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

Francesco Decarolis[*]

The University of Chicago

3rd December 2008

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 theoretically 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. 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 monitoring. 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. The estimation procedure proposed uses the informational content of the reserve price to account for unobserved heterogeneity in auctions.

JEL: DL22, L74, D44, D82, H57.

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 the study by Spulber (1990) on auctions for contracts, the bid consists in the bidder's obligation to perform a work at a certain predefined price. When the penalty for not completing the work is not high enough, the contractor may default if he incurs a cost overrun. In Zheng (2001), a limited liability regulation limits the losses of a winner who chooses to default on his bid and go bankrupt.[1] 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 probabity of winning and, also, of going into bakruptcy. 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. In this paper I follow this line and consider an environment in which by paying a penalty a bidder who wins the auction can default on his bid after the true value of the good (contract) is realized.[2] I assume that bidders are asymmetric with regard both to this penalty and to the (ex post) value they assign to the good. I also assume that the auctioneer cannot rely on surety bonds or similar market based mechanisms to solve the problem of risky bidders.[3] For such an environment I study the choice problem an auctioneer faces when the choice is restricted to four auction formats: a first price auction or an average bid auction both of which can be with or without an ex post monitoring of bids.

A first price auction without ex post monitoring is just a regular first price in which the highest bidder wins. However, this bidder is also the one most likely to default on his bid as Spulber (1990) and Zheng (2001) have illustrated. One of the most common solutions used to address this problem is to let the auctioneer monitor the bids received to evaluate their responseviness. Therefore, in a first price auction with monitoring the winner is the highest responsive bidder. The average bid auction is another method sometimes used to reduce the risk that an excessively high winning bid leads to a subsequent default on the part of the winner. In this format the bidder closest to the average of the bids wins (paying his own price). This format has been proposed by Ioannou and Leu (1993) in engineering literature.[4] Although it has not received much attention in economics, this type of auction has been adopted by the public procurement codes of several countries. For instance, among the possible auction

---

[1] The effects of limited liability on bidders behavior has also been studied by Board (2008).

[2] Waehrer (1995) considers a similar environment in which the defaulting bidder must pay a penalty.

[3] This is perhaps because of imperfections in the insurance market. Calveras et al. (2004) discuss the regulatory practice of surety bonds and how they might solve the problem of abnormally low tenders in public procurement.

[4] Liu and Lai (2000) instead proposed a version of this auction in which the winner is the one offering the price "closest-from-below" to the average of all the prices offered.

formats that the Florida Department of Transportation (DoT) can use to procure its contracts there is the following form of average bid auction:[5]

"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).

In an average bid auction, the equilibrium bidding function cannot be strictly monotonic in the bidders valuations. In fact, this format implies that the highest bid is automatically eliminated every time it is the lone highest bid. Hence, intuitively an average bid auction does not appear to be an interesting mechanism for an auctioneer concerned with her revenues.[6] However, the main factor motivating my research is the seemingly puzzling evidence that this mecahnism 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 allowed public administrations the freedom to choose alternatively between the average bid auction (AB) and the first price auction (FP).[7] 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. An obvious candidate to explain for such behavior is corruption in public officials. Since Italian Law requires an ex post monitoring of bids whenever the first price rule is used, corrupt public officials could use their discretionary power to eliminate some bids and award the contract to their corruptor. Nevertheless, since the rule envisaging the automatic elimination of the highest bidder is used in countries with very different levels of corruption (for instance Italy and Switzerland) and also considering the specific experience of the Italian reform, corruption may not be so important in explaining the preference of AB over FP.

My explanation as to why average bid auctions are used by auctioneers who could instead resort to a first price auction is based on the cost that this latter format induces through high risks of bidders' defaulting. In the case of no monitoring, a first price rule can cause large damages to an auctioneer who only obtains a low salvage value when the winner defaults. On the other hand, an effective monitoring technology that eliminates all bidders who have a positive probability of defaulting is likely to be very expensive. A way to interpret this cost of monitoring is as the fixed cost that needs to be paid to hire a team of engineers who evaluate the match between the bid and the firm's costs. In a broader sense this monitoring cost is the cost of all the resources that an auctioneer must pay to eliminate the risk of a winning bidder going into bankruptcy. Therefore, in the model that I present, when both the cost of bankruptcy

---

[5]I am grateful to Giancarlo Spagnolo for having signaled me that a form of the average bid auction was used by the Florida Dot.

[6]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.

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

and that of monitoring are very high the two FP mechanisms may give worse results than an average bid auction.[8] In this interpretation the AB auction is used because it is a mechanism that, without the payment of any monitoring cost, can achieve a substantial reduction in the risk of defaults. This result appears to be in line with the experience of the Italian reform that showed a high propensity of large local administrations to abandon the average bid auction in favor of the first price model. Using a large sample of Italian public procurement auctions for road construction, I show that proxies for the size of the administrations are positively and significantly associated with the choice of FP over AB.[9] Moreover, some indirect evidence of the presence of a cost of monitoring in FP auctions is obtained by looking at how a switch from AB to FP is associated with an increase of about 12 days between when the bids are opened and when the contract is awarded. Therefore, a positive monitoring cost may be a possible explanation for why AB auctions are used despite the fact that FP auctions would appear to be associated with lower procurement costs. My reduced form 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 10 points (from an average of 12% to an average discount of 22%).[10] Switching to FP is also estimated to increase the extra payment renegotiated by the contractor by about 5% of the reserve price. Therefore, for an administration that decides to use the AB, a naive estimate of the monitoring cost is that it must be equal to at least 5 percent of the contract value.

However, it is possible to obtain a more precise estimate of the monitoring cost by using a structural approach. In estimating the bidders' underlying cost distributions, I use the modification of the Guerre, Perrigne and Voung (2000) procedure introduced to study unobserved heterogeneity by Krasnokutskaya (2004). These distributions are then used jointly with equilibrium bidding conditions to infer what is the distribution of the minimum level of monitoring cost such that an auctioneer prefers an AB over a FP. The estimates suggest that on average this cost equals about a quarter of the reserve price. This large estimate has two main implications. First of all, the cost we are capturing might not be just that of a monitoring technology (the team of engineers of the example). Since the AB is the status quo, part of the cost might be due to the cost of switching. It can be that some administrations lack the resources needed to learn how to use the different mechanism of a FP with monitoring. The second, related implication is that since the FP is considerably better than the AB in terms of

---

[8]The average bid rule is always used without the monitoring. In the theoretical analysis I show that the expected revenues from an average bid auction with monitoring are lower than those of a first price with monitoring.

[9]According to the proxy that I used, a local administration is "large" in terms of the size of the population living on the territory it administers and in terms of the frquency with which it runs auctions.

[10]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 local administrations in five regions in the North of Italy.

revenues, significant reductions in public expenditures may be attained through policies that facilitate the swittch toward FP by reducing the cost of monitoring (examples could be more effective systems of pre-qualification and of reputation).

The main contribution of this paper consists in illustrating and making a structural estimation of a model that accounts for the auctioneer's choice of auction format in an environment with risky bidders. The methodology that I apply for the structural estimation is based on the model of unobserved heterogeneity of Krasnokutskaya (2004). I show that within the framework of unobserved heterogeneity the reserve price can be used to identify the bidders' underlying cost distributions when the only other available information is the winning bid.

Another relevant contribution of this paper is the theoretical and empirical analysis of the average bid auction. Albano et al. (2006) and Wambach et al. (2006) have analyzed this format before, uncovering some interesting features of this mechanism. However, their analyses involve mainly the presentation of examples whereas I seek to reach more general results. For instance, I have found that within the standard independent private value paradigm the AB auction is inefficient and, when there are many bidders, it is revenue minimizing for the auctioneer. Instead, with a pure common value (same value ex ante and ex post) this format is optimal if the auctioneer can set a reserve price equal to the expected value of the good. The most relevant result, however, is that the AB rule can give higher revenues than the standard FP rule if bidders have a relevant common component in their valuation and if some of them can default on their bid at a low penalty.[11] Moreover, my empirical analysis of AB versus FP is new and makes use of a large dataset of auctions that has been assembled for this research. In future work, I will use these data to address other research questions that I could only sketch in this paper, like the presence collusion in AB auctions regarding which some preliminary results are presented in Appendix III.

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. Some recent studies to which my paper is related are those 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).[12] As for this last paper I also share with the author the analysis of the auctioneer's preference for auction formats as a function of the salvage value. Board (2008) compared the case of the first and

---

[11]For the trivial case in which bidders share the same (ex ante and ex post) value for the good, the AB can also be shown to be an optimal mechanism if the auctioneer can set the reserve price equal to the expected value of the good.

[12]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.

second price auctions under different scenarios for the recovery rate of the auctioneer. His analysis shows that a first price rule is preferred to a second price rule when the auctioneer only recovers a small fraction of what was promised by the winning bidder. My analysis complements that of Board (2008) by looking at other relevant mechanisms. Moreover, 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: the following sub section is an introduction to the main problem studied through a simple example. Then section 2 presents evidence from public procurement regulations illustrating the pervasiveness of auctions where the highest bidder does not win. Section 3 presents the theoretical analysis, Section 4 the data, Section 5 the reduced form empirical analysis, Section 6 the structural analysis, and finally section 7 concludes the study.

1.1   Example: FP vs. AB when bidders may go bankrupt

The following example will clarify the problems associated with first price auctions when bids are not binding promises and it will show how an average bid auction can help to mitigate them. Consider having (N+1)>3 bidders who are competing for a single good which is auctioned off. The value of this good is the same for all bidders. However, at the time of bidding this value is uncertain. Bidders know that the good is equally likely to be worth either 2 or 4, so the ex ante expected value of the good is 3. Bidders have different budgets: N of them have a budget greater than 4 while the remaining bidder has a budget equal to m, $m \in [0, m^*]$, $m^* < 1$. I call the first N bidders "deep pocket" (DP) and the remaining one "financially distressed" (FD). After the winner is declared but before he pays his bid the true value of the good is disclosed. At that point the winner has the option of fulfilling his bid (paying b_w and getting the good) or defaulting on his obligation. In this case a court declares him bankrupt and takes away his budget. The auctioneer, instead, cannot observe the bidders' budgets. In case the winner refuses to collect the good the auctioneer gets a salvage value K otherwise, if the winner fulfills his bid, she gets b_w. The figure below illustrates the timeline just described:
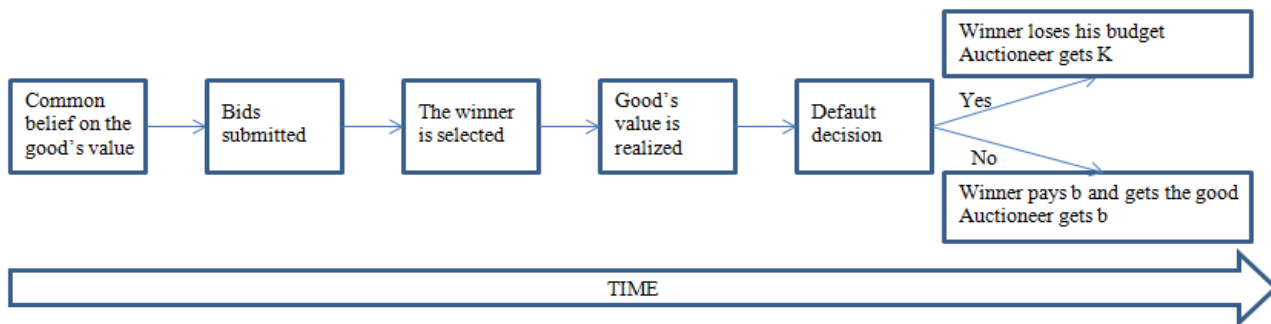
We shall now consider two different auction formats that the auctioneer can use to sell her good: a first price auction (FP) and an average bid auction (AB). In the first price auction the highest bid wins while in the average bid auction the bid closest to the simple average of all the bids wins.[13] In both formats the winner pays his own price and ties of winning bids are broken with a fair lottery. There is a publicly announced reserve price is equal to 2. If we analyzethe way bidders behave by looking exclusively at symmetric Bayes Nash Equilibria (BNE) we derive the following results:[14]

A) First Price Auction: the DP bidders bid 3 and never default on their bid. The FD bidder bids $3 + \varepsilon$, fulfill s his bid if the good is worth 4 and defaults if the good is worth 2.[15]

B) Average Bid Auction: all bidders (DP and FP) bid the same constant c, $c \in [2,3]$. DP bidders never default while the FD bidder defaults if the good is worth 2 and $m < 2 - b_{FD}$, otherwise he fulfills his bid.

Discussion of the equilibria under the two rules: There are three basic conclusions we can take from this example. First, under the average bid rule the FD bidder is no more likely to win than any of the DP bidders while, instead, he is certainly the winner in the first price auction. Second, under the average bid rule the winner pays a lower price to the auctioneer than he would in a first price auction, $3 + \varepsilon > c$, $c \in [2,3]$. Hence, the AB rule reduces the risk

---

[13]Regardless of whether it is the closest bid from above or from below the average.

[14]A bidder's strategy in this game consists in a decision of whether to default conditional on the value of the good (i.e. default or not when the good is worth 2 or 4) and a bid $b \in \{2, 2 + \varepsilon, 2 + 2\varepsilon, ..., 4\}$, where ε is a very small, positive minimum bid increment. Bids below 2 are assumed to be rejected by the auctioneer while bids above 4 can be disregarded as they would be dominated for every bidder. Also notice that I am not restricting the bids to be smaller or equal to the budget so I am implicitly assuming that firms can freely borrow.

[15]With a budget greater than 4 defaulting can never be optimal for DP bidders. A simple Bertrand argument then explains why they all bid the expected value of the good, 3, and completes the description of their equilibrium strategy. As regards the FD bidder it can be checked that the proposed strategy assures him the highest expected payoff conditional on the DP strategy. The FD expected payoff is strictly positive. My example with the FP auction is just a simplification of the model of Zheng (2001) where there is a distribution for the bidders' budget and it is shown that the BNE bidding function is decreasing in the size of the budget.

of default by the winner both because the winner is less likely to be the FD and because, even if the FD wins, he does so at a price that makes fulfilling the bid relatively more convenient. The third consideration is that, if the salvage value, K, is low enough, the auctioneer prefers AB over FP. Since bankruptcy occurs only if the value of the good is low, it is safe to assume that $K \leq 2$. Consequently, the auctioneer's expected revenues from AB, $E[R^{AB}]$, are greater than those from FP, $E[R^{FP}]$, when:[16]

$$E[R^{AB}] = \frac{N}{N+1}c + \frac{1}{N+1}[(\frac{1}{2})K + (\frac{1}{2})c] > (\frac{1}{2})K + (\frac{1}{2})(3 + \varepsilon) = E[R^{FP}]$$

Without a theory that selects a focal equilibrium for the AB auction, the value of c can be anywhere in $[2, 3]$. In the best case for the auctioneer $c = 3$ and to have $E[R^{AB}] > E[R^{FP}]$ it is enough that $K < 3 - \varepsilon(\frac{N+1}{N})$. Even in the worst case for the auctioneer, $c = 2$, that revenue ranking is obtained if $K < 2 - (1 + \varepsilon)(\frac{N+1}{N}) < 1$.

Although the AB outperforms the FP in this case, this rule, nevertheless, appears to be problematic especially because of the uncertainty caused by the multiple equilibria. The obvious question is, can we do any better with a different mechanism? The answer crucially depends on the instruments and information available to the auctioneer. If she knows that the expected value of the contract is 3 and she can set the reserve price equal to 3, then her expected revenues will be maximized. However, exactly the same expected revenues are also obtained if she uses the FP and forbids bids above 3. In the rest of the paper, I do not consider these instruments because they are are less useful beyond the simple case of a pure common value. However, I will consider a different instrument that is often available to the auctioneer: the use of a monitoring technology that identifies non reliable bidders. In the above example if the auctioneer can use this technology at a cost I, her expected revenues will be equal to $3 - I$. Whether these revenues are greater or lower than those of the standard FP or of those of the AB depends on the exact values of the parameters of the game.

Summing up, the example illustrates that when bids are not binding commitments for the bidders and when the auctioneer's salvage value is low, the first price rule has a severe impact on the auctioneer's revenues. Both these conditions are likely to be met in the case of public procurement auctions for the execution of works. Auctions for contracts are the focus of Spulber (1990) which, to my knowledge, is the first paper that showed this problem. The reason is that in this environment it is likely that bidders are ex ante uncertain about the cost of the works and that a cost overrun can occur during the prolonged time that it takes to complete the work. 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.[17] In public procurement,

---

[16]Moreover, to simplify the analysis I am looking at the case of a FD who has a budget equal to zero and who decides to default when he is indifferent about doing so.

[17]The European Commission Enterprise & Industry (2002) report presents some evidence on the auctioneer's

this problem is further exacerbated by the rigid rules that limit the auctioneer's flexibility to renegotiate the price ex post. These rules, aimed at reducing the risk of corruption, might force the auctioneer to let the contractor abandon the work even if ex post she might find it preferable to help the same contractor rather than putting the contract up for another auction.[18]

The solution proposed by Spulber is 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.[19] However, alternative solutions might be needed when there are imperfections in the insurance or credit markets or when it is hard for the auctioneer to prove the contractor's misconduct to a third party (the insurance company or a court). Two methods often adopted in public procurement that are more immune to these problems are: (1) augmenting the first price auction with an ex-post verification of the responsiveness of the bids and (2) using an average bid auction. The aim of this paper is to shed some light on the relative merits of these two auction mechanisms. The next section illustrates some institutional details of public procurement auctions in several countries. These illustrate the interest behind the two auction mechanisms that I have decided to study. However the reader not interested in such institutional details can skip directly to Section 3 where a formal model is presented.

2   Some Motivating Cases from Public Procurement Regulations

Numerous studies on the construction industry, like Hinze (1993) and Clough and Sears (1994), show that the procurement of works often takes place through competitive auctions. This appears to be true also for the case of public procurement. The regulation of public procurement in the countries in the table below requires the use of competitive auctions. However, an interesting difference exists regarding to how the winner is selected in such auctions. Assume that an auctioneer publicly announces the maximum price she is willing to pay and that bidders bid percentage discounts on this price. Hence, in a standard first price auction the highest bid (i.e. the highest discount) should win. A careful look at the institutional details of the rules of public procurement in these countries reveals that in none of them is this truly the case.

---

costs due to bidders failure to comply with their contractual obligations. An interesting analysis is also the recent study by Bajari and Lewis (2008) where the authors try to quantify how delays in the execution of works might affect the welfare of an auctioneer concerned with social welfare.

[18]Ex post price renegotiations are, however, very common in public procurement auctions. The study of Bajari et al (2007) presents a framework for studying the problem of renegotiation in public procurement auctions. Their model assumes that firms have perfect foresight, while an essential component of my analysis is the firms' uncertainty about the cost of the work.

[19]In the US the Miller Act requires a 100% insurance coverage through a surety bond for every federal contract above $100,000.

Rules for automatic identification and elimination of abnormal tenders		
Automatic elimination	Only identification	No explicit rules
Florida (Dept. of Transp.)	Belgium	Canada
Italy	Brazil	USA (Most of the States)
Peru	Germany	
Switzerland	Portugal	
Taiwan	Romania	
	Spain	
	Turkey	
	UK	

The countries in the left column are the ones where this fact is most striking. There are rules in these countries that identify and automatically eliminate "abnormally" high tenders.[20] 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. For the countries in the middle column the identification of an abnormal tender does not mandate its automatic elimination but requires that further checks on the reliability of the bid are undertaken before the contract can be awarded to such a bidder.[21] Even when there are no explicit rules for detecting abnormal tenders, as is true of countries in the right column, the auctioneer can exclude bids that are so high as to jeopardize the correct execution of the job. For example, Bajari, Houghton and Tadelis (2007) report that this is why 4 percent of the auctions in their database of the California Department of Transportation (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.

My analysis in this paper differs from that of Bajari et al. (2007) in that I explicitly consider the auctioneer's choice of the auction mechanism. This analysis leads me to study auctions in which the highest bidder is certainly and irrevocably eliminated. The average bid is the base line case of these types of auctions and, although it is rather new to Economics (exceptions are Albano et al., 2006, and Engel et al., 2006), it has been proposed as an "optimal mechanism"

---

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

[21]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 PPAA. 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 arithmetical mean 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.

by the engineering literature (see Ioannou and Leu, 1993). Forms of the average bid auction have been used in Taiwan and by the Florida DOT.[22] Spurious forms of this auction, in which the winner is the bid closest to a rather complicated function of the average bid, have been used in Italy and Peru.[23] [24] Strategic incentives similar to that of the average bid auction are also those produced by the Swiss rule of eliminating the highest bidder and awarding the contract with a "second-highest-bid-wins" rule.[25] In the table below an example is given of how bids are ranked under these three forms of elimination of highest bids using the rules in place in Italy, Taiwan and Switzerland for the case in which 5 bidders submit their bids ranging from a discount of 30% to one of 23% on the contract value announced by the auctioneer:

---

[22]In Taiwan the rule is simply that the bid closest to the average of the submitted bids wins. In Florida, instead, the DoT can decide between several different awarding rules that its code mentions. Among these rules the one set forth in subarticle 3-2.1 states that when there are only only three or four bidders the bid closest to the average is selected. However, when five or more contractors bid, the lowest bid and the highest bids are excluded, and the bid closest to the average of the remaining bids is selected. To my knowledge the Florida DoT has not used this rule since 2001.

[23]The awarding rule used in Italy is provided for in Art. 21 Law 109/94 (which is the same rule as that set forth in Art 122 Law 163/06 of the new Public Procurement Code) for any contract below European Community Interest (approximately this means any contract below 5 Million Euro). The rule is that if the number of bidders is less than 5, then the contract is awarded to the bidder offering the highest discount (this is always the rule for contracts above 5 Million Euro). If, instead, there are 5 or more bidders, the winner is 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, call it A2; (step4) eliminate all the bids that are greater or equal to (A1+A2); (step5) the winning bidder is then the bidder with the highest bid among those not eliminated.

[24]Regulations change over time: for instance the rule for Peru was that all the procurement auctions held by the Public Procurement Authority (PPA) had the PPA calculate the average of the bids submitted and then eliminate those bids that were 10% above and 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 the second average. However, a change in the procurement law was recently introduced 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.

[25]The information presented in this section on the Italian and Peruvian regulations is the result of in depth research work that I carried out personally. For all the other regulations mentioned the information comes from indirect sources. Future work will involve checking directly each of the regulations described above.

EXAMPLE: Ranking of bidders under three rules for elimination of highest bid				
BIDDER	DISCOUNT	Italy	Taiwan	Switzerland
Bidder 1	30%	Eliminated	5'	Eliminated
Bidder 2	27%	Eliminated	2'	1'
Bidder 3	26%	1'	1'	2'
Bidder 4	25%	2'	3'	3'
Bidder 5	23%	3'	4'	4'

NOTE: how to calculate the ranking of bids

Italy: (Trimmed) Average: (27+26+25)/3=26

                Averaged-average: 26+(27-26)=27 Closest to 27 from below wins.

Taiwan: Simple average: (30+27+26+25+23)/5=26.2 Closest to26.2 wins.

Switzeralnd: Second highest bidder wins.

Therefore, in this example, if the contract value announced by the auctioneer is 100, the price at which the contract is awarded is 75 in Peru, 74 in Italy and 73 in Switzerland. The three rules produce different outcomes because in each country the bid classified first is different. However all these rules share the property that, if a bidder knows he is going be the highest bidder, he also knows for sure he will lose the auction.

The central idea of this paper is to look not only at bidders' optimal behavior under different rules in dealing with abnormal tenders but also at the auctioneer's incentives to choose such rules. In this respect an interesting document is the European Commission 2002 report on "Prevention, Detection and Elimination of Abnormally Low Tenders in the European Construction Industry". This report suggests that "contractors who intentionally submit abnormal tenders might be those who seek an ex post renegotiation of the terms of the contract. They could also be firms in bad financial conditions that, however, are either reluctant to lay off their employees or are in search of a contract in order to obtain a cash advance from their client or bank".[26] The two mechanisms on which I focus my analysis, a first price rule plus an ex post monitoring of the reliability of bids and an average bid auction, are potentially useful

---

[26]This report offers three other reasons for which a firm might offer an abnormally low price: (1) Imprecise and ambiguous project and tender documentation. (2) Inadequate time to prepare tenders (excessively short deadlines for the preparation of tenders prevent enterprises from carefully calculating their costs). (3) Errors in evaluating tender documents from previous auctions (on the basis of historical data, because over-estimation actually eliminates a tender, all errors are under-estimates). All these reasons can be seen as instances of imperfect information regarding the true value of the contract. If the uncertainties concerning the cost of completing the contract affect all the bidders in the same way and are more important than the idiosyncratic components, then the legislator may have opted for the elimination of abnormally high tenders to limit the risk of the winner's curse phenomenon. Although the winners' curse is not an equilibrium outcome, Kagel and Levin (1986) have shown that players learn to internalize the winner's curse effect only through time. A frequent influx of inexperienced new players might then explain the concerns for the winner's curse behavior. Nevertheless frequent interaction with participants of Italian public procurement auctions convinced me that the sort of problems described in this note are far less important than the possible abuse of post-tender negotiations to explain the auctioneer's concern about abnormal bids.

mechanisms to limit the problems that can arise when the contractor seeks to abuse the post-tender negotiation.[27] These two methods can be seen as allowing the auctioneer to have totally different degrees of discretionary power in dealing with this problem. Where there is no explicit rule to identify abnormal tenders this power is highest, while it is null with a purely automatic rule. A possible explanation for the different mechanisms adopted lies in the different levels of the risk of corruption of the public administrations of different countries. Although the Italian Public Administration may appear to be more prone to corruption than its US counterpart, the presence of Switzerland among countries with reduced levels of discretionary power does not fit in well with this explanation. A different interpretation is that the effective use of this power carries a fixed cost. This cost can be, for instance, that of hiring a team of engineers to evaluate the bids after they have been received by the auctioneer. On the basis of both empirical evidence following a recent policy change in Italy (presented in Section 4) and the comparative analysis of the institutional differences between the Italian and US procurement systems, I opted for this latter explanation.[28] Therefore, in the theoretical analysis presented in the next section the discretionary power to exclude bids is assumed to be costly for the auctioneer but effective in eliminating risky bids.

3   Theoretical Analysis

3.1   The auctioneer's decision problem

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 monitoring of bids. The average bid rule says that the bid closest to the average of all bids wins. In all formats ties are broken with a fair lottery. The choice problem is represented in the figure below. The auctioneer observes how much the monitoring would cost and then decides which of the four possible auction mechanisms to

---

[27]My analysis excludes issues related to the quality of the job and the ensuing moral hazard problem that would arise if this quality cannot be verified. The implicit assumption is that the job is simple enough to make it possible to write a detailed contract that overcomes all quality issues. For the simple road construction works of my empirical analysis this seems reasonable. In fact, when the job is highly non standard and quality matters, the awarding rule is very different from the form being discussed here, and consists of a scoring rule in which the price is just a part of the overall score. See Asker and Cantillon (2008) for an analysis of procurement when both price and quality matter.

[28]The institutional details regard the fact that in Italy the portion of the contract guaranteed by an insurance is generally small, around 10%, while in the US it is generally 100%. Moreover, in Italy most of the auctions for road constructions are held by the smaller local administrations (municipalities), whereas in the US the process is more centralized, and comes under the State Department of Transportation. Both these features are likely to imply that for the Italian auctioneer it is harder to perform an effective ex post monitoring of the bids.

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.
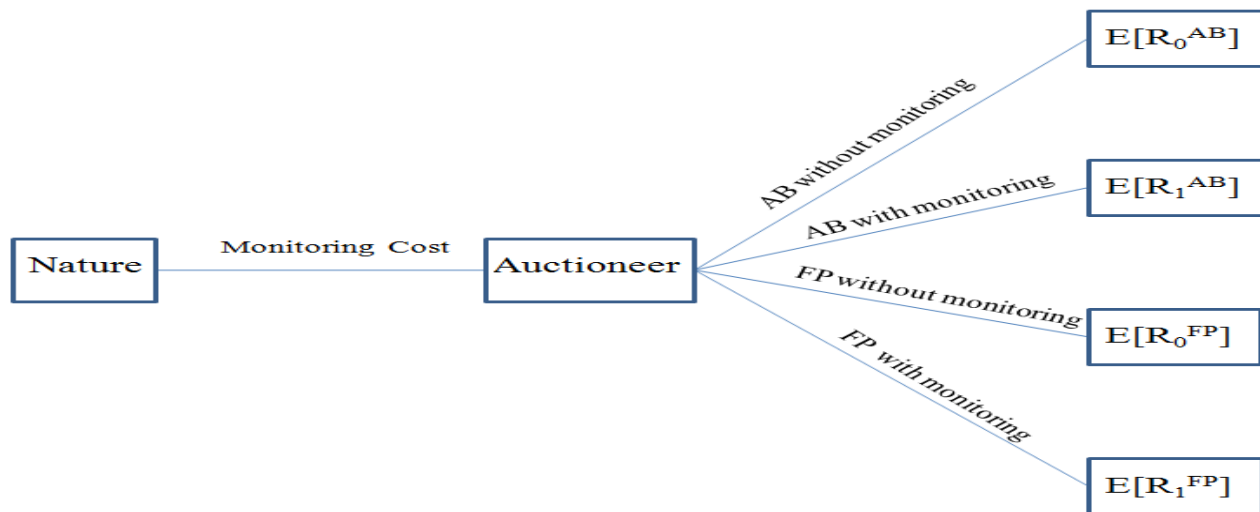
The reason why the auctioneer may want to deviate from a standard first price without any ex post monitoring of the bids is that she knows that some bidders may decide not to fulfill their bid. I make the following assumption regarding the monitoring:

Assumption (i): *(Monitoring Technology) If the auctioneer pays the monitoring 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 winners' insolvency. This, however, has both a direct cost (the monitoring cost) and an indirect cost. This second cost is due to reduced competition that bidders face when they know that some of their N competitors will be eliminated.

In an average bid auction the winner is the bidder whose bid is the closest to the simple average of all the bids submitted. The example in Section 1 suggests that this kind of mechanism reduces the incentives to submit aggressive bids and, in this way, it eliminates the advantage that the first price gives to bidders who can more cheaply renege their bids. However, this effect comes at the cost of a low awarding price at the time of the auction. Adding monitoring to an average bid auctions adds the direct cost of monitoring to this low competition effect. Indeed, the following analysis will show that this latter format (AB w. monitoring) is never optimally chosen by an auctioneer. However, which of the other three auction formats is optimal for a revenue maximizing auctioneer depends crucially on both her recovery rate in case of winner's insolvency (like in Board, 2008) and on the size of the monitoring cost. The analysis of the auctioneer's decision problem starts by illustrating the firms' behavior under

14

each of the four auction formats and then continues by specifying the ensuing expected revenues of the auctioneer.

## 3.2 Firms' bidding behavior under the four auction formats

Monitoring technology is useless if bids were binding commitments for the bidders. In turn, uncertainty about the value of the good is a key factor in the motivation whereby bidders may want to default on their bids. As in Spulber (1990), I consider a set up with both uncertainty about the good's value and imperfect enforcement of the promises represented by the bids. Zheng (2001) considered a similar environment in which firms share a common value (ex ante and ex post) for the good, and can default on their bids under a limited liability regulation. Bidders have asymmetric budgets which are their private information. Zheng shows that in a first price auction, if the budget is not a constraint on firms as to how much they can bid, but only on the size of their loss, then the bidder with the smallest budget is the one who bids higher. However, this is also the bidder most likely to defult on his bid.

The model that I present below differs from Zheng's model in that I consider bidders' valuation to be private but with a privately and a commonly observed component. Moreover, in my model a bidder's penalty in case of default (which plays the role of the budget in Zheng's model) is observable to all the bidders. Finally, while Zheng analyzed only the case of a first price rule without monitoring, I consider bidding under three other mechanisms.

Bidders know exactly which auction format has been chosen by the auctioneer. Assuming that there are $N > 2$ risk neutral bidders in the auction and that they behave competitively, their bids will depend on their valuation for the contract and on the probability of winning. The valuation is wholly private, each firm would not learn more regarding his own valuation from a knowledge of the other firms' valuation. Moreover the true value of the object is unknown at the time of bidding. 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 I will say that the value of the contract is "high" (state of the world is "good") and in the second that it is "low" (state of the world is "bad"). Part of the private valuation, x_i, is only privately observed by each bidder i, $i = 1, ..., N$. Instead, another 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 that the probability of this loss of value is θ and that the true value of the good will be known immediately after the auction is over. The random variables Y and X that are distributed on $[\underline{y}, \bar{y}] \times [\underline{x}, \bar{x}]^N$, $y \geq 0$, $x \geq 0$ 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 he does not get the object and has to pay a penalty p. 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. The figure below illustrates the timeline of the problem:
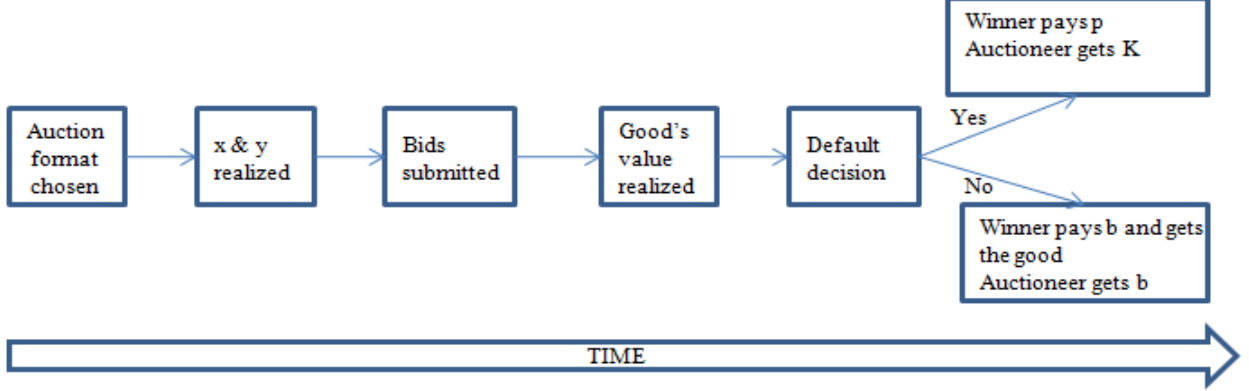
I also assume that the penalty is bidder specific (for instance because it is proportional to his budget) and, to simplify the analysis, I consider only two levels of penalties:

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 type L that only pay a low penalty (p_L) and $n_H = N - n_L$ bidders type 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 monitoring cost. I also make the following assumptions:

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, however, is not binding.*

Analysis of bidders behavior.[29] Restricting the analysis to the case in which only non

---

[29]I analyze bidders' optimal behavior only within each of the four auction formats disregarding the effect of this behavior on the auctioneer's choice of the format. For instance, in the case of the AB auctions where multiple equilibria are present, I will not address the issue that, if firms coordinate on one equilibrium instead

dominated strategies are played implies we can disregard situations in which the winning bidder declares himself insolvent even if the value of the contract is "high".[30] Therefore 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 $b_j : [\underline{y} + x_j, \overline{y} + \overline{x_j}] \rightarrow R_+$ 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. The equilibrium characterization requires specifying the rules of the auction because they determine the probability of winning. However, regardless of the exact probability of winning, it is possible to 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 a first price auction, then the bid is fulfilled only if the ex-post value of the good is "high".[31]

Lemma 1. *Assume y is the realization of Y observed by all bidders and $\varepsilon > (\frac{1}{1-\theta})x_L$. Then, if $p_H \geq y + \overline{x_H} - \theta\varepsilon = p_H^*$, bidders type H neither play $b_H > y + \overline{x_H} - \theta\varepsilon$ nor decide to default on their bid in case of victory. Moreover, if the format is a first price auction with monitoring, no bidder plays $b_j < y - \theta\varepsilon$; in case $p_L < (1 - \theta)\varepsilon - \overline{x_L} = p_L^*$ bidders type L fulfill their bids exclusively in the "good" state of the world .*

The following figure shows how the default choice (in the case the state of the world is "bad") changes as the size of the penalty increases. Recall that default is, instead, never optimal if the state of the world is "good".
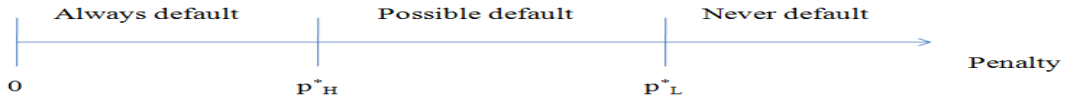
In the following analysis of the four auction formats I will assume:

---

of another, this might change the auctioneer's choice of which format to use and through that the firms' payoffs.

[30] 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 $(1 - \theta)\varepsilon > 0$.

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

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

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

$$\text{Type H:} \quad (1-\theta)(y + x_H - b_H) + \theta(y + x_H - \varepsilon - b_H) = A + x_H - b_H$$

$$\text{Type L:} \quad (1-\theta)(y + x_L - b_L) + \theta(-p_L) = (1-\theta)[B + x_L - b_L] \tag{1}$$

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.

3.2.1 First price auction with monitoring

This is a standard sealed bid first price auction where, however, all bids are subject to an ex post monitoring of their validity. Under Assumption (i) every bidder that would optimally default in the "bad" state of the world is eliminated. Therefore, Assumption (v), according to which all type L bidders optimally default in the "bad" state of the world, implies that L bidders do not have a bidding strategy that, in equilibrium, gives them a positive expected payoff. If they bid less than $y - \theta\varepsilon$ they might not be eliminated but they have a zero probability of winning. If they bid above that value they will be eliminated by the monitoring technology. Therefore, since their probability of winning is zero, their presence in the auction is irrelevant for type H bidders. Hence, for a type H bidder the probability of winning is simply the probability of making the highest bid among bidders of his same type. Therefore, a 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 the state of the world is "bad" 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:[32]

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

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 can be found by looking at 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 the auctioneer's revenues since type L bidders are irrelevant for that.

---

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

3.2.2 First price auction without monitoring

Where monitoring is absent, low penalty bidders cannot be prevented from winning the first price auction. Indeed, as the following analysis shows, they are the bidders who are most likely to win. To establish this result without restricting the analysis to some special distribution of valuations (and utility function), the following assumption, introduced by Maskin and Riley (2000) to characterize some properties of the equilibrium in first price auctions with asymmetric bidders, will be made:[33]

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

Notice that if we assume that both F_{X_L} and F_{X_H} and their supports are identical and equal to F_X, then because the bidders' problem as represented in (1) corresponds to the case where for type H bidders $F_X \sim [A, A + \bar{x}]$ and for type L bidders $F_X \sim [B, B + \bar{x}]$. Since $B - A = \frac{\theta}{1-\theta}[(1-\theta)\varepsilon - p_L] > 0$, it is easy to verify that the distribution of bidders L valuation is just a rightward shift of the distribution of the H bidders. Hence Assumption (v) is always verified. On the basis of this assumption we can state the following proposition:

Proposition 1. *A type-symmetric equilibrium exists. In equilibrium two cases are possible: (a) if $[(B - A) > (\bar{x}_H - x_{\underline{L}})]$, then type L bidders always bid above the greatest bid of type H bidders; (b) if $0 < (B - A) < (\bar{x}_H - x_{\underline{L}})$, 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. Therefore, a type-symmetric BNE is a strategy profile in which type H bidders bid their true value and always fulfill their bid while bidders type L fulfill their bid only in the "good" state of the world and bid according to:

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

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 $[(B - A) > (\bar{x}_H - x_{\underline{L}})]$.[34]

---

[33]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.

[34]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.

Part (b) of the proposition, instead, says that if the advantage of L type over H type is not too big, $[(B - A) < (\bar{x}_H - x_L)]$, then H bidders are not necessarily outbidded by L bidders. 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.

3.2.3 Average bid auction with monitoring

In an average bid auction the winner is the bidder whose bid is closest to the average. Therefore, under the assumption that ties are broken with a fair lottery, we have that for a bidder i, regardless of his type, 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.[35] To characterize the BNE of this auction game it is useful to start the analysis looking at a simpler setup. 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 $[x, \bar{x}]$, (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, (e) bids below x are not valid. The following proposition characterizes the BNE of the average bid auction:[36]

Lemma 2: *For any N, the strategy profile in which all players bid according to the constant bidding function $b(x) = x$ for every possible x is a symmetric BNE. Moreover, four properties characterize any other symmetric BNE that might exist. The bidding function (1) is weakly*

---

[35]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.

[36]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 $[x, \bar{x}]$. 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.

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 simply says that the strategy profile in which all bidders always bid the minimum bid, $\underline{x}$, regardless of their type is always a BNE .[37] 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.[38] Notice that with N=2 bidding $\underline{x}$ is the unique equilibrium. Even though it cannot be guaranteed that bidding $\underline{x}$ produces a unique equilibrium when there are more than two bidders, the second part of the proposition ensures that any other equilibrium lies close to it.[39] 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.[40]

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

---

[37]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 $(1/N)(x_i - \underline{x})$.

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

[39]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 clearly 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, we can conclude that the only candidate strategies for equilibria are those in which every type is bidding the same constant. However, the only possible equilibrium with constant strategy is clearly the one where every type bids the minimum valuation, otherwise types below any other candidate constant could profitably deviate by bidding their own value.

[40]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.

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 average bid auction 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 game.*

Combining the results of the two lemmas above we obtain the following characterization of the type-symmetric BNE in the average bid auction plus monitoring where type L and type H bidders participate:

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

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 bidder.[41] Therefore, while the AB auction reduces the risk that the good goes to a type L bidder it does so at the cost of inducing a very low price competition among bidders. Moreover, the allocation it generates is inefficient. Using monitoring in the AB auction reduces the auctioneer's expected revenues not only for tits direct cost but also because it induces type L bidders to make bids so low that they would optimally decide not to default even in the bad state of the world (so that they are not eliminated by the monitoring technology).

3.2.4   Average bid auction without monitoring

The case of the average bid auction without monitoring is very similar to the previous one. The only relevant difference is that removing the monitoring 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. Therefore, the type-symmetric equilibria are all the strategy profiles in which all bidders, regardless of their type and value, bid the same constant value c, where $c \in [0, \min\{A + x_H; B + x_L\}]$, and never default if they are of type H and default if they are of type L but only if $x < (y + p_L - \varepsilon - c)$ and the realized state of the world is "bad".

---

[41]The fact that the monitoring technology eliminates bidders that would optimally default means that only if type L bidders bid less than $(y + x_L + p_L - \varepsilon)$ 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.

3.3 Revenue ranking for the four formats

It is now possible to analyze the auctioneer's expected revenues under the four different auction formats. For the case of a first price auction with monitoring we have the standard result that the auctioneer's expected revenues equals 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 $E(X_{H,2nd}^{(n_H)})$) minus the monitoring cost (which I denote I). Therefore,

$$E[R^{FP_1}] = A + E(X_{H,2nd}^{(n_H)}) - I$$

As regards the revenues in the first price auction without monitoring there are 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.[42] Furthermore, denote by $E(X_{L,2nd}^{(n_H)})$ the expectation of the second highest value of X_L among the n_L bidders. Then the expected revenues are:

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

Where $E[R^{Asym.FP_0}]$ is the expected revenue in an auction where bids are binding (no default 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 $E[R^{FP_0} - Asym.] > E[R^{FP_1}]$. A more precise description of the revenues in the asymmetric bidders' case is not possible without further assumptions.[43] However, it is already possible to see that, given θ, n_L and I, the smaller K and p_L are, the more likely it is that $E[R^{FP_1}] > E[R^{FP_0}]$.

As regards the two average bid auctions, multiple type-symmetric equilibria exist in both.[44] However, a first step we can take to simplify the analysis is to note that $E[R^{FP_1}] > E[R^{AB_1}]$,

---

[42] 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.

[43] The revelation principle for Bayesian games would allow to write a system of differential equations that, together with an initial condition, would define the auctioneer's expected revenues. However, the system would admit an explicit solution only in some special cases. See Krishna (2002).

[44] The set of equilibria of the auction without monitoring contains all the equilibria of the auction with monitoring plus some others in which the winning bid is strictly greater than that of any equilibrium of the auction with monitoring. However, it could happen that the focal equilibrium in the game with monitoring ends up being with a higher bid than that of the game without monitoring.

so that a revenue maximizing auctioneer never optimally chooses an average bid auction with monitoring. To see why notice that in both FP_1 and AB_1 the auctioneer pays I and avoids the risk of the winner's defaulting. However, the density of the winning bid in the FP_1 is positive only in the interval $(A + \underline{x_H}, A + \bar{x_H})$ while in the case of the AB_1 this interval is $[0, A + \underline{x_H}]$.

Finally, consider that the expected revenues in the case of an average bid auction without monitoring are:

$$E[R^{AB_0}] = c + (K - c)(\frac{n_L}{n_L + n_H})\lambda\theta$$

Where $c \in [0, \min\{A + \underline{x_H}; B + \underline{x_L}\}]$ and $\lambda = F_{X_L}(c + \varepsilon - p_L - y)$.[45] It depends on the values of several parameters of the game, whether these revenues are ranked above or below those of the first price auctions. For instance, in the comparison with a first price auction with monitoring, the size of the monitoring cost is crucial. On the other hand, in the simple example of section 2 in which the valuation had only a common component, it was shown that, even with $n_L = 1$, it was possible that $E[R^{AB_0}] > E[R^{FP_0}]$ if K was low enough.

The conclusion that we obtain is that, on a theoretical ground, we cannot rule out the possibility that an auctioneer chooses a first price, with or without monitoring, or an average bid format without knowledge of the size of the parameters of the game. The next section uses data from the Italian change in the public procurement auction regulation to try to estimate the fundamental parameters of the model.

4   Data

For this research I collected a new set of data on Italian public procurement auctions for works which are run alternately under a version of the AB[46] rule or under the FP rule. Variations in auction format are rare and, therefore, these data are rather unique. Not only this, but also the great economic importance of these auctions in Italy (worth about €10 billion or 0.7% of the GDP every year) account for the need to quantify the effects of the two mechanisms in terms of revenues generated and allocation efficiency. An assessment of the economic relevance of the auctions that I study is presented in Table 2.

The data collected are grouped into two samples.[47] The first sample, called Reform Sample,

---

[45] 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.

[46] Details of the Italian rule are described in section 2. In the rest of the paper I will refer to the Italian format just as AB. Indeed, symmetric BNE of the simple average bid game and the Italian averaged-average bid share the same properties.

[47] See also Appendix II for a description of the data.

contains all the auctions for road construction works worth less than €2.5 million held between November 2005 and June 2008 by local administrations (counties and municipalities) in five regions in the North of Italy (Piedmont, Lombardy, Veneto, Emilia and Liguria). Variations in the auction format used can be seen in this sample because it contains auctions held both before and after the national reform of July 2006. This reform allowed individual Public Administrations to freely choose between the Italian version of the AB rule or a standard FP rule.[48] For the approximately 1,000 auctions in this sample (Table 3 reports the summary statistics) I have both the bids and the identities of each participant. Table 1 presents some statistics based on an extended version of this sample which contains data for all the Italian regions. The data are presented by grouping the auctioneers along the lines of their geographical location (North, Center, South and the Islands) and by their type (Comune and Provincia). Interestingly, there is sharp a difference between the winning discount in AB auctions held in the South and those held in the rest of Italy. Moreover, at least until June 2008, only about 20 administrations switched to the FP auction format and they were all in the North. For this reason in the rest of this paper I will restrict my attention to auctions held in the aforementioned five regions in the North where FP auctions have been adopted.[49]

My second 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 1999 while the latest are from January 2008. This sample does not contain the bid and identity of all the bidders but only of the winner 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 bankruptcy occurred). Several summary statistics are reported in Table 4. Unfortunately, this sample does not allow for a fine distinction of the kind of public works involved, but only dummy variables for macro categories of works. Moreover, since the 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 Provincia and Comune 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 based on the Authority Sample. This mainly consists in a Difference-in-differences analysis where the switch from AB to FP is the treatment. The treated group (Turin's auctions) is compared to a control group (made up of the auctions of

---

[48]Under the new law, 163/06, the FP is the default mechanism. To use the AB format, the PA must make an express statement in the document that announces the auction by invoking Art. 122 Law 163/2006 (which prescribes exactly the same procedure as set forth in the old art. 21 of Law 109/1994).

[49]Figure 1 shows that the distributions of the winning bid and of the number of bidders under the two auction formats have a similar pattern whether we look at the whole sample or only at a sample consisting of PAs located exclusively in the North. Nevertheless, restricting our attention to the five regions in the North is important to guarantee that the prices used by the auctioneers to announce the contract value are similar enough across auctioneers.

local administrations comparable to Turin for their location and population size.[50] The figure below is suggestive of how sharply the change of the awarding rule affects the winning bid (expressed as percentage discount over the announced contract value). In the left panel the densities of the winning bid under AB (before treatment) and under FP (after treatment) for Turin's auctions are reported. The shift toward greater discounts is noticeable. Moreover, the panel on the right shows that, for all the other local administrations of Piedmont comparable to Turin, almost no change occurred to the density of winning bids in the same time periods.
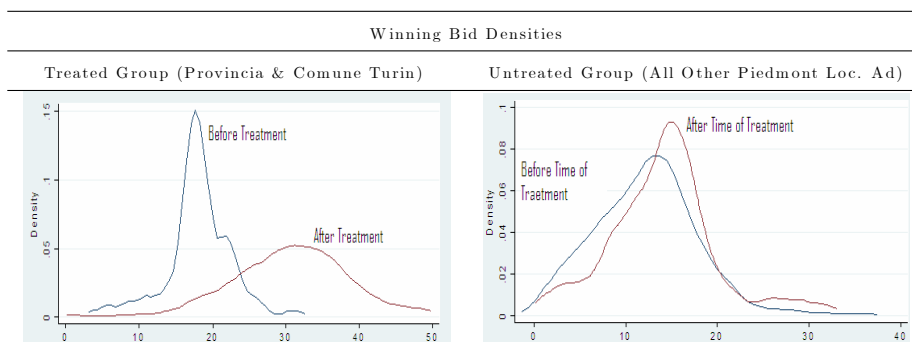
5 Reduced Form Analysis

5.1 Empirical Strategy

The reduced form analysis is based on data from both the Authority and the Reform samples. One of the main tasks of this analysis is to provide some support for the assumption that in the Italian auctions the auctioneers' choices conform to revenue maximizing behavior. One basic implication of such behavior is that an auctioneer that changes from one auction format to another on average increases her revenues. Both my samples allow us to observe public administrations switching from AB to FP (but not the other way round). Hence, it would be useful to quantify the effect that such a change has on the administrations' revenues. The case of the Authority Sample contains all the auctions of an administration, Turin, for a prolonged time both under the AB and the FP regimes. Therefore, a Difference-in-differences model can be 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):

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

---

[50]The first months of FP auctions (between January and July 2003) were excluded. Moreover, all the auctions held by the Comune of Casale Monferrato (which followed Turin's reform in 2005) and the other FP auctions held by other administrations after the reform of 2006 (just 9 auctions) were excluded from the sample.

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. Some results that will be discussed later and that are reported in Table 8 indicate that, when in 2006 the national Law ruled that every public administration was free to choose between AB and FP, only the administrations with more resources moved to FP. Hence, I constructed the control group by selecting only administrations that have resources comparable to Turin and maintain the assumption that for each of them the switch to FP would produce, all else equal, the same effect observed for Turin.[51]

Since I only observe proxies for the administrations' total resources, I construct three different control groups using three different proxies. The first two control groups are selected trying to match the size of Turin in terms of population and experience (i.e. the number of auctions held).[52] The last one, instead, combines a requirement on population and location being in Piedmont region in order to capture some possible specificity of this region.[53]

The use of the Diff-in-diff for auctions in the Authority sample as well as that of a Heckman's treatment regression for auctions in the Reform sample is mainly intended to assess the effect of whether the choice of moving from one auction format to another is compatible with the objective of maximizing expected revenues. On the other hand, the reduced form analysis that I present also tries to shed some light on other issues like the presence of ex post monitoring in FP auctions and the behavior of bidders in both AB and FP.

5.2   Results

The results of the reduced form analysis concern three main aspects: whether there is any empirical content to the assumption that the auctioneer cares about revenues, whether the observed first price auctions do or do not have an an ex post monitoring of the bids and, finally, whether the observed firms' behavior appears to be consistent with the Nash equilibrium predictions.

Auctioneer's revenues and auction format choice

Although a reduced form analysis cannot test whether the auctioneer's behavior conforms to the assumption of expected revenues maximization, it can still be useful to identify whether the observed choice is at least compatible with it. Indeed, the Diff-in-diff estimates presented in Tables 5 (first two columns) indicate a large increase in the winning discount for the auctioneer

---

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

[52] 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.

[53] To belong to this group the local administration must administer a territory counting at least 50,000 people.

that decides switch to a FP. The estimated benefit is a reduction in procurement prices of about 10 percent of the contract value.[54] Since the theoretical analysis has shown that FP auctions are more exposed to the risk of contract violations, the effect of the change in auction format has to be evaluated on the total cost of procurement. The results in Table 6 present estimates of the increase in renegotiations associated with a transition to 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.[55] 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 2 and 10 percent of the contract value.[56] This result is therefore in line with the objectives of a revenue maximizing auctioneer. However, 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, another likely source of unobserved costs is due to the usage of an ex post monitoring technology for bids. Although we observe greater renegotiations under FP, there is no single bankruptcy case in my whole sample of FP auctions.[57] Moreover, as the next set of results show there is consistent evidence pointing in the direction that the FP in my sample are FP with monitoring.

FP auctions with or without monitoring?

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 monitoring of bids.

1) Mandatory monitoring and its application: The 2006 national reform that introduced FP auctions requires public administrations to do an ex post monitoring of all bids that appear "abnormal". The Law states that abnormal bids are all those presenting a discount that is greater than the discount that would win if the awarding rule were the AB. In essence this means that when the AB is used the public administration is not required to perform the monitoring while it is obliged to do so for (a part of) the bids submitted in FP auctions. 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. Out of about 100 auctions held after 2006, the number of those in which the highest bid was judged to be abnormal and eliminated was 16. Moreover, also for the auctions held by Turin after its local reform there is evidence that the use of FP was jassociated with the systematic use of ex post monitoring. The results of the Diff-in-diff presented in Tables 5 (last two columns) indicate that the switch

---

[54]The estimated savings rises if we use data from the Reform Sample. The estimates presented in Table 9 indicate that this savings is between 14 and 19 percent of the contract value.

[55]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 proxy for the true final cost of procurement.

[56]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.

[57]As regards the sample of AB auctions although bankruptcies are present they appear to be a rather rare finding as only 12 contracts out of the 17,000 auctioned with AB ended up with a bankruptcy.

to FP is associated with an increase by almost two weeks in the time span between the day bids are opened and the day the contract is awarded to the winner. This extra time may be justified as the time needed for an attentive ex post monitoring of FP bids.

2) The selection into the usage of FP: When in 2006 administrations became free to choose between AB and FP very few of them moved to FP. In my sample only 20 administrations out of 500 did so. Moreover, these administrations appear to be clearly characterized by some distintive features. The probit regression in Table 8 shows that they tend to be geographically close to Turin and large in terms of population (and also of their "experience", i.e. the number of auctions they run). While a social learning model could be behind the spread of the FP usage from Turin to neighboring administrations, the second feature might be explained by the size of the monitoring cost associated with FP. In fact, it is sensible to deduce that small PAs that run very few auctions per year do not want to pay the high fixed costs that building up the resources required for an effective monitoring would entail.

3) Drop in the number of bidders: The estimates of the negative binomial model presented in Table 11 clearly show that, for both the Authority and the Reform samples, the switch from AB to FP is associated with a drop of about 40 bidders per auction.[58] Analysing this result is complex and requires understanding collusion by firms in AB auctions (the argument is briefly addressed in Appendix III and is the subject of a forthcoming paper). Nevertheless, part of the explanation may lie in the fact that low penalty bidders stay out of the auction if they know that the FP will involve an ex post monitoring that will make their elimination certain.

4) Winners' optimal default decision: As I already mentioned I do not observe bankruptcies but only frequent cases of contract renegotiations. To the extent that renegotiations reflect 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 monitoring, 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). 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

---

[58]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.

firm's budget is taken as a measure of the penalty.

Density Estimate of Contract Renegotiation
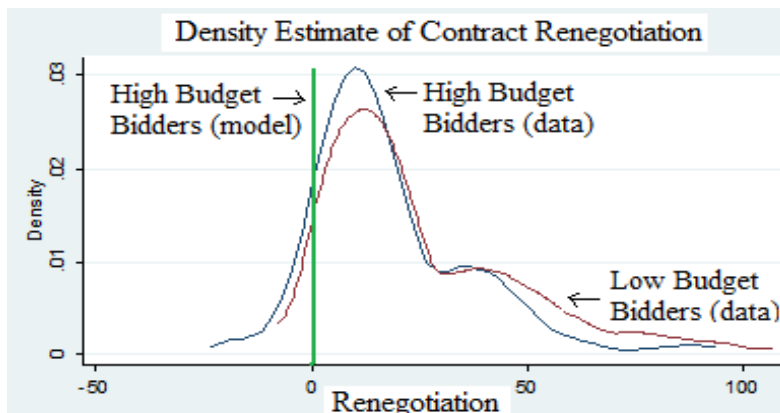
As before, renegotiations are measured as the difference between the winning bid and the final price and are expressed as a percentage of the reserve price. The budget, instead, is the firm's underwritten capital. I consider a winner as "low budget" if his underwritten capital is less than the difference between the auction's reserve price and his bid.[59] A "high budget" winner is one that is not "low budget". Although the average renegotiation of low budget winners exceed 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, also with these other measures I was not able to identify any significant difference in the behavior of the two groups of winners.[60]

Reduced form bidding functions for AB & FP auctions

The estimates presented in Table 10 report the results of OLS regressions for a standard reduced form specification of the bidding function. The estimates are obtained using the Reform Sample in its panel form (all the bids submitted in each auction). Bajari et al. (2007) discuss the appropriateness of the regression specification for bidding for construction contracts. In particular, they suggest that the private cost dimension of completing the contract might be proxied by the geographic distance between the firm and the site of the work. In the FP

---

[59] 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.

[60] I also tested these behavioral implications using different concepts of penalty but the result was always the same. One of the possibilities I tested entailed dividing low and high penalty bidders according to their distance from the auctioneer. In fact, 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.

sample the estimate of this coefficient is economically and statistically significant only when the fixed effects for the auction are excluded. This might be an indication that the common cost component prevails over the idiosyncratic one. However, it could also reflect the fact that either distance is not a good proxy for the private cost or that the model has some other misspecification. The next section on structural estimation deals more carefully with bidding in FP auctions.

As regards the bids submitted in AB auctions, the results are again reported in Table 10. It emerges that basically only the common components (fixed effects) appear to have a relevant explanatory power and, moreover, that the proxy for the private cost has the "wrong" sign. An explanation of the sign of this coefficient can possibly be attributed to collusion among firms.[61] Analyzing collusion in AB auctions is probably very important to understand departures from the BNE predictions. In fact, while the BNE requires all bidders to bid the same price, only few a AB auctions exhibit this property. Within the 864 AB auctions of my Reform Sample, only 3 percent have a difference between the highest and lowest discounts of less than 2 percent of the contract value.

Although the within-auction distribution of all bids does not conform to the BNE, this distribution truncated of the 10 percent of the lowest and highest bids looks quite consistent with having all bidders bidding the same value. The Italian version of the AB rule implies that the winning bid comes from this truncated distribution. Therefore, only this distribution matters for a revenue maximizing auctioneer. Even if the within-auctions variation in the truncated sample is small, the across-auctions variation of winning bids is rather large. An interesting result, however, is that this latter source of variation might be used to pin down the focal equilibrium of the AB auction. There is rich anecdotal evidence that each administration gets "stuck" at a certain value on which all bids converge. A striking case is that of Sicily where the whole island appears to have auctions 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 averge. The auctioneer, in turn, knows this fact and can rather accurately forecast her expected revenues. This suggests a way for estimating the focal equilibrium in auctions held by auctioneers that appear multiple times in the sample. Using the large cross section of AB auctions in the Authority Sample I estimate the following OLS regression:

$$B_i^w = \alpha X + \beta B_i^{w-1} + \varepsilon$$

where the dependent variable, B_i^w, is the winning discount and B_i^{w-1} is the average of the

---

[61]In essence, firms that are further away from the location of the contract submit very high discounts with the intention of not winning the auction but of piloting the average bid so as to favor some other firm. It is very likely this is done with the understanding that their beneficiary will reciprocate at some later point in time. See Appendix III for a discussion of collusion in AB auctions.

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).

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

The results seem to indicate that, at a first approximation, for an auctioneer who has already played the auction game past winning bids can give a rough indication of what equilibrium will be selected. In the following section on structural estimation I will use this rough estimate to pin down the focal equilibrium in the AB auctions. Future research is nevertheless needed to better understand the mechanics of the equilibrium selection.

6 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 monitoring cost.

The theoretical analysis suggests that it is not possible to infer the firm's valuation from their bids in the average bid auction because they all bid the same constant regardless of their value. Moreover, the reduced form empirical analysis provides evidence supporting the fact that the first price auctions in my sample are not simple FP but FP plus monitoring. For this latter auction format our theory implies that low penalty bidders do not have an equilibrium strategy that gives them a strictly positive expected payoff. None of the main theoretical predictions change if we assume that a bidder who is indifferent to participating or not participating chooses to stay out. However, making this assumption simplifies our analysis because it implies that only high penalty bidders participate in FP plus monitoring auctions. Since these bidders never default in equilibrium, the only part of their strategy that we need in order to retrieve their valuation is their bid. The approach that I use to estimate the underlying bidders' valuation 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 from observed bids the underlying

distributions of both the private and the commonly observed components of bidders' valuations. 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 these two latter papers.

6.1 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 up from data the underlying distributions of both the privately (X) and the commonly (A) observed components of firms' valuations. 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 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 firms' 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 bidders' 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 bidders 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 in case of victory an extra payment of ηr. Apart from these modifications all the model's assumptions are kept unchanged and so (2) in can be expressed as:

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

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:

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

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 in 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, then the observed bids cannot be used directly to get B and, through it, identify F_X a la GPV. Notice that this is a standard problem of unobserved hetherogeneity.

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 that 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 also all the bidders commonly observe, A. The maximum price that the 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 $A = 0$.[62] 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 hetherogeneity using the informational content of the reserve price.[63]

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 shown in Krasnokutskaya this allows to identify the characteristic functions of A,

---

[62]The fact that the observed highest offered price (lowest discount) is generally significantly higher than the announced contract value is in line with the above assumption. Moreover, an explanation for why an auctioneer that optimally chooses the auction format does not also optimally set the reservation price might be that while the first choice is in the hands of the auctioneer the second is not. In the Italian auctions the auctioneer decides the auction formats but the list of prices to be used in calculation of the contract value that will be announced is fixed yearly by the Regions. Future work on endogenous entry will study more carefully how reservation prices are set and address the consequences of relaxing Assumption (iv').

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

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 inputing 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.

6.2   Estimation

The data observed by the econometrician consist in m auctions. For each of them $(n_i, b_i^{wo}, b_i^{lo}, \eta, r_i, z_i)_{i=1}^m$ 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 hetherogeneity using the homogeneization approach of Haile et al. (2004).

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

1) Trasforming the bids to account for expected renegotiation:

For every auction i the value ηr_i is added to both b_i^{wo} and b_i^{lo}. 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:

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

Wehere 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:

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

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

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

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

and where d_{T_u} is a dumping factor that reduces the problem of fluctuating tails.[64] The smoothing factor T_u should diverge slowly as m goes to infinity to ensure uniform consistency of the estimators.[65] [66]

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.[67]

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:

---

[64] 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.

[65] 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.

[66] 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).

[67] 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 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.

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

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

with bandwidth $h_g = (M)^{-1/6} 2.978 \mathrm{x} 1.06 \overset{\wedge}{\sigma}_{B_w^s}$, 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:

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

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.

6.3   Results

The following results are based on a sample of auctions with 6 bidders and a reserve price between euro 100,000 and 1 million.

Fit of the model: The model fit is assessed by repeatedly simulating from the estimated distributions and using the model's equilibrium conditions to produce a set of simulated winning bids. Figure 2 reports the 5 percent confidence interval for the simulated winning bids along with the real data. The band of the interval is rather large indicating that the simulation is not very precise in matching the data although it captures the basic features of the data distribution.

Efficiency of the two auction formats: decomposing the variance of the total cost into its private and common components, we find that 64 percent of the variation in the total cost is due to its private component. Figure 3 reports the estimated densities of the private and common components. The FP rule under which this result was estimated is an efficient mechanism.

However, this is not the case for the AB auction that allocates the contract at random among all the participants. Therefore, by indicating a relevant private costs component exists, this result suggests that using AB auctions generates non negligible inefficiency. Nevertheless, the high propensity of winners of AB auctions to subcontract a relevant part of the work (as claimed by several firms in the industry) may indicate that market mechanisms are active to mitigate this inefficiency. Future study shall address more thoroughly the effects of subcontracting.

Bidders' Markup: I define the markup as the difference between the winner's bid and his cost. The estimates indicate that, on average the markup is 17 percent of the total cost. This estimate rises if I repeat the analysis on a sample with a lower number of bidders per auction. The highest estimate is 24% in the case of auctions with two bidders. This values are comparable to those estimated by Krasokutskaya (2004) 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).

Bounding the monitoring cost: Analogously to what we did for X_H, we can construct simulated data also for A and X_r. I denote the simulated values with A^s, X_r^s and X_H^s. Consistently with what assumed for bidders, I assume that the auctioneer expects to pay ηr in an ex post renegotiation phase. These values can be used to express the auctioneer's expected cost of procurement under FP as:

$$E^s[C^{FP_1}] = A^s + E[X_{H,n-1}^s] + \eta(A^s + X_r^s) + I$$

where I is the cost of monitoring and $E[X_{H,n-1}^s]$ is the expectation of the second lowest statistics from the distribution of X_H^s. It is possible to use this formula to estimate a bound for the minimum value that I must take to justify the auctioneer's preference for AB over FP. The rest of the analysis focuses on this bound. The expected cost of procurement expressed in terms of simulated values is:

$$E^s[C^{AB_0}] = (1 - \gamma + \eta^+)(A^s + X_r^s)$$

where $\gamma \in [0,1]$ is the percentage discount over the reserve price that the auctioneer expects to obtain and $\eta_{AB} \in (0,1)$ is the fraction of contract value that the auctioneer expects to concede in renegotiation.[68]

Therefore, using a dataset of T simulated data A_t^s, X_{rt}^s and $X_{H,n-1t}^s$, for $t = 1, ..., T$, and fixing η_0, η_0^+ and γ_0, it is possible to obtain an estimate for the bound of I as:[69]

---

[68]Compared to the expression for $E[R^{AB_0}]$ presented in the theoretical section, the formula $E^s[R^{AB_0}]$ does not include the term $(K - c)(\frac{n_L}{n_L + n_H})\lambda\theta$ because I assume $\lambda = 0$. For this term to be non zero it must be that a low penalty bidder has a positive probability of defaulting when winning with a bid c. Since in my data there are only 12 cases of insolvency out of 12,000 AB auctions, I consider them negligible.

[69]The sample of T simulated data $X_{H,n-1t}^s$ is obtained by making simultaing T auctions each with n bidders and then picking the second lowest value for each auction; n was chosen equal to 6.

$$I_t^s = (1 - \gamma_0 + \eta_0^+ - \eta_0)(A_t^s + X_{rt}^s) - A_t^s - \frac{1}{T}\sum_{t=1}^{T}[X_{H,n-1,t}^s]$$

For T equal to 2,000 and η_0, η_0^+, γ_0 equal to the sample averages in the data, the resulting average value of I^s is equal to 27 percent of the reserve price.[70] The top panel Figure 4 reports the estimated density of the monitoring cost. This estimate was obtained with simulated data and without directly using any real data. However, we can use real data to comapre this value with a more naive estimate of the monitoring cost under the assumption that the auctioneer correctly forecasts his revenue from a FP auction. In this case it is possible to calculate the monitoring cost by constructing the counterfactual AB for each of the observed FPs.[71] Elements required for this are the reserve price and the values of η, η^+, γ. Provided with them, we can express the monitoring cost as:

$$I_i^0 = (1 - \gamma_i + \eta_i^+ - \eta_i)(R_i) - B_i^w$$

Table 4 eports in the two bottom panels the estimated density for I^0 under two scenarios for the value of $Q_i = (1 - \gamma_i + \eta_i^+ - \eta_i)$. In the left panel Q_i is specific to every contract i and, on average, equal to 0.74. The resulting monitoring cost is, on average, 8 percent of the reserve price.[72] The bottom right panel, instead, fixes $Q_i = .82$ for all contracts. This was the value used to caluclate I^s. The resulting distribution is characterized by an average monitoring cost equal to 24 percent of the reserve value.

Concluding, we found a large estimate for the monitoring cost. In part this might be due to the procedure used and, in particular, to the estimates of η_0, η_0^+, γ_0. These values are needed to pin down a focal equilibrium among the many possible for the AB auctions. However, a stronger theory regarding equilibrium selection is certainly required. Another issue that might explain the large estimate of the monitoring cost is that our estimate is capturing more than a mere technological constraint. If it were just the cost of hiring a team of engineers to evaluate bids, we would not expect such a large estimate. However, the AB is the status quo and perhaps we are in part capturing the cost of leaving it. The fact that administrations close to Turin were the first to move toward the FP may mean that there is a social learning of how the two mechanisms work. Finally, the difference between my estimated monitoring cost and rough mesure of the cost of the monitoring technology (for instance the cost of days of work of an engineer) could be a measure of the "passive waste" present in the Italian public

---

[70] In particular the values are: $\eta_0 = 6$ $\eta_0^+ = 14$, $\gamma_0 = 12$.

[71] Instead, it is not possible to construct the FP counterfactual of an observed AB auction. The reason is that we do not separately observe A.

[72] For every FP auction I obtained a value for η_i, η_i^+, γ_i by taking average values for the percentage of contract value renegotiated and for the winning bid using previous auctions (FP in the first case and AB for the other two). These auctions must have been held by the same auctioneer and must have a value differing by no more than euro 500,000 from contract i.

procurement system. Bandiera, Prat and Valletti (2008) distinguish between two determinants of the cost of procurement: active and passive waste. The presence of the first one increases the utility of the public official and corruption is the classic example. The presence of the second one, instead, does not benefit the public official. This cost reflects the inefficiency in procurement that arises when there is excessive regulation or when public officials do not have the skills or the incentives to minimize the cost of procurement. Bandiera, Prat and Valletti (2008) study the case of the procurement decision with regarding goods and services using data from a large number of Italian public adminstrations that could either buy on their own or buy under the conditions of the framework agreements signed by CONSIP (the Italian Central Public Procurement Agency). One of the main conclusions of their research is that passive waste accounts for about 83% of total waste. Therefore, it is possible that my large estimate for the monitoring cost is in part capturing the passive waste associated with the use of average bid auctions when first price ones are available.

Another possible explantion is that, since in the real world there is no such thing a a perfect monitoring thechnology, the large estimate reflects the expected damages caused by using a FP and failing to eliminate the risky bidders from the auction. A weak administration may fear that, if the monitoring fails, than she will fall prey to the "high bids & broke winners" equilibrium of Zheng. For a samll public administration it may be particularly hard to deal with an insolvent contractor. Indeed, a better understanding of the bargaining process between the auctioneer and the contractors would be important in the analysis of the auctioneer's choices and appears to be an interesting direction for future research.

7   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. Spulber (1990) 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.[73]

When the insurance market has imperfections relevant for firms' behavior, the auctioneer

---

[73]Calveras et al. (2004) discuss the regulatory practice of surety bond and how the it might solve the problem of abnormally low tenders in public procurement. They also give an intuition for why a system of contract guarantees based on letters of credit does less well to address this problem than a system based on surety bonds.

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 monitoring technology. Instead, the 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 monitoring cost. However, the average bid auction is inefficient whenever the private component of bidders valuations is relevant. Moreover, it leads to low and uncertain revenues for the auctioneer.

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 contracts' 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 monitoring 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 monitoring, more auctioneers can be induced to use a 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 monitoring cost. However, two ways to obatin this result may consist in making the identification of risky bidders easier and in lowering their probability of winning. The first task could be attained, for instance, by facilitating the access to the monitoring technology. In the case of Italy, this could be achieved by centralizing the process of verification of the bids so that small public administrations that run infrequent auctions do not need to hire their own team of engineers to evaluate bids. Instead, the second way to reduce the monitoring 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 surity bonds, but also through rigorous pre-qualification mechanisms that focus on how likely is the bidder to default.

8   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", mimeo.

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

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

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

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

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

13. 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.

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

15. 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.

16. 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

17. 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.

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

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

20. 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.

21. Hinze, J., (1993). Construction Contracts, McGraw-Hill Series in Construction Engin-

eering and Project Management. Boston: Irwin/McGraw-Hill.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

38. 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.

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

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

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

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

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

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

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

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

Appendix I: Proofs of the Results

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 monitoring 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, $r_L = B + x_L$ and, for bidders type H, $r_H = A + x_H$. Moreover, l, the non serious bid of RZ, in y setup can be anything in $[0, \min(A + \bar{x_H}, B + \bar{x_L})]$. 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 proof 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. 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 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, $\bar{v}$, such that for all $x \in [\bar{v}, \bar{x}]$ bidding some constant $\bar{b} < \bar{v}$ (the flat top of the bidding function) with $\bar{b} > \underline{x}$ gives a greater or equal expected payoff than bidding anything different than $\bar{b}$. Clearly the interesting case is to look at the type $\bar{v}$ (because this is the type that would have the greatest incentive to deviate) and to compare the expected payoff from bidding $\bar{b}$ versus any other $b' < \bar{b}$ (because any $b" > \bar{b}$ will necessairly lead to a zero probability of winning given that all the other types' bids are assumed between $\underline{x}$ and $\bar{b}$). Hence consider the equilibrium condition for agent N who drew $\bar{v}$ when all other players use the strategy b^*:

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

where

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

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

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

Where by the event that the bid $\bar{b}$ wins, I mean that $\bar{b}$ 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 $\bar{v}$:

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

Moreover define the following probabilities:

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

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

...

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

Now define α_M to be the probability that $\bar{b}$ 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 $\bar{v}$. That is:

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

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

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

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

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 $v < \bar{v}$, then bidding $\bar{b}$ 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 $\bar{b}$ 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 $\bar{b}$ and one of the bids less than $\bar{b}$. Then it must be by construction that, for the highest average formed by these couples, call it A1, $\bar{b}$ 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 $\bar{b}$ to A0. Therefore $\bar{b}$ 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 $\bar{v}$ then the average bid will be strictly less than $\bar{b}$. Therefore we can always take a $b' < \bar{b}$ but ε-close to $\bar{b}$, such that conditional on having at least one player drawing $x < \bar{v}$, b' leads to a probability of winning strictly greater than $\bar{b}$. Moreover the payment in case of victory with the bid b' is strictly less than that in case of winning with $\bar{b}$. Define β_M as follows:

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

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:

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

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

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

Which, rearranging the terms, means that:

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

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:

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

Therefore, if we see the left hand side of the above inequality as a function of $\bar{v}$, say $g(\bar{v})$, then only the values of $\bar{v}$ such that $g(\bar{v}) > 0$ respect the necessary condition. The function $g(\bar{v})$ starts at 1 for $\bar{v}$ equal to $\underline{x}$ and converges toward zero $\bar{v}$ equal to $\bar{x}$. Moreover with $N > 2$ the function has a unique critical point, a minimum that is attained at the value of $\bar{v} = z$, 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 $g(\bar{v})$ starts at one, decreases util it reaches a minimum value and then converges to zero from below, reaching exactly zero at $\bar{v} = 1$. Hence it must be that $g(\bar{v})$ crosses zero from above just once so that the only values of $\bar{v}$ for which $(**)$ is respected are those that lie in $[\underline{x}, v^*)$ where v^* is defined to be the value of $\bar{v}$ 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: $|\bar{v}_{\eta,F} - \underline{x}| < \varepsilon.$

To see why this is the case just consider that by definition of v^* the values of $\bar{v}$ such that $(**)$ holds are the ones for which $g(\bar{v}) > g(v^*) \longrightarrow \bar{v} < v^*$ 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 $g(\overline{v})$ 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.
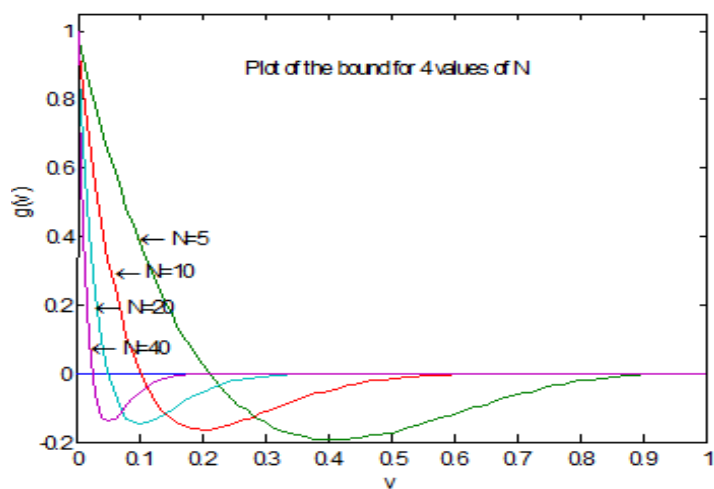
Appendix II: Details on the Data

The data used in the paper are grouped into two samples of procurement auctions:

Reform Sample. This sample consists of almost all the public procurement auctions for road construction works held in Italy between November 2005 and June 2008. I call this sample Reform Sample because in July 2006 the nationwide reform allowing individual Public Administrations to freely choose between the Italian version of the AB rule or a standard FP rule became effective.[74] This sample consists of all the auctions for which: (a) the procedure is sealed bid and open to all firms possesing the qualification for the job auctioned off, (b) the PA released information regarding all bidders (their identity and their bid) after the auction is over, (c) the awarding rule is either AB (Art. 21 Law 109/1994 or, for auctions held after July 2006, Art. 122 Law 163/06) or FP (Art. 82 Law 163/2006), (d) the proportion of the contract value directly connected to road construction /maintenance must be more than half the total contract value, (e) the PA is a Local Administration (Comune or Provincia), (f) the contract value is below Euro 2,500,000.[75] The sample size is of about 1,500 auctions. However, for the analysis presented in this paper I restricted the attention to a smaller sample of about 1000 auctions which were held in five regions in the North (Piedmont, Lomardy, Liguria, Veneto and Emilia). For these auctions I also obtained the identity and the bids of each participants.

Authority Sample. This sample comes from the database of the Italian Observatory for Public Contracts covering information on the life of all public contracts above Euro 150,000. The earliest auctions in this sample are from 1999 while the latest are from January 2008. The Authority sample is complementary to my Reform sample since only the first one contains ex-post information like, for instance, contract renegotiations, while only the second one contains data on all the bids and identities of all participants. This second sample, however, does not allow for a fine distinction of the kind of public works involved, only dummy variables are available to distinguish among macro categories of works. Moreover, another issue with this sample is that, given that the national reform is of July 2006, very few contracts awarded after that date have already the complete ex-post information. Neverthless, the interesting feature of this second sample is that two of the biggest PAs of the Piedmont region, the Provincia and the Comune of Turin, had already introduced a reform in 2003 and had adopted the FP rule as their only mechanism. This implies that many of the jobs they procured have by now been completed. Applying the same criteria used to select the Reform sample, with the exception of (b) and (d), I obtain my Authority sample. This sample contains both auctions held by Turin (before and after the switch to FP) and auctions held by the other local administration in the

---

[74]Under the new law, 163/06, the FP is the default mechanism. To use the AB format, the PA must make an express statement in the document that announces the auction by invoking Art. 122 Law 163/2006 (which prescribes exactly the same procedure of the old art. 21 of Law 109/1994).

[75]The rule for automatic elimination applies only to contracts below "European Community Interest". The threshold for this value has varied over time but during the years covered by my sample it was around 5 Million Euro. Therefore the contracts I look at are safely within the boundary where AB applies.

North (that never abandoned the AB rule).[76] Therefore it allows for a difference in differences analysis where the treated group is Turin (Comune and Provincia).[77]

Firms Data. In addition to the auctions data I supplement my analysis with various other data. The most prominent ones are those on the firms participating at the auctions and which come from the Infocamere database. These data include information on the firms' capital, revenues, sales, number and type of employees, identity of shareholders and managers, location of the plant. This last piece of information was used as an input for a web spider that collected the distance between the firm and the place of the work from http://www.mapquest.it/mq/directions/mapbydirection.do.

A Note of the Legislative Reform. The procedure for automatic elimination described in the text as the Italian version of the average bid auction became compulsory in 1998 (4th modification to Law 109/1994). Then, until July 2006, when the reform introducing the first-price rule across the country became effective, almost all the public procurement of works occurred through auctions with an automatic elimination of high bids based on their distance from the average bid (Art. 21 Law 109/1994). During these period few regions (like Sicily, Friuli and Valle d'Aosta) and some other single local administrations (notably the municipality of Turin) introduced substantial modifications to the awarding rule they used. In particular, in 2003, one of the biggest local administrations of the Piedmont region, the Comune (Municipality) of Turin, abandoned the "averaged-average" rule in favor of the first-price method.[78] This reform was important important because Turin was able to provide convincing arguments on how the AB rule caused an increase in the cost of procurement and fostered firms' collusion. Turin's reform was ratified after five years of trials by the European Court of Justice Ruling of May 15th, 2008, which declared the rules for automatic elimination based on the average of bids not compatible with the fundamental principles of non discrimination of the European Treaty. The consequence of this sentence is that on October 17th in Italy a new reform of the state legislation became effective limiting the use of AB auctions only to the cases in which at least 10 bidders participate and the contract is worth no more than 1 million euro. One last important point to stress is that neither Turin's 2003 reform nor the national reform of 2006 modified the rules concerning the minimum contract guarantees which in Italy is generally partial covering between 10 and 20 percent of the contract value.[79]

---

[76] All the auctions held by the Comune of Casale Monferrato (which followed in 2005 the reform of Turin) and the very few other FP auctions held after the reform of 2006 are excluded from the sample.

[77] The first months of FP auctions (between January and July 2003) were excluded. In complex games the inital response to a new game can substantially differ from the equilibrium behavior on which my theoretical anlysis is centered.

[78] The Provincia (Province) of Turin followed few months later and the (close by) municipality of Casale Monferrato followed in 2005.

[79] If the winning discount is below or equal to 10% then the insurance must be 10% of the contract value. If the discount is above 10% the guarantee has to be increased by the same amount of points as those of the discount in excess of 10%. If the winning discount is above 20% the guarantee has to be increased by the double of points of the discount in excess of 20%.

Appendix III: On Collusion in Average Bid Auctions

The analysis of collusion in average bid auctions is crucial to understanding how bidders bid in such auctions. I will address this line of reseach in a different paper but here I will introduce some key empirical evidence in support of my statement on the relevance of collusion. In a sense this is almost inevitable since with a competitive equilibrium that consists in a flat bidding functionany coalition of two players would be able to deviate and win the contract for sure. Moreover, it is also known that the road construction industry is characterized by numerous conditions that facilitate collusion (see Porter and Zona, 1993).

The first piece of evidence that motivates a study of collusion in AB is the unusual participation behavior in these auctions. The many studies on FP auctions for road construction contracts in the US report an average bidder turnout that ranges from 3 to 7 firms per auction. The corresponding value for the auctions run in Italy under the averaged-average rule is 50 firms. My data from the Authority Sample can be used to illustrate how the number of bidders dropped dramaticallyin the treated group (left panel) when it switched from AB to FP. No such effect appears in the control group (right panel).
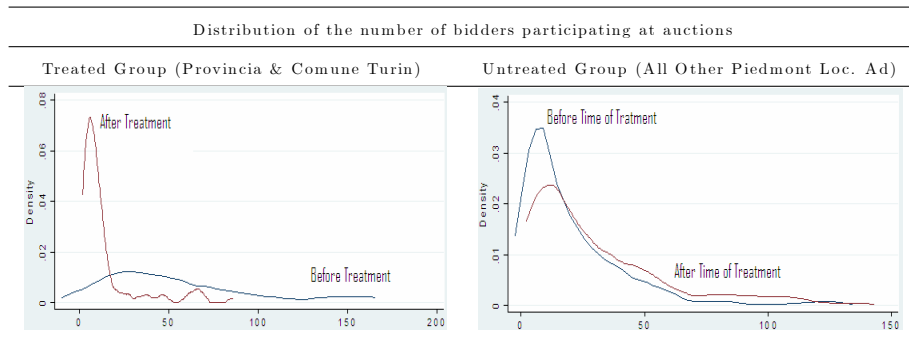
The regressions presented in Table 11 and described in the text provide econometric evidence supporting the association between the drop in number of bidders and the switch from AB to FP. A possible explanation of this phenomenon is that two forms of non competive bidding, jump and shill bidding, that were profitable under AB were no more so under FP. These two forms of collusion are now illustrated with the aid of some examples taken from my data.

Jump Bidding

The idea behind a jump bid is that, by submitting a particularly high bid, a bidder significantly alters the average of the bids and favors some colluded firm. The definition of what exactly constitues jump bidding is necessarily subjective. I will consider a bid as a jump bid if it satisfies two conditions: it must be discontinuously greater than the next smaller bid and it must be a bid in the upper end of the bid distribution. Any bid greater than a jump bid is also a jump bid. The figure below presents the examples of four auctions in which bids that qualify

as jump bids are present. The horizontal axis lists the bidders ordered according to the size of their bid (i.e. the discount over the contract value announced by the auctioneer). For each of the four curves, each representing all the bids submitted at an auction, it is evident that a group of bidders submitted bids that are discontinously greater than those of all other bidders.
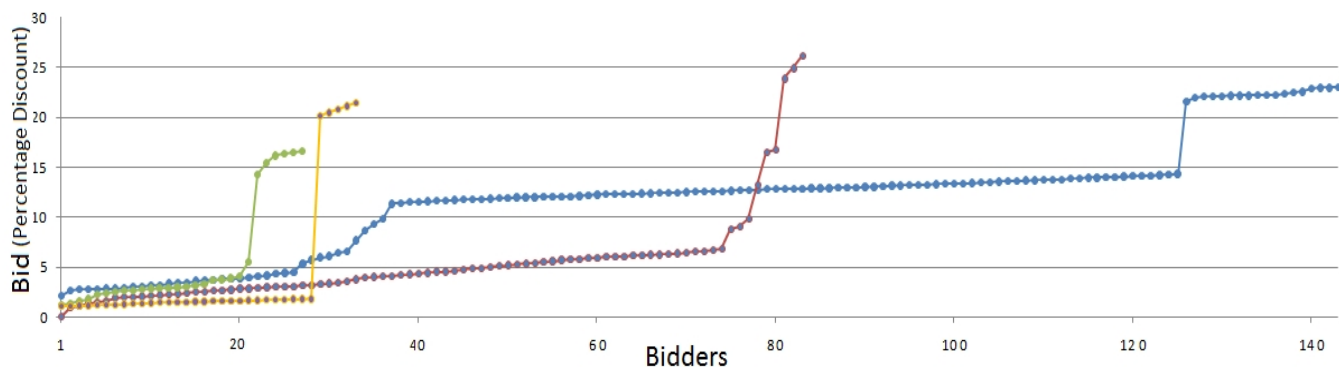
Jump bids are the action of bidders who are not interested in winning the auction but in piloting the average. This can be done to help the "mother" company in case (see the discussion about shill bidding below), or to get a subcontract from the winner or to have the favour reciprocated in some other auction. The following table illustrates that jump bids are rather frequent phenomena in my sample. Looking at the 864 AB auctions of the Reform that have more than four bidders, it is possible to see that: (1) if the size of the tail considered is the top 30% of bids and (2) if the discontinuity is required to be either to 2.5% or to 5%, then respectively 639 and 249 bids can be identified as jump bids.

Two Possible Definitions of Jump Bidding

Jump = 2.5		Jump = 5	
No. Auctions w. Jumps	Tot. No. of Jumps	No. Auctions w. Jumps	Tot. No. of Jumps
212	639	80	249

These jump bids are a form of collusion specific to AB auctions that are pointless under FP auctions. Therefore, the drop in participation that followed the transition toward FP auctions can in part be explained by the end of this practice. A similar argument can also be made for the phnenomenon of shill bidding descibed below.

Shill Bidding

Shill bidding consists in the practice of a firm submitting multiple bids at an auction thought several fictitious firms. The Italian law considers a this behavior to be a crime but the reward in terms of increase in the probability of winning can be very large in an auction trasformed into a

lottery by the AB rule. The detection of this phenomenon requires at least some knowledge of the identities of the managers and owners of firms. For the reasons explained above, a firm that has one or more shill bidders may decide to use them to place jump bids. However, another interesting strategy that appears to be employed by Italian firms in the construction industry is that of using the bid submitted by the shill to increase the chances of guessing the average. An example of this kind of strategy is given in the figure below which reports all the 57 bids (ordered by the discount offered) submitted at an AB auction.
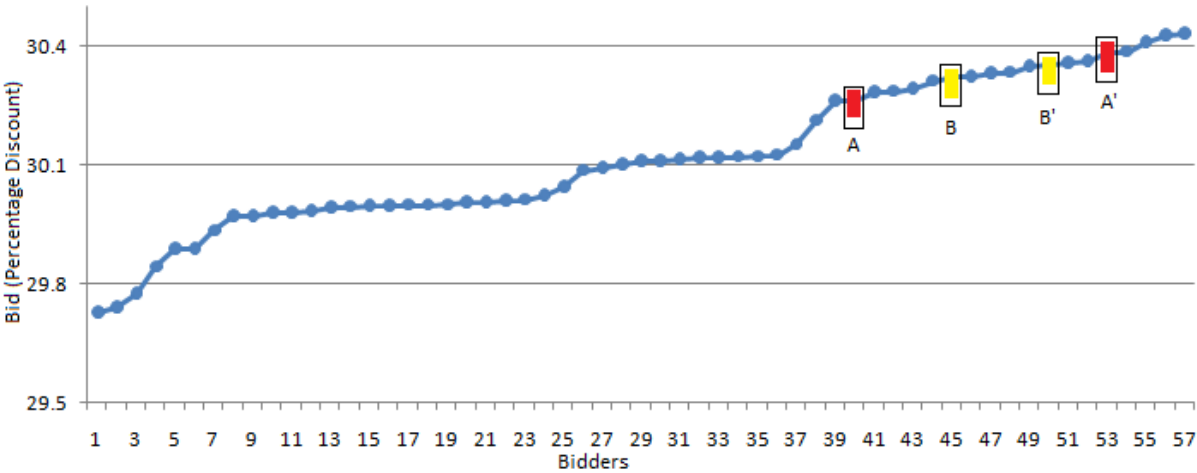
The discounts range from 29.7 to 30.5 percent (the function in the graph looks almost flat) and the winner selected by the averaged-average algorithm is the one offering 30.29. What is particularly interesting in this auction is the presence of two couples of bidders, which I renamed A and A' and B and B'. The two firms in each couple have almost exactly the same name (something like: John Smith Maintenance and John Smith Constructions), according to the official Italian registry of firms they are registered at the same identical mailing address and, finally, they submit bids that are very close to each other. Clearly, with 57 firms bidding almost the same discount, as in this case, the auction becomes a sort of lottery. Finally, a last indication consistent with the interpretation that the four firms are in reality just two comes from the participation behavior of these firms. Throughout my dataset I observe firms belonging to the same group that always participate together in auctions which is consistent with the fact that, since constructing a shill entails some fixed cost, once constructed, the shill will be used systematically to increase the probability of winning. Future research on collusion in average bid auctions will offer a careful examination of the issues of jump and shill bidding and their implications on several auction outcomes.

57

9 TABLES AND FIGURES

TABLE 1: Winning Bid and Contract Value by Location and Type of PA						
	AB Auctions Art21, Law 109/1994			FP Auctions Art82, Law 163/2006		
	Contr. Val.	Win. Bid	No. Obs.	Contr.Val.	Winning Bid	No. Obs.
LOCATION OF PA:						
North	372,735	13.59	843	506,721	30.20	144
Center	321,621	17.31	233	-	-	-
South	290,423	27.02	298	-	-	-
Islands	340,907	14.69	103	-	-	-
TYPE OF PA:						
Comune	322,985	17.02	1,017	568,300	32.82	54
Provincia	397,449	16.87	460	470,334	28.66	90

Data from the extended version of the Reform sample. It includes all auctions to procure road construction worksheld by local administrations in all Italy

TABLE 2: Distribution of Public Works Procured by Contract Value						
	Reform Sample		Authority Sample		Whole Italyˆ	
	AB Rule	FP Rule	AB Rule	FP Rule	All Procured Works	
Contract Value Thousands €	Percentage of the Number of Contracts				Number	%
<150	19.7	13.3	-	-	29,061	61.8
>=150<500	60.2	58.3	70.7	52.8	11,843	25.2
>=500<1,000	14.2	11.8	19.3	25.5	3,076	6.5
>=1,000<5,000	-	-	-	-	2,628	5.6
>=1,000<1,500	2.9	8.3	6.0	13.1	-	-
>=1,500<2,500	3.0	8.3	4.0	8.6	-	-
>=5,000	-	-	-	-	432	0.9
Tot. Number of Contracts	929	144	12,706	639	47,040	-
Contract Value Thousands €	Percentage of the Value of Contracts				Million €	%
<150	14.3	30.2	-	-	1,799	7.0
>=150<500	5.2	6.9	40.5	23.3	3,213	12.6
>=500<1,000	45.1	39.6	28.2	27.8	2,141	8.4
>=1,000<5,000	-	-	-	-	5,172	20.2
>=1,000<1,500	26.4	13.4	15.3	24.6	-	-
>=1,500<2,500	9.0	9.9	16.0	24.3	-	-
>=5,000	-	-	-	-	13,266	51,8
Tot. Value of Contracts Millions €	346	72	6,060	419	25,592	-

(ˆ) Data for 2004 from the 2007 Report of the Authority. Roughly 83% of the value and 49% of the number of contracts below 5 Millions is procured with AB.

TABLE 3.a: Summary Statistics for the Average Bid Auctions - **Reform Sample**

	Mean	SD	Median	p25	p75	Min	Max	Obs.
Contract:								
Contract Value	373,187	349,346	259,250	162,696	433,000	10,355	2,257,536	928
Expected Days Work	173	121	150	90	210	15	1095	906
Auctioneer:								
Miles PA-Turin	164	77	168	106	220	0	385	929
MinutesPA-Turin	153	64	155	105	207	0	363	929
Experience	32	43	13	4	38	1	157	929
Population	254,272	418,454	55,143	12,979	355,354	407	3,869,037	929
Winner:								
Bid (discount)	13.8	5.2	14.0	10.5	17.2	0.5	36.8	929
Miles Winner-Work	63	116	29	16	59	0	954	929
Minutes Winner-Work	75	108	47	28	80	0	953	929
Number of Bidders	56.4	44.5	48	27	74	1	326	929

TABLE 3.b: Summary Statistics for the First Price Auctions - **Reform Sample**

	Mean	SD	Median	p25	p75	Min	Max	Obs.
Contract:								
Contract Value	506,721	505,896	287,182	193,041	607,982	30,000	2,402,922	144
Expected Days Work	211	139	180	120	276	30	730	144
Auctioneer:								
Miles PA-Turin	57	74	0.6	0	101	0	229	144
MinutesPA-Turin	64	85	2	0	100	0	293	144
Experience	69	39	90	20	103	1	103	144
Population	1,133,647	954,879	900,608	179,767	2,242,775	5,420	2,242,775	144
Winner:								
Bid (discount)	30.1	10.5	30.6	22.2	37.0	1.2	53.4	144
Miles Winner-Work	51	117	17	6	45	0	709	144
Minutes Winner-Work	59	102	35	14	64	0	647	144
Number of Bidders	8.5	10.3	6	4	10	1	95	144

TABLE 4: Summary Statistics for the AB and FP Auctions- **Authority Sample**

	AB Auctions				FP Auctions			
	Mean	SD	Median	Obs.	Mean	SD	Median	Obs.
Contract:								
Contract Value	477,020	406,900	323,004	12,705	655,995	507,561	468,592	639
Expected Days Work	235	158	180	9,231	301	142	325	565
Actual Days Work	365	214	329	5,720	377	160	363	326
Days to Award	20	19	15	10,451	28	19	23	470
Auctioneer:								
Experience	81	133	29	12,701	781	276	960	639
Population	240,932	536,131	27,408	12,611	1,297,587	613,031	900,608	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:								
$\Delta C1$	11	15	6	5,381	13	14	12	272
$\Delta C2$	5.8	10	4	4,895	14	5	12	217
$\Delta C3$	9	11	6	3,340	23	21	14	224
$\Delta T1$	161	184	114	5,933	90	120	59	337
$\Delta T2$	155	181	108	5,634	89	122	59	321
$\Delta T3$	104	109	87	4,951	73	95	58	305

The Observatory for Public Contracts is the organ of the Authority that collects the information on the life all public contracts procured by all public administration. The data in the Authority sample come from the seven forms that the administrations have to fill from the time when the contract is awarded to the time the completed work is tested and approved. While data in the first form (regarding the contract awarding procedure) is rather complete, data in all the other forms are often missing or inconsistent. This explains the relative scarcity of observations for the ex post variables.

The ΔC variables are expressed as percentage of the (in parenthesis the exact Authority's form and the relative field used are reported):

All ΔC variables are percentages of the value of the contract [(A-93) + (A-101)]. The winning price is [(A-93)*(1-(A-201))+(A-101)]

- $\Delta C1$ is the difference between the winning price and the final amount paid (B6-3)

- $\Delta C2$ is the difference between the winning price and the final cost of the contract [(B5-39)+(B5-47)]

- $\Delta C3$ is the difference between the winning price and the final cost after change orders [(B3-26)+(B3-34)]

The ΔT variables are constructed as follows:

- $\Delta T1$ is the difference in days between the date of Certified End of Work (B4-21) and the Contractual Term to Finish (B1-49)

- $\Delta T2$ is the difference in days between the date of Effective End of Work (B4-29) and the Contractual Term to Finish (B1-49)

- $\Delta T3$ is the difference in days between the actual [(B4-29)-(B1-45)] and the expected [(B1-49)-(B1-45)] dates of completion

Finally, the Days to Award variable is the number of days elapsed between the last valid day to submit a bid and the day the contract is awarded.

Table 5: Time of the Auction Variables

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

Control = Population > 500,000

	Winning Bid		Days to Award	
FPSB	10.66	10.34	8.81	11.44
	(1.16)***	(1.12)***	(4.60)*	(5.13)**
Obs.	2540	2510	2082	2064
R^2	0.63	0.71	0.3	0.32

Control = Experience > 200

	Winning Bid		Days to Award	
FPSB	10.47	9.94	7.65	9.52
	(0.86)***	(0.89)***	(4.86)	(5.26)*
Obs.	2327	2307	1860	1844
R^2	0.61	0.67	0.33	0.36

Control = (Population > 50,000) * (Piedmont Region = 1)

	Winning Bid		Days to Award	
FPSB	10.04	9.88	10.01	11.90
	(1.26)***	(1.20)***	(5.09)*	(5.72)**
Obs.	1720	1699	1433	1417
R^2	0.59	0.66	0.25	0.28

Data from the Authority sample. For every dependent variable the left colum

For every dependent variable the coefficient of two regressions are reported. In the column on the left X is a vector

of ones while in the colum on the right X also includes log(Contr.Value) and dummies for work type.

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

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

Table 6: Ex Post Changes in the Price Paid for the Job Completion

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

Control = Population > 500,000

	$\Delta C1$		$\Delta C2$		$\Delta C3$	
FPSB	3.20	3.00	6.12	5.69	5.00	5.12
	(1.81)*	(1.62)*	(1.98)***	(1.95)***	(2.77)*	(2.75)*
Obs.	1390	1366	1278	1258	711	704
R^2	0.15	0.19	0.17	0.2	0.28	0.31

Control = Experience > 200

	$\Delta C1$		$\Delta C2$		$\Delta C3$	
FPSB	4.72	4.22	8.26	7.74	6.66	5.46
	(1.39)***	(1.15)***	(1.34)***	(1.37)***	(2.53)**	(2.60)**
Obs.	1214	1198	1108	1095	613	607
R^2	0.11	0.16	0.14	0.16	0.26	0.31

Control = (Population > 50,000) * (Piedmont Region = 1)

	$\Delta C1$		$\Delta C2$		$\Delta C3$	
FPSB	5.09	4.93	6.66	6.17	6.50	4.58
	(1.98)**	(1.93)**	(2.09)***	(2.12)***	(2.02)***	(2.01)**
Obs.	887	871	791	779	436	430
R^2	0.2	0.23	0.16	0.18	0.31	0.36

Data from the Authority sample.

For every dependent variable the coefficient of two regressions are reported. In the column on the left X is a vector of ones while in the colum on the right X also includes log(Contr.Value) and dummies for work type.

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

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

Table 7: Ex Post Changes in the Number of Days for the Job Completion

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

Control = Population > 500,000

	$\Delta T1$		$\Delta T2$		$\Delta T3$	
FPSB	12.52	3.06	11.96	4.89	16.17	11.64
	(20.71)	(20.69)	(19.56)	(20.06)	(15.92)	(16.61)
Obs.	1606	1582	1551	1528	1413	1391
R^2	0.13	0.21	0.11	0.19	0.09	0.18

Control = Experience > 200

	$\Delta T1$		$\Delta T2$		$\Delta T3$	
FPSB	26.12	18.65	22.00	15.41	24.35	22.14
	(17.72)	(19.49)	(16.55)	(18.97)	(12.94)*	(15.59)
Obs.	1428	1411	1378	1362	1272	1256
R^2	0.05	0.15	0.06	0.16	0.06	0.16

Control = (Population > 50,000) * (Piedmont Region = 1)

	$\Delta T1$		$\Delta T2$		$\Delta T3$	
FPSB	21.25	13.69	15.39	10.17	1.37	-0.15
	(20.77)	(22.43)	(19.87)	(22.23)	(13.83)	(15.07)
Obs.	1037	1020	993	977	916	901
R^2	0.13	0.21	0.13	0.2	0.12	0.22

Data from the Authority sample.

For every dependent variable the coefficient of two regressions are reported. In the column on the left X is a vector

of ones while in the colum on the right X also includes log(Contr.Value) and dummies for work type.

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

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

TABLE 8: Probit Regressions

Choice of the FP Auction Format

Miles PA to Turin	-.010	-.009	-.008	-.008
	(.001)***	(.001)***	(.001)***	(.001)***
Log(PA Population)		.453		.621
		(.071)***		(.111)***
PA Experinece			.005	-.004
			(.001)***	(.002)*
Constant	.010	-2.48	-.292	-3.155
	(.095)	(.408)***	(.123)**	(.533)***
Observations	956	956	956	956
P-Value Chi^2	0.000	0.000	0.000	0.000

Data from the Reform sample used as a cross section of auctions. Standard errors are in parentheses.

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

TABLE 9: Winning Discount Regressions

	OLS	OLS^	TREAT°
First Price	16.39	13.59	19.02
	(2.16)***	(1.57)***	(1.43)***
Log (Contr. Val.)		6.48	6.07
		(0.73)***	(0.54)***
Constant	13.68	-25.41	-23.91
	(0.60)***	(4.34)***	(3.03)***
Observations	956	956	956
R^2	0.47	0.6	-

Data from the Reform sample.

Robust standard errors are in parentheses, clustered by administration

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

^Dummy for type and geographical location of the PA included.

°Heckman treatment effect model: the selection equation is that of column two in Table 8

TABLE 10: Bidding Function Reduced Form Estimates

	FP Sample		AB Sample	
	OLS	OLS	OLS	OLS
Constant	-25.61	-40.31	1.37	-11.63
	(4.64)***	(33.71)	(0.41)***	(5.46)**
Miles Firm-Work	-.004	-.002	.003	.001
	(.002)**	(.001)	(.000)***	(.000)***
Log(Contract Value)	8.31	9.53	2.18	6.83
	(.86)***	(5.91)	(.08)***	(.91)***
Expected Days Work	.01	.036	-.002	.001
	(.003)***	(.017)**	(.000)***	(.002)
Unlim. Liability Firm	-2.49	-.769	-.676	-.049
	(.746)***	(.609)	(.065)***	(.041)
Fixed Effect^	-	Yes	-	Yes
Observations	1,112	1,112	43,181	43,181
R^2	0.15	0.60	0.03	0.65

Data from the Reform sample used as an unbalanced panel auctions with all the relative bids.

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

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

TABLE 11: Number of Bidders Regressions

	Authority Sample°		Reform Smaple	
	NEG.BIN^	Pred.Change	NEG.BIN^	Pred.Change
First Price	-1.84	-38.32	-1.87	-44.03
	(.15)***		(.18)***	
Observations	2,548		956	
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%

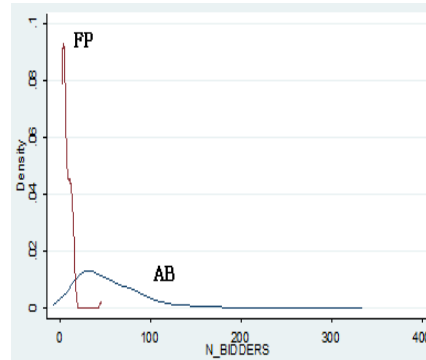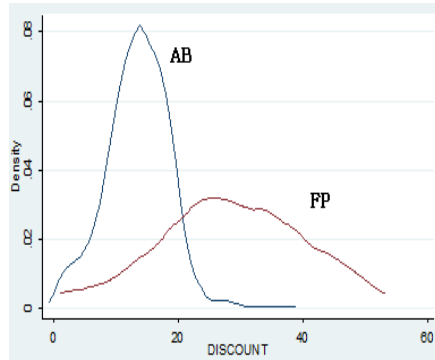^Log(contract value) and dummy variables for type and geographical location of the PA included.

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

FIGURE 1: Distributions of Winning Discount & Number of Bidders in AB & FP Auctions

ALL ITALY
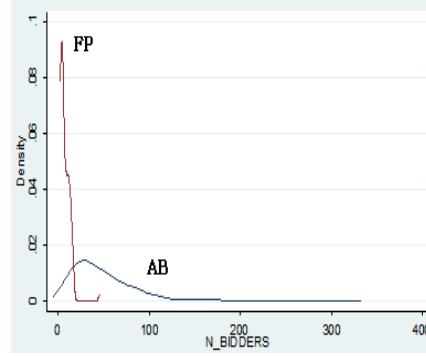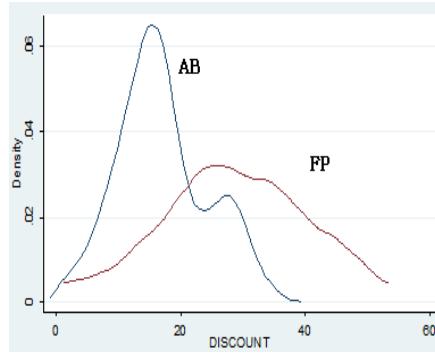
ONLY NORTH

The figures at the bottom refer to data of the Reform sample. The figures at the top refer to an extended version of this sample containing the

public procurement auctions for road construction works of all Italian public administrations (not only of those in the North) using Ab or FP
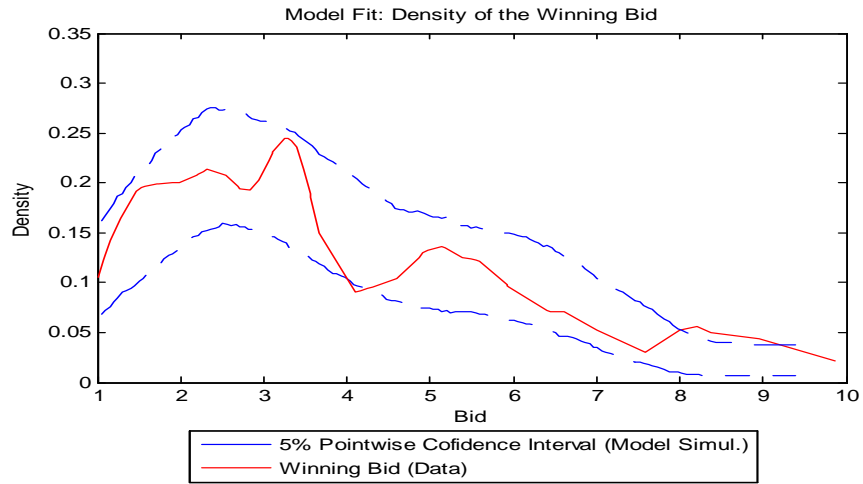
between November 2005 and June 2008.

Figure2 : Model Fit

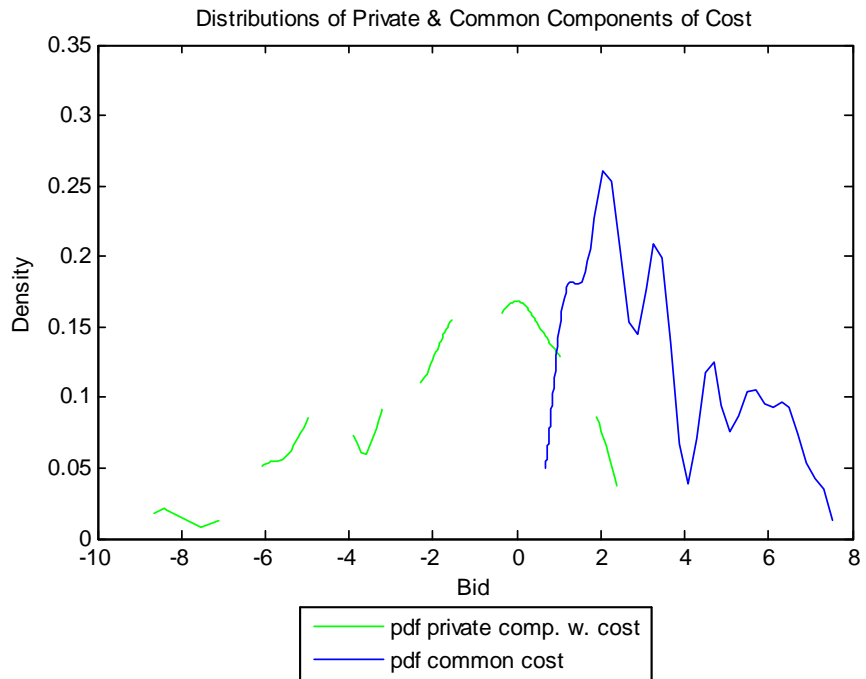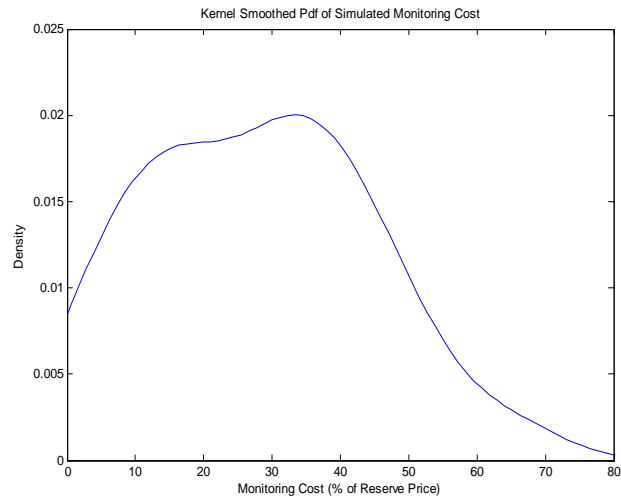Figure 3: Estimated Distributions of Costs

Figure 4: Monitoring Cost: structural vs. naive estimates

Estimated density of the monitoring cost calculated with simulated data

Estimated density of the monitoring cost calculated only with real data