the features of a data set on the capital structure of firms that we obtained from the Bank of Italy. The data show that there are large differences in the capitalization of bidders. Subscribed capital ranges from €10,000 to more than €10 million. The first, second and third quartiles are, respectively, €20,000, €52,000 and €105,000. The mean is €538,000 and the standard deviation almost 4 million. Therefore, there seems to be considerable dispersion. Moreover, since the mean contract value is €260,000, the value of the contract is often greater than the capital of most of the bidders.[28]

Finally, several other institutional features of the market are likely to generate asymmetries in the cost of default. For instance, the Italian Law allows an administration to exclude from its auctions for one year a contractor that defaulted on his obligations. Therefore, it is likely that contractors located far away from the administration will suffer a (relatively) low damage by being forbidden to participate in future auctions. The opposite is true for bidders close to the administration since the administration is more likely to be an important client for them. We constructed a variable measuring the distance between the bidder and the place of the work (measured at the zip code level) which is a good proxy for the distance between the firm and the PA. This variable ranges from zero to more than 1,100 miles, the average is 78 and the standard deviation 134 miles. The average size of Italian municipalities, instead, is just 23 miles. Hence, it seems plausible that bidders with potentially different costs of defaults are participating at the auctions.

2) Alternative Explanations

[26] See Decarolis, Giorgiantonio and Giovanniello (2010) for more details.

[27] In the theoretical model I will not explicitely deal with the insurance issue.

[28] PAs lament that the requirements imposed by the national law to qualify firms for public procurement auctions are too light.

Several alternative explanations could be formulated as to why some auctioneers prefer AB over FP. Here we explore some of them. First of all, the EC (2002) report we mentioned above presented a second argument for why bidders may submit too high bids based on the well known, non-equilibrium concept of the winner's curse. In this case winning the contract means having underestimated its true cost. In our setting, characterized by cost uncertainty, errors in evaluating a contract's cost are possible. However, we do not think that firms are systematically making this type of mistake. This is mainly because, in the market that we study, firms are experienced players that repeatedly participate in similar auctions taking place with high frequency. Moreover, we are focusing only auctions for very simple roadwork contracts where evaluating the cost should be simple for an experienced firm.[29]

A more relevant concern regards the role of quality. A model, isomorphic to the one we will build in the next section to address the risk of default, could be constructed for the risk of poor quality of work. In construction contracts the concern about quality may be important, especially when the project design is incomplete. Therefore, since more contract incompleteness is likely associated with more complex works (see Bajari and Tadelis, 2001), our strategy is to focus only on simple contracts. All of our empirical analysis looks only at basic roadwork contracts (like paving and roundabouts) for which it should be feasible for the auctioneer to fully specify the project design. We assume that for these contracts the PAs were able to fix the level desired quality, so that quality concerns should not affect the choice between AB and FP. To grasp the implications of our approach, we can look at the case of Padua. This large city in the North moved to FP only for the auctions for simple roadwork contracts while it continued using AB in the auctions for more complex contracts, like the construction of buildings. Officers in Padua told us that quality concerns motivated their choice. Our analysis will not deal with why Padua used different formats for different types of contracts but, instead, will address why Padua switched to FP for simple contracts while many of the neighboring smaller administrations continued using AB for similar simple contracts.

[29] On the other hand, the winner's curse might have been an issue in the case of new inexpereinced fimrs joining the market or with firms having to bid on very complex contracts. See Kagel and Levin (1986).

Table 3: Probit Model for the Choice of FP

Dependent Variable is 1 if the Public Administration Chose FP; 0 if AB Chosen.					
WBid t-1	.03	.04	.03	.06	.05
	(.04)	(.04)	(.04)	(.04)	(.04)
No.Auct.	.09	.09	.08		
	(.02)***	(.03)***	(.02)***		
Corrupt.		-.20	-.14	-.88	
		(.49)	(.48)	(.59)	
MilesTO			-.11	-.06	-.14
			(.19)	(.19)	(.18)
Population				.88	.65
				(.30)***	(.25)***
Obs	198	198	198	198	198
Pval Chi^2	.000	.000	.001	.004	.006

SE in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

Another factor affecting the choice of AB lies in the risk of corruption. In a FP a corrupted auctioneer may let his favored firm win at a very high discount and then renegotiate the price ex post. In an augmented FP a corrupted auctioneer may, instead, use the screening stage to selectively eliminate bids. On the other hand, in an AB the winning price is endogenous and hence it is harder for a corrupted auctioneer to help the favored firm.[30] Since these different auction formats leave very different degrees of discretionary power to the PA, it may be that corruption is among the determinants of the cross-country variation in auction formats. Even within Italy, the risk of corruption may explain part of the geographical variation.[31] Our main strategy with respect to this problem consists of analyzing the variation in auction formats exclusively within five regions in the North of Italy where corruption is less relevant. Table 3 reports the results of a probit regression in which the dependent variable is equal to one if the local administration voluntarily used a FP and zero if it used AB. Several measures of corruption were tested but none were statistically significant.[32]

Table 3 also illustrates the effects of other factors on the choice of the auction format. However, apart from the size of the PA (proxied by the size of the population it administers in millions or by the total number of auctions within the IE sample), all other variables have no significant effect. With the variable MilesTO (the distance in miles/100 from the PA to Turin) we tested whether proximity to Turin increased the likelihood of switching to FP. Turin was the very first adopter of the FP (it was introduced there in 2003 in derogation of the national law) and in 2006 the first administrations to move to FP were those close to Turin. However, this effect has vanished rapidly and the regression does not support a story of social learning.

[30] For instance, she should open all the sealed bids before the auction and let the favored firm revise his bid.
[31] Fear of corruption induced a region in the South, Campania, to forbid the use of FP in its territoy.
[32] This variable the Golden and Picci (2006) index. See the web appendix for more details.

Analogously, there is no evidence that having low average winning discounts in 2005 makes an administration more likely to switch to the FP (see the estimates for W.Bid t-1). Although we cannot claim that we addressed every possible alternative explanation[33], we believe that the above evidence is sufficient to support the assumptions a model based on default risk like the one we will now introduce.

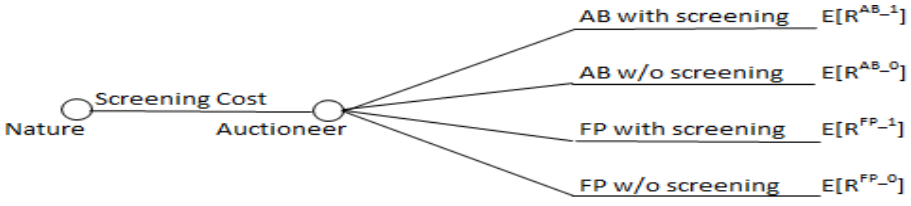
4 Theoretical Analysis

4.1 The auctioneer's decision problem

The model proposed here is mostly based on Zheng (2001). He considers an environment where, both ex ante and ex post, firms all value a good of ex ante uncertain value the same. Firms can default on their bids under a limited liability regulation and in this case they lose their budget. Budgets are bidders' private information and asymmetric across bidders. In our model we add a privately observed value to the formulation of bidders' valuations. However, we make bidders' penalties in case of default (which play the role of the budget in Zheng's model) observable to all the bidders. Finally, while Zheng analyzed only the case of a first price rule without screening, I consider bidding under various other mechanisms. The model is formulated using the language of auctions instead of that of procurement but this is without loss of generality.

Consider the problem of a risk neutral, revenue maximizing auctioneer who has to choose an auction format to sell one unit of a good (or award a contract) to one of N buyers. Her choice is restricted to four auction formats: an average bid auction or a first price auction both of which can be with or without the ex post screening of bids. The choice problem is represented in the figure below. The auctioneer observes how much the screening would cost and then decides which of the four possible auction mechanisms to use. The payoffs at the end of each branch of the tree are the auctioneer's expected revenues. Bidders perfectly observe the mechanism chosen by the auctioneer.

Figure 4: The Auctioneer's Decision Problem



What makes the screening technology interesting is that bidders can default and, if this

[33] A possible explantion not addressed in this paper is that AB may work as a sort of indirect bid preference system. By lowering competition, they allow even small and inefficient firms to survive in the market.

happens, the auctioneer is left with a salvage value K. I make the following assumption regarding the screening:

Assumption (i): *(Screening Technology) If the auctioneer pays the screening cost then she can perfectly observe which bidders would fulfill their bid if they win and which would not.*

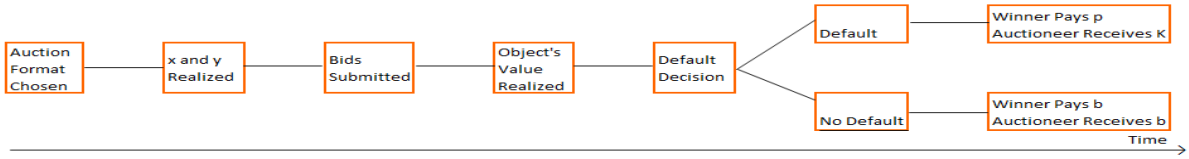
Under the above assumption the auctioneer can perfectly eliminate the risk of the winner's insolvency. This, however, generates both a direct cost of screening, $I \geq 0$, and an indirect cost. This second cost is due to reduced competition that bidders face when they know that some of their competitors will be eliminated. The following analysis will show that the AB with screening is always strictly dominated by the FP with screening. Instead, the relative ranking of the other formats depends on the value of the screening cost, I, and the salvage value, K.

4.2 Firms' bidding behavior under the four auction formats

There are $N > 2$ risk neutral bidders that compete for the good. The model is of private value (PV): for any bidder i with probability $(1-\theta)$ the value of the good is $v_i = y + x_i$, while with probability θ, $0 < \theta < 1$, the value is $v_i - \varepsilon, 0 < \varepsilon < y$. In the first case we will say that the value of the object is high ("good" state of the word) and in the second that it is low ("bad" state of the world). One part of the valuation, x_i, is only privately observed by each bidder i, $i = 1, ..., N$. Instead, the other part, y, is commonly observed by all bidders. Likewise, ε is a loss of value specific to the good and thus common to all bidders. At the time of bidding, all bidders know θ. The true value of the good, instead, will be known immediately after the auction is over. The random variables Y and X that are distributed on $[\underline{y}, \bar{y}]$ x $[\underline{x}, \bar{x}]^N$, $\underline{y} \geq 0$, $\underline{x} \geq 0$ independently of θ according to the joint cumulative probability distribution is $F(y, x)$.

The bidder who wins the auction has the possibility of refusing to fulfill his bid. In this case his payoff is equal to a penalty, $-p \geq 0$, that he pays. Therefore, for each bidder a strategy consists in a bid and a decision of whether to fulfill his bid or not, in each of the two possible realizations of the value of the good. Figure 5 illustrates the timeline of the problem:

Figure 5: Game Timeline



I also assume that there are two types of bidders, depending on the level of the penalty:

Assumption (ii): *(Asymmetric Bidders) There are two types of bidders, L and H, who face different penalties in case of refusal to fulfill their bid. There are n_L bidders of type L that*

only pay a low penalty (p_L) and $n_H = N - n_L$ bidders type of H that pay a large penalty (p_H), $p_H > p_L \geq 0$.

The number and type of bidders is observable to all bidders but the auctioneer just knows N. She cannot distinguish among types without paying the screening cost. Moreover, we assume:

Assumption (iii): *(Values' Independence) All the components of the valuations for all types of bidders are independently distributed:*

$$F_{YX}(y, x_{1L}, ..., x_{n_L L}, x_{1H}, ..., x_{n_H H}) = F_Y(y)\Pi_{i=1}^{n_L} F_{X_L}(x_{iL})\Pi_{j=1}^{n_H} F_{X_H}(x_{jH})$$

where F_Y, F_{X_L}, F_{X_H} are marginal distributions that are absolutely continuous and have support respectively on $[\underline{y}, \bar{y}], [\underline{x_L}, \bar{x_L}], [\underline{x_H}, \bar{x_H}]$.

Assumption (iv): *(Reservation Price) Bids have to be non negative and there is a reservation price which is not binding.*

Analysis of bidders behavior.[34] Restricting the analysis to the case in which only non dominated strategies are played implies that we can disregard situations in which the winning bidder declares himself insolvent even if the value of the contract is "high".[35] The expected payoff for a bidder of type $j = \{L, H\}$ who has a value $v = y + x$ and chooses a bidding strategy b_j is:

$$[(1-\theta)(y + x - b_j) + \theta \max\{-p_j, y + x - \varepsilon - b_j\}] \Pr(win|b_j)$$

The following analysis illustrates for each of the four auction formats the type-symmetric Bayes Nash equilibrium (BNE). Throughout the paper I will focus on this type of equilibrium which consists for every bidder i of type $j = \{L, H\}$ in a function $b_j : [\underline{y} + \underline{x}_j, \bar{y} + \bar{x_j}] \rightarrow R_+$ and a decision of whether to default if the value of the good is low; these two elements together maximize i's payoff conditional on the other bidders bidding according to b_j. We can identify two threshold values for the penalty, $p_H^* > p_L^* \geq 0$, such that every bidder with a penalty greater than p_H^* always complies with his bid. Instead, if the penalty is less than p_L^* and the format is FP, then the bid is fulfilled only if the ex-post value of the good is "high".[36]

Lemma 1. *Assume y is the realization of Y observed by all bidders and $\varepsilon > (\frac{1}{1-\theta})\underline{x_L}$. Then, if $p_H \geq y + \bar{x_H} - \theta\varepsilon = p_H^*$, bidders type H neither play $b_H > y + \bar{x_H} - \theta\varepsilon$ nor decide to default*

[34] I analyze bidders' optimal behavior only within each of the four auction formats.

[35] Under the stated assumptions, if a bidder optimally chooses to pay the penalty and not get the good in the "high" state of the world, then he must do so also in the "low" state. Therefore the payoff of this strategy in case of victory is $-p \leq 0$. However, this strategy is strictly dominated by bidding $v - \varepsilon$ which guarantees a payoff in case of victory of $(1-\theta)\varepsilon > 0$.

[36] The first part of the following Lemma is similar to Lemma 3.1 in Zheng (2001).

on their bid in case of victory. Moreover, if the format is a first price auction with screening, no bidder plays $b_j < y - \theta\varepsilon$; in case $p_L < (1-\theta)\varepsilon - \bar{x_L} = p_L^*$ bidders type L fulfill their bids exclusively in the "good" state of the world .

Assumption (v): *the two types of bidders have respectively $p_H > p_H^*$ and $p_L < p_L^*$.*

This implies that H types always fulfill their bid while L types never do so in the "bad" state of the world. Therefore, the payoffs in case of victory for the two types of bidder are:

$$\begin{aligned} &\text{Type H:} \quad (1-\theta)(y + x_H - b_H) + \theta(y + x_H - \varepsilon - b_H) = A + x_H - b_H \\ &\text{Type L:} \quad (1-\theta)(y + x_L - b_L) + \theta(-p_L) = (1-\theta)[B + x_L - b_L] \end{aligned} \tag{1}$$

Where $A \equiv (y - \theta\varepsilon)$ and $B \equiv (y - \frac{\theta}{1-\theta}p_L)$. Notice also that a function b_L that solves the problem of type L is also optimal for a bidder whose payoff in case of victory is $B + x_L - b_L$ and vice versa. I shall now move on to describe the remaining part of the bidders' expected payoff, that is the probability of winning, which depends on the auction format used.

4.2.1 First price auction with screening

This is a standard sealed bid first price auction where, however, all bids are subject to an ex post screening of their validity. Under Assumption (i) every bidder that would optimally default in the "bad" state of the world is eliminated. Therefore, it follows from Assumption (v) that the L bidders cannot make profits in equilibrium. If they bid strictly less than $y - \theta\varepsilon$ they are not eliminated but they have a zero probability of winning. If they bid above that value they are eliminated through the screening. Since L types have a zero probability of winning, their presence is irrelevant for type H bidders. Hence, one type-symmetric BNE is a strategy profile in which: (a) the type L bidders always bid the constant bid $b_L^{FP_1} = y - \theta\varepsilon$ and default only if object's value is low and (b) the type H bidders always fulfill their bid and bid as in a standard first price auction with n_H bidders according to the bidding function $b_H^{FP_1}$ such that:[37]

$$b_H^{FP_1} = A + [x_H - \frac{\int_{\underline{x}_H}^{x_H} F_{X_H}(u)^{n_H - 1} du}{F_{X_H}(x_H)^{n_H - 1}}] \tag{2}$$

Clearly, $b_H^{FP_1}$ and $b_L^{FP_1}$ are mutually best responses but they are not the unique equilibrium. Other type-symmetric equilibria have different strategies for the L types (where they bid $b_L^{FP_1} \in [0, A]$). However, $b_H^{FP_1}$ is unique and this is all that matters to determine revenues.

[37] The derivation of $b_H^{FP_1}$ is standard, see for instance Krishna (2002).

4.2.2 First price auction without screening

Low penalty bidders cannot be prevented from winning the first price auction without screening. Indeed, they are the bidders who are most likely to win. The auction is now FP with asymmetric bidders. To use results form Maskin and Riley (2000) we introduce one more assumption:[38]

Assumption (vi): *for every $r<q$ with r and q belonging to $[B, B+\bar{x_L}]$, $\frac{F_{X_L}(r)}{F_{X_L}(q)} < \frac{F_{X_H}(r)}{F_{X_H}(q)}$.*

On the basis of this assumption[39] we can state the following proposition:

Proposition 1. *A type-symmetric equilibrium exists. In equilibrium two cases are possible: (a) if $[(B-A) > (\bar{x}_H - \underline{x}_L)]$, then type L bidders always bid above the greatest bid of type H bidders; (b) if $0 < (B-A) < (\bar{x}_H - \underline{x}_L)$, then the bids distribution of type L bidders dominates that of type H bidders despite the fact that type L bidders shade their value more than type H, $b_H^{FP_0}(x) > b_L^{FP_0}(x)$.*

Part (a) of the proposition means that if the advantage of the L bidders is very big (they have a very low penalty p_L) they will always outbid the H bidders in equilibrium. Hence, in one type-symmetric BNE type H bidders bid their true value and always fulfill their bid while bidders type L fulfill their bid only if the object has high value and bid:

$$b_L^{FP_0} = B + [x_L - \frac{\int_{\underline{x}_L}^{x_L} F_{X_L}(u)^{n_L-1} du}{F_{X_L}(x_L)^{n_L-1}}]$$

There are other type-symmetric BNE but all are characterized by the same strategies for the type L bidders as the one above. Therefore, the above equilibrium is enough to fully characterize the auctioneer's revenues in the case $[(B-A) > (\bar{x}_H - \underline{x}_L)]$.[40]

Part (b) of the proposition, instead, says that if the advantage of L type over H type is not too big, $[(B-A) < (\bar{x}_H - \underline{x}_L)]$, then L bidders do not necessarily win. However, H bidders are less likely to win because, despite the fact that they bid more aggressively than type L do ($b_H^{FP_0}(x) > b_L^{FP_0}(x)$), their bid distribution is dominated by that of type L.

[38] See Krishna (2002) and the references in it for a discussion of the cases in which an explicit solution for the bidding function can be found.

[39] Notice also that Assumption (vi) is always verified if we assume that both F_{X_L} and F_{X_H} and their supports are identical and equal to F_X. In this case it is easy to verify that the distribution of bidders L valuation is just a rightward shift of the distribution of the H bidders.

[40] Notice that in this case the auctioneer can announce that she will eliminate bids above $(A + \bar{x}_H)$, thus forcing L types to bid less aggressively and bringing H types back into the competition.

4.2.3 Average bid auction(s) with screening

In this section we will characterize bidders' equilibrium behavior both in a "simple" AB and in the Italian AB. Call I_AB the Italian AB whose awarding rule was illustrated in Section 3. Then I_AB$_1$ is the I_AB with screening. Call S_AB an auction where the awarding rule states that the bidder closest to the average (regardless of whether from above or from below) wins and pays his own price. Then S_AB$_1$ is a S_AB with screening. We maintain all other assumptions, including the one that ties are broken with a fair lottery. We begin the analysis form the S_AB. To characterize the BNE of this auction it is useful to further simplify the environment. Assume for the moment that bids are binding (no possibility of default) and that there is no commonly observed component in the valuation. Hence, we have a standard independent private value auction in which (a) each bidder i values this good x_i, where x_i is an i.i.d. drawn from a (publicly known) distribution $F_X(x)$ that is absolutely continuous and has support $[\underline{x}, \bar{x}]$, (b) the payoff for bidder i, drawing a value x_i and winning with a bid b_i, is $(x_i - b_i)$, (c) there are $N > 2$ bidders and this is common knowledge, (d) bids below $\underline{x}$ are not valid. The following proposition characterizes the BNE of the S_AB:[41]

Lemma 2: *For any N, the strategy profile in which all players bid according to the constant bidding function $b(x) = \underline{x}$ for every possible x is a symmetric BNE of the S_AB. Moreover, four properties characterize any other symmetric BNE that might exist. The bidding function (1) is weakly increasing, (2) is flat at the top, (3) has all types greater than the lowest one bidding strictly less than their own value and (4) for any (absolutely continuous F_X) and $\forall$ $\varepsilon > 0$, $\exists$ $N^*_{\varepsilon,F}$ such that $\forall N \geq N^*_{\varepsilon,F}$ the following is true: $|\bar{v}_{\varepsilon,F} - \underline{x}| < \varepsilon$, where $\bar{v}_{\varepsilon,F}$ is implicitly defined by $1 - N(\frac{N-2}{N-1})[F_V(\bar{v}_{\varepsilon,F})(1 - F_V(\bar{v}_{\varepsilon,F}))^{-1}] = 0$.*

The above proposition says that the strategy profile in which all bidders always bid the minimum bid, $\underline{x}$, regardless of their type is always a BNE .[42] Moreover, it adds that any other symmetric BNE that might exist lies close to this one in the sense that the difference between the highest equilibrium bid and $\underline{x}$ can be made arbitrarily small by picking a large enough N.[43]

[41] Notice that this game looks like an auction form of the so called p-mean games analyzed at length in the behavioral literature (see Nagel, 1995 and subsequent works). In particular, under the assumption that bidders do not play weakly dominated strategies, the probability of winning in the average bid auction is that of winning a p-mean game with p=1, N players and messages on $[\underline{x}, \bar{x}]$. Costa-Gomes and Crawford (2006) also study non-Nash initial responses in this kind of games. Despite many interesting results in this literature, I believe that the auctions that I study are more suitable for an equilibrium analysis because in these auctions the players participate repeatedly in the game and put the survival of their firms in the market at stake.

[42] This is the case because if all other bidders are bidding $\underline{x}$ and a bidder i unilaterally deviates by bidding something other than $\underline{x}$, he will be further away from the average bid than the other bidders. Therefore his expected payoff will become zero, whereas, if he had not deviated, it would have been $(1/N)(x_i - \underline{x})$.

[43] Therefore, as N goes to $+\infty$ all symmetric BNE different from $b(x) = \underline{x}$ that might exist converge toward

Notice that with N=2 bidding $\underline{x}$ is the unique equilibrium. With $N > 2$, even though it cannot be guaranteed that bidding $\underline{x}$ is the unique equilibrium, the second part of the proposition ensures that any other equilibrium lies close to it.[44] The reason is that, with $F_X(x)$ absolutely continuous, the function describing the probability that N draws from F_X are all greater than x, $(1-F_X(x))^N$, rapidly becomes more and more convex as N rises. The exact argument is fully developed in the appendix which also presents an example where x is uniformly distributed on $[0,1]$ and it is shown that even with a small N, the highest possible equilibrium bid is not far from $\underline{x}$ and it fast approaches $\underline{x}$ as N rises.[45]

Consider now the opposite case in which the bidders' valuation consists only of the common component. That is, every bidder values the object y, $y \geq 0$. Assume also that the auctioneer does not set a minimum bid but just requires bids to be non negative. In this case there is a continuum of symmetric equilibria in the S_AB as stated by the following lemma:

Lemma 3: *With all the players bidding the same constant, c, in the interval* $[0, y]$ *is an equilibrium. These are the only symmetric equilibria of the S_AB.*

Provided with these results, we can now move back to the full model with type L and type H bidders:

Proposition 2: *Every strategy profile in which all bidders, regardless of their type and their value, bid the same constant value c, where* $c \in [0, \min\{A + \underline{x}_H; B + \underline{x}_L; y - \varepsilon + p_L + \underline{x}_L\}]$, *and always fulfill their bid is a type-symmetric BNE of the* S_AB_0.

In essence the above proposition says that with the average bid auction all bidders bid the same value. Moreover, bidding this value must be individually rational even for the weakest

$b(x) = \underline{x}$.

[44] An idea of the proof can be given assuming that there is an arbitrarily large number of players. In this case, it is easy to show that any non constant bidding function cannot be an equilibrium because it would allow a profitable deviation for all the types required to bid more than the expected value of b. First, notice that $E(b)$ is the value to which the sample average of the bids converges for an arbitrarily large N. Then, consider the types required by the strategy b to bid more than $E(b)$: they can deviate from b and bid less than $E(b)$ in such a way as to leave between their new bid and $E(b)$ the same probability mass that there is between $E(b)$ and the bid prescribed by b for their type. This kind of deviation is feasible, and would leave the probability of winning unchanged while strictly decreasing the expected payment in case of victory. For instance, in the case in which the equilibrium bid distribution is symmetric around $E(b)$, these types could reduce their bid by the double of the difference between the prescribed bid and $E(b)$. Therefore, the only candidate strategies for equilibria are those in which every type is bidding the same constant. Hence, the only possible equilibrium is where every type bids the minimum valuation.

[45] It should be noted that the usefulness of the four properties described above is that they also characterize equilibrium bidding in IPV games with several different forms of elimination of the highest bid like those described in Section 2. Only the exact characterization of the bound, in property four, is affected by the specific rule for automatic elimination.

bidder.[46] The above results can be used to characterize bidding in the I_AB$_0$

Proposition 3: *In the I_AB$_0$ with $N > 4$ there is a unique type symmetric BNE. In this equilibrium all bidders submit the minimum bid and never default.*

Before commenting these results let us introduce the case of the AB with no screening.

4.2.4 Average bid auction(s) without screening

The case of the average bid auction without screening is very similar to the previous one. The equilibrium of the I_AB$_0$ is the same of the I_AB$_1$. For the S_AB$_0$, instead, the only relevant difference is that removing the screening implies that type L bidders cannot be induced to bid so low that they would not default even in the "bad" state of the world. The set of type-symmetric BNE on which we focus is such that: all bidders, regardless of their type and value, bid the same constant value c, where $c \in [0, \min\{A + \underline{x}_H; B + \underline{x}_L\}]$. Moreover, type H never defaults while type L does so only if $x < (y + p_L - \varepsilon - c)$ and the object's value is low.

These results indicate that the I_AB is inefficient and leads to the lowest possible winning price. The equilibrium allocation of the I_AB is equivalent to a random allocation at the minimum price. Both forms of the S_AB are, instead, equivalent to random allocation at a random price. A recent work by Chillemi and Mezzetti (2010) has extended Myerson's optimal selling mechanism result to an environment in which bidders can default. Their result is that, when defaults are very costly for the auctioneer, the optimal mechanism takes the form of a random lottery at the reserve price. It is therefore very interesting to notice the similarity between the average bid auctions and the optimal mechanism. Although I_AB leads to the lowest winning price, this is not the same as revenue minimization because defaults are eliminated. In general, it seems possible to conclude that AB formats reduce the risk of default both because they randomize across all bidders, so that type L have no advantages, and because by eliminating competition they reward the winner with a higher payoff which will make him less likely to defaults. Nevertheless, we do not see any good reason why an AB should be considered better than a lottery. We know from the literature that the proposers of the AB were not aware of the equivalence with a lottery. Therefore, we can only conjecture that the similarities with the optimal mechanism helped the survival of the AB in the market.

Surprisingly, another factor that might explain the longevity of AB in Italy is collusion among firms. AB are conducive to collusion since, starting from a situation of competitive equilibrium, in the S_AB a coalition of 2 bidders can break the equilibrium and win the contract for sure. In the I_AB the minimum coalition size for this is (0.1N+2). Conley and

[46] The fact that the monitoring technology eliminates bidders that would optimally default means that only if type L bidders bid less than $(y + \underline{x}_L + p_L - \varepsilon)$ their bid is not eliminated. Whichever is the lowest value between this latter quantity and the lowest extreme of the valuation distribution of the two groups of bidders becomes the highest possible symmetric BNE bid.

Decarolis (2010) empirically study collusion in the I_AB and argue that competition among cartels raised auctioneers' revenues above what possible in the competitive BNE of the I_AB.

4.3 Revenue ranking of the auction formats

It is now possible to analyze the auctioneer's expected revenues under the different auction formats. The following proposition is the main theoretical result:

Proposition 4: *The expected revenues under the AB auctions with monitoring are strictly dominated by those of the FP with monitoring,* $E[R^{FP_1}] > E[R^{S_AB_1}] \geq E[R^{I_AB_1}]$. *Without knowledge of* I *and* K*, the pairwise ranking of the expected revenues of the FP with monitoring,* $E[R^{FP_1}]$*, of the FP without monitoring,* $E[R^{FP_0}]$*, of the I_AB without monitoring,* $E[R^{I_AB_0}]$*, and of the S_AB without monitoring,* $E[R^{S_AB_0}]$*, is not determined.*

The intuition for the first part of the proposition is straightforward. Once the screening cost is paid, no default can occur and so it is strictly better to use FP_1 which fosters competition among bidders. Moreover, the simple AB is weakly better then the Italian AB because in the I_AB_1 all bidders always bid the minimum bid while in the S_AB_1 there are equilibria in which bidders bid strictly more than the minimum. The idea of the second part of the proposition is that there is always a value of K such that defaults are so costly for the auctioneer that the first price without screening cannot be the preferred mechanism. Analogously, there is always a value of I such that screening is so costly that the first price with screening cannot be the preferred mechanism. Therefore, there are combinations of high screening cost and high default cost for which the AB are better than the FP formats. However, without knowledge of K we cannot even rank I_AB_1 and S_AB_1 since in the second defaults have a positive, albeit small probability of occurring. Overall, our theoretical framework suggests that a rather large I is needed to rationalize the choice of Italian administrations of using AB. The empirical analysis that follows aims to estimate a bound for I.

5 Data

For this research I collected a new set of data on Italian public procurement auctions for works which are alternately run under a version of the AB rule or under the FP rule. Variations in auction format are rare and, therefore, these data are rather unique. Moreover, to my knowledge there are no other empirical studies of the AB auctions.

The data collected are grouped into two samples.[47] The first sample, called IE sample, contains all the AB and voluntary FP auctions for road construction works (mostly pavings and roundabouts) worth less than €2.5 million held between November 2005 and December

[47] See also the web appendix for a description of the data.

2009 by counties and municipalities in five regions in the North of Italy (Piedmont, Lombardy, Veneto, Emilia and Liguria). It is part of a broader datest containing information on all Italian public procurement auctions for works that I bought from an "information entrepreneur". An information entrepreneur is a private firm that sells to bidders information about both forthcoming and awarded auctions. Table 4 reports the summary statistics. For approximately 2,000 of these auctions I have both the bids and the identities of all participants. The summary statistics indicate that FP auctions attract less bidders, on average 9 compared to 57 in the AB. Moreover, in the FP sample the winning discount, the reserve price and the measures of the size of the PA are greater than the counterparts in the AB sample. However, the average discount in the AB is not zero as required by BNE behavior. This issue will be addressed in the next section. This IE sample does not contain the FP that administrations were "forced" to use (i.e. FP auctions held by PAs that always use AB when it is allowed). In the next section I will explain how I used these extra auctions.

TABLE 4: Summary Statistics for AB & FP Auctions - IE sample

	AB Auctions				FP Auctions			
	Mean	SD	Median	Obs.	Mean	SD	Median	Obs.
Contract:								
Reserve Price/1,000	364	319	262	1,826	522	483	305	356
Duration (Days)	171	121	140	794	213	151	180	134
Auctioneer:								
Miles PA-Turin	151	71	145	813	52	71	1	134
Experience	13.3	30.8	4.3	1,826	28	16	38	361
Population/1,000	247	495	29	1,826	1,038	849	901	361
Winner:								
Bid (discount)	15	5	15	1,826	31	10	32	361
Miles Winner-Work	58	108	28	812	48	108	16	134
Number of Bidders	57	41	49	1,826	9	7	7	361

My second sample, called Authority sample, comes from the database of the Italian Observatory for Public Contracts which contains information on the life of all public contracts above €150,000. The earliest auctions in this sample are from 2000 while the latest are from January 2008. This sample does not contain the bid and identity of all the bidders but only of the winning bid together with the minimum and maximum bids submitted. However, it contains several useful categories of ex post information on the auctioned contracts (like the amount of renegotiation and whether a default occurred). Several summary statistics are reported in Table 5. Unfortunately, this sample does not allow for a fine distinction of the kind of public works involved. Moreover, since the first national reform dates from July 2006, the complete ex post information is available only for very few post-reform auctions. However, the interesting feature of this sample is that two of the biggest PAs of the Piedmont region, the county and

municipality of Turin, had already switched to the FP in 2003. This implies that many of the jobs they procured have by now been completed. The auctions held by Turin are, thus, the core of my analysis of bidders' ex post behavior in FP auctions.

TABLE 5: Summary Statistics for AB & FP Auctions- Authority Sample

	AB Auctions				FP Auctions			
	Mean	SD	Median	Obs.	Mean	SD	Median	Obs.
Contract:								
Reserve Price/1,000	477	407	323	12,705	656	508	469	639
Duration (days)	235	158	180	9,231	301	142	325	565
Auctioneer:								
Experience	12	133	29	12,701	781	276	960	639
Population/1,000	241	536	27	12,611	1,298	613	901	639
Winner:								
Bid (discount)	11.9	6.0	11.9	12,621	32.6	9.6	33.2	634
Number of Bidders	31.4	33.1	22	12,622	8.2	6.0	7	639
Ex Post Variables:								
ΔC (% Cost Increase)	5.8	10	4	4,895	14	5	12	217
ΔT (# Days of Delay)	161	184	114	5,933	90	120	59	337

Various other data have been collected for this analysis. In particular, detailed firms' financial and ownership data was obtained from the Bank of Italy. Moreover, data on characteristics of the PAs was obtained form the ISTAT (Italy's national statistical institute). The Web Appendix gives further details about all the data used.

Finally, since the reserve price will play an important role in my analysis, it is worth discussing here. In the auctions that I analyze, the PAs are not in full control of the reserve price. The PAs' engineers evaluate the types and quantities of inputs needed to complete a project. However, every year regions set prices for inputs to which counties and municipalities must adhere. Among the reasons that led me to select the five Northern regions as the focus of my analysis, was the similarity of the prices these regions set for the main inputs.[48] Furthermore, in the case of simple roadwork jobs it seems plausible to assume that there is not too much discretion in the types and quantities of inputs to use. The technology of the work determines them. Moreover, since the geographical area that I study is rather homogeneous, similar roadwork jobs likely require the same types and quantities of inputs in all the PAs in my sample. In light of this reasoning I assume that the reserve price is not in the hands of the single auctioneer and that the reserve prices of different PAs are drawn from the same distributions. Finally, as regards the assumption that the reserve price is not binding, I found overwhelming support for

[48] The Web Appendix reports data from all Italy and shows that in the South the average winning discounts are much higher than in the North. The likely reason for this is that prices in the South are often more inflated than in the North.

this assumption from market participants (both PAs and firms) who explain this fact with the inflated prices that regions post. Moreover, as the summary statistics clearly illustrate, there is very broad participation at AB auctions. This may be seen as an indication that even inefficient firms have a positive expected payoff conditional on winning the auction at the reserve price. On the other hand, discounts in the FP are frequently around 40% or above. The last point that is worth noting is that PAs cannot set the reserve price in a different way on the basis of the auction format chosen. This should be clear from the description of how the reserve price is set given above. However this is also confirmed by a regression analysis of the reserve price on a list of regressors including the FP dummy. For this dummy, the results (in the Web Appendix) do not indicate any statistically significant effect.

6 Reduced Form Analysis

6.1 Empirical Strategy

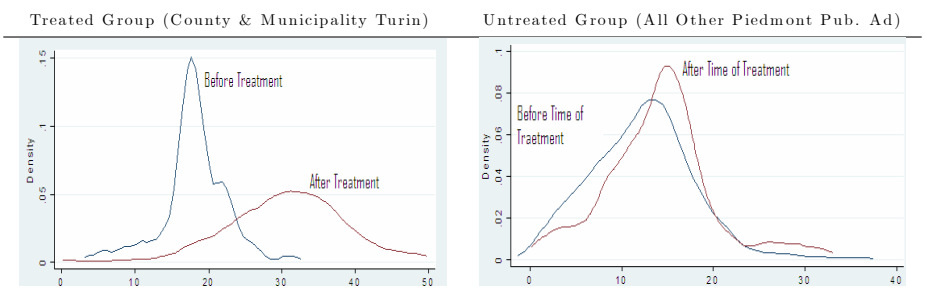
The reduced form analysis is based on data from both the Authority and the IE samples. A reduced form analysis of bids is useful to assess whether the observed bidding behavior is compatible with the equilibrium predictions of the model developed. To perform this analysis I look at all bids submitted in each auction in the IE sample and divide this sample in two subsamples according to whether the format is AB or FP. Then, for each of these two samples, I run least squares regressions for a reduced form analog of the bidding function. This analysis will show that bidders' behavior in AB is not compatible with BNE bidding. However, I will argue that bidders' collusion is the most likely explanation for this and illustrate an alternative, atheoretical "rule of thumb" approach to approximate the auctioneer's expected revenues in AB. This information is necessary to study the choice of the auction format. For the same reason it is crucial to observe ex post outcomes. The auctioneer's interest likely lies more in the final price than in the price that wins at the auction stage. The Authority Sample contains ex post information about costs. As explained in Section 5, Turin's policy change in 2003 allows me to estimate the effect of FP not only on the winning discount but also on the amount of renegotiation and the probability of defaults. In particular, a Difference-in-differences model is used to assess the effects of a transition toward FP on a dependent variable Y, conditional on time (B) and auctioneer (A) dummies and on a set of covariates (X):

$$Y_{ist} = A_s + B_t + cX_{ist} + \beta FP_{st} + \varepsilon_{ist}$$

Since Turin was not randomly assigned to use FP but decided to do so autonomously, an endogeneity problem is likely to bias β. Therefore, the control group in the Diff-in-diff cannot be any random sample of administrations using AB. In light of the role that administrations' size and geography seem to play, I constructed several control groups by selecting only admin-

istrations similar to Turin in terms of population, experience and population.[49] This implies assuming that for each of them the switch to FP would produce, all else equal, the same effect observed for Turin.[50] Figure 6 illustrates, for the case of the winning discount, the type of variation that the Diff-in-diff captures:

Figure 6: Winning Bid Densities



A robustness check is performed using the data in the IE sample. Although this sample does not contain ex post data, it can be useful to evaluate the results concerning the winning bid. Both ordinary least squares (OLS) and propensity score matching (PSM) regressions are presented. The PSM is particularly interesting because using the score to decide which observations to match helps to evaluate the choice of the control groups made in the Diff-in-diff. Finally, I take advantage of the 2008 reform to try to correct for the endogeneity problem. After that date the FP became compulsory for auctions above €1 million. I also argued the auctioneer is not in control of the reserve price. Therefore, data from this policy could potentially allow estimation of an unbiased effect of FP. However, my sample of auctions worth more than €1 million and held after this reform is small, only 30 observations. Therefore, I will only use the analysis of this sample as a way to further check my other estimates. In particular, I use a regression discontinuity design around the €1 million threshold.

6.2 Results

The results of the reduced form analysis concern three main questions: do the observed firms' behavior in AB and FP appears to be consistent with the BNE predictions; is there any empirical content in the assumption that the auctioneer, on average, improves her revenues by switching format; do the observed first price auctions have ex post screening or not?.

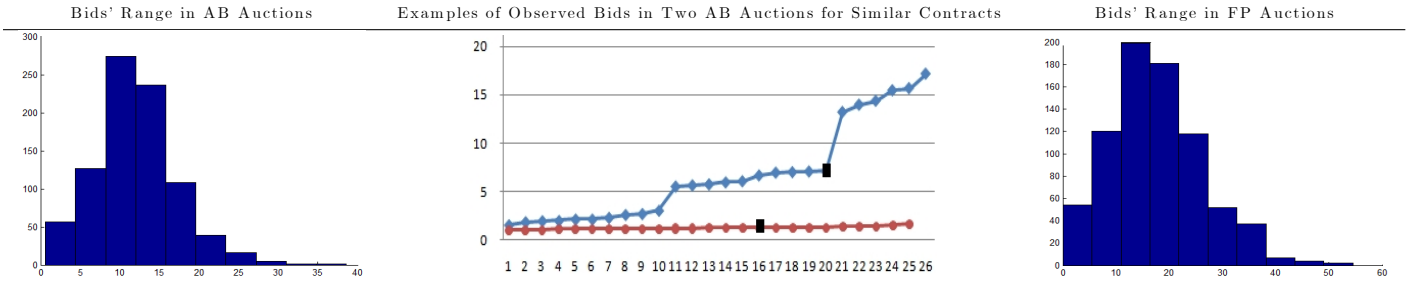
[49] All local administrations that have more than 500,000 people in their territory form the first control group, while all local administrations that in the sample have more than 200 auctions form the second control group. I also interact the requirement that a PAs is whithin the same region of Turin and that its population is at least 50,000.

[50] Clearly, the external validity of such estimates cannot be claimed for the case of administrations with very different resources from Turin.

1) Bidding Behavior in AB and FP

The model in Section 4 illustrates that all bidders should bid a zero discount in AB auctions. The summary statistics of Section 5 already showed that this is not the case. Moreover, the analysis of the bids in the IE sample reveals great variety in the bidding patterns. Figure 7 reports the histograms of the bids' range (the within auction difference between maximum and minimum bid). Although the range is much wider in the FP, in the AB it is clearly not zero. Among all AB auctions, only the 0.7% have a range less than 1 (i.e. bids differing by less than 1% of the reserve price). An example of how different bidding patterns in AB look even for auctions that to the econometrician look almost identical is reported in the center of Figure 7. Bids are sorted from the lowest to the highest discount. The number of bidders is 25 in one case and 26 in the other. Moreover, all other possible relevant dimensions are close (geography, reserve price, time, etc.). However, bidding in the two auctions looks rather different. Within the IE sample, apparently, a large variety of bidding patterns emerge.

Figure 7: Histograms of the Bid's Range in AB & FP, Plus Example



More formally, Table 6 reports the results of OLS regressions for a standard reduced form specification of the bidding function (see Bajari et al., 2007 and Krasnokutskaya, 2009). The dependent variable is the discount offered. It has been suggested in the literature that the private cost dimension may be proxied by the geographic distance between the firm and the site of the work. In Table 6, for each of the two samples I look at the effect that distance and other covariates have on the winning discount. The results for the FP samples are those reported in the first three columns. Consistent with the theory, firms further away from the job offer lower discounts. This result is unaffected by the inclusions of firm specific (a limited liability dummy and the level of capitalization) or contract specific (the reserve price, the duration and the number of tasks) controls. However, the coefficient of the distance variable is significant only in the specification without the auction fixed effects and this may indicate that the common cost component prevails over the idiosyncratic one (Section 7 address this issue).

TABLE 6: Bidding Function Reduced Form Estimates

	FP Sample			AB Sample		
Constant	-20.77	-21.20	29.04	.68	6.08	30.89
	(11.92)*	(12.41)*	(.67)***	(3.24)	(4.77)	(.16)***
Log(Miles Firm-Work)	-1.04	-1.04	-.43	0.37	.35	.03
	(.31)***	(0.32)***	(.32)	(.11)***	(.10)***	(.04)
Unlim. Liability Firm	1.29	1.25	1.46	-.70	-.75	.10
	(1.09)	(1.08)	(1.59)	(.21)***	(.20)***	(.10)
Firm's Capital (million)	.99	0.92	0.46	-.14	-.11	.07
	(3.17)	(3.16)	(2.63)	(.09)	(.08)	(.06)
Log(Reserve Price)	3.59	3.65		.90	.42	
	(.97)***	(1.04)***		(.25)***	(.44)	
No. Tasks	-.76	-.78		.02	.003	
	(.70)	(.73)		(.13)	(.13)	
Duration (days)	.01	.01		-.002	-.001	
	(.01)	(.01)		(.002)	(.002)	
No. Bidders		-.03				
		(.18)			.007	
Fixed Effects^			Yes		(.007)	Yes
Observations	674	674	674	33,731	33,731	33,731
R^2	.18	.18	.58	.03	.03	.66

* significant at 10%; ** significant at 5%; *** significant at 1%. Robust Std. Err. in parentheses.

(^) Dummy variables for both the auction and the time of the auction.

The dependent variable is the discount offered. Data from the IE sample used with all the bids in all auctions.

An different result, instead, emerges for AB auctions. The last three columns of Table 10 show that without fixed effects the proxy for the private cost has the "wrong" sign. With fixed effects the coefficient becomes statistically insignificant. Moreover, none of the other covariates seem to matter once the fixed effects are included. The competitive BNE prediction of flat bids would be compatible with bids that are unrelated to measures of private costs. However, we have already seen that bidding patterns are not flat. Therefore, bids do not conform to the BNE and our regression does not help to assess the determinants of bids. How bidders bid in AB auctions remains unclear. Conley and Decarolis (2010) explore whether bidders' collusion might be the explanation to this puzzle. In Section 4 I discussed why AB auctions are conducive to collusion. Moreover, the Italian judicary recently condemned numerous firms for colluding in AB auctions for roadwork contracts in the North. For instance, in Piedmont eight cartels had been competing to win AB auctions between 1998 and 2002. Developing an equilibrium model of competition among cartels in AB auctions is beyond the scope of this paper and we leave the analysis of collusion to the work of Conley and Decarolis (2010). On the other hand we will next discuss a simple atheoretical, rule of thumb that bidders in AB auctions use to decide how to bid and that, in turn, allows us to form a rough approximation of what could be

the auctioneer's expected revenue.

2) Auctioneer's Revenues

A measure of the expected revenues is needed to study the rational choice of the auction format. Therefore, in this section I present two results that are useful to understand how auctioneer's expected revenues might be formed. The first result is an atheoretical rule of thumb that shows how the auctioneer might use past winning bids to form an expectation over the winning bid. The second result is an analysis of contract renegotiations in AB and FP.

2.1) "Rule of Thumb" Approach: Focal Bids in AB

The strategy space of an auction game with an uncertain number of cartels competing in an AB auction is a complicated object, even within a stylized model. Since the reality is even more complex, it is not surprising that firms have developed rules of thumb to guide them. Italian firms actively search for data on past auctions and use this information to decide their bids.[51] In particular, it is commonly known by both firms and PAs that each PA gets "stuck" at a certain value on which most of the bids converge. An example will clarify this point. All of Sicily Island is stuck at a winning discount of 7.3xx. That is, a firm that wants to win a public contract has only to decide the few decimals it wants to add to the 7.3 discount. The firm already knows that all other bidders are doing the same and, hence, converging to 7.3 is the only way to be close to the average. More generally, interviewing firms and PAs I discovered that they all knew "focal" values at which the various PAs in their area were stuck. The data in our sample can be used to check whether there is evidence in support of the presence of these "focal bids". The following OLS regression is estimated using the large cross section of AB auctions in the Authority sample

$$B_i^w = \alpha X_i + \beta B_i^{w-1} + \varepsilon_i$$

β	Robust S.E.	R^2	Obs.	Covariates
.81	(.04)	.43	1,570	if X=1
.72	(.05)	.54	1,566	if X=1+Z

where the dependent variable, B_i^w, is the winning discount and B_i^{w-1} is the average of the winning discounts taken over all auctions held by the same auctioneer in the previous 365 days and for contracts similar to B_i^w (in terms of type of work and reserve price). The X is a matrix of covariates: the estimates presented below consider the case in which X is just a vector of ones and that in which, in addition to the constant, it includes the matrix Z (consisting of the log reserve price, the number of bids and dummies for the auctioneer). Although neither of the two coefficients is equal to one, these results seem to indicate that, at a first approximation,

[51] Indeed, according to one of the so called "information enterpreneurs", IE, that sell these data to construction firms, at least 80% of the firms in the market are served by one IE.

for an auctioneer who has already played the auction game, past winning bids can give a rough indication of what winning bid will be selected if he keeps on using AB. Therefore, this result gives a useful, although rough way to pin down the expected winning bid in AB auctions even without a formal analysis of the exact strategy of the cartels. I will use this result in the following section about structural estimation to analyze the choice of a PA between AB and FP. The limitation is that the results will apply only to PAs for which I have data on past AB. Moreover, I will be unable to simulate the behavior of the cartels.

2.2) The Effect of the Auction Format on Winning Bid & Final Cost

An analysis of the winning bids and ex post costs is useful to identify whether the choice of switching format is compatible with revenue maximization. The first point to notice is that we observe contract renegotiations occurring under both AB and FP but defaults are extremely rare. In particular, in all the Authority sample there is no single bankruptcy case associated with FP and only 12 defaults out of the 17,000 contracts auctioned with AB.[52] Although this result may seem surprising for FP auctions, the final part of this section argues that this is consistent with other evidence indicating that those observed are with screening. Hence, defaults should not occur in equilibrium.

As regards winning bids and renegotiations, Table 7 presents the results of the Diff-in-diff estimates. They indicate that a switch to FP is associated with a large increase in the winning discount. The increase is around 10% of the reserve price. This estimate is robust to the inclusion of various controls and to the choice of different control groups. Nevertheless, renegotiation also increases with FP. Renegotiation is measured as the difference between the winning bid and the final price and it is expressed as a percentage of the original contract value.[53] The estimates obtained indicate a positive and significant increase in renegotiations. However, this increase is lower than the increase in the winning discount, thus suggesting that an auctioneer switching from AB to FP would save between 3 and 5% of the reserve price.[54] This does not seem to be a large saving. Moreover, the calculation of the saving is likely to be rather imprecise because of the presence of transaction costs that make each renegotiated dollar cost more than one dollar. Moreover, if the FP were with screening, also the (unobserved) cost of the screening technology was paid.

[52] This is true within our sample but defaults are present in the broader dataset of the Authority for Public Contracts from which I created my sample. However, defaults are often associated with the most expensive contracts and my Authority sample contains only contracts worth at most 2.5 million euros.

[53] In my database the variable "final price" is measured with error. At the end of Table 4, I briefly describe the three measurements used as a proxy for the true final cost of procurement.

[54] Moreover, Table 7 indicates that there is no statistically significant association between the change in the auction format and the ex post changes in the number of days taken to complete the work.

Table 7: Diff-in-diff for Winning Bids & Renegotiations

$$Y_{ist} = A_s + B_t + cX_{ist} + \beta FP_{st} + \varepsilon_{ist}$$

	Control: Pop. > 500,000		Control: Exper. > 50		Control: Piedmont & Pop>50,000	
	W Bid	Reneg.	W Bid	Reneg.	W Bid	Reneg.
β	9.28	5.66	9.52	7.00	9.45	6.09
	(1.33)***	(1.90)***	(5.26)	(1.37)***	(1.39)***	(2.10)***
Obs.	1251	1251	1095	1095	769	769
R^2	0.74	0.20	0.36	0.16	0.72	0.18

Data from Authority sample. Standard errors clustered by administration and year. * signif 10%; ** signif 5%; *** signif 1%

In the column on the left X is a vector of ones while in the colum on the right X also includes log(Res. Price) and dummies for work type.

The above estimates used the Authority sample and are based on the policy change in Turin. However, it is possible to check whether in the IE sample there is evidence that the switch to FP affects the winning discount. Table 8 shows that a similar increase in the winning bid is estimated using OLS, 12 %, and PSM, 11 %.[55]

[55]I use only observations that have a score (according to the probit regression in Table 8) that is greater than 0.025 and lower than 0.975. This reduces my Reform Sample from 933 to 422 observations. Figure 1B plots the density of the propensity score for both the full (933) and selected (422) samples.

TABLE 8: Winning Discount OLS & PSE Estimates

Probit Regression, Pr(FP=1)		
Log(Pop)	0.580	(0.20)***
Experience	-0.007	(0.00)***
Log(Dist.Turin)	-0.476	(0.07)***
Municip. Dummy	-0.040	(0.24)
Regions Dummies	Yes	
Log(Res.Price)	-0.083	(0.22)
Days to Complete	0.002	(0.00)***
P-Value Chi^2		0.000
Obs.		933

* signif. a 10%; ** signif. at 5%; *** signif. at 1%. SE. in parentheses.

Notice: of the 933 obs., only 422 have a propensity score >0.975 & <0.025.

Winning Discount Regressions		
	OLS	Matching
First Price	12.00	11.01
	(1.18)***	(0.94)***
Observations	422	422
R^2	0.68	-

* significant at 10%; ** significant at 5%; *** significant at 1%

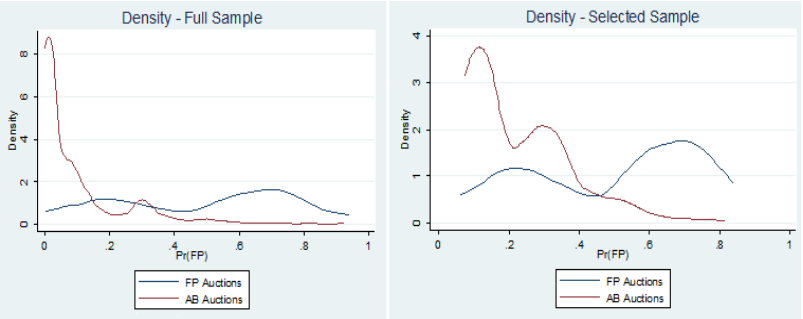
Robust standard errors are in parentheses.

IE sample . All covariates of the Probit regression included.

Nearest Neighbor Matching for ATE using 4 matches,

PSM with bias adjustment and robust standard errors.

Figure 8: Density of the Propensity Score



Finally, I address the concern that, since the choice of FP was voluntary, my estimates are plagued by an endogeneity bias. The policy change of 2008 is potentially ideal to address this issue. However, since I have only 30 FP auctions that were run under the new regulation, I just present the results as a check of the previous estimates. Using a regression discontinuity approach we obtain:

$$Y_i = \alpha + \beta D_i + \gamma x_i + \varepsilon_i$$
$$\beta = 9.7\ (3.7); \quad R^2 = .24; \quad \text{Obs.}=129\ (30 \text{ with D}=1)$$

Where: Y_i is the winning bid; x_i is the reserve price; D_i is a dummy equal to one if $x_i >$€1 million and zero otherwise. The estimates reported (using clustered standard errors) show a statistically significant effect of FP with a magnitude broadly in line with the previous estimates.

3) FP auctions with or without screening?

In addition to the lack of bankruptcies, at least four more pieces of evidence support the idea that the FP auctions in my sample involve an ex post screening of bids.

a) Mandatory screening and its application: The two policy changes that extended the role of FP over AB both required to conduct FP with screening. The obvious question is whether the regulatory prescription is followed or not. Indeed, in my data the administrations that use the FP appear to actively screen bids. In about 10% of the auctions in the IE sample, the contract was not awarded to the highest bidder because his bid was judged abnormal. A similar result is also true for the auctions held by Turin after its 2003 reform. Moreover, the Diff-in-diff estimates (reported in the Web Appendix) of the effect of a switch to FP on the time that it takes to award the contract after all bids are opened indicate an increase of almost 14 days. This extra time may be justified as the time needed for an attentive ex post screening of FP bids.

b) The selection into the usage of FP: As discussed in Section 3, FP appear to be used by larger PAs and these PAs are more likely to have a lower unit cost of the screening technology.

c) Drop in the number of bidders: Table 9 presents estimates of a negative binomial model for the effect of the switch from AB to FP on participation. The switch is associated with a drop of about 40 bidders per auction.[56] The interpretation of the effect of the auction format on the number of bidders is rather complex and likely regards not only the screening but also the end of forms of collusion specific to AB and the increased competition in FP. Conley and Decarolis (2010) study this issue in greater detail. However, this result is compatible with an effective screening of bidders.

TABLE 9: Number of Bidders Regressions

	Authority Sample°		Reform Sample	
	NEG.BIN^	Pred.Change	NEG.BIN^	Pred.Change
First Price	-1.84	-38.32	-1.85	-44.96
	(.15)***		(.09)***	
Observations	2,548		2,210	
P-Value Chi^2	.000		.000	

Pred.Change is the predicted discrete change of the number of bidders due to FP switching from 0 to 1.

Robust standard errors are in parentheses, clustered by administration and year.

* significant at 10%; ** significant at 5%; *** significant at 1%

^Log(Res.Price) and dummy variables for type and geographical location of the PA included.

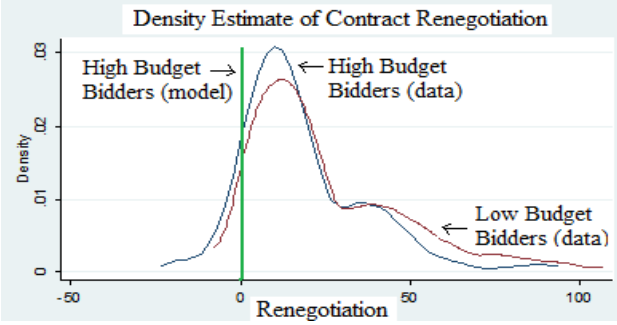
°Control group: all the PA with population $>$ 500,000. Results are very close with the other control groups.

d) Winners' optimal default decision: A strong indication that FP auctions are with screening comes form an in depth analysis of renegotiations. To the extent that renegotiations reflect

[56] The variable measuring the number of bidders in both my samples is highly not normal (the skewness and kurtosis are respectively much greater than zero and three). Therefore the model I use is that of a negative binomial regression with robust standard errors. The negative binomial model is preferred to a Poisson regression because the variance of the number of bidders variable is quite a bit larger than its mean and the estimated coefficient on over dispersion in the negative binomial model is statistically different from zero.

the auctioneer's concessions when the threat of bankruptcy is credible we should expect a renegotiation to occur in equilibrium only when the firm is a low penalty type. Therefore, if the FP auctions in my sample were without screening, we would expect a positive probability of a renegotiation conditional on a victory by a low penalty bidder and no renegotiation at all conditional on a victory by a high penalty bidder. To test this key prediction I collected data on firms' budgets from Infocamere (the database of the Italian Registry of Firms in the version managed by the Bank of Italy). However, the result that I obtain is that the same contract renegotiation takes place regardless of the size of the penalty of the winner. The picture below shows this result for the case in which the firm's budget is taken as a measure of the penalty.

Figure 9: Contract Renegotiations



As before, renegotiations are measured as the difference between the winning bid and the final price and are expressed as a percentage of the reserve price. The budget, instead, is the firm's underwritten capital. I consider a winner as "low budget" if his underwritten capital is less than the difference between the auction's reserve price and his bid.[57] A "high budget" winner is one that is not "low budget." Although the average renegotiation of low budget winners exceeds that of high budget winners the difference is not statistically significant. Moreover, I tried operationalizing the idea of high/low penalty bidders with numerous other possible measures of the firm's own inflicted damages in case of default. However, with these other measures I was not able to identify any significant difference in the behavior of the two groups of winners.[58]

[57] Hence, I am assuming that if the contract turns out to be "bad" its execution will cost the firm an amount equal to the auctioneer's reserve price. Other definitions of high and low types were tested obtaining very similar results.

[58] I also tested these behavioral implications using different concepts of penalty but the result was always the same. For instance, I explained in Section 2 why the distance from the auctioneer could be used to divide bidders into low and high penalty. However, as with the capitalization, I could not detect significant differences in the renegotiation behavior conditional on the distance between the winner and the PA.

7 Structural Estimation

The usefulness of a structural estimation approach is that it allows one to infer quantities that are not directly observable in the data but that might be crucial for policy analysis. This section deals with the identification and estimation of the underlying distribution of the bidders' valuation. It also presents estimates, based on this inferred distribution, of the firms' markup under the AB and FP auctions, of the relative allocative efficiency of the different auction formats and of the size of the screening cost.

Given the combined results of the theoretical analysis and the reduced form analysis, there is no clear way to use bids in the AB auctions to infer the firms' costs. Instead, the previous results show that it seems plausible to assume that the sample of FP that we observe consists of FP plus screening. Moreover, the combined results of the reduced form bidding function, the drop in the number of bidders and the aggressive discounts seem compatible with the assumption of competitive behavior in the FP. Moreover, none of the main theoretical predictions change if we assume that in an FP with screening, type L bidders do not participate.[59] The assumptions that FP auctions are with screening and that all bidders compete and will never default allows me to use the observed bids in the FP sample to recover firms' costs. The approach that I use to estimate the underlying bidders' valuations is based on the extension by Krasnokutskaya (2004) of the fundamental result of Guerre, Perrigne and Vuong (2000) (GPV from now on) that the first order condition of a bidder's problem can be expressed in terms of observables. The approach proposed by Krasnokutskaya is based on statistical deconvolution and, in essence, allows one to recover the underlying distributions of both the private and the commonly observed components of bidders' valuations from observed bids. The first paper to propose the use of deconvolution was Li and Vuong (1998) in the context of a classical measurement error problem. The methodology was later applied to auctions by Li, Perrigne and Vuong (2000), Krasnokutskaya (2004) and Asker (2008). My application of deconvolution is very similar to that applied in two latter two papers.

7.1 Identification

The identification strategy follows very closely that of Krasnokutskaya (2004). Valuations are not directly inferred from bids and their distribution as in GPV. Instead, a deconvolution technique is used to back out the underlying distributions of both the privately (X) and the commonly (A) observed components of firms' valuations from data. Identification is proved for the case in which the winning bid, the reserve price and the average value of ex post contract renegotiation are available for a sample of identical auctions. Roberts (2008) presents a different approach to the issue of identification and estimation of the distributions of private valuations and unobserved heterogeneity when only data on the reserve price and the winning bid are

[59] Low penalty bidders do not have an equilibrium strategy that gives them a strictly positive expected payoff.

available.

First of all, since in the estimation I will need to use the auctioneer's announced value, I shall abandon the notation of bids as discounts over this value and use standard procurement terminology. Therefore, the firm's payoff in case of victory is the bid minus the cost, $(b-x)+A$, where $A=(y-\theta\varepsilon)$. Moreover, since the reduced form analysis indicates a significant association between FP auctions and contract renegotiations, I modify the bidder's problem to account for the possibility of an ex post increase in the payment they will receive. I abstain from modeling the bargaining process behind this renegotiation. Instead, I assume that every bidder knows that the average amount of renegotiation is ηr, where r is the reserve price and $\eta \in (0,1)$. Every bidder expects to receive an extra payment of ηr if he wins. Apart from these modifications all the model's assumptions are kept unchanged and so (2) can be expressed as:

$$b_H^{FP_1} = (A-\eta r) + [x_H + \frac{\int_{x_H}^{\bar{x_H}} [1-F_{X_H}(u)]^{n_H-1} du}{[1-F_{X_H}(x_H)^{n_H-1}]}] \qquad (2')$$

The monotonicity of this bidding function allows us to use the GPV's procedure of inverting the distribution of costs into that of bids. Moreover, since ηr is observable it can be added to the bids. Using these transformed bids and abandoning the subscript H, equation (2') becomes:

$$x = [b - \frac{[1-F_B(b)]}{(N-1)f_B(b)}] - A \qquad (2")$$

where the bid b and the relative cdf and pdf, $F_B(b)$ and $f_B(b)$, are conditional on $A=0$. I will denote the random variable of these (unobserved) conditional bids by B. I also denote by B_w (winning bid) the random variable consisting of the lowest order statistics (out of n draws) of B. I will also denote with $\tilde{B}_w$ the observed winning bid. Since we do not observe A, the observed bids cannot be used directly to get B and, through it, identify F_X through the GPV approach. Notice that this is a standard problem of unobserved heterogeneity.

Krasnokutskaya solved this problem using data from many auctions with multiple bids in each of them. My Authority sample does not contain all the bids submitted by all bidders. However, it contains both the winning bid and the reserve price. To use her method with my data Assumption (iv) is replaced by the following:

Assumption (iv'): *(Reservation Price) The (non binding) reservation price, r, is such that $r = A + x_r$ where x_r is the realization of a random variable X_r independent of Y and X_H and is distributed on a finite support whose lower bound is not lower than $\bar{x_H}$. (The reservation price is thus a random variable that will be denoted by R)*

The rationale behind this assumption is that the auctioneer observes what all the bidders commonly observe, A. The maximum price that she is willing to pay is equal to the sum of this

commonly observed cost and another component that could be intended as the bid that the most inefficient firm in the market would make if $A = 0$. Notice also that I am requiring that, if the data come from different auctioneers, all these auctioneers are symmetric. Assumption (iv') allows us to use the method of Krasnokutskaya with very sparse data: winning bids and reserve prices. This is an interesting result because it shows a simple way to address the problem of unobserved heterogeneity using the informational content of the reserve price.[60]

Moreover, a normalization is also needed:

Assumption (viii): *(Normalization)* $E(B_w) = 0$.

Under assumptions (i) to (vii) we can apply to $\tilde{B}_w = A + B_w$ and $R = A + X_r$ a result, due to Kotlarsky (1966), that the characteristic function of the sum of two independent random variables is equal to the product of the characteristic functions of these variables. Analogously to what is shown in Krasnokutskaya this allows me to identify the characteristic functions of A, B_w and X_r from the joint characteristic function of $\tilde{B}_w$ and R_p . This joint characteristic function is in turn identified non parametrically from the observed data $(\tilde{B}_w,\ R_p)$. Once the distribution of B_w is identified it can be used to generate a sample of pseudo-winning-bids. This sample can then be used to generate a sample of pseudo-lowest-costs through a standard GPV procedure. This step amounts to the inputting of the pseudo-winning-bids into (2') setting $A = 0$ and noticing that in equilibrium the identification of the distribution of B_w identifies the distribution of B according to the following relationships:

$$F_B(b) = [1 - [1 - (F_{B_w}(b))^{1/n}]] \quad \& \quad f_B(b) = \frac{f_{B_w}(b)}{N[1-(F_{B_w}(b))^{1/n}]^{n-1}} \quad (*)$$

Finally, once we have a sample of pseudo-lowest-costs this can be used to identify the pdf and the cdf of the pseudo-lowest-costs non parametrically. The formula in (*) can also be applied to the pseudo-lowest-costs to obtain the pdf and the cdf of the pseudo-costs, which is the desired distribution of X.

It is worth noticing that essentially the same procedure could be applied using another instrument instead of the reserve price. For instance, using all bids in a sample of auctions where two bidders participate. Moreover, a recent study by Hu, McAdams and Shum (2009) illustrates that neither independence of all the components nor additive (or multiplicative) separability are essential for the identification.

[60] Notice also that this result does not readily extend to the case of asymmetric bidders.

7.2 Estimation

The data observed by the econometrician consist of m auctions. For each of them $(n_i, b_i^{w_0}, b_i^{l_0}, \eta, r_i, z_i)_{i=1}^m$ are recorded, where n_i is the number of bidders, b_i^w is the winning bid, b_i^l is the last classified bid (i.e. the bid furthest away from the winning bid), η is the average renegotiation (expressed as a percentage of the reserve price), r_i is the reserve price and z_i is a vector of auction characteristics. The estimation procedure described below is for the case of a subsample with $n_i = n_0$ and $z_i = z_0$. The procedure can be extended to account for observed heterogeneity using the homogenization approach of Haile et al. (2004).

The estimation method closely follows the identification procedure and consists of the following steps:

1) Transforming the bids to account for expected renegotiation:

For every auction i the value ηr_i is added to both $b_i^{w_0}$ and $b_i^{l_0}$. The resulting bids are indicated respectively with b_i^w and b_i^l. They are the bids used in the following steps.

2) Estimation of the distributions of the common and idiosyncratic components of bids:

As discussed for identification, we first need to estimate the joint characteristic function of a winning bid and the relative reservation price. This is done non parametrically using:

$$\hat{\psi}(t_1, t_2) = \frac{1}{m} \sum_{j=1}^{m} \exp(it_1 b_j^w + it_2 r_j)$$

Where i denotes the imaginary number. Then, the result of Kotlarski is exploited together with the normalization and independence assumptions to estimate the characteristic functions of the common and idiosyncratic components of bids using:

$$\hat{\phi}_A(g) = \exp \int_0^g \frac{\partial \hat{\psi}(0,t_2)/\partial t_1}{\hat{\psi}(0,t_2)} dt_2$$

$$\hat{\phi}_{B_w}(g) = \frac{\hat{\psi}(g,0)}{\hat{\phi}_A(g)} \quad \text{and} \quad \hat{\phi}_{X_r}(g) = \frac{\hat{\psi}(0,g)}{\hat{\phi}_A(g)}$$

Finally, the estimated densities of A, B_w and X_r are obtained through an inverse Fourier transformation:

$$\hat{g}_u(q) = (2\pi)^{-1} \int_{-T_u}^{T_u} d_{T_u}(t) \exp(-itq) \hat{\phi}_u(t) dt \quad \text{where } u \in \{A, B_w, X_r\}$$

and where d_{T_u} is a dumping factor that reduces the problem of fluctuating tails.[61] The

[61] This factor is constructed like in Krasnokutskaya (2004) so that $d_{T_u}(t) = 1 - (|t|/T_u)$ if $|t| < T_u$ and zero otherwise.

smoothing factor T_u should diverge slowly as m goes to infinity to ensure uniform consistency of the estimators.[62] [63]

The above procedure should produce an estimated density that outside the support goes to zero as T_u goes to infinity. However, as explained in Krasnokutskaya (2004) and also in Asker (2008), in practice the above procedure generates estimated densities which have very thin tails over an extremely long support. I employ the same procedure of Krasnokutskaya to solve the problem of the bounds estimation and this is the reason why the last classified bid (i.e. the bid furthest away from the winning bid) must be available for each auction.[64]

3) Estimating the distribution of the idiosyncratic component of firms' cost:

This step involves constructing a sample of pseudo-winning-bids, B_w^s, from the estimated density of B_w. A rejection method is used for this task. I denote by M the size of this sample and by $F_{B_w^s}(b_w^s)$ and $f_{B_w^s}(b_w^s)$ the cdf and pdf of B_w^s. The non parametric estimation of the cdf uses its empirical analog. Instead, to estimate the pdf I follow GPV and use a triweight kernel:

$$\hat{F}_{B_w^s}(b_w^s) = \frac{1}{M}\sum_{j=1}^{M} 1(B_{wj}^s \leq b_w^s)$$

$$\hat{f}_{B_w^s}(b_w^s) = \frac{1}{M}\sum_{j=1}^{M} \frac{1}{h_g}[\frac{35}{32}(1-(\frac{B_{wj}^s - b_w^s}{h_g})^2)^3 1(|\frac{B_{wj}^s - b_w^s}{h_g}| < 1)]$$

with bandwidth $h_g = (M)^{-1/6} 2.978\text{x}1.06\hat{\sigma}_{B_w^s}$, where the last term is the standard deviation of B_w^s.

The formulas (*) are then used to pass from the estimated cdf and pdf of the pseudo-winning-bid to the analogous ones (call them $\hat{F}_{B^s}$ and $\hat{f}_{B^s}$) for pseudo-bids (B^s). Then, for each of the M pseudo auctions the pseudo-lowest-costs (X_w^s) is obtained using:

$$X_w^s = [B_w^s - \frac{[1-\hat{F}_{B^s}(B_w^s)]}{(N-1)\hat{f}_{B^s}(B_w^s)}]$$

[62] I fix $T_A = 10$ and $T_{B_w} = T_r = T$, where T minimizes the integrated absolute error, $IAE = \int |f(x) - \hat{f}(x)| dx \in [0, 2]$, where the densities in the integral are those of the data and the simulated data.

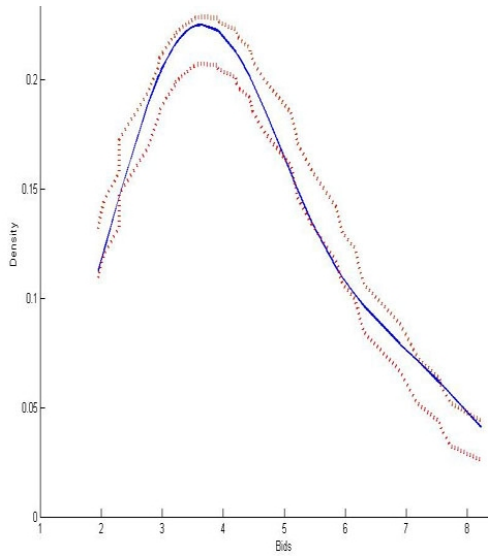
[63] For uniform consistency to hold, a maintained assumption is the following: the characteristic functions ϕ_u are ordinary smooth with an order greater than 1 (see Krasnokutskaya, 2004).

[64] In particular, the maximum within-auction difference between the highest and the lowest bid is used to estimate the maximum and the minimum of the support of B_w, maintaining E(B_w)=0. The lower bound of the common component is then estimated as the difference between the minimum losing bid and the estimated lower bound of B_w, while the upper bound of the common component is estimated as the difference between the maximum winning bid and the estimated upper bound of B_w. As regards X_r, consistently with the assumption of non binding reserve price, I estimate the lower bound as the estimated upper of B_w, while I estimate the upper bound as the difference between the highest reserve price and the estimated upper bound of A.

Finally, once we have this sample of pseudo-lowest-costs we can use it exactly as we did for the sample of pseudo-winning-bids to non parametrically estimate the relative cdf and pdf. In turn through the formulas in (*) they are used to obtain the estimated cdf and pdf of the pseudo-costs.

With the estimated distribution of the idiosyncratic cost component (step 2) and that of the commonly observed cost component (step 1) we have access to the primitives of the model and we can use them to answer several questions. The next section illustrates some prominent examples.

Figure 10: Fit of the Model



The solid line is the density of the data.

The dotted lines are the 5 and 95% Bootstrap confidence interval.

7.3 Results

Table 10 reports the summary statistics by the number of bidders for the sample of auctions used in the structural estimation. Only auctions with a reserve price between €500,000 and €1.5 million are considered. I report bids and reserve prices in €/100,000. Consistently with the assumptions of the structural model, we find that the within auction correlation between couples of bids and between the winning bid and the reserve price is above 90%. Finally, the data also reveals that bidders participating at FP auctions are systematically bigger than those participating at AB auctions in terms of their capital, workforce, profits and revenue. Therefore, this evidence is consistent with the assumption that only bidders of type H attend FP auctions. More details on how we used the data to validate the assumptions of the structural model are

in the Web Appendix.

Table 10: Summary Statistics

N Bidders	Tot Bids	Win. Price	Std Win. Price	Min Win. Price	Max Win. Price	Mean Res. Price	Mean (W-2nd)/R
2	101	5.71	1.87	2.58	9.97	9.26	9.7%
3	92	5.67	5.73	1.85	8.37	8.38	6.3%
4	97	5.16	1.61	2.01	7.77	9.02	2.8%
5	114	4.76	1.60	2.31	8.32	8.77	1.2%
6	125	4.35	1.64	1.96	8.22	8.73	2.6%
7	90	4.60	1.71	2.53	8.34	9.04	2.4%
8	85	5.21	1.88	2.51	8.89	9.63	3.10%
9	83	4.65	1.75	2.08	8.11	8.96	2.8%
10	62	3.93	1.56	2.23	7.16	7.43	2.5%

Unless otherwise specified, the results reported in the rest of this section are based on the subsample of auctions with 6 bidders. Estimates obtained with different values of N are in line with the ones presented here. Figure 10 reports the model fit. It is assessed by repeatedly simulating from the estimated distributions and using the model's equilibrium conditions to produce a set of simulated winning bids. The 5 percent boothstrap confidence interval is reported along with the true data. We use our estimates of the costs distributions for the following analyses:

Auctioneer's cost of procurement. Figure 11 reports the estimated densities of the private and common components. Through the deconvolution estimator we can recover the distributions only up to a location parameter. However, once through the GPV inversion step we recover the costs distributions, we can use economic theory to define an interval where these distributions may lie. We denote as leftmost shift the location in which the distribution of the private cost has the minimum of its support equal to zero. The location of the distribution of the common component will be shifted to the left in such a way to leave the average mean winning bid unchanged. The same thing is done for the "rightmost shift" inverting the roles the roles of the common and private components. Table 11 reports these results. The average private cost ranges from 240,000 to 340,000 euros while the average common cost ranges from 110,000 to 211,000 euros. If bidders were bidding competitively in a simple AB auction, the average cost of procurement would be somewhere between 520,000 and 871,000 euros. However, the former value is likely only a lower bound for the auctioneer's cost.[65] The latter value, instead, is the average reserve price. Therefore, it would also be the average cost of procurement

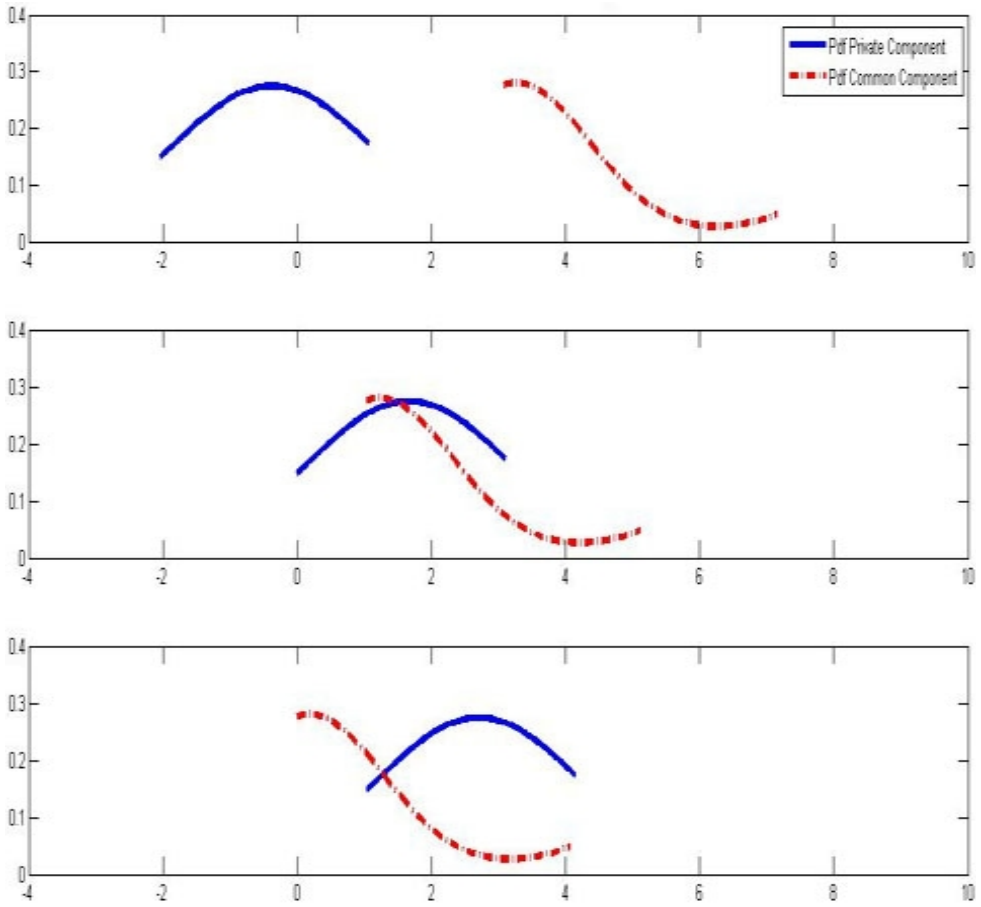
[65]This value is obtained as the sum of the mean common cost compoent and the maximum private cost. Indeed, it was shown that in the Simple AB there is a multiplicity of equilibria in which all bidders offer the same price and this price is between what the least efficient firm could offer without losing money and the reserve price. Therefore, our calculation is valid only if the upperbound of the private cost component for the firms that participate in FP is equal to that of firms that participate in AB. Likely less efficient firms attend AB and hence our estimate is of 520,000 euro is a lower bound for the cost.

in the Italian AB auctions if bidders were bidding according to the BNE prediction. As regards the FP, our estimated average cost of procurement is 413,000 (our estimate is slightly below the average winning bid in the data, 435,000 euros). The next point offers a qualification of these results.

Table 11: Bounds on the Costs Distributions

	Common Component			Private Component		
	Min	Max	Mean	Min	Max	Mean
Starting Values	3.08	7.14	4.25	-2.04	1.05	0.26
Leftmost shift	1.04	5.10	2.11	0	3.09	2.40
Rightmost shift	0	4.06	1.10	1.05	4.14	3.41

Figure 11: Distributions of Private & Common Components of Costs



Top plot: deconvolution estimates under the mean zero normalization for X. Middle plot:leftmost shift of f(x). Lower plot: rightmost shift of f(x)

Bounding the screening cost: According to our model, an administration chooses AB when its screening cost is such that the expected cost of procurement using FP and paying the screening cost is at least as big as the expected cost of procurement using AB. Therefore a bound for the screening cost, I, is obtained as the value of I that makes the auctioneer indifferent between the FP with screening and the AB. Hence, $I_{Bound} = R(1 - discount_{AB} + renegotiation_{AB}) - WB_{FP}$. Where R is the reserve price, $discount_{AB}$ is the "rule of thumb" percentage winning discount in AB described in Section 6, $renegotiation_{AB}$ is the percentage of contract renegotiated in AB and WB_{FP} is the average winning bid under FP already corrected for the ex post renegotiation. Therefore, we can use our estimates of WB_{FP} and R along with data on discounts and renegotiation in AB to estimate I_{Bound}. Since most of the auctions in our sample were held by the county and municipality of Turin, our analysis is mostly relevant for administrations comparable to Turin. For instance, the county of Alexandria which is close to Turin both geographically and in terms of population size, has a $discount_{AB}$ of 15.68% and a $renegotiation_{AB}$ of 2.7%. Therefore, we can estimate that the average value for the bound on the screening cost is 160,000 euros. Analogously, we can estimate the bound using the average values of $discount_{AB}$ and $renegotiation_{AB}$ reported in Table 4, respectively 11.9% and 5.8%. These values lead to an estimate of 222,000 euros. These values are larger than those implied by comparing the average winning bids and renegotiations in the Authority sample (such comparison indicates a saving of 125,000 euros associated with FP). The reason of this difference is that, compared to the Authority sample, the average winning bid in the structural estimation sample is higher, 40.2% instead of 32.6%. As regards what could justify the presence of such a large screening cost, interviews with PAs revealed that in addition to the cost of having engineers analyzing firms' cost justifications, strong concerns are the costs associated with litigations with excluded firms and the slowing down of the procurement process. Finally, it is possible that our estimates capture other factors like the inefficiency or corruption of the PAs. In a related study on the public procurement of goods by Italian PAs, Bandiera, Prat and Valletti (2009) show that the purchasing behavior of PAs is consistent with high levels of "passive waste" (inefficiency) as opposed to "active waste" (corruption). Thier estimates have a similar magnitude to those presented in this paper.

Efficiency of the two auction formats: as regards the FP auctions, we can use our estimates to decompose the variance of the total cost into its private and common components. Our finding is that 39% of the variation in the total cost is due to its private component. The FP rule under which this result was estimated is an efficient mechanism. The AB, instead, in equilibrium is equivalent to a random allocation and hence our estimates suggest that it will generate strong inefficiencies in the market that we study. However, three features of this market are worth discussing to clarify this result. First of all, the number of bidders in AB auctions is on average nine times the number of bidders in FP auctions. Some of the bidders in AB auctions are likely less efficient than the average FP bidder and hence our estimates should be a lower bound for the inefficiency. Nevertheless, two forces active in AB auctions mitigate this inefficiency: subcontracting and firms' cartels. Indeed, Conley and Decarolis (2010) show

that a larger fraction of the contract is subcontracted in AB than in FP. Moreover, cartels' behavior alters the probability of winning and, since they are more likely to win auctions in their geographical area, they may increase the allocative efficiency. However, cartels' behavior is such that cartels subcontract the work to other members of the cartel and not necessarily to the most efficient firm on the market.

Bidders' Markup: It is interesting to study how bidders' markups change from one auction format to the other. I define the markup as the difference between the winner's price-bid and his cost. For the FP the estimates indicate that, on average, the markup is 8.7% of the total cost. [66] Surprisingly, for the AB the average markup is often lower than in the FP. The reason is that in this case the cost of the winner is the cost of a randomly chosen firm in a simulated auction with six bidders. Therefore, although the winner's price-bid is higher than in the FP, also the winner's cost is higher than that of the FP winner. In particular, using the values of $discount_{AB}$ and $renegotiation_{AB}$ for the county of Alessandria and the "average" PA using AB we obtain an average markup of, respectively, 6.77% and 7.46%. However, the same three arguments we made with respect to the analysis of allocative efficiency in AB apply to the analysis of markups in this type of auction. Therefore, on the one hand within the large number of firms attending AB auctions many could be less efficient than those participating at FP auctions. Therefore, the true markups may be even lower than what my estimates suggest. However, to the extent that cartels active in AB designate the most efficient firm as the winner, their activity should rise the winners' markup. Finally, since a larger fraction of the contract is subcontracted in AB than in FP, it is likely that the winners of AB are able to profit from subcontracting to more efficient firms.

Optimal Reserve price: When default is not possible, the result of Myerson (1981) characterizes the optimal reserve price. However, in order to compute such price the auctioneer's option value of not selling must be knowe. As regards the FP auctions with screening, default is not an option and thus, if we assume that the auctioneer's option value is equal to this average reserve price of €877,000, we find that the optimal reserve price is on average €685,000. This reserve price was derived under the assumption that the auctioneer can observe the realization of the common cost component. Therefore, this result is consistent with the rest of our analysis indicating that the PAs uses a reserve price that is above the optimal level. Moreover, if the option value that we are using is higher than the true value, then the optimal reserve price should be even more stringent.

[66] This estimate rises if I repeat the analysis on a sample with a lower number of bidders per auction. With four bidders my estimates are comparable, although slightly lower, than those of Krasokutskaya (2009) for her model with asymmetric bidders. Using auctions with four bidders, she obtains a winner's markup ranging between 16% and 14% depending on the type of the bidder (weak or strong).

8 Conclusions

In this research I have analyzed auctions in which the highest bidder may not win. His elimination takes place automatically when the auctioneer is using an average bid rule. Otherwise, when the auction is a first price, it can come after an ex post verification of the responsiveness of his bid. The rationale for such auction formats was found in the risk that a standard first price auction may excessively favor those bidders that are less likely to fulfill their bid if they discover ex post that the object that they won has a lower than expected value. The economics literature already recognized this problem and stressed the necessity to combine FP auctions with strong incentives for the contract enforcement. The use in certain countries, like the US, of surety bonds that fully insure the administration from breach of contract goes in this direction.

When the insurance market has imperfections relevant for firms' behavior, the auctioneer may want to internalize the process of screening out risky bidders. This screening could take place by augmenting the first price auction with an ex-post stage in which bids are verified. However, a cost has to be paid to implement this screening technology. Instead, the potential advantage of an automatic elimination procedure like the average bid auction, is that it reduces the probability that a risky bidder wins without the need to pay any screening cost. Nevertheless, we showed that the AB does no better than a random lottery. Hence, it is inefficient whenever the private component of bidders' valuations is relevant. Moreover, it leads to low revenues for the auctioneer. These revenues are also uncertain if the format chose is a Simple AB or if, like in the Italian case, firms' collude.

Indeed, the estimates presented in the paper indicate that in the road construction industry in Italy the average bid auctions have generated both significant inefficiency in contract allocation and high costs of procurement. Thus, a transition toward first price auctions could produce improvements along these two dimensions, but only if the ex-post screening of bids is not too expensive. Therefore, the main policy implication that can be derived from this research is that large benefits can be obtained if, by reducing the cost of screening, more auctioneers can be induced to use FP auctions in which bids are binding commitments for the bidders.

This research has not dealt with the question of what is the best way to reduce the screening cost. However, two ways to obtain this result may consist of making the identification of risky bidders easier and in lowering their probability of winning. The first task could be attained, for instance, by facilitating access to the screening technology. In the case of Italy, this could be achieved by centralizing the process of verifying bids so that small public administrations that run infrequent auctions do not need to hire their own team of engineers to evaluate bids. The second way to reduce the screening cost could be to implement a series of "side mechanisms" that reduce the probability that a risky bidder is awarded the contract. This can be attained with market based mechanisms, like the surety bonds, but also through rigorous pre-qualification mechanisms that focus on how likely the bidder is to default.

9 Bibliography

1. Albano, G., M. Bianchi and G. Spagnolo, (2006). “Bid Average Methods in Procurement”, Rivista di Politica Economica, 2006, (1-2): 41-62.

2. Asker, J., (2008). "A Study of the Internal Organisation of a Bidding Cartel", American Economic Review, forthcoming.

3. Asker, J., E. Cantillon, (2008). "Procurement when Price and Quality Matter". Mimeo

4. Athey, S., J. Levin, and E. Seira, (2004). “Comparing Open and Sealed Bid Auctions: Theory and Evidence from Timber Auctions”, Stanford University Working Paper.

5. Bajari, P., G. Lewis, (2008). "Procurement Contracting with Time Incentives: Theory and Evidence", mimeo.

6. Bajari, P., L. Ye, (2003). ”Deciding Between Competition and Collusion”, The Review of Economics and Statistics, November, 971-989.

7. Bajari, P., S. Tadelis, S. Houghton, (2007). “Bidding for Incomplete Contracts: An Empirical Analysis”, mimeo.

8. Bajari, P., G. Lewis (2009). "Procurement Contracting with Time Incentives: Theory and Evidence", mimeo.

9. Bandiera, O., A. Prat, T. Valletti, (Forthcoming). "Active and Passive Waste in Government Spending: Evidence form a Policy Experiment", American Economic Review.

10. Barbe, P., (1994). "Joint Approximation of Processes Based on Spacings and Order Statistics", Stochastic Processes and their Applications, 53, 339-349.

11. Board, S., (2008). "Bidding into the Red: A Model of Post-Auction Bankruptcy", Journal of Finance, 62, 6, 2695-2723.

12. Calveras, A., J. Ganuza, E. Hauk, (2004). "Wild Bids. Gambling for Resurrection in Procurement Contracts", Journal of Regulatory Economics, 26, 1, 41-68.

13. Che, YK, J. Kim, (2009). "Bidding with Securities: Comment", American Economic Review, forthcoming.

14. Chillemi, O., C. Mezzetti, (2009). "Procurement Under Default Risk: Auctions or Lotteries?", mimeo.

15. Clough, R. H., G. A. Sears, (1994). Construction Contracting, 6th ed. New York: Wiley.

16. Costa-Gomes, M. A., V. Crawford, (2006). "Cognition and Behavior in Two-Person Guessing Games: An Experimental Study", American Economic Review, 96, 5, 1737-1768.

17. Day, R, P. Milgrom, (2007). "Core-Selecting Package Auctions", International Journal of Game Theory, July, 2007.

18. Engel, A., J.J. Guanza, E. Hauk, A. Wambach, (2006). "Managing Risky Bids", in Handbook of Procurement, N. Dimitri, G. Piga and G. Spagnolo editors. NY: Cambridge University Press.

19. Epstein, R., L. Henriquez, J. Catalan, G.Y. Weintraub, C. Martinez, (2002). "A Combinatorial Auction Improves School Meals in Chile", Interfaces, 32, 6, 1-14.

20. Epstein, R., L. Henriquez, J. Catalan, G.Y. Weintraub, C. Martinez, F. Espejo, (2004). "A Combinatorial Auction Improves School Meals in Chile: a Case of Operations Research in Developing Countries", International Transactions in Operations Research, , 6, 593-612.

21. European Commission, (2002). "Prevention, Detection and Elimination of Abnormally Low Tenders in the European Construction Industry", http://ec.europa.eu/enterprise/construction/alo/altfin.h

22. Guasch, J.L., J.J. Laffont, S. Straub, (2005). "Infrastructure concessions in Latin America : government-led renegotiations," Policy Research Working Paper Series, N' 3749, The World Bank.

23. Guerre, E., I. Perrigne and Q. Vuong, (2000). "Optimal Nonparametric Estimation of First-Price Auctions", Econometrica, 68, 3, 525-574.

24. Haile, P. A., H. Hong and M. Shum, (2003). "Nonparametric Tests for Common Values in First Price Sealed Bid Auctions", mimeo.

25. Hendriks, K., J. Pinske, R. H. Porter, (2003). "Empirical Implications of Equilibrium Bidding in First-Price, Symmetric, Common Value Auctions", Review of Economic Studies, 70, 1, 115-145.

26. Hinze, J., (1993). Construction Contracts, McGraw-Hill Series in Construction Engineering and Project Management. Boston: Irwin/McGraw-Hill.

27. Hong, H., M. Shum, (2004). "Increasing Competition and the Winner's Curse: Evidence from Procurement", Review of Economic Studies, 69, 871-898.

28. Hu, Y., D. McAdams, M. Shum, (2009). "Nonparametric Identification of Auction Models with Non-Separable Unobserved Heterogeneity", mimeo.

29. Ioannou, P., S.S. Leu, (1993). "Average-Bid Method. Competitive Bidding Strategy". Journal of Construction Engineering and Management, 119, 1, 131-147.

30. Ishii, R., (2008). "Collusion in Repeated Procurement Auction: A Study of a Paving Market in Japan", mimeo.

31. Jofre-Bonet, M., M. Pesendorfer, (2003). "Estimation of a Dynamic Auction Game", Econometrics, 71, 5, 1443-1489.

32. Kagel, J. H., D. Levin, (1986). "The Winner's Curse and Public Information in Common Value Auctions", American Economic Review, 76, 5, 894-920.

33. Kotlarski, I., (1966). "On Some Characterizations of Probability Distributions in Hilbert Spaces", Annali di Matematica Pura e Applicata, 74, 129-134.

34. Krasnokutskaya, E., (2004). "Identification and Estimation in Highway Procurement Auctions under Unobserved Heterogeneity", mimeo.

35. Krishna, V., (2002). Auction Theory, Academic Press. San Diego, CA.

36. Laffont, J.J. and J. Tirole, (1993). A Theory of Incentives in Procurement and Regulation. Cambridge, Mass.: MIT Press.

37. Li, T. and Q. Vuong, (1998). "Nonparametric Estimation of the Measurement Error Model Using Multiple Indicators", Journal of Multivariate Analysis, 65, 139-165.

38. Li, T. I. Perrigne and Q. Vuong, (2000). "Conditionally independent private information in OCS wildcat auctions", Journal of Econometrics, 98, 129-161.

39. Li, T., X. Zheng, (2006). "Entry and Competition Effects in First-Price Auctions: Theory and Evidence from Procurement Auctions", mimeo.

40. Liu,S., Lai, K.K., (2000). "Less Averge-Bid Method. A Simulating Approach". International Journal of Operations and Quantitative Management, 6, 4, 251-262

41. Milgrom, P., R. Weber, (1982). "A Theory of Auctions and Competitive Bidding", Econometrica, 50, 1089-1122.

42. Mongell S., A. Roth, (1991). "Sorority Rush as a Two-Sided Matching Mechanism", Amrican Economic Review, 81, 3, 441-464.

43. Myerson, R., B., (1981). "Optimal Auction Design", Mathematics of Operations Research, 6, 58-73.

44. Nagel, R., (1995). "Unravelling in Guessing Games: An Experimental Study", American Economic Review, 85, 1313-1326.

45. Paarsch, H.J., (1992). "Deciding between the Common and Private Value Paradigms in Empirical Models of Auctions", Journal of Econometrics, January-February, 51, 1, 191-215.

46. Porter, R., D. Zona, (1993). "Detection of Bid Rigging in Procurement Auctions", Journal of Political Economy, 101, 3, 518-538.

47. Reny, P. J., S. Zamir (2004). "On the Existence of Pure Strategy Monotone Equilibria in Asymmetric First-Price Auctions", Econometrica, 72, 4, 1105-1125.

48. Roberts, J., (2008). "Unobserved Heterogeneity and Reserve Prices in Auctions", mimeo.

49. Rhodes-Kropf, M., S. Viswanathan, (2000). "Corporate Reorganizations and Non-Cash Auctions", Journal of Finance, 55, 4, 1807-1849.

50. Rhodes-Kropf, M., S. Viswanathan, (2005). "Financing Auction Bids," RAND Journal of Economics, Winter, 36, 4, 789-815.

51. Spulber, D.F., (1990). "Auctions and Contract Enforcement", Journal of Law, Economics and Organization, 6, 2, 325-344.

52. Waehrer, K., (1995). "A Model of Auction Contracts with Liquidated Damages", Journal of Economic Theory, 67, 2, 531-555.

53. Zheng, C., (2001). "High Bids and Broke Winners", Journal of Economic Theory, 100, 129-171.

54. Zheng, X., (200?). "A Research on Bid-Averaging Methods in Construction Procurement Auctions: Theory and Evidences from Guangdong Construction Industry", mimeo.

Appendix: Proofs

Proof of Lemma 1: To see why a bidder i of type H would always fulfill his bid when $p_H \geq p_H^*$ consider that if he does not do so it must be that $p_H \leq b_H - (y + x_i - \varepsilon)$. His payoff in case of victory must, thus, be negative because:

$$\begin{aligned}(1-\theta)(y+x_i-b_H)-\theta p_H &\leq (1-\theta)(y+x_i-b_H)-\theta(y+\bar{x_H}-\theta\varepsilon)\\ &\leq (1-\theta)(y+x_i-p_H-(y+x_i-\varepsilon))-\theta(y+\bar{x_H}-\theta\varepsilon)\\ &= \varepsilon-(y+\bar{x_H})<0\end{aligned}$$

Therefore, given that this bidder will never default on his bid, his expected value for the contract is $y+x_i-\theta\varepsilon \leq y+\bar{x_H}-\theta\varepsilon$ so that bidding anything above $y+\bar{x_H}-\theta\varepsilon$ would generate a negative payoff in case of victory and is hence strictly dominated by bidding any $b \leq y+x_i-\theta\varepsilon$ that yields a non negative payoff in case of victory.

In the second part of the Lemma the fact that in a first price auction with screening no bidder, regardless of his type, would bid in equilibrium less than $y-\theta\varepsilon$ follows from a simple Bertrand argument. Therefore, if $p_L < p_L^*$ we have that a type L bidder faced with the decison of whether to default on his bid or not will always do so because $p_L < (1-\theta)\varepsilon - \bar{x_L} \leq b_L - (y+\bar{x_L}-\varepsilon)$.

Proof of Proposition 1: Existence of a pure strategy monotone equilibrium is proved using a theorem in Reny and Zamir (2004), RZ from now on. The structure of my game conforms with that of RZ: bids can be seen as coming from $B_i \in \{l\} \cup [r_i, \infty)$, where, for bidders type L, $r_L = B + \underline{x_L}$ and, for bidders type H, $r_H = A + \underline{x_H}$. Moreover, l, the non serious bid of RZ, in y setup can be anything in $[0, \min(A+\underline{x_H}, B+\underline{x_L})]$. Notice also that my description in term of bidders drawing their private valuation from an interval $[\underline{x}, \bar{x}]^N$ is analogous to a formultation with bidders drawing signals s on $[0,1]^N$ and then having these signals converted into valuation through a monotonic function $x : [0,1]^N \to [\underline{x}, \bar{x}]^N$. I will now show that all the assumptions of the RZ theorem are satisfied by my first price auction with asymmetric bidders with payoffs described by (1). The theorem's assumptions regard both the utility function and the distribution of the private signals. As regards this second aspect, my assumption that signals are independently distributed means that signal's affiliation weakly holds and that for any x_i the support of i's conditional distribution does not change. Hence Assumption A.2 in RZ is satisfied. As regards the assumptions about the utility function, I assume risk neutral bidders whose payoff in case of victory is $u_i = c_t + x_i - b_i$, where c_t is equal to A or B depending on whether the bidder is type H or L. This payoff function is: (i) measurable, it is bounded in

$[\underline{x}_t, \bar{x}_t]$ for each b_i and continuous in b_i for each x; (ii) define $\tilde{b} \equiv \max(A + \bar{x}_H, B + \bar{x}_L)$, then $u_i(b_i, x) < 0$ for all $b_i > \tilde{b}$ and for any $x \in [\underline{x}_t, \bar{x}_t]$; (iii) for every bid $b_i \geq c_t + \underline{x}_t$ we have that $u_i(b_i, x)$ is constant in x_{-i} and strictly increasing in x_i; (iv) $u_i(\bar{b_i}, x) - (\underline{b_i}, x)$ is constant in x. Therefore also the other assumption (A.1) required by the RZ Theorem 2.1 holds. Hence, the auction possesses a monotone pure-strategy equilibrium. With the existence of the equilibrium assured, then the claims (a) and (b) in the proposition follow from the analysis of Maskin and Riley (2000).

Proof of Lemma 3: Since all bidders have the same valuation, y, which they all perfectly observe, then if every player bids the same constant $c \in [\underline{x}, y]$ this strategy profile is both feasible for all players and does not allow any unilateral profitable deviation. Every bid different from c leads to an expected value of zero, while, as long as $c < y$ the bidder has positive expected profits from bidding c. When all other bidders are playing y a single bidder that bids something different will lose for sure, hence he will be indifferent between bidding y or anything else. Moreover, given that with perfectly correlated values bidders are symmetric not only ex ante (before the realization of their signal) but also ex post (after the realization of the signal) the kind of strategy just described represents the unique (pure strategy) symmetric equilibria.

Proof of Proposition 2: The first part of the proposition follows directly from the combined results of Lemma 2 and Lemma 3.

Proof of Lemma 2: Consider the average bid auction game with N>2 symmetric players. In this auction for a bidder i the probability of winning when bidding b_i is:

$$\Pr(win|b_i) \equiv \Pr[|b_i - \frac{1}{N}\sum_{r=1}^{N} b_r| < |b_j - \frac{1}{N}\sum_{r=1}^{N} b_r| \ \nabla b_i \neq b_j] * (\frac{1}{\sum_{r=1}^{N} 1(b_i = b_r)})$$

Where $1(b_i = b_r)$ is an indicator function equal to 1 every time one of the bids submitted is equal to b_i.[67] It is clear that offering the minimum bid is an equilibrium. As regards the other symmetric BNE that might exist I will show here that there are a number of conditions that they must all satisfy: (1) the equilibrium bidding function is weakly monotonic, (2) it is flat at the top; (3) all types greater than the lowest one bid less than their value, (4) as N grows the equilibrium "approaches" the one in which every bidders always bids the lowest extreme of the valuation distribution. I also present a numerical example using uniformly distributed i.i.d. valuations to show that the number of bidders required to be "close" to the equilibrium

[67] Therefore, the first part of the expression is the probability that b_i is closer to the average bid than any other different bid, while the second part is the probability of winning the fair lottery run among all those bidders who submitted a bid equal to b_i.

where everybody bids $\underline{x}$ is rather small.

STEP 1: NON DECREASING FUNCTION

Assume that the equlibrium bidding function, b, has a decreasing trait. Then we can take two types, x_1 and x_0, with $x_1 > x_0$ such that $b(x_1) < b(x_0)$. Then by the assumption that b is equilibrium, it must follow that:

$[x_1 - b(x_1)] \Pr(win|b(x_1)) \geq [x_1 - b(x_0)] \Pr(win|b(x_0))$ and

$[x_0 - b(x_0)] \Pr(win|b(x_0)) \geq [x_0 - b(x_1)] \Pr(win|b(x_1))$.

Therefore from the first inequality we have that:

$\Pr(win|b(x_1)) \geq \{[x_1 - b(x_0)]/[x_1 - b(x_1)]\} \Pr(win|b(x_0))$

and from the second inequality we have that:

$\Pr(win|b(x_0)) \geq \{[x_0 - b(x_1)]/[x_0 - b(x_0)]\} \Pr(win|b(x_1))$

Define $P_0 \equiv \Pr(win|b(x_0))$ and $P_1 \equiv \Pr(win|b(x_1))$. Then for the these inequalities to hold there must exist a solution to the following system of two equations in two unknowns (P_0, P_1) :

$$\begin{cases} P_0 \leq \{[x_1 - b(x_1)]/[x_1 - b(x_0)]\} P_1 \\ P_0 \geq \{[x_0 - b(x_1)]/[x_0 - b(x_0)]\} P_1 \end{cases}$$

Therefore for a solution to exist it must be that

$\{[x_1 - b(x_1)]/[x_1 - b(x_0)]\} - \{[x_0 - b(x_1)]/[x_0 - b(x_0)]\} \geq 0$

Which requires:

$[x_1 - b(x_1)][x_0 - b(x_0)] - [x_0 - b(x_1)][x_1 - b(x_0)] \geq 0$

After some algebra that becomes:

$[x_0 - x_1][b(x_0) - b(x_1)] \geq 0$

However this is impossible because we assumed $x_1 > x_0$ and $b(x_1) < b(x_0)$. Therefore the system does not have any solution and hence it is impossible to find a decreasing bidding function satisfying the inequalities that have to hold at equilibrium. An equilibrium bidding function cannot have any decreasing trait.

STEP 2: NON STRICTLY INCREASING FUNCTION AT THE TOP

Assume that the equilibrium bidding function is strictly increasing at the top. From the previous step we know that this means that it is the highest type who submits the highest bid and the function can be either weakly or strictly increasing. In either of the two cases, if N-1 bidders are using a strategy that is strictly increasing at the top, then the remaining bidder has a profitable deviation. In particular consider this alternative strategy: to follow the proposed

equilibrium strategy for every type differing from the one required to submit the highest bid and, for this remaining type, to bid ε, where $\varepsilon > 0$ and small enough. This new strategy is a unilateral profitable deviation for the bidder because, compared to the proposed equilibrium one, it gives him the same revenue and probability of winning for every type different than the highest and a strictly greater probability of winning and revenue for the highest type. The revenue is higher because the highest type pays less when he wins under the deviating strategy. The probability of winning is higher because (irregardeless of whether N is finite or not) the probability of the average bid being less than the highest bid possible under the assumed equilibrium function is equal to one. Hence by reducing the bid the probability of winning, that was zero under the assumed equilibrium strategy, becomes strictly positive (given that the other N-1 players are still playing with the original strictly increasinge function). Therefore what we claimed to be equilibrium cannot be so and hence there cannot be any equilibrium bidding function that is strictly increasing.

We have at this point established that the only possible form of a symmetric equilibrium bidding function is that of a weakly increasing function.

STEP 3: IN EQUILIBRIUM BIDDERS SHADE THEIR VALUE

Any candidate equilibrium strategy, b, requiring a bidder to bid for some or all of his types strictly above their own valuation can be shown to be strictly dominated and, hence, not an equilibrium. Consider a player that unilaterally deviates to the strategy, b', that is equal to b for the types (if any) required to bid weakly less than their valuations by b and requires the types that were bidding above their own valuation under b to bid their own valuation. Clearly b' is a unilateral profitable deviation from b, because it avoids expected losses. Hence such a strategy b is strictly dominated by b' and thus will never be used in equilibrium.

Now assume that we have a candidate symmetric equilibrium strategy, b, that for some types $x > \underline{x}$ requires these types to bid exactly their valuation and the remaining ones (if any) to bid strictly less than their own valuation (given our previous argument this is the only form an equilibrium might take). If N-1 players are using b then it is easy to show that the remaining Nth player has a unilateral profitable deviation away from b. Consider a strategy b' that is equal to b for the types (if any) required to bid strictly less than their valuations by b and requires the types that were bidding their own valuation under b to bid an ε (where ε is small and positive) less than that. To see that for player N this is a unilateral profitable deviation notice that this strategy b' gives him the same expected payoff for any of his type that is required to bid less than his own valuation by both b and b'. Moreover, for all the types that reduced their bid by ε, this leads to a positive expected gain of $\varepsilon * \Pr(win|b'; b_{-N})$ which is strictly positive given that, under the assumption that the remaining N-1 bidders are using b, the probability that the average bid lies strictly below one's valuation is always strictly positive as long as this valuation is more than $\underline{x}$. This is true becuase types between $\underline{x}$ and this valuation have positive probability of being drawn and, if drawn, they are prescribed to bid no more then their

own valuation. Therefore we can conclude that any strategy, that requires at least some of the types that have a valuation greater than $\underline{x}$ to bid their own valuation, is strictly dominated and cannot be used in equilibrium.

STEP 4: RESTRICTION ON THE HIGHEST EQUILIBRIUM BID

With N finite for every possible flat top of the bidding function (this is the only possibility allowed by steps 1 and 2), there is always a non zero probability that all the other bidders draw a value high enough so that they will also all bid the same highest value. Therefore ruling out the possibility that this flat top is greater than $\underline{x}$ requires checking the optimization problem of the agents to see if a profitable deviation exists. I have not been able to show that the equilibrium in the case of N finite is unique. However the following argument serves to find a boundry value on what can be the highest type, $\overline{v}$, such that for all $x \in [\overline{v}, \overline{x}]$ bidding some constant $\overline{b} < \overline{v}$ (the flat top of the bidding function) with $\overline{b} > \underline{x}$ gives a greater or equal expected payoff than bidding anything different than $\overline{b}$. Clearly the interesting case is to look at the type $\overline{v}$ (because this is the type that would have the greatest incentive to deviate) and to compare the expected payoff from bidding $\overline{b}$ versus any other $b' < \overline{b}$ (because any $b" > \overline{b}$ will necessairly lead to a zero probability of winning given that all the other types' bids are assumed between $\underline{x}$ and $\overline{b}$). Hence consider the equilibrium condition for agent N who drew $\overline{v}$ when all other players use the strategy b^*:

$u(\overline{v}, \overline{b}, b^*_{-N}) \geq u(\overline{v}, b, b^*_{-N})$ for any $b < \overline{b}$ $\qquad (*)$

where

$$b^* = \begin{cases} \overline{b} & \text{if } x \geq \overline{v} \\ b(x) < x & \text{if } x < \overline{v} \end{cases}$$

where it is known that $b(x) < x$ for $x < \overline{v}$ is weakly increasing. Given the other N-1 players are using this strategy b^*, rewrite the equation $(*)$ as:

$\Pr(win|\overline{b})[\overline{v} - \overline{b}] \geq \Pr(win|b)[\overline{v} - b]$ for any $b < \overline{b}$.

Where by the event that the bid $\overline{b}$ wins, I mean that $\overline{b}$ is the bid closest to the average bid conditional on all other players playing b^*. Define p to be the probability that all the other N-1 players drew a value above $\overline{v}$:

$p \equiv \Pr[(X_1 \geq \overline{v}) \cap (X_2 \geq \overline{v}) \cap ... \cap (X_{N-1} \geq \overline{v})]$.

Moreover define the following probabilities:

$q_1 \equiv \Pr[(X_1 < \overline{v}) \cap (X_2 \geq \overline{v}) \cap (X_3 \geq \overline{v}) \cap ... \cap (X_{N-1} \geq \overline{v})]$

$q_2 \equiv \Pr[(X_1 < \overline{v}) \cap (X_2 < \overline{v}) \cap (X_3 \geq \overline{v}) \cap ... \cap (X_{N-1} \geq \overline{v})]$

...

$q_{N-2} \equiv \Pr[(X_1 < \overline{v}) \cap (X_2 < \overline{v}) \cap ... \cap (X_{N-2} < \overline{v}) \cap (X_{N-1} \geq \overline{v})]$

Now define α_M to be the probability that $\overline{b}$ is the bid closest to the average bid conditional on all other players playing b^* and M of them drawing a valuation that is strictly less than $\overline{v}$. That is:

$$\alpha_M \equiv \Pr[|\overline{b} - \tfrac{1}{N}\sum_{r=1}^{N} b_r^*| < |b(x_j) - \tfrac{1}{N}\sum_{r=1}^{N} b_r^*| \text{ for any } x_j < \overline{v} \text{ and } j = 1, 2, ..., M \ |q_M = 1]$$

where M=1,2,...,N-2.

Therefore we can now rewrite $\Pr(win|\overline{b})$ as:

$\Pr(win|\overline{b}) = p(\frac{1}{N}) + [q_1(\frac{1}{N-1}) + q_2\alpha_2\ (\frac{1}{N-2}) + ... + q_{N'}\alpha_{N'}(\frac{1}{N-N'})]$.

where N' is $(\frac{N}{2} - 1)$, or the closest lower integer if N is odd.

Where we have used the facts that, if all the other N-1 players use b^*, $\alpha_1 = 1$ and, also, that if all the other N-1 players draw $v < \overline{v}$, then bidding $\overline{b}$ leads to lose with probability one. Moreover notice that $\alpha_M = 0$ whenever $M \geq \frac{N}{2}$. This is the case because whenever M is at least equal to $\frac{N}{2}$, then $\overline{b}$ is certainly further away from the average bid than at least one of the lower bids submitted. This can be easily shown by considering the case of N even and $M = \frac{N}{2}$. Then the average can be expressed as a weighted sum of pairwise averages where the weight is $\frac{2}{N}$. Consider the case that these couples of averages are each composed by taking one $\overline{b}$ and one of the bids less than $\overline{b}$. Then it must be by construction that, for the highest average formed by these couples, call it A1, $\overline{b}$ is exactly at the same distance from this average as the other bid, call it $\tilde{b}$ composing this average. However, since A1 is the highest average couple, the overall average bid must be less than A1. However the distance between any value, A0, lower than A1 and $\tilde{b}$ is less than the distance from $\overline{b}$ to A0. Therefore $\overline{b}$ cannot be the closest bid to the overall average. Clearly if $M > \frac{N}{2}$ this is even more the case.

Whenever there is at least one bidder drawing a valuation strictly less than $\overline{v}$ then the average bid will be strictly less than $\overline{b}$. Therefore we can always take a $b' < \overline{b}$ but ε-close to $\overline{b}$, such that conditional on having at least one player drawing $x < \overline{v}$, b' leads to a probability of winning strictly greater than $\overline{b}$. Moreover the payment in case of victory with the bid b' is strictly less than that in case of winning with $\overline{b}$. Define β_M as follows:

$$\beta_M \equiv \Pr[|b' - \tfrac{1}{N}\sum_{r=1}^{N} b_r^*| < |b(x_j) - \tfrac{1}{N}\sum_{r=1}^{N} b_r^*| \text{ for any } x_j < \overline{v} \text{ and } j = 1, 2, ..., M \ |q_M = 1]$$

where M=1,2,...,N-2.

Therefore we can now rewrite $\Pr(win|b')$ as:

$\Pr(win|b') = [q_1 + q_2\beta_2 + ... + q_{N-2}\beta_{N-2}]$.

Where I have used the fact that, given that b' is outside the flat top, the probability that another agent bids exactly b' is zero, so that if the agent wins when bidding b', then he is the unique winner. Now, given the way we chose b' we have that:

$[q_1 + q_2\beta_2 + ... + q_{N-2}\beta_{N-2}][\overline{v} - b'] > [q_1 + q_2\alpha_2 + ... + q_{N'}\alpha_{N'}][\overline{v} - \overline{b}]$.

Notice that the left hand side of the above inequality is exactly $u(\overline{v}, b', b^*_{-N})$. Therefore, for $(*)$ to hold, b' must not be a profitable deviation. A necessary condition for this to happen is then:

$\{p(\frac{1}{N}) + [q_1(\frac{1}{N-1}) + q_2\alpha_2\ (\frac{1}{N-2}) + ... + q_{N'}\alpha_{N'}(\frac{1}{N-N'})]\}[\overline{v} - \overline{b}] > [q_1 + q_2\alpha_2 + ... + q_{N'}\alpha_{N'}][\overline{v} - \overline{b}]$.

Which, rearranging the terms, means that:

$p > N[q_1(\frac{N-2}{N-1}) + q_2\alpha_2\ (\frac{N-3}{N-2}) + ... + q_{N'}\alpha_{N'}(\frac{N-N'-1}{N-N'})]$.

Hence, a necessary condition for the above to hold, is that:

$p > Nq_1(\frac{N-2}{N-1})$

which can be rewritten using the definitions of p and q_1 as:

$(1 - F(\overline{v}))^{N-1} - N(\frac{N-2}{N-1})[F(\overline{v})(1 - F(\overline{v}))^{N-2}] > 0 \quad (**)$

Therefore, if we see the left hand side of the above inequality as a function of $\overline{v}$, say $g(\overline{v})$, then only the values of $\overline{v}$ such that $g(\overline{v}) > 0$ respect the necessary condition. The function $g(\overline{v})$ starts at 1 for $\overline{v}$ equal to $\underline{x}$ and converges toward zero $\overline{v}$ equal to $\overline{x}$. Moreover with $N > 2$ the function has a unique critical point, a minimum that is attained at the value of $\overline{v} = z$, where z is the (unique) value such that the following equation is satisfied:

$F(z) = \frac{2N^2-4N+1}{N^3-N^2+1}$

Since the denominator is larger than the nominator with F absolutely continuous, z must always exist. Therefore $g(\overline{v})$ starts at one, decreases util it reaches a minimum value and then converges to zero from below, reaching exactly zero at $\overline{v} = 1$. Hence it must be that $g(\overline{v})$ crosses zero from above just once so that the only values of $\overline{v}$ for which $(**)$ is respected are those that lie in $[\underline{x}, v^*)$ where v^* is defined to be the value of $\overline{v}$ such that the inequlaity of $(**)$ would be an equality. Moreover since $v^* < x$ we have the following result:

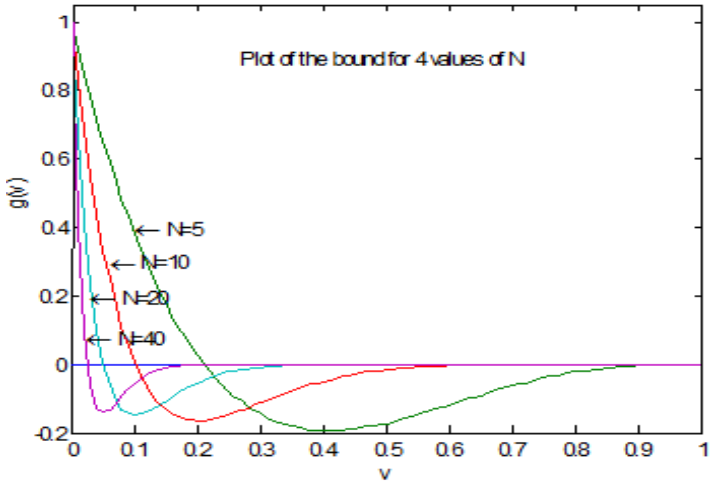
For any (absolutely continuous) F_X and $\forall\ \eta > 0$, $\exists\ N^*_{\eta,F}$ such that $\forall N \geq N^*_{\eta,F}$ the following is true: $|\overline{v}_{\eta,F} - \underline{x}| < \varepsilon$.

To see why this is the case just consider that by definition of v^* the values of $\overline{v}$ such that $(**)$ holds are the ones for which $g(\overline{v}) > g(v^*) \longrightarrow \overline{v} < v^*$ because g is strictly decreasing until

$z > v^*$. However the expression defining z is such that, in the limit for N that goes to infinity, $z = \underline{x}$. Therefore it must be the case that also v^* and hence $\bar{v}$ go to $\underline{x}$ as N goes to infinity. Therefore there is always an $N^*_{\eta,F}$ that for any F and for any $\eta > 0$ it is large enough so that the difference between $\bar{v}$ and $\underline{x}$ is less than η.

Finally one can see that using $(**)$ a thershold for checking that any symmetric equilibrium must have an highest bid strictly lower than v^* is very conservative. In particular, while for N=3 this is almost as a good characterization as one can get, for a greater N the actual maximum bid might be much lower than this bound. However, given the very high concavity of $(1-F(\bar{v}))^{N-1}$ this is not likely to reduce the usefulness of this bound because as N rises the bound reduces the size of the interval $[\underline{x}, v^*)$ very rapidly by bringing v^* closer to $\underline{x}$. Therefore even for small N, v^* will be close to $\underline{x}$. This is the reason why even for small N $(**)$ gives a bound that is useful.

Finally, to see an example of what the ranges of values of v^* as N changes are, the figure below illustrates the case of i.i.d. valuations uniformly distributed on [0,1] and N bidders. The graph shows the results for N equal to 5, 10, 20 and 40. One can read on the plots the value of v^* which is the one for which $g(\bar{v})$ crosses zero from above. Even for N=5 this value is fairly close to $\underline{x}$ and as N rises it approaches $\underline{x}$ very rapidly.



Proof of Proposition 3: Recall that the I_AB differs from the S_AB because of: (1) the trimming of the tails of the bid distribution, (2) the use of a threshold given by a trimmed average plus positive standard deviation and (3) the requirement that the winning discount is the closest from below to the threshold. Moreover, there are two different rules that PAs can use to deal with the event that more than 10% of the bids are all bidding the same highest discount: rule 1 (R1) says that all of them are trimmed while rule 2 (R2) says that only (.1 x

N) bids among them are picked at random and trimmed. It should be noticed that Step 1, 2 and 3 in the proof of Lemma 2 hold unchanged in the I_AB case. Therefore, like for Lemma 2 (and using the same notation) we can concentrate on the problem of the marginal bidder, $\bar{v}$, the one on the lower bound of the flat top. It is easy to see that regardeless of whether R1 or R2 is used, unless the flat top equals the minimum bid, this type always has a unilateral profitable deviation by lowering his bid. By being on the flat top he could win if and only if everybody else was drawing a value greater or equal to $\bar{v}$. But in this same event, if the marginal type were to unilaterally lower his bid he would win with probability 1 and strictly increase his profits. Under R1 this is clear since the trimming eliminates all the other bidders and he is left as the only valid bidder. Under R2 the anomaly threshold (A2 in the text in Section 3) coincides with the flat top and, hence, the deviating strategy leads him to be the only valid bidder. Moreover, in any other event (i.e. when it is not the case that everybody draws a value greater or equal to $\bar{v}$) having deviated cannot worsen his payoff since, by being on the flat top he had a zero probability of winning.

Proof of Proposition 4: As regards the first part of the proposition, showing that $E[R^{S_AB_1}] \geq E[R^{I_AB_1}]$ is trivial. In both cases I is paid but all the equilibrium winning bid of the S_AB_1 are greater or equal than the unique equilibrium of the S_AB_1. As regards $E[R^{FP_1}] > E[R^{S_AB_1}]$, in both auction formats the auctioneer pays I and avoids defauls. However, the density of the winning bid in the FP_1 is positive in the interval $(A + \underline{x}_H, A + \bar{x}_H)$ while this density in the S_AB_1 is positive only on $[0, A + \underline{x}_H]$.

As regards the second part of the proposotiton, we start by showing why we cannot rank $E[R^{FP_1}]$ and $E[R^{FP_0}]$ without knowing K and I. For FP_1 we have the standard result that the auctioneer's expected revenues equal the sum of the common component $A = y - \theta\varepsilon$ and the expectation of the second highest value of X_H among the n_H bidders (I denote this value $E(X^{(n_H)}_{H,2nd})$) minus the screening cost I. Hence: $E[R^{FP_1}] = A + E(X^{(n_H)}_{H,2nd}) - I$. Instead, for FP_1 we have two possible cases depending on how large the difference between A and B is. Denote by K, $K < A + \max(\bar{x}_H, \bar{x}_L)$, the salvage value that the auctioneer gets from the good in case the winner of the auction defaults on his bid.[68] Furthermore, denote by $E(X^{(n_H)}_{L,2nd})$ the expectation of the second highest value of X_L among the n_L bidders. Then the expected revenues are:

$$E[R^{FP_0}] = \begin{cases} (1-\theta)(B + E(X^{(n_L)}_{L,2nd})) + \theta K & if\ (B - A) > (\bar{x}_H - \underline{x}_L) \\ (1-\theta)E[R^{Asym.FP_0}] + \theta \Pr(L\ wins)K & otherwise \end{cases}$$

Where $E[R^{Asym.FP_0}]$ is the expected revenue in an auction where bids are binding (no default

[68] The salvage value K is likely affected by many factors. A minimum assumption is that $K \leq (y - \varepsilon) + \max(\bar{x}_H, \bar{x}_L)$ by which I require that K is smaller than the highest value the good can take in the bad state of the world. A winner's default, in fact, reveals that the good value is low. K is not restricted to be positive.

is possible) and there are n_L and n_H asymmetric bidders having expected payoffs described by (1). Notice that these revenues must be greater than those that a second price auction would raise in this same environment. In turn, the revenues of a second price auction with $(n_L + n_H)$ bidders are greater than those of a second price auction with just n_H bidders, which are identical to $E[R^{FP_1}] + I$ by revenue equivalence. Therefore, we can conclude that $E[R^{Asym.FP_0}] > E[R^{FP_1}]$. However, it is clear that without knowledge of I and K ranking $E[R^{FP_0}]$ and $E[R^{FP_1}]$ is not possible.

As regards AB_0, the expected revenues are:

$$E[R^{S_AB_0}] = c + (K - c)(\frac{n_L}{n_L + n_H})\lambda\theta$$

Where $c \in [0, \min\{A + \underline{x}_H; B + \underline{x}_L\}]$ and $\lambda = F_{X_L}(c + \varepsilon - p_L - y)$.[69] Fixing $c = 0$ the above formula equals $E[R^{I_AB_0}]$. First of all notice that since c enters into λ we cannot rank $E[R^{I_AB_0}]$ and $E[R^{S_AB_0}]$ without knowledge of K. Moreover, there is always an I low enough so that $E[R^{FP_1}] > E[R^{S_AB_0}]$ but the reverse relationship holds with a high I and a low K. Therefore, without knowledge of I and K no pairwise ranking of $E[R^{FP_0}]$, $E[R^{FP_1}]$, $E[R^{I_AB_0}]$ and $E[R^{S_AB_0}]$ can be established.

[69] The term λ is the probability that a low penalty bidders who wins by bidding c decides to default when the good turns out to have low value.