Title
Past performance and entry in procurement: An experimental investigation

Authors
Butler, Jeffrey V
Carbone, Enrica
Conzo, Pierluigi
et al.

Publication Date
2020-05-01

DOI
10.1016/j.jebo.2020.02.019

Peer reviewed

Past Performance and Entry in Procurement: an Experimental Investigation*

Jeffrey V. Butler
University of California, Merced

Enrica Carbone
University of Campania "Luigi Vanvitelli"

Pierluigi Conzo
University of Turin
Collegio Carlo Alberto

Giancarlo Spagnolo†
Stockholm School of Economics-SITE
University of "Tor Vergata," EIEF & CEPR

This version: February 23, 2020

Abstract

There is widespread concern that incentive mechanisms based on past performance may hinder entry in procurement markets. We report results from a laboratory experiment assessing this concern. Within a simple dynamic procurement game where suppliers compete on price and quality we study how an incentive mechanism based on past performance affects outcomes and entry rates. Results indicate that some past-performance based mechanisms indeed hinder entry, but when appropriately designed may significantly increase both entry and quality provision without increasing costs to the procurer.

JEL Codes: H57, L14, L15
Keywords: Bid subsidies, Entry, Past performance, Procurement, Quality, Supplier selection, Vendor rating.

*We are grateful to Gary Charness, Martin Dufwenberg, Dan Levin, Marco Pagano and Marco Pagnozzi for detailed comments and very useful discussions. We gratefully acknowledge research funding from the Swedish Competition Authority (Konkurrensverket). We also thank two anonymous referees and the associate editor for many excellent comments that have greatly improved the paper.

†Address correspondence to: *Giancarlo Spagnolo, Stockholm School of Economics-SITE, Sveavägen 65, Box 6501, SE-11383, Stockholm; Fax: +46-8-31 81 86; E-mail: giancarlo.spagnolo(at)hhs.se.*

1 Introduction

Do selection criteria based on past performance deter entry in procurement markets? If buyers are allowed to formally consider suppliers' track records, does this necessarily hinder the ability of new firms, those with little or no performance history, to win contracts?

Understanding how procurement markets should be designed is a first order concern for firms and governments. Public procurement alone accounts for 15 to 20 percent of GDP in developed countries and is on the rise as continuing budget shortages cause governments to rely more and more on private providers. Private procurement is even larger and each well run firm has a system to evaluate and reward supplier past performance, typically with a preference in the allocation of new supply contracts. Given the economic importance of procurement markets, the lack of consensus among policy and law makers around the world on fundamental questions like the consequences and appropriateness of allowing current contracts to depend on past performance is surprising.

In the US, for example, the Federal Acquisition Regulation (FAR) *requires* government agencies to record contractors' past performance in a common database and to take it into account when awarding new contracts.[1] This policy was introduced by the Federal Procurement Streamlining Act (1994) with the intention of making public procurement less bureaucratic and more effective, closer to private procurement practices, but has recently drawn criticism. Several prominent US senators voiced their concern that the extensive use of past performance scores at the contractor selection stage could hinder the ability of new or small businesses to enter into and win competitions for public contracts.[2] The debate led the Government Accountability Office (GAO) to study dozens of procurement decisions across multiple government agencies in 2011. The resulting report, while inconclusive, contains some intriguing support for the senators' concern.[3] Despite extensive and costly policies aimed at fostering small business' access to US procurement markets,[4] the report "...identified only one procurement in which offerors ...lacked relevant past performance."

On the other side of the pond, European regulators appear to have always been convinced that allowing the use of past performance indicators as criteria for selecting among contractors leads to manipulations in favor of local incumbents, hindering entry, cross-border procurement and common market integration—the main objective of the EU. For this reason EU Procurement Directives *prohibited* taking suppliers' track records into account when comparing their bids,

[1] See, e.g., Manuel (2015), a non-technical Congressional Research Service report available for download at https://fas.org/sgp/crs/misc/R41562.pdf.

[2] The concerns emerged in the Committee on Homeland Security and Governmental Affairs of the US Senate, leading to a formal request of information to the GAO signed by Senators Lieberman and Tester, respectively Chairman and member of that Committee. The first page clarifies that the GAO 2011 report is a direct response to the specific request of information by the US Senators.

[3] See Government Accountability Office (2011). The inquiry had a qualitative nature and did not reach clear conclusions in our reading.

[4] See e.g. Athey et al. (2013), and references therein.

with minor exceptions, until very recently. New directives open some scope for past-performance based selection.

The main reason US regulators and European public buyers push for the use of past-performance indicators in selecting among contractors is that they consider them essential to obtain good value for taxpayers' money. Direct and indirect litigation costs are high and court-enforced contracts are typically not sufficient to achieve satisfactory governance of all qualitative aspects of exchanges. Since procurement is rarely occasional, mechanisms that reward past performance, which are widely used in private procurement, can complement and improve substantially on what formal contracting can achieve (e.g. Kelman, 1990).[5]

Private buyers use past performance as a supplier selection criterion because they are concerned about the price and quality of the intermediate goods and services they buy, a crucial determinant of their competitiveness. Governments and regulators in charge of public procurement may also be interested in objectives other than the price/quality ratio of publicly purchased goods. For example, they are also usually concerned that the public procurement process is transparent and open in order to stimulate cross-border procurement and market integration—as in the case of the EU—as well as for obvious integrity/accountability reasons.[6] They may want to ensure that small businesses are not excluded from public procurement, a concern that in the US has led to large programs like the one started by the Small Business Act.[7] However, if the use of past-performance indicators in the selection of suppliers deters entry, then there may be a trade-off between the improvement in price/quality ratios buyers can secure using these past-performance indicators and the decrease in the likelihood that new, possibly more efficient or innovative, suppliers will enter the market—as US senators feared for the US federal procurement market.

To shed light on this controversial issue, we implement in the lab a simple repeated procurement game with incentives implemented through a pre-announced and transparent bid subsidy linked to past quality provision. We then study the effects of these incentives on the entry decision of a more efficient supplier. Theoretically, it is well known, at least since Klein and Leffler (1981), that in markets where asymmetric information makes past performance important, new entrants must produce below cost to build up an advantageous track record. With imperfect

[5]This is why Steven Kelman introduced them in the big reform of US federal procurement he led when serving as Administrator of the Office of Federal Procurement Policy in the Office of Management and Budget during the Clinton administration, with the reform leading, among other things, to the Federal Procurement Streamlining Act (1994).

[6]This may not always be the case in practice. Djankov et al. (2002), in a cross section comparison of 85 counties, show that stricter regulation of entry is associated with higher levels of corruption and greater size of unofficial economic activity, suggesting entry is often regulated in the interest of regulators and not of the consumers. See also Bandiera et al. (2009) as well as Coviello and Gagliarducci (2016).

[7]This includes rules limiting bundling, the establishment of the Small Business Agency and "set aside" programs trying to stimulate small business entry in many procurement markets. Athey et al. (2013) provide empirical evidence that such "set-asides" typically foster entry by smaller firms at the cost of lower efficiency and revenues. They go on to show that a policy similar to the one we study, i.e., subsidizing small bidders, may foster entry without reducing efficiency or revenues. See also Marion (2007).

financial markets, this may lead to entry deterrence of smaller, more financially constrained firms. However, quantitative studies on this possible effect are lacking, while policy makers are increasingly wary of policy recommendations coming from complex theoretical models that disregard crucial institutional aspects and are sensitive to changes in simplifying assumptions needed to solve them. Some type of evidence is needed to convince policy makers. In this paper we provide more structured evidence than the qualitative assessments in the GAO report mentioned above. An ideal dataset to study these questions would contain observations of behavior in procurement markets that differ only in the role played by the supplier's past performance. For lack of such an exogenous variation in real-world procurement systems we conduct a tightly controlled laboratory experiment based on the simplest procurement game we could envisage that reflects the relevant environment and the issues at stake.[8]

We augment a three-period competitive procurement game among two suppliers with a decision by each period's winner on whether to provide costly quality in that period, and with the possibility of entry by a third, more efficient competitor in the final period, which represents the future. We then allow past performance to matter by adding a mechanism that generates a pre-announced advantage at the bidding stage for a supplier that provided high quality in the past. We implement this past performance advantage in the form of a transparent bid subsidy, a mechanism which Athey et al. (2013) single out as being particularly promising in real-world procurement auctions. Across treatments, we vary both the existence of an incentive mechanism and, when a mechanism is present, the relative size of the bid subsidy that a potential entrant—with no track record yet—may be given.

We use this framework, first and foremost, to ask whether past performance-based procurement can or must necessarily deter entry, our main research question. We then dig deeper to investigate precisely how the relative size of the entrant's advantage (bid subsidy) affects both the quality level delivered by sellers and the total costs paid by the buyer. This leads us to also evaluate the effects of these mechanisms on welfare functions with different weights for quality, price and entry, respectively.

One main novelty of our past performance mechanism is the provision of a bid subsidy to the potential entrant. This aspect of our design is meant to address a common misconception. It is often taken for granted in the policy debate that past performance mechanisms must be designed so that entrant firms with no history of production would start on equal footing with an incumbent firm having the worst possible track record—which would obviously provide incumbent firms with an advantage that might deter new entrants. However, in order to be

[8]In this sense, our study belongs to the kind of experiments that Al Roth (1986) categorizes as "Whispering in the ears of princes." See e.g. Feldman and Ruffle (2015) and Abeler and Jäger (2015) for recent laboratory experiments that take a similar path to shed light on other important policy design questions. A field experiment would of course be ideal as an external validity test, but it is not easy to change procurement rules for parts of a country or region. Experiments with firms, on the other hand, can be arranged to clarify this question. See Decarolis et al. (2016) for a step in this direction.

effective in providing incentives, mechanisms must typically be based on clear rules that suppliers know and trust, which give commitment power to the buyer and allow these systems to be designed in a variety of ways. The mechanism may therefore award a positive rating to new entrants—e.g., the maximum possible rating, or the average rating in the market, putting entrants at less of a disadvantage—and ensure that this is taken into account by the scoring rule that selects the contractor, even if the contractor has never interacted with the buyer before.

As a preview of our results, our data suggest that there need not be a trade-off between past performance and entry in procurement. We do find that standard mechanisms—i.e., those that assign zero score to potential entrants—increase quality but reduce entry. In this sense, the concerns of the US senators are in principle justified. However, when the mechanism is designed so that it awards a positive score also to potential entrants, we find that both entry and quality may significantly increase relative to the baseline treatment without an incentive mechanism. More surprisingly, we find that these increases in quality and entry raise the final price paid by the buyer only moderately and sometimes not at all—even incorporating all applicable bid subsidies. That is to say, well calibrated mechanisms of this type may elicit higher quality and more frequent entry at no additional cost to the buyer, a kind of "nirvana" result.[9]

Providing a modicum of evidence on the external validity of this phenomenon, an analogous result appears to be observed in a recent field study on the effects of the introduction of a past performance system for the suppliers of a large corporation (Decarolis et al., 2016). One potential explanation for this puzzling result is that the kind of multidimensional and intertemporal competition induced by a mechanism like this simply makes tacit collusion more difficult. The past performance mechanism makes players asymmetric after the first round, and tacit collusion being hindered by asymmetry is a recurrent finding in experimental oligopoly games in general (Mason et al., 1992; Fonseca and Norman, 2008), and in homogeneous Bertrand games in particular (Boone et al., 2012; Dugar and Mitra, 2016). In this sense, our results could be seen as consistent with these previous experimental and empirical findings. In our experiment, however, the asymmetry is endogenously generated by multidimensional intertemporal competition, not exogenously imposed. Also, Dufwenberg and Gneezy (2000, 2002) find that only by increasing the number of competitors to three or more or concealing losing bids in past games is the Bertrand equilibrium eventually reached in one-shot interactions. Therefore, prices consistently above the Bertrand solution in the first two rounds of our baseline treatment were somewhat expected. The increase in competition we observe when a past performance mechanism is introduced could then be due to the "increased complexity" of the competitive

[9]The "nirvana" result is puzzling because in a dynamic Bertrand-like environment, the prospects of a future advantage after winning the first contract and obtaining a bid preference should induce tougher competition with an incentive system in place, but only in the first stage (see e.g. Cabral and Villas Boas 2005). After that, the incumbent should recoup the investment and overall (average) prices should in the end reflect the higher costs of higher quality provision.

environment, rather than to the asymmetry undermining tacit collusion. This is in line with the theoretical hypothesis of Gale and Sabourian (2005) that more complexity induces faster convergence to the competitive solution. Other more "behavioral" explanations for our "nirvana" results could also be envisaged. Unfortunately, our experiment was not designed to discriminate between these alternative explanations (we did not anticipate such a result), so clarifying the robustness and the origin of this puzzling effect can be seen as an interesting line for future work.

Our study is confined to a simple procurement game tested in a stylized laboratory setting. However, if confirmed by further empirical and experimental evidence, our results imply that the dual goals of providing incentives for quality provision and for increasing entry are not mutually exclusive—they are both achievable through an appropriately designed past performance mechanism. Moreover, since the reaction of prices to the presence of bid subsidies that we observe is weak, it seems that the increase in quality and entry may come at very little cost to buyers.

The remainder of the paper proceeds as follows. In the next section, we describe our procurement game, before discussing our experimental design. In Section 3, we present the results from our experiment. Section 4 discusses how our results relate to the existing literature, while in Section 5 we provide concluding remarks.

1.1 The procurement game

Our experiment will use variants of a dynamic procurement auction game featuring three sequential auctions. We chose to use three sequential auctions to make our experiment as simple as possible while still allowing us to investigate the features we are primarily interested in. Specifically, three is the minimum number allowing for investing in high quality (auction 1) and potentially reaping the gains from such investment (auction 2) before a new, more efficient firm has the option of entering the market (auction 3). In this section we describe the basic structure of the game.

Our dynamic procurement auction game consists of three periods, each of which is composed of two stages: an auction stage and a production stage. In each game, Periods 1 and 2 contain two sellers who compete in the auction stage, with the winner choosing a quality level in the production stage. Prior to Period 3, a third seller decides whether to enter the Period 3 auction, which then proceeds as Periods 1 and 2, but with either 2 or 3 players depending on the third seller's entry decision. Each auction consists of homogeneous-good price competition involving only the firms described.[10]

[10]Each static period is similar to the game studied in Dufwenberg and Gneezy (2000). We adopt their assumption that firms are fully informed because it simplifies the environment, allowing us and the subjects to better focus on the *per se* complex dynamic choices of price, quality provision and entry under different past performance regimes.

Hereafter, we will refer to the two sellers that compete in all three auctions as "Incumbent firms," or simply Incumbents. The other seller, which competes in at most Auction 3, is referred to as the "Entrant [firm]."

In the auction stage of each of these three periods, all participating firms submit bids simultaneously. Bids are restricted to a discrete finite set, $\{0, 0.01, ..., \bar{b}\}$. The firm submitting the lowest bid wins the auction and must produce a good in the production stage of the period. Ties in bids are broken by uniformly randomly selecting the winner from among the set of firms submitting the lowest bid. Goods can be produced at one of two quality levels, high or low.

While the Entrant firm has a cost advantage relative to the Incumbents for producing a low quality good, for all firms producing high quality is more costly than producing low quality.[11] Any firm losing a particular auction earns 0 from that period. While Incumbents' earnings come solely from the auctions, the Entrant firm earns an outside wage of w for each auction it does not participate in.[12]

Between each period, all three firms (including the Entrant) are informed of all bids submitted as well as the quality level produced, high or low, by the winning firm in the immediately previous period. Between Periods 2 and 3 – after the quality production stage of the second period, but before the auction stage of Period 3 – the Entrant must decide whether or not to participate in Auction 3. If it chooses to participate in Auction 3 it forgoes its outside wage of w, but may earn profits from the auction. Consequently, an Entrant that chooses to stay out of Auction 3 earns a total of $3w$ for the game, while an Entrant that chooses to enter into and compete in Auction 3 earns $2w$ plus whatever additional profit it earns from Auction 3.

To incorporate past-performance incentives we use a bid subsidy with limited (one-stage) memory. To be clear, the essential characteristic of a past performance benefit is that, holding current auction bids constant, it puts a firm with good past performance at an advantage relative to competitors with a poor past performance. Our bid subsidy implements this benefit in a simple and transparent way and is analogous to the mechanism studied in Athey et al. (2013). Specifically, for $t \in \{2, 3\}$, if the winning Incumbent firm in Period $t - 1$ delivered the high quality good and also wins Auction t with bid b, this firm is paid a multiple of its Auction t bid, Bb, by the procurer. Because our bid subsidy effectively reimburses the winning firm a multiple of its bid, we refer to it from here on as a "reimbursement multiplier."[13] The reimbursement multiplier allows a firm with good past performance to earn a positive profit with a lower bid than an identical firm with poor past performance, conferring an advantage

[11] We limit the price advantage to low quality since an Entrant firm will never optimally choose to produce high quality—the game ends after the Entrant firm makes its production decision.

[12] We assign the Entrant an outside wage in anticipation of our experiment. The outside wage provides participants assigned the role of the Entrant with experimental earnings comparable to those we may expect participants assigned the Incumbent role to earn. Since it is a fixed wage it should have little impact on the strategic environment.

[13] We thank an anonymous reviewer for suggesting the "reimbursement multiplier" terminology.

in terms of the ability of profitably winning the current Auction.[14] To analyze the market implications of assigning a positive score to a potential entrant, we also assign a reimbursement multiplier $\beta \geq 1$ to the Entrant firm.

In our experiment, detailed in the next section, we will vary the magnitude of the Entrant firm's multiplier across treatments. In addition to the reimbursement multipliers, other parameters of interest are the cost of producing a high or low quality good, c_L and c_H, and the Entrant's (additive) cost advantage at producing a low quality good, k. That is to say, the Entrant firm's cost of producing a low quality good is $c_L^e = c_L - k$

To illustrate how the reimbursement multipliers work, consider the following sequence of events. In Auction 1, Incumbent firm 1 submits the bid $b_1 = c_L$ while Incumbent 2 submits $b_2 = c_L + 0.01$. Incumbent 1 wins the auction and produces a high quality good, yielding total Period 1 earnings of $c_L - c_H$. Incumbent 2's Period 1 earnings are zero. In Auction 2, the Incumbent firms submit bids of $b_1 = c_L$ and $b_2 = c_L + 0.01$ again. Incumbent 1 wins again, but produces low quality. Incumbent 1's Period 2 earnings are $Bc_L - c_L = c_L(B-1)$, and its total earnings from the first two periods are $(c_L - c_H) + c_L(B-1) = Bc_L - c_H$. Incumbent 2's Period 2 profits are again zero, and its total earnings from the first two periods are also zero. Between Periods 2 and 3, the Entrant firm decides to enter into and compete in Auction 3. The Entrant submits the bid $b_e = c_L$, while the Incumbent firms submit the bids $b_1 = c_L + 0.01$ and $b_2 = \bar{b}$. The Entrant firm wins Auction 3 and produces low quality. The Entrant's profits from Period 3 are $\beta c_L - c_L^e = c_L(\beta - 1) + k$, while both Incumbent firms earn zero profits from Period 3. Overall, the Entrant's profits from the game are $2w + c_L(\beta - 1) + k$. Incumbent 1 earns $Bc_L - c_H$ from the entire game, while Incumbent 2's overall profits are zero.

In the Theoretical Appendix, we solve the game for general parameter values using the solution concept Subgame Perfect Nash Equilibrium (SPNE) plus one additional restriction. In particular, we impose the restriction that weakly dominated strategies not be played. In the sections that follow, for concreteness we consider only the game variants we implemented in the lab and solve our game only for those parameter values.

2 Experimental design

Participants play between twelve and fifteen rounds of the (three-period) dynamic procurement auction game described in the previous section.[15] Before each round, participants are randomly and anonymously divided into groups of three and then randomly assigned one of two roles: two participants in each three-person group are assigned the role of "Incumbent firm," while

[14]Note that the bid advantage lasts only for one period, i.e. the length of the buyer's memory of seller's past performance is just one auction.

[15]The number of rounds varies due to time constraints. Our participants had little, if any, prior experience with experiments. Game play therefore proceeded relatively slowly. Each session featured as many rounds as we could feasibly implement given a two-hour pre-scheduled time constraint.

the third person in each group is assigned the role of "Entrant firm."[16] We implement multiple rounds in order to allow participants the opportunity to learn how to play optimally. However, they are instructed that at the end of the experiment only one round will be randomly chosen to count towards their experimental earnings.[17] At the end of each period, within each round, all firms learn the bids of the other firms in their own group and the quality production decision of the winning firm in their group. Firms learn nothing about bids or choices in groups other than their own. Before the third period begins, Incumbent firms are informed of the entry decision of the Entrant firm in their group.

We fix several parameters of the game to be constant across all rounds and all treatments: $c_H = 2.00, c_L = 1.50, k = 1.375, w = 1.00$ and $\bar{b} = 4.50$.[18] Our choice of specific parameter values balanced two concerns: expository simplicity to facilitate experimental participants' understanding of the game against our desire for variation in equilibrium predictions across treatments.

Across treatments, the only parameters we vary are the reimbursement multipliers, B and β. Specifically, we conduct one "Baseline" treatment in which $B = \beta = 1$, which can be thought of as implementing no past-performance incentive mechanism at all. In three other treatments, we fix the Incumbents' reimbursement multiplier at $B = 2$ and vary the Entrant firm's reimbursement multiplier.

2.1 Treatments

As mentioned above, the Entrant firm's reimbursement multiplier, $\beta \geq 1$, allows us to analyze the market implications of assigning a positive score to a potential entrant. We vary the magnitude of β across treatments, considering three main cases: i) treatment **HM** ("high multiplier"), where the reimbursement multiplier for the Entrant firm is equal to the maximum possible for an Incumbent firm, i.e. $\beta = B$; ii) treatment **LM** ("low multiplier"), where the Entrant firm's reimbursement multiplier is the minimum possible for the Incumbent, i.e. $\beta = 1$, effectively no multiplier; and finally iii) treatment **MM**, or "medium multiplier," in which the Entrant firm's reimbursement multiplier is between the maximum and the minimum possible for Incumbent firms, i.e., $\beta = \frac{(B+1)}{2}$.

Treatment **HM** is analogous to supplier qualification and quality assurance systems common in the private sector where all qualified suppliers start with a fixed maximum number of points,

[16]We use the terms "Incumbent" and "Entrant" here for clarity of exposition. Neutral language was used in the experiment. Specifically, roles were referred to as "Firm A," "Firm B" and "Firm C," with the first two being Incumbents and the latter the Entrant.

[17]This is a standard practice in experimental economics and serves to provide proper incentives in each round by, for example, ameliorating across-round hedging motives.

[18]We capped allowable bids at 4.50 euros as a precaution against the unlikely possibility of firms colluding on very high bids. This maximum was set to be substantially higher than would be expected in any equilibrium of the game. The precaution turned out to be unnecessary, as even though setting an explicit upper bound on bids in all likelihood enhanced the opportunity for collusion by creating a focal point, successful collusion on bids of 4.50 euros was essentially non-existent in the data.

lose points for bad performance, and may regain them through good performance but only up to the initial, maximum level. Points-based driver's license incentive systems are also designed this way in many countries. The **LM** treatment corresponds to a more standard past performance system where new firms without track records start out with minimal score. The remaining treatment, **MM**, represents a compromise between these two extremes, i.e. $\beta = \frac{(B+1)}{2}$, and corresponds to the case where Entrant firms enjoy the average market past performance score in a market where one of the two Incumbent firms has a good past performance. These rules are common knowledge among all players.

2.2 Equilibrium predictions

In this section, we describe equilibria in our game for the parameter values we use in our experiment. In a Theoretical Appendix we discuss equilibria in the game more broadly. For equilibrium predictions both here and in the Theoretical Appendix we use the solution concept of subgame perfect Nash equilibrium (SPNE) with the additional restriction that weakly dominated strategies not be played.[19] We discuss this restriction in the Theoretical Appendix. Here we merely state that we view the restriction as reasonable in that it rules out some types of non-credible threats that SPNE would rule out in a purely sequential-moves setting. It rules out, e.g., an Incumbent without a reimbursement multiplier bidding below c_L in the Period 3 auction.

To analyze the game, we first fix notation. Denote Player i's bid in Auction t by b_i^t, where $t \in \{\mathrm{I}, \mathrm{II}, \mathrm{III}\}, i \in \{1, 2, e\}$. Subscripts $i = 1, 2$ refer to Incumbent 1 and Incumbent 2, respectively, while the subscript $i = e$ refers to the Entrant. Label the quality production decision in Period t by $Q_i^t \in \{H, L\}$, $i \in \{1, 2, e\}$, $t \in \{\mathrm{I}, \mathrm{II}, \mathrm{III}\}$, where H and L mean H(igh) and L(ow) quality, respectively. We include the Entrant to simplify notation, but note that it can only submit a bid or make a quality production decision in (at most) Period 3. Denote by $E \in \{in, out\}$ the Entrant's decision between Periods 2 and 3 about whether to enter into and compete in Auction 3 ($E = in$) or to stay out of Auction 3 ($E = out$). While all of these actions can be conditioned on all prior information sets, for simplicity we suppress this dependence in our notation.

For ease of exposition, we will typically assume that the winning Incumbent, as well as the Incumbent submitting the (weakly) lowest bid, is Incumbent 1. For expositional simplicity, we will also sometimes refer to the addition to profits resulting only from actions taking place within a subgame as profits in that subgame.

We analyze our Baseline treatment first, followed by the HM, LM and MM treatments. We begin by remarking that in all treatments, since Period 3 production concludes the game, there

[19] To provide some empirical evidence about whether this additional restriction is reasonable in our experiment, we focus on Auction 3 where its implications are the clearest and compute the proportion of observations in our data satisfying the restriction. We find that it is satisfied in about 92% of our Auction 3 observations. The proportion is similar across treatments and across rounds, being typically above 90%.

is never any monetary incentive to produce high quality in Period 3 but there is a monetary cost. This implies that low quality is produced by the firm winning Period 3 in all equilibria: $Q_i^{\mathrm{III}} = L,\ i \in \{1, 2, e\}$.

2.2.1 Baseline

We start with Period 3 and work backwards. Because there is no reimbursement multiplier for any firm, Incumbents never bid below c_L (by assumption) in Auction 3 in any equilibrium: $b_i^{\mathrm{III}} \geq 1.50, i = 1, 2$. As a consequence, Entrants choosing $E = in$ can always win Auction 3 in subgame equilibrium by, for instance, submitting a bid of $b_e^{\mathrm{III}} = 1.49$ against Incumbent bids of $b_1^{\mathrm{III}} = 1.50, b_2^{\mathrm{III}} \geq 1.50$. Another type of subgame equilibrium features $b_e^{\mathrm{III}} = 1.50$ against Incumbent bids of $b_1^{\mathrm{III}} = 1.51, b_2^{\mathrm{III}} \geq 1.51$. In these latter equilibria, the Entrant obtains a profit of $1.50 - c_L^e = 1.50 - 0.125 = 1.375$, while in the former type the Entrant's profit is 1.374. Since the Entrant's profit from staying out is $w = 1 < 1.374 < 1.375$, the Entrant always chooses to compete in Auction 3 and wins with $b_e^{\mathrm{III}} \in \{1.49, 1.50\}$. Consequently, Incumbents always earn zero profit from Period 3 in equilibrium.

Working back one step, since Incumbents always earn zero profit on the equilibrium path from Period 3, there is no benefit to producing high quality in Period 2. The winning Incumbent, Incumbent 1 by convention, therefore produces low quality in Period 2 in any subgame equilibrium: $Q_1^{\mathrm{II}} = L$.

Working backwards, in the auction stage of Period 2, there are two types of subgame equilibria to consider. In one type, both Incumbents' bids are exactly equal to (low quality) cost: $b_1^{\mathrm{II}} = 1.50 = b_2^{\mathrm{II}}$, yielding zero equilibrium profits for both Incumbents from Period 2. In the other type of equilibrium, $b_1^{\mathrm{II}} = 1.51 = b_2^{\mathrm{II}}$. Because ties are broken with a coin flip, in this type of equilibrium both Incumbents earn an expected profit of 0.005. Consequently, Incumbents' additional profits from subgames starting at Auction 2 are always either 0 or 0.05 in equilibrium.

Working backwards once more, since there is no subsequent benefit to producing high quality to offset its additional cost, low quality is always produced in any equilibrium in Period 1 ($Q_1^{\mathrm{I}} = L$). Bids in Auction 1 follow the same general pattern as bids in Auction 2 in equilibrium: bids are identical to one another and are both either low-quality cost ($b_1^{\mathrm{I}} = c_L = 1.50 = b_2^{\mathrm{I}}$) or one cent above ($b_1^{\mathrm{I}} = c_L + 0.01 = 1.51 = b_2^{\mathrm{I}}$). Consequently, profits from Period 1 by itself are always approximately zero (0 or 0.005) in equilibrium.

Summing up, in the Baseline treatment equilibrium predictions are that: i) low quality is always produced ($Q_i^t = L, i = 1, 2, e, t = \mathrm{I}, \mathrm{II}, \mathrm{III}$); ii) entry always occurs ($E = in$); iii) winning bids are approximately equal to low-quality cost and, in particular, are always in the set $\{1.49, 1.50, 1.51\}$; and iv) Incumbents' bids in Auctions 1 and 2 are always equal and always either 1.50 or both 1.51.

2.2.2 HM treatment: $B = 2, \beta = 2$

In treatments with a formal incentive mechanism, equilibrium predictions are more complicated. We start with the HM treatment. In Auction 3, if Incumbent 1 has a reimbursement multiplier, the lowest bid it can submit in any subgame equilibrium is $\frac{c_L}{B} = 0.75$. Bidding below this would guarantee itself a negative Auction 3 profit. Similarly, if neither Incumbent has a reimbursement multiplier the lowest an Incumbent's bid can be in equilibrium is $c_L = 1.50$.

In the first case, where an Incumbent has a reimbursement multiplier, the Entrant can win Auction 3 with a bid of $b_e^{\mathrm{III}} = 0.74$ against Incumbent bids of $b_1^{\mathrm{III}} = 0.75$ and $b_2^{\mathrm{III}} \geq 1.50$.[20] The Entrant's profit in this type of equilibrium would be $2 \times 0.74 - c_L^e = 1.355$. In the second scenario, where neither Incumbent has a reimbursement multiplier, one type of equilibrium entails the Entrant submitting $b_e^{\mathrm{III}} = 1.49$ against Incumbent bids of $b_1^{\mathrm{III}} = 1.50$ and $b_2^{\mathrm{III}} \geq 1.50$, yielding Entrant profits of $2 \times 1.49 - c_L^e = 2.855$.[21]

Considering the entry decision, it is the case that in all subgame equilibria an Entrant who chooses $E = in$ earns Period 3 profit larger than $w = 1$, the profit it would earn from choosing $E = out$. Consequently, Entry always occurs in equilibrium ($E = in$).

Stepping backwards and considering the production stage of Period 2, note that because along the equilibrium path $E = in$ always occurs, the increment to an Incumbent's revenue from producing high quality would be zero – it loses Auction 3 with or without a reimbursement multiplier – while the increment to its cost would be strictly positive. Therefore, in any subgame equilibrium the winning Incumbent produces low quality in Period 2 ($Q_1^{\mathrm{II}} = L$).

Moving backward to the auction stage of Period 2, if neither incumbent enters this stage with a reimbursement multiplier then in equilibrium Auction 2 bids follow the same pattern as in the Baseline treatment considered above: $b_1^{\mathrm{II}} = 1.50 = b_2^{\mathrm{II}}$ or $b_1^{\mathrm{II}} = 1.51 = b_2^{\mathrm{II}}$, yielding Period 2 profits from this type of subgame of either 0 or 0.005. If, on the other hand, Incumbent 1 enters Period 2 with a reimbursement multiplier it wins Auction 2 in (subgame) equilibrium with either a bid of $b_1^{\mathrm{II}} = 1.49$ against $b_2^{\mathrm{II}} = 1.50$ or a bid of $b_1^{\mathrm{II}} = 1.50$ against $b_2^{\mathrm{II}} = 1.51$.[22] Consequently, Period 2 profits for Incumbent 1 from this type of subgame equilibrium are either $2 \times 1.49 - c_L = 2.98 - 1.50 = 1.48$ or $2 \times 1.50 - c_L = 3.00 - 1.50 = 1.50$.

Working backwards to the production stage of Period 1, notice that the increment to profits from producing high quality in Period 1 are at least $1.48 - 0.005 = 1.475$, which is greater than the associated 0.50 increase in costs. As a result, high quality is always produced by the

[20] Incumbent 2 cannot also have a reimbursement multiplier and therefore by assumption cannot bid less than c_L.

[21] Other equilibria when Incumbent 1 has a reimbursement multiplier involve the Entrant bidding $b_e^{\mathrm{III}} = 0.75$ against $b_1^{\mathrm{III}} = 0.76$ and $b_2^{\mathrm{III}} \geq 1.50$ resulting in Entrant profits of 1.375 or, when neither Incumbent has a reimbursement multiplier, the Entrant bidding $b_e^{\mathrm{III}} = 1.50$ against $b_1^{\mathrm{III}} = 1.51$ and $b_2^{\mathrm{III}} \geq 1.51$ and earning profits of 2.875.

[22] The other Incumbent firm cannot bid strictly below 1.50 by our restriction on equilibrium strategies since this would result in an addition to profit from the subgame of at most $1.49 - 1.50 + 0.005 = -0.01 + 0.005 < 0$.

winning firm in equilibrium in Period 1 ($Q_1^{\mathrm{I}} = H$).

At the initial information set, i.e., the auction stage of Period 1, total subsequent equilibrium profits from winning and producing high quality are either $b_1^{\mathrm{I}} - c_H + 1.48 = b_1^{\mathrm{I}} - 0.52$ or $b_1^{\mathrm{I}} - c_H + 1.50 = b_1^{\mathrm{I}} - 0.50$. Since Incumbents are symmetric in Auction 1, (approximately) all future profits are bid away in equilibrium. As a consequence, there are multiple essentially equivalent types of equilibria. In one type of equilibrium, both Incumbents submit a bid exactly driving away subsequent profits. For example, if the subsequent profits from Auction 2 forward along the equilibrium path are 1.50, then bids in this type of equilibrium satisfy $b_i^{\mathrm{I}} - c_H = -1.50$, i.e., $b_1^{\mathrm{I}} = 0.50 = b_2^{\mathrm{I}}$. The other type of equilibrium involves both Incumbents submitting bids which would leave one cent of continuation game profits, yielding an expected profit from the game of 0.005. In the previous example, this would require $b_1^{\mathrm{I}} = 0.51 = b_2^{\mathrm{I}}$.

In summary, our predicted behavior in the HM treatment is as follows: i) extremely low bids ($b_i^{\mathrm{I}} < c_L, i = 1, 2$) coupled with high quality production ($Q_1^{\mathrm{I}} = H$) in Period 1; ii) bids at cost ($b_i^{\mathrm{II}} \approx c_L, i = 1, 2$) together with low quality production ($Q_1^{\mathrm{II}} = H$) in Period 2; iii) entry between Periods 2 and 3 ($E = in$) followed by bids of approximately (low-quality) cost ($b_e^{\mathrm{III}} \approx c_L, min\{b_1^{\mathrm{III}}, b_2^{\mathrm{III}}\} \approx c_L$) in Auction 3. That is to say, all the equilibria in the HM treatment share a feature which we call "**Entrant Accommodation**:" the Incumbent firm that wins the auction in Period 1 produces high quality in that period, exploits this advantage to win Auction 2 as well, but then cashes in on this advantage and accommodates the Entrant by producing low quality in Period 2. Accommodation here refers to the fact that by entering Auction 3 without a reimbursement multiplier the Incumbent permits the Entrant to earn a much higher profit than it could otherwise.

2.2.3 LM treatment: $B = 2, \beta = 1$

In the LM treatment the Entrant is on equal footing with an Incumbent without a reimbursement multiplier. At the auction stage of Period 3, there are four types of subgames to consider: Incumbent 1 has or does not have a reimbursement multiplier and entry did or did not occur between Periods 2 and 3.

First consider subgames following $E = in$. If Incumbent 1 has a reimbursement multiplier and the Entrant chose to enter Auction 3, then on the equilibrium path the Entrant wins the auction with a bid of $b_e^{\mathrm{III}} = 0.74$ against bids of $b_1^{\mathrm{III}} = 0.75$ and $b_2^{\mathrm{III}} \geq 1.50$. The Entrant's Period 3 profit in this type of subgame is $0.74 - c_L^e = 0.615$.[23] In the type of subgame where neither Incumbent has a reimbursement multiplier and entry occurs ($E = in$), the Entrant wins Auction 3 with a bid of $b_e^{\mathrm{III}} = 1.50$ against bids of $b_1^{\mathrm{III}} = 1.51$ and $b_2^{\mathrm{III}} \geq 1.51$ and earns a Period 3 profit of $1.50 - c_L^e = 1.375$.[24]

[23] Another type of subgame equilibrium involves $b_e^{\mathrm{III}} = 0.75$ against bids of $b_1^{\mathrm{III}} = 0.76$ and $b_2^{\mathrm{III}} \geq 1.50$, yielding the Entrant a Period 3 profit of 0.625.

[24] Alternatively, in this type of subgame, $b_e^{\mathrm{III}} = 1.49$ against bids of $b_1^{\mathrm{III}} = 1.50$ and $b_2^{\mathrm{III}} \geq 1.50$ also constitute

In the type of subgame following $E = out$ the Entrant always earns its outside wage $w = 1$ from Period 3, while the Incumbents' profits depend on whether Incumbent 1 has a reimbursement multiplier or not. If Incumbent 1 has a reimbursement multiplier, it wins Auction 3 with a bid of $b_1^{\mathrm{III}} = 1.50$ against $b_2^{\mathrm{III}} = 1.51$ yielding Incumbent 1 a Period 3 profit of $2 \times 1.50 - 1.50 = 1.50$.[25] If neither Incumbent has a multiplier, then since the Incumbents are symmetric the two possible subgame equilibria both entail approximately zero Period 3 profit for both Incumbents: the bids $b_1^{\mathrm{III}} = 1.50$ and $b_2^{\mathrm{III}} = 1.50$ constitute an equilibrium yielding zero profit; the bids $b_1^{\mathrm{III}} = 1.51$ and $b_2^{\mathrm{III}} = 1.51$ also constitute an equilibrium and yield (expected) profits of 0.005 for each Incumbent.

Working backwards to the entry decision, the Entrant chooses $E = in$ whenever neither Incumbent has a reimbursement multiplier since its minimum profit from Period 3 along the equilibrium path in this type of subgame is $1.365 > 1 = w$. On the other hand, whenever Incumbent 1 has a reimbursement multiplier the maximum Period 3 profit the Entrant could earn from entry in this type of subgame equilibrium would be $0.625 < 1 = w$, so that the Entrant chooses to stay out of Auction 3. In summary, the Entrant always chooses $E = out$ if Incumbent 1 produces high quality in Period 2 and always chooses $E = in$ otherwise.

Stepping back to the production stage of Period 2, the winning Incumbent can deter entry on the equilibrium path by producing high quality. An Incumbent entering the auction stage of Period 3 with a reimbursement multiplier earns Period 3 profits of at least 1.48 in equilibrium, while producing low quality always results in (approximately) zero Period 3 profits. Because the increment to an Incumbent's profit from producing high quality is greater than the 0.50 cost increase, the Incumbent who wins Auction 2 always produces high quality ($Q_1^{\mathrm{II}} = H$) in subgame equilibrium.

In the auction stage of Period 2, there are again two types of subgames: either i) Incumbent 1 has a reimbursement multiplier; or ii) neither Incumbent has a reimbursement multiplier. In either case, our restriction on equilibrium bids implies that the bid of a firm without a reimbursement multiplier satisfies $b_i^{\mathrm{II}} - c_H \geq -$Period 3 profit. Assume firms are in the type of subgame where Period 3 profits for the Incumbent winning Auction 2 will be 1.50 in equilibrium. In case i), Incumbent 1 wins the auction with a bid of $b_1^{\mathrm{II}} = 0.50$ against a bid of $b_2^{\mathrm{II}} = 0.51$ yielding subgame equilibrium profits of $0.50 = 2 \times 0.50 - c_H + 1.50$.[26] In case ii) where neither Incumbent firm has a reimbursement multiplier, symmetric Bertrand competition for Period 3 profits of 1.50 yields equilibrium bids which ensure (approximately) zero profits from the subgame in equilibrium. For example, if $b_1^{\mathrm{II}} = b_2^{\mathrm{II}} = 0.50$, then the winning Incumbent earns

mutual best replies, yielding the Entrant a Period 3 profit of 1.365.

[25] Another equilibrium in a subgame of this type features $b_1^{\mathrm{III}} = 1.49$ against $b_2^{\mathrm{III}} = 1.50$, yielding Incumbent 1 a profit of $2 \times 1.49 - 1.50 = 1.48$.

[26] Alternatively, Incumbent 1 wins the Auction in equilibrium with $b_1^{\mathrm{II}} = 0.49$ against $b_2^{\mathrm{II}} = 0.50$, yielding Incumbent 1 subgame equilibrium profits of $2 \times 0.49 - c_H + 1.50 = 0.48$

profits of $0.50 - c_H + 1.50 = -1.50 + 1.50 = 0$ in the subgame along the equilibrium path. These bids constitute one type of subgame equilibrium. The other equilibrium, as should be familiar by now, involves bids one cent higher ($b_1^{\mathrm{II}} = b_2^{\mathrm{II}} = 0.51$) and subgame profits of 0.005 for both Incumbents.

At the production stage of Period 1, subgame profits of 0.50 are possible following $Q_1^{\mathrm{I}} = H$, while approximately zero additional profit is associated with choosing $Q_1^{\mathrm{I}} = L$. Assume the equilibrium being played is one in which 0.50 is the increase in subsequent subgame equilibrium profit from $Q_1^{\mathrm{I}} = H$, while $Q_1^{\mathrm{I}} = L$ entails no increase in subsequent subgame profit. Since the 0.50 increase in subgame profit from producing high quality exactly offsets the 0.50 increase in costs, the winning Incumbent is indifferent between its two actions in this stage. Therefore, either $Q_1^{\mathrm{I}} = H$ or $Q_1^{\mathrm{I}} = L$ are possible in equilibrium.

At the game's initial information set, the auction stage of Period 1 features symmetric Bertrand competition for some fixed amount of subsequent equilibrium profit, which depends on the equilibrium being played. Bids in Auction 1 drive away these future profits. As an example, suppose $Q_1^{\mathrm{I}} = H$ on the equilibrium path and the equilibrium being played is of the type described in the preceding paragraph. Then in equilibrium, bids must offset the cost of producing high quality in Period 1. Consequently, the bids $b_1^{\mathrm{I}} = b_2^{\mathrm{I}} = 2.00$ are possible in equilibrium, as are the bids $b_1^{\mathrm{I}} = b_2^{\mathrm{I}} = 2.01$.[27]

Summarizing, in the LM treatment there are, broadly speaking, two types of equilibria. In the first type, Period 1 bids are high ($b_i^{\mathrm{I}} \approx c_H, i = 1, 2$) and high quality is produced ($Q_1^{\mathrm{I}} = H$); Period 2 bids are low ($b_i^{\mathrm{II}} < c_L, i = 1, 2$) and high quality is produced ($Q_1^{\mathrm{II}} = H$); between Periods 2 and 3 entry never occurs ($E = out$); in Period 3, bids are moderate ($b_i^{\mathrm{III}} \approx c_L, i = 1, 2$).

In the second type of equilibrium, Period 1 bids are moderate ($b_i^{\mathrm{I}} \approx c_L, i = 1, 2$) and low quality is produced ($Q_1^{\mathrm{I}} = L$); Period 2 bids are low ($b_i^{\mathrm{II}} < c_L, i = 1, 2$) and high quality is produced ($Q_1^{\mathrm{II}} = H$); between Periods 2 and 3, entry never occurs ($E = out$); in Period 3, bids are moderate ($b_i^{\mathrm{III}} \approx c_L, i = 1, 2$).

Notice that in either of these two broad types of equilibrium, high quality is produced in Period 2, which deters entry. Because of this, we refer to both of these broad types of equilibria as examples of "**Entry Deterrence**" equilibria.

2.2.4 MM treatment, $B = 2, \beta = \frac{2+1}{2} = 1.5$

Finally, consider the MM treatment. In the auction stage of Period 3, our restriction on equilibrium bids implies that the lowest an Incumbent firm can bid is 0.75, if it has a reimbursement multiplier, or 1.50 if it does not. There are four types of subgames leading into Auction 3 to consider: either Incumbent 1 has a reimbursement multiplier or neither firm has a reimbursement

[27] Similarly, in equilibria featuring $Q_1^{\mathrm{I}} = L$ the bids $b_1^{\mathrm{I}} = b_2^{\mathrm{I}} = 1.50$ and $b_1^{\mathrm{I}} = b_2^{\mathrm{I}} = 1.51$ constitute mutual best responses and hence can be played in equilibrium.

multiplier and, for each of these cases, entry did or did not occur.

Consider first the type of subgame equilibrium, following $E = in$. If neither Incumbent has a reimbursement multiplier, the Entrant firm wins the auction with a bid of either $b_e^{\mathrm{III}} = 1.50$ or $b_e^{\mathrm{III}} = 1.49$.[28] The Entrant's profits from Period 3 are therefore $b_e^{\mathrm{III}} \times 1.5 - c_L^E = b_e^{\mathrm{III}} \times 1.5 - 0.125$, i.e., either 2.125 or 2.11. If Incumbent 1 has a reimbursement multiplier, the Entrant also wins the auction in subgame equilibrium with a bid of either $b_e^{\mathrm{III}} = 0.75$ or $b_e^{\mathrm{III}} = 0.74$.[29] The Entrant's Period 3 profits in this type of subgame equilibrium are consequently either $0.75 \times 1.5 - c_L^E = 1.125 - 0.125 = 1$ or $0.74 \times 1.5 - c_L^E = 0.985 < 1$. The Incumbents' Period 3 profits following $E = in$ are always zero in this type of subgame equilibrium.

In the type of subgame following $E = out$, the Entrant's Period 3 profits are always $w = 1$, while the description of the subgame equilibria for the Incumbents is identical to the description provided for the other treatments, above. If Incumbent 1 has a reimbursement multiplier it wins the auction with a bid of $b_1^{\mathrm{III}} \in \{1.50, 1.49\}$ yielding Incumbent 1 a Period 3 profit of either 1.50 or 1.48 from the subgame. If neither Incumbent has a reimbursement multiplier, the two subgame equilibria ($b_1^{\mathrm{III}} = b_2^{\mathrm{III}} = 1.50$ or $b_1^{\mathrm{III}} = b_2^{\mathrm{III}} = 1.51$) both entail approximately zero Period 3 profit for each Incumbent.

Moving backwards, the Entrant's decision between Periods 2 and 3 is as follows: if neither Incumbent has a reimbursement multiplier, the Entrant always chooses $E = in$ since $2.11 > 1$; if Incumbent 1 has a reimbursement multiplier, then either $E = in$ or $E = out$ are possible in equilibrium. Either the Entrant is indifferent – when its Period 3 equilibrium profits are exactly equal to 1 – or the Entrant strictly prefers $E = out$. The latter is true when its Period 3 equilibrium profits will be 0.985.

Working backward, when choosing which quality level to produce in Period 2 the winning Incumbent's subsequent total profits depend on the equilibrium being played. Any equilibrium where the Entrant firm chooses $E = in$ leaves zero profit for an Incumbent irrespective of its reimbursement multiplier. For these subgames, we can immediately see what types of strategies must be played in any equilibrium for all previous periods: they coincide with the "**Entrant Accommodation**" equilibria characterized in our discussion of the HM treatment above. In contrast, in any subgame equilibrium featuring $E = out$ between Periods 2 and 3 the winning Incumbent produces high quality in Period 2 ($Q_1^{\mathrm{II}} = H$). In this case, strategies in all previous periods in any equilibrium resemble the strategies played in the "**Entry Deterrence**" equilibria described in connection with the LM treatment above.

Summing up, in the MM treatment we can expect to observe two broad types of equilibria. On the one hand, any of the *Entry Deterrence* equilibria we described in connection with the LM

[28] Incumbent bids supporting the former Entrant bid are $b_1^{\mathrm{III}} = 1.51$ and $b_2^{\mathrm{III}} \geq 1.51$, while the bids $b_1^{\mathrm{III}} = 1.50$ and $b_2^{\mathrm{III}} \geq 1.50$ support the latter.

[29] Incumbent bids supporting $b_e^{\mathrm{III}} = 0.75$ are $b_1^{\mathrm{III}} = 0.76$ and $b_2^{\mathrm{III}} \geq 1.50$, while the bids $b_1^{\mathrm{III}} = 0.75$ and $b_2^{\mathrm{III}} \geq 1.50$ support $b_e^{\mathrm{III}} = 0.74$.

treatment may occur. On the other hand, all of the *Entrant Accommodation* equilibria appearing in our discussion of the HM treatment above are also possible. As a result, we predict a mix of the features of these two broad types of equilibria in our data. Overall, Period 1 and 2 bids should be moderate and high quality should sometimes be produced in these periods. Entry should sometimes occur.

2.3 Implementation

All sessions of the experiment were conducted in the laboratory facilities at the Einaudi Institute for Economics and Finance in Rome, Italy, using the software *z-Tree* (Fischbacher, 2007). Twelve sessions were conducted involving a total of 243 participants. Average earnings in the experiment were approximately 12 euros, including a show-up fee and payment for a risk elicitation task conducted after all rounds of the game were completed but *before* participants knew which round would be chosen to determine their earnings.[30] Because participants did not know about the risk elicitation task when playing the auction game, it should not have affected decisions there. Each session lasted about two hours. Information on all four treatments is summarized in Table 1.

Insert Table 1 about here.

3 Results

Our experimental outcomes of interest are the proportion of winning firms producing high quality, the cost to the buyer—which we call the "buyer's (total) transfer" to avoid confusion with the sellers' costs of producing—as well as the proportion of Entrant firms choosing to enter. We first consider each of these outcomes in isolation and then consider buyers' welfare, which may incorporate some or all of these outcomes simultaneously.

3.1 Quality provision

Let us first examine quality provision, since encouraging high-quality goods provision is a primary reason buyers might prefer to implement some form of incentive mechanism. In Table

[30] We included the risk elicitation task in order to ensure participants of a reasonable amount of money, as our equilibrium predictions suggested they would make little money from the auctions—a common dilemma when implementing Bertrand competition games in the lab. This concern turned out to be warranted, as competition indeed drove profits from the auctions alone down to around €1.30, on average. While it may seem low, participants' average earnings of €12 for two hours of their time is commensurate with their opportunity costs. For example, work-study positions pay €5.50 per hour at a private college near the EIEF in Rome, whose pay structure we are familiar with. The risk elicitation task involved a sequence of choices between a sure payment of €5 and a lottery involving a 50% chance of a low payoff (€2.50) and a 50% chance of a high payoff, which increased over the sequence from €7.50 to €17 in steps of €0.50. More risk averse individuals should switch from preferring the sure payment to the lottery later in the sequence, so we take this switch point as an index of each participant's risk aversion. If there were multiple switch points, we follow much of the literature using related mechanisms and only consider the first switch point. One choice in the sequence was randomly chosen to count, with uncertainty being resolved, if necessary, by flipping a coin.

2, we report the average proportion of winning firms providing high quality. As expected, we observe a remarkable increase in high-quality provision in the first two periods in all treatments which involve an incentive mechanism relative to the baseline treatment, which lacks such a mechanism. For example, in Period 1 about 80% of winning firms provide high quality whenever there is an incentive mechanism, whereas in the baseline treatment only 18% of winning firms provide high quality—a 340% increase in the likelihood of high quality provision.[31] Averaging across all three periods (Table 2, last column), high quality provision is consistently about four times more likely with an incentive mechanism than without one.[32]

Insert Table 2 about here.

Result 1: *The introduction of an incentive mechanism significantly increases supplied quality.*

More formally, in Table 3 we estimate probit models of the binary decision to provide high quality in each of the periods separately (columns 1-3). In column 4, we pool observations from all three periods and estimate a Tobit model, using as the dependent variable the proportion of the three periods in which the winning firm provided high quality. In each of these estimates we cluster standard errors by session and, to control for dynamic effects such as learning, we include the round of the observation as a control.[33] In these and all subsequent model estimates, unless otherwise noted, we cluster standard errors by session to allow for arbitrary within-session correlation of behavior. Confirming appearances in the raw data, we find that high-quality provision is significantly higher in all of our incentive mechanism treatments relative to the baseline treatment (the excluded category).

Finally, notice that in all treatments except the baseline, quality provision declines precipitously from the second period to the third. This suggests that participants generally understood the strategic incentives inherent in each three-period sequence, as there is no incentive to produce high quality in Period 3. At the same time, even in Period 3 quality provision is significantly lower in the baseline treatment than in any other treatment. One plausible explanation that would provide a further unintended benefit of implementing an incentive mechanism is that participants acquired a "habit" of high-quality provision in the first two periods which carried

[31] It is somewhat surprising that even in the Baseline treatment with no incentives, 18% of winning firms choose to provide costly high quality. A likely explanation is a framing or labeling effect of high quality producing " good reputation" even when there are no concomitant financial incentives. This could be an interesting point worthy of further investigation in future research. However, for now we only note that this framing effect is constant across our treatments so that it should not contaminate across-treatment comparisons.

[32] In the Appendix (Table A1), we report a battery of pairwise non-parametric Mann-Whitney tests confirming the statistical significance of many of the large differences observed in the raw numbers: in Periods 1 and 2, Mann-Whitney tests reveal that quality provision in the baseline treatment is significantly different from all other treatments; differences among the non-baseline treatments themselves are generally not significant.

[33] In the Appendix (Table B1), we allow for more flexible dynamic effects by introducing a full set of round dummies into our model estimates. Nothing changes either qualitatively or in terms of statistical significance.

over to the third period. Other possible explanations include "framing" or symbolic effects generated by the incentive mechanism. In any event, the effect is relatively small in magnitude, so we do not focus on it here.

Insert Table 3 about here.

3.2 Entry

Having confirmed that introducing an incentive mechanism can substantially increase costly quality provision, we are now in a position to address the central question of our inquiry: is there necessarily a trade-off between past performance and entry?

In Table 4, we report the proportion of Entrant firms choosing to enter the Period 3 auction. These raw data suggest that an incentive mechanism which assigns no reimbursement multiplier to the Entrant firm (LM) may indeed hinder entry, as feared by US senators and EU regulators. At the same time, however, our data suggest that a *properly calibrated* incentive mechanism need not hinder entry. Indeed, in both treatments where the Entrant firm is not assigned the worst possible score—MM and HM—our incentive mechanism tends to *increase* entry, without reducing quality provision.[34]

Insert Table 4 about here.

To get a more formal sense of the significance of the effect of our incentive mechanism on entry, in Table 5 we report marginal effects estimates from a probit model using, as the dependent variable, an indicator taking the value one if the Entrant firm decided to enter the Period 3 auction. On the right-hand side, we include a set of treatment dummy variables with the baseline treatment as the excluded category. We cluster standard errors by session and, to account for dynamic patterns in a simple way, we control for the round of the observation.[35] We find that entry is significantly higher relative to the baseline treatment, both economically and statistically, whenever the Entrant firm is not assigned the worst possible score. In treatments MM and HM, the estimated marginal effect of an incentive mechanism is to increase entry by 8 to 10 percentage points. On the other hand, we also find that the decline in entry observed in the raw data when Entrant firms are assigned a poor score (LM) is not statistically significant.

Insert Table 5 about here.

Result 2a: *The introduction of an incentive mechanism that assigns a poor score to an entrant reduces the frequency of entry, although the effect is not statistically significant.*

[34]As before, a battery of pairwise non-parametric tests by treatment is reported in the Appendix (Table A2), supporting the notion that the introduction of an incentive mechanism can either significantly increase or decrease entry, depending on the relative score assigned to the Entrant firm.

[35]A more flexible specification for dynamic patterns, incorporating a full set of round dummy variables, can be found in the Appendix, Table B2. This more flexible specification does not yield substantially different estimates.

Result 2b: *The introduction of an appropriately designed incentive mechanism that assigns a positive score to an entrant significantly increases the frequency of entry relative to the benchmark treatment without incentives, and does not reduce quality provision.*

Result 2a shows that the concerns raised in the policy debate about the possibility that rewarding past performance may hinder entry of new suppliers are justified and are captured by our experimental set up. Result 2b is our first main result. It shows that the answer to our main research question is negative: there is *not* necessarily a trade-off between past performance/quality and entry. A well designed and calibrated incentive mechanism that rewards past performance with a higher chance of winning (e.g. with a bid preference) can achieve both higher quality *and* higher entry.

3.3 Buyer's transfer

Because our results suggest that the effect of past performance on entry depends on the relative level of the Entrant firm's reimbursement multiplier, and quality provision is costly for the supplier, a natural question to ask at this point is whether the most desirable outcome of high quality coupled with high entry comes at a significant increase in costs to the buyer. To avoid confusion with firms' costs of production, in the discussion that follows we refer to the total amount the buyer pays to the winning seller, accounting for any relevant reimbursement multiplier, as the "buyer's transfer."

In Table 6 we report average buyers' transfers by treatment and period, as well as the average buyer's transfer across all three periods. Somewhat surprisingly (at least for us) our data suggest there is only a very mild effect of even large bid subsidies on buyers' transfers, even though supplied quality increases. Buyers' transfers are generally lower in the first period when there is a an incentive mechanism than when there is not, reflecting competition for the bid advantage that high quality production entails in the subsequent period. In subsequent periods, buyers' transfers are generally higher when there is an incentive mechanism. Considering the average buyer's transfer across all three periods, there is typically only a mild increase in buyers' transfers associated with our incentive mechanism. The mildest increase is associated with the MM treatment (4.2%) while the largest increase, associated with the most generous Entrant reimbursement multiplier (HM), is still only 12.6%.

Insert Table 6 about here.

Moving from raw averages to more formal econometric models, in Table 7 we present OLS estimates of buyers' transfers across treatments and periods. As usual, we cluster standard errors by session and control for dynamic effects in a simple manner, reporting estimates allowing for more flexible dynamic patterns in the Appendix (Table B3). In both specifications, we find that introducing an incentive mechanism significantly lowers buyers' transfers in Period 1, while it significantly increases buyers' transfers in subsequent periods. Considering buyers' transfers averaged over all three periods (Column 4), the increase in buyers' transfers associated with introducing an incentive mechanism ranges from small in magnitude and non-significant (MM; 4.8%) to moderate in magnitude and highly significant (HM; 12.1%), matching well the values gleaned from our inspection of raw averages.

Overall, the patterns suggest that in a properly calibrated past-performance incentive mechanism profit opportunities may be essentially fully competed away so that the associated increase in costly quality provision and entry comes at little or no cost to the buyer. At the same time, the data suggest that the negative consequences of a poorly calibrated mechanism accrue primarily through increased buyers' transfers and through entry. While there is little variation in quality provision across our three non-baseline treatments, our past-performance incentive mechanism increases entry in both our HM and MM treatments, but it does not increase, and may even decrease, entry in our LM treatment relative to our baseline treatment.

Insert Table 7 about here.

Result 3: *The introduction of an incentive mechanism that increases both quality and entry may not substantially increase the transfer paid by the buyer.*

This is our second main result, and perhaps the most surprising one. The increase in costly quality provision and in the frequency of entry generated by the incentive mechanism may not entail additional costs to the buyer. An increase in supplier competition, linked to either the (endogenous) asymmetry or to the increased complexity introduced by the incentives mechanism, appears to us a likely explanation.[36]

3.4 Buyer's preferences: theoretical and empirical welfare functions

As a final exercise before concluding, in this section we construct a welfare function for buyers and examine how buyer's welfare varies, both theoretically and empirically, over our treatments.[37] In particular, we suppose that the buyer derives utility from three additively separable components: buyer's transfer (negatively), quality and entry. We model this in a flexible manner by assuming buyer's welfare is a simple weighted average of these three components. We then compare the welfare generated by each of our treatments—both theoretically, using equilibrium predictions, and empirically, using the experimental data—in two cases: i) buyers

[36]As will be discussed in the literature review, several previous experiments showed that asymmetry may have pro-competitive effects in oligopolistic environments. The argument that increased complexity may foster competition is theoretical instead, and goes back to Gale and Sabourian (2005). A recent empirical study by Decarolis et al. (2016) appears to find an analogous "nirvana" result for the buyer—introducing an incentive mechanism for suppliers increases supplied quality but not the price paid by the buyer—providing some reassurance about the external validity of Result 3.

[37]We are grateful to Gary Charness for suggesting this last exercise.

place equal weight on entry, quality and buyer's transfer; and ii) buyers do not care directly about entry, but rather divide all weight equally between the remaining two components. One can think of the first case as representing the situation in the EU, where increasing cross-border entry *per se* is a main political objective; the latter case may be closer to the US, where entry is valued only insofar as it increases efficiency and value-for-money for the taxpayer.

The welfare function we consider is $W = \alpha D + \delta Q + \gamma Pr(E)$, where $\alpha + \delta + \gamma \leq 1$; $D = \frac{4.5 - \frac{\sum_{t=1}^{3} T_t}{3}}{4.5}$; and T_t is the transfer from buyer to seller (i.e., [winning bid]*[relevant reimbursement multiplier]) in Period t. Notice that since 4.5 is the maximum allowable bid in the experiment, D is a measure of the "discount" below the maximum possible price buyers could pay excluding bid subsidies. This serves as a convenient normalization of the buyer's transfer component of welfare on a $0-1$ scale. The other two components of the welfare function are straightforward: Q is the proportion of the three periods in which high quality is produced; and $Pr(E)$ is the probability that—or the proportion of observations in which—entry occurs in the third period. Weights are also normalized so that $\delta = (1 - \alpha - \gamma)$.

Using the parameters chosen for the experiment, we calculate the buyer's theoretical welfare by computing the equilibrium values of D, Q and $Pr(E)$ for each treatment and then evaluating buyer's welfare in each treatment for the welfare function weights implied by the two cases mentioned above: case i) $\alpha = \gamma = \frac{1}{3}$; and case ii) $\alpha = \gamma = \frac{1}{2}$. We report the buyer's theoretical welfare levels in these two cases in Table 8.

Insert Table 8 about here.

In case i) where buyers care about entry, quality and transfers equally, we find the highest buyer welfare in the HM treatment (when $B = \beta = 2$, $W = 0.71$), where the theoretical equilibrium frequency of entry is largest. On the other hand, in case ii) where buyers do not care about entry directly, but only about quality and transfers instead, buyer's welfare is maximized in the LM treatment (when $B = 2$ and $\beta = 1$, $W = 0.73$), where the possibility of entry constrains bids and increases quality. Importantly, in both cases we consider that having an incentive mechanism in place increases buyer's welfare. To determine whether a similar result holds in our data, we next consider the empirical analogue of our theoretical buyer's welfare function. We measure quality, Q, by the average proportion of winning firms providing high quality across all three periods. We measure entry probability, $Pr(E)$, as the average proportion of Entrant firms entering the Period 3 auction. As our measure of buyer's transfers, we calculate D according to the formula described above. Table 9 reports our empirical estimates of buyer's welfare.

Insert Table 9 about here.

As with theoretical welfare, for both sets of weights considered buyers can always achieve higher welfare with an incentive mechanism than without. In contrast to our theoretical analysis, however, buyer's welfare is always maximized in the MM treatment, where Entrant firms are given neither the highest nor lowest possible score. This difference is likely due to Entrant firms basing their entry decisions on the reimbursement multiplier to a lesser extent than our simple theoretical framework predicts. For example, entering the Period 3 auction with probability of less than one when the Entrant firm's reimbursement multiplier is relatively high (HM), as we observe in the data, reduces the empirical welfare advantage of HM over MM when buyers care about entry directly.

Result 4: *Introducing an incentive mechanism increases buyer's welfare, whether or not the buyer cares directly about the likelihood of entry.*

3.5 Predictions and behavior

In this subsection we compare the experimental results with our theoretical prediction. The most evident inconsistencies between predictions and actual behavior appear in bidding behavior and quality provision. First, strong price competition does not emerge as subjects overbid especially in Period 1 (Period 2) in the Baseline and HM (LM) treatments (see Table C1 in the Appendix). Second, quality provision is higher than expected in Period 2 of the HM and MM treatments. In the LM treatment subjects seem to behave according to the first equilibrium discussed in Section 2.2.3 above, with large winning bids and high quality provision in Period 1, though in Period 2 the provision of high quality is lower than expected (see also Tables C1 and C2 in the Appendix). The behavior observed in the MM treatment is consistent with the theoretical predictions for the entrant accommodation equilibrium (introduced in Section 2.2.2), with participants bidding low prices in Period 1 and exploiting it in Period 2 – they accommodate the entrant by producing low quality in Period 2. Even if in this latter period high quality was less frequent than in the equivalent period of the HM treatment (where entrant accommodation is the predicted strategy), high quality production in the MM is still higher than expected. In summary, subjects on average bid less aggressively and are more likely to produce high quality than theory predicts. Possible explanations for these inconsistencies are a limited ability to apply backward induction – perhaps due to the complexity of the game – as well as risk aversion or self-image motives.

The first explanation can only partially account for the reported inconsistencies. Even if a small share of subjects produce high quality when this is not a profit-maximizing strategy (e.g. in Period 3), most of them seem to understand the game incentives. For instance, entry is lower whenever entry-deterrence is the most commonly played strategy (e.g. in the LM treatment) and the winning bids get close to the low-quality production cost in the last period of all the treatments.

Asymmetries in risk aversion may explain non-aggressive bidding in our context as more risk averse bidders may lower their profits to improve the chance of winning (Campo 2012). In order to test this hypothesis, we first regress the winning bids at each bidding stage on our measure of participants' risk aversion (this measure is explained in footnote 30), controlling for a set of treatment dummies and the round of the observation. Results are reported in Table C2 in the Appendix and show that risk aversion has the expected sign but is not significant, leading us to exclude risk aversion as a primary explanation for the discrepancies between theory and behavior.

Another potential explanation for prudent bidding may be framing. We framed our experiment as a procurement auction, which – as Seifert and Strecker (2003) argue – may lead participants to bid more defensively than in alternative frames such as sales auctions. They show that the "sales" vs. "procurement" auction frame affects deviations from the dominant strategy, with participants bidding aggressively in a sales context and defensively in a procurement context. In addition, as overbidding (i.e. bidding defensively —above the private cost) especially occurs in our experiment in Periods 1 and 2, subjects may perceive higher winning chances if they bid less aggressively.

We also check whether the probability of choosing high quality is affected by participants' risk aversion. Table C3 in the Appendix shows that risk aversion negatively predicts high-quality production in Periods 1 and 2. Considering within-treatment patterns, less risk-averse participants seem to provide high-quality more often in the periods and treatments where they are less expected to do so, i.e. Periods 1 and 2 of the Baseline treatment and Period 2 of the HM treatment (results available upon request). This may suggest that when the cost of deviating from equilibrium increases, the more risk-averse subjects are those more likely to play Nash.

The effects of risk aversion are robust to the inclusion among the controls of the bid previously submitted by the winner (Table C4 in the Appendix). The previous bid has negative effects on the quality produced in Periods 2 and 3, highlighting that the subjects winning the auction with large bids are more likely to provide low-quality in order to maximize profits. This evidence, jointly with the negligible fraction of subjects producing high quality in the last Period, would also reduce the role of self-image motives in explaining why high quality is produced when it is not profit-maximizing to do so.

4 Related literature

Our work focuses on past-performance based incentive mechanisms and transparent selection rules to which the buyer can (or must) commit, as is often the case for large corporations and government procurement.

Closer to our paper are the laboratory experiments by Brosig and Reiss (2007) and Brosig-Koch and Heinrich (2014). The former analyzes capacity-constrained suppliers' decisions to enter and bid in the various stages of a sequential procurement game. It finds that entry and bidding in the sequential procurement auctions are indeed affected by the opportunity cost of early bidding generated by the capacity constraints. It also finds that entry decisions and average bids systematically deviate from equilibrium predictions, and that giving subject additional information on winners and prices tends to reduce the extent of this deviation. The latter asks what would happen if transparency rules that impose open price competition were removed and more discretion was left to public buyers, so that information on past behavior could matter for supplier selection. It finds that when buyers have discretion to choose among sellers, the latter invest in providing high quality. In contrast, when buyers lack the discretion needed to reward past behavior, sellers provide instead low quality to reduce short-term costs. Consequently, in the absence of a structured mechanisms rewarding past performance (such as the one discussed in this paper) buyer discretion increases market efficiency, with the benefits accruing entirely to buyers. Our study complements these previous studies as it also deals with entry decisions and past performance in a sequential laboratory procurement game. Our setup, however, is rather different (no capacity constraints, new entrant at the last stage, and pre-announced bid subsidies for past quality provision), as are the main research questions we focus on.

Related to our work are also experimental studies of one-shot and finitely repeated homogeneous good Bertrand price competition, as they share several features with our procurement game. Dufwenberg and Gneezy (2000, 2002) study finite-price one-shot homogeneous Bertrand games, repeated to allow for learning but with random and anonymous re-matching between the repetitions, that can be alternatively interpreted as homogeneous Bertrand competition with discrete prices or as first-price sealed bid procurement auctions. They find that only by increasing the number of competitors to three or more is the Bertrand equilibrium reached after learning, and that disclosing the losing bids in previous rounds leads to higher prices than only disclosing the past winning bids. Even though our environment is more complex than a one-shot Bertrand game (three repetitions in each round, with possible entry in the third, and quality choices), the fact that we observe prices consistently above the Bertrand solution in our Baseline treatment—the most closely related to a one-shot Bertrand game—can be seen as consistent with their results, as the first stages of each round are similar to a Bertrand duopoly and information on losing bids is disclosed after each bidding stage. This suggests that with more competitors, or without disclosing past losing bids, in our Baseline treatment bids would possibly be lower. On the other hand, our finding that competition seemingly increases with the introduction of transparent past-performance based mechanisms, leading to higher quality but not higher prices, suggests that these mechanisms, by introducing complexity in terms of multidimensional and intertemporal competition, may have effects similar to an increase in the number of competitors or the non-disclosure of losing bids. Our result is also consistent with several previous experimental studies, starting with Mason et al. (1992) and including Fonseca and Norman (2008), Boone et al. (2012), Dugar and Mitra (2016), addressing the effect of asymmetry in static and finitely repeated oligopolies and finding that it typically increases competition. In particular, the fact that we find more entry in HM than in Baseline appears in line with Dugar and Mitra's (2016) finding that subjects play the asymmetric Bertrand solution more often the larger the cost asymmetry among players. In contrast to these studies, however, in our treatments with a past-performance based mechanism the asymmetry between incumbents is not exogenous, but endogenously generated by the decision of the supplier to invest, provide high quality and earn the bid subsidy for the following period.

Closely related to our study is the recent strand of literature that focuses on past performance in procurement. Examples here include Calzolari and Spagnolo (2009), Board (2011), and Albano et al. (2017). Overall, these papers suggest that when important dimensions of the exchange are not contractible and there are many competing suppliers, a dynamic incentive mechanism based on past performance must complement standard competitive auctions to obtain decent value for money. In contrast to our study, however, none of these papers directly focuses on the consequences of dynamic incentive mechanisms for the entry of new firms.

Finally, on the empirical side outside of a laboratory environment, we are aware of only two studies that shed light on issues closely related to our paper: Koning and Van de Meerendonk (2014) and Decarolis et al. (2016). The former study documents an improvement in service quality following an increase in the scoring-weight given to supplier, in the scoring rule of public procurements of work-to-welfare programs. The latter study documents a significant increase in quality following the announcement of the introduction of a past-performance based vendor rating system in a large utility company, not followed by a corresponding increase in price. Both of these empirical studies appear broadly consistent with our experimental results.

5 Concluding remarks

In this paper, we ask whether the use of indicators based on past performance always entails a trade-off between increased quality provision and reduced entry of new suppliers in procurement markets. This question is important to private and government procurement design, and is at the center of a transatlantic policy debate as current regulations in the US and Europe reflect differing answers. In the US, where past-performance based mechanisms are currently required in Federal procurement, the Senate recently expressed concerns that such past-performance based selection criteria could hinder small businesses' ability to enter and successfully compete for contracts. On the other hand, in Europe, where regulators explicitly prohibit the use of past-performance indicators as criteria for selecting contractors on the grounds that they discriminate against cross-border entrants, public buyers and their national representatives have had recent limited success in overturning the prohibition.

We have investigated this question experimentally, augmenting a simple repeated procurement game with quality choices and potential entry by a more efficient supplier. Our treatments differed in the presence and design of a past-performance based mechanism that rewards high quality provision in a transparent way, i.e. with a pre-announced rule that assigns a bid subsidy for the subsequent procurement auction to suppliers that provide high quality in the current period.

Our results indicate that poorly calibrated mechanisms may indeed hinder entry, but that a trade-off between quality and entry is not necessary. To the contrary, we find that a well calibrated mechanism, in which new entrants with no history of past performance are awarded a moderate or high score – as is sometimes the case in private sector vendor rating systems or, for example, with point systems for drivers' licenses – actually *fosters* entry and, at the same time, delivers a substantial increase in quality.

Perhaps more surprisingly, we find that the increase in both costly quality provision and in entry made possible by properly calibrated incentive mechanisms may come at very little cost to the buyer. In our data, the increase in total cost to buyers is always mild and, in some cases, non-existent when the incentive mechanism is introduced, even when both costly quality provision and entry increase substantially. The introduction of well calibrated bid subsidies for good past performance appears therefore to benefit the buyer by driving winning bids down enough to fully offset the potential increase in procurement costs due to bid subsidies and the costly quality provision they generate. This "nirvana" result for the buyer has already found some confirmation in the field, has obvious implication for public and private buyers, but is rather puzzling from a theoretical perspective. Additional experimental and field work appears therefore warranted to further test its robustness and to identify the driving forces behind it.

Summing up, our results imply that there need not be a trade-off between the use of appropriately designed past-performance based mechanisms and entry by new firms into a procurement market. A well calibrated mechanism based on past-performance may instead increase entry and quality provision simultaneously, without increasing the cost for the procurer. If confirmed in further studies, our findings suggest that the emphasis placed on past performance by the revised Federal Acquisition Regulation and by private procurer is fully justified, and that European regulators may have been imposing large deadweight losses on their citizens by forbidding the use of past-performance indicators as selection criteria in public procurement. They also suggest that policy makers and regulators may want to refocus their attention on finding the past-performance based mechanisms that best suit their specific goals, rather than on whether such mechanisms should be allowed at all.

References

[1] Abeler, Johannes, and Simon Jäger. 2015. “Complex tax incentives”. *American Economic Journal: Economic Policy*, 7.3: 1-28.

[2] Albano, Gian Luigi, Bernardino Cesi, and Alberto Iozzi. 2017. “Public procurement with unverifiable quality: The case for discriminatory competitive procedures.” *Journal of Public Economics*, 145: 14-26.

[3] Athey Susan, Coey Dominique, and Jonathan Levin. 2013. “Set-Asides and Subsidies in Auctions.” *American Economic Journal: Microeconomics*, 5(1): 1-27.

[4] Bandiera, Oriana and Andrea Prat and Tommaso Valletti. 2009. “Active and passive waste in government spending: evidence from a policy experiment.” *American Economic Review*, 99(4): 1278-1308.

[5] Bar-Isaac, Heski and Steve Tadelis. 2008. “ Seller Reputation.” *Foundations and Trends in Microeconomics*, 4: 273-351.

[6] Board, Simon. 2011. “Relational Contracts and the Value of Loyality,” *American Economic Review*, 101(7): 3349–67.

[7] Boone, Jan, María Jose Larraín Aylwin, Wieland Müller, and Amrita Ray Chaudhuri. 2012. “Bertrand competition with asymmetric costs: experimental evidence.” *Economics Letters*, 117: 134-137.

[8] Brosig, Jeannette and J. Philipp Reiss. 2007. “Entry decisions and bidding behavior in sequential first-price procurement auctions: An experimental study.” *Games and Economic Behavior* 58(1): 50-74.

[9] Brosig-Koch, Jeanette and Timo Heinrich. 2014. “ Reputation and Mechanism Choice in Procurement Auctions - An Experiment.” *Production and Operations Management.*, 23(2): 210-220.

[10] Cabral, Luis and Miguel Villas-Boas. 2005. “Bertrand Supertraps.” *Management Science*, 51(4): 599-613.

[11] Calzolari, Giacomo and Giancarlo Spagnolo. 2009. “Relational Contracts and Competitive Screening.” *CEPR Discussion paper* No. 7434.

[12] Campo, Sandra. 2012. “Risk aversion and asymmetry in procurement auctions: Identification, estimation and application to construction procurements”, *Journal of Econometrics*, 168 [1]: 96-107.

[13] Coviello, Decio and Stefano Gagliarducci. 2016. "Tenure in Office and Public Procurement." *American Economic Journal: Economic Policy*, forth.

[14] Decarolis, Francesco, Riccardo Pacini and Giancarlo Spagnolo. 2016. "Past Performance and Procurement Outcomes", (No. w22814). National Bureau of Economic Research.

[15] Dellarocas, Chrysanthos, Federico Dini and Giancarlo Spagnolo. 2006. "Designing Reputation (Feedback) Mechanisms" in *Handbook of Procurement*, Nicola Dimitri, Gustavo Piga and Giancarlo Spagnolo, eds. Cambridge University Press.

[16] Djankov, Simeon, Rafael La Porta, Florencio Lopez-de-Silanes, and Andrei Shleifer. 2002. "The Regulation of Entry". *The Quarterly Journal of Economics*, 117(1): 1-37.

[17] Dufwenberg, Martin and Uri Gneezy. 2000. "Price Competition & Market Concentration: An Experimental Study" , *International Journal of Industrial Organization*, 18(1): 7-22

[18] Dufwenberg, Martin and Uri Gneezy. 2002. " Information Disclosure in Auctions: an Experiment" , *Journal of Economic Behavior and Organization*, 48: 431-444.

[19] Dugar, Subhasish, and Arnab Mitra. 2016. "Bertrand competition with asymmetric marginal costs" *Economic Inquiry*, 54(3): 1631-1647.

[20] European Commission. 2011a. Green Paper on the modernization of EU public procurement policy Towards a more efficient European Procurement Market. Available at `https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0015:FIN:EN:PDF`

[21] European Commission. 2011b. Green Paper on the modernization of EU public procurement policy Towards a more efficient European Procurement Market. Synthesis of Replies. Available at `https://ec.europa.eu/docsroom/documents/18481/attachments/2/translations/en/renditions/pdf`

[22] Feldman, Naomi E., and Bradley J. Ruffle. 2015. "The impact of including, adding, and subtracting a tax on demand." *American Economic Journal: Economic Policy*, 7.1: 95-118.

[23] Fischbacher, Urs. 2007. "z-Tree: Zurich toolbox for ready-made economic experiments," *Experimental Economics*, 10(2): 171–178.

[24] Fonseca, Miguel A., and Hans-Theo Normann. 2008. "Mergers, asymmetries and collusion: experimental evidence." *The Economic Journal*, 118: 387-400.

[25] Government Accountability Office. 2011. (GAO-12-102R, Oct. 18, 2011). Prior Experience and Past Performance as Evaluation Criteria in the Award of Federal Construction Contracts. Available at `http://www.gao.gov/products/GAO-12-102R`

[26] Gale, Douglas and Hamid Sabourian. 2005. "Complexity and Competition." *Econometrica*, 73(s): 739-769.

[27] Heinrich, Timo. 2011. "Communication and reputation in procurement auctions – Some empirical evidence." *Economics Letters*, 114(2): 164–167.

[28] Kelman, Steven. 1990. Procurement and Public Management: The Fear of Discretion and the Quality of Government Performance: *American Enterprise Institute Press.*

[29] Koning, Pierre, and Arthur Van De Meerendonk. 2014. " The Impact of Scoring Weights on Price and Quality Outcomes: An Application to the Procurement of Welfare-to-Work Contracts," *European Economic Review*, 71: 1-14.

[30] Mailath, George and Larry Samuelson. 2006. Repeated Games and Reputation: Long-Term Relationships. *Oxford: Oxford University Press*

[31] Manuel, Kate M. 2015. "Evaluating the 'Past Performance' of Federal Contractors: Legal Requirements and Issues." Congressional Research Service Report no. R41562. Available at `https://fas.org/sgp/crs/misc/R41562.pdf`.

[32] Marion, Justin. 2007. "Are bid preferences benign? The effect of small business subsidies in highway procurement auctions," *Journal of Public Economics*, 91: 1591-1624.

[33] Mason, Charles F., Owen R. Phillips, and Clifford Nowell. 1992. "Duopoly behavior in asymmetric markets: an experimental evaluation." *The Review of Economics and Statistics*, 74: 662-670.

[34] Milgrom, Paul and John Roberts. 1982. "Predation, reputation and entry deterrence," *Journal of Economic Theory*, 27: 280-312.

[35] Roth, Alvin. 1986. "Laboratory Experimentation in Economics," *Economics and Philosophy*, 2: 245-273.

[36] Seifert, Stefan, and Stefan Strecker. 2003. "A Note on Over- and Underbidding in Vickrey Auctions - Do We Need a New Theory?", Available at `http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.304.5116&rep=rep1&type=pdf`.

Tables and Figures

Table 1: Summary of treatments

Treatment	Incumbents			Entrant			Participants	Sessions
	Multiplier	C_H	C_L	Multiplier	C_H	C_L		
HM	2	2	1.5	2	2	0.125	51	3
MM	2	2	1.5	1.5	2	0.125	60	3
LM	2	2	1.5	1	2	0.125	42	2
Baseline	1	2	1.5	1	2	0.125	90	4

Table 2: Proportion of winning firms producing high quality

	Period 1	Period 2	Period 3	All Periods
Baseline	0.18	0.09	0.06	0.11
	(0.047)	(0.034)	(0.035)	(0.037)
LM	0.82	0.57	0.14	0.51
	(0.018)	(0.048)	(0.024)	(0.018)
MM	0.77	0.49	0.17	0.48
	(0.010)	(0.075)	(0.026)	(0.031)
HM	0.78	0.60	0.09	0.49
	(0.04)	(0.025)	(0.040)	(0.018)
Observations	1,011	1,011	1,011	1,011

Notes: [1] Robust standard errors resulting from estimations of means over treatments, clustered by session, appear in parentheses. [2] The last column, "All Periods," reports the total number of times high quality was produced by the winning firm divided by the total number of periods.

Table 3: Quality provision, by period and treatment

	Period 1	Period 2	Period 3	All Periods
LM	0.51***	0.55***	0.10*	0.73***
	(0.043)	(0.063)	(0.061)	(0.110)
MM	0.53***	0.50***	0.14**	0.69***
	(0.050)	(0.075)	(0.060)	(0.116)
HM	0.52***	0.58***	0.04	0.69***
	(0.049)	(0.059)	(0.067)	(0.111)
Round	-0.01*	-0.01**	-0.01**	-0.02***
	(0.006)	(0.006)	(0.003)	(0.005)
Observations	1,011	1,011	1,011	1,011

Notes: [1] Columns 1-3 present marginal effects estimates from a (separate) probit model, using as a dependent variable a dummy taking the value one whenever the winning firm produced high quality in the relevant period (column heading). [2] The fourth column presents results of a tobit regression in which the dependent variable is the n. of times high quality has been produced by the winning firm standardized by the n. of periods. [3] Robust standard errors, clustered by session, appear in parentheses. [4] *** p<0.01, ** p<0.05, * p<0.1

Table 4: Entry propensity

	Period 3
Baseline	0.61
	(0.019)
LM	0.42
	(0.161)
MM	0.69
	(0.046)
HM	0.67
	(0.033)
Observations	1,011

Notes: Robust standard errors resulting from estimation of means over treatments, clustered by session, appear in parentheses.

Table 5: Entry, by treatment

LM	-0.19
	(0.125)
MM	0.10**
	(0.040)
HM	0.08**
	(0.031)
Round	-0.02***
	(0.006)
Observations	1,011

Notes: [1] Reported values are marginal effects from a probit model, using as a dependent variable a dummy taking the value one whenever the Entrant firm entered Period 3 rather than staying out. [2] Robust standard errors, clustered by session, appear in parentheses. [3] *** p<0.01, ** p<0.05, * p<0.1

Table 6: Buyer's transfer, by period and treatments

	Period 1	Period 2	Period 3	Average Over Periods 1 to 3
Baseline	2.14	1.97	1.58	1.90
	(0.079)	(0.092)	(0.106)	(0.091)
LM	1.87	2.38	1.98	2.08
	(0.115)	(0.130)	(0.168)	(0.026)
MM	1.67	2.33	1.93	1.98
	(0.079)	(0.081)	(0.135)	(0.083)
HM	1.91	2.39	2.11	2.14
	(0.085)	(0.062)	(0.068)	(0.064)
Observations	1,011	1,011	1,010	1,011

Notes: Robust standard errors resulting from estimation of means over treatments, clustered by session, appear in parentheses.

Table 7: Average buyer's transfer, by period and treatment

	Period 1	Period 2	Period 3	Average Over Periods 1-3
LM	-0.28**	0.41***	0.40**	0.18*
	(0.111)	(0.127)	(0.157)	(0.085)
MM	-0.46***	0.38***	0.37**	0.10
	(0.103)	(0.110)	(0.158)	(0.114)
HM	-0.22**	0.43***	0.55***	0.25**
	(0.101)	(0.097)	(0.115)	(0.099)
Round	-0.02***	-0.03***	-0.03**	-0.03***
	(0.006)	(0.008)	(0.009)	(0.007)
Constant	2.27***	2.16***	1.77***	2.07***
	(0.084)	(0.105)	(0.124)	(0.101)
Observations	1,011	1,011	1,010	1,011
R-squared	0.191	0.067	0.116	0.077

Notes: [1] Each column presents a simple OLS regression using as the dependent variable winning bids in the relevant period (column heading). [2] Robust standard errors, clustered by session, appear in parentheses. [3] ***p<0.01, **p<0.05, *p<0.10. [4] The dependent variable in this table is the average buyer costs (transfers) over the tree periods.

Table 8: Buyer's theoretical welfare

	Baseline	*LM*	*MM*	*HM*
$\alpha = \gamma = \delta = 1/3$	0.389	0.488	0.599	0.710
$\alpha = \gamma = ½; \delta = 0$	0.333	0.731	0.648	0.565

Notes: [1] Each cell reports buyer's theoretical welfare evaluated according to the model (described in text). [2] In this theoretical welfare function: α is the weight the buyer places on total transfer, expressed as a discount below the maximum possible transfer without bid subsidies; γ is the weight the buyer places on high quality provision; and δ is the weight placed on entry *per se.*

Table 9: Buyer's empirical welfare

	Baseline	*LM*	*MM*	*HM*
$\alpha = \gamma = \delta = 1/3$	0.433	0.489	0.577***	0.561***
$\alpha = \gamma = ½; \delta = 0$	0.344	0.524***	0.520***	0.507***

Notes: [1] Each cell reports buyer's empirical welfare (described in text) evaluated using our experimental data. [2] In this empirical welfare function: α is the weight the buyer places on total transfer, expressed as a discount below the maximum possible transfer without bid subsidies; γ is the weight the buyer places on high quality provision; and δ is the weight placed on entry *per se.* [3] significance levels from t-tests comparing LM , MM or HM treatments vs. Baseline with standard errors clustered by session are reported; ***p<0.01, **p<0.05, *p<0.1

For Publication Online

Instructions Appendix
(Translated into English)

A. Instructions

Welcome!

This is a study about how people make decisions. The study is being financed by the Swedish Competition Authority and by EIEF. In this experiment you will participate in auctions allocating contracts for the production of a good or service. If you pay attention to the instructions they will help you make decisions and earn a reasonable amount of money. Your earnings from this experiment will be paid to you in cash at the end of today's session.

We ask you to please turn off your cell phones and to refrain from talking with other persons present in the room until the end of the experiment. If you have questions, please raise your hand and one of the experimenters will respond to you privately.

Today's experiment consists of [12,15] rounds. Every round is composed of three auctions. At the beginning of each round every participant in the room will be assigned randomly and anonymously two other participants. Each of the resulting groups of three participants will take part in a sequence of three auctions of which each round is composed. After the three auctions are concluded, a new round will begin by again randomly and anonymously re-assigning participants into groups of three. This process continues until all [12, 15] round have been completed.

At the beginning of each round, each of the three participants in a group will be assigned (as always, randomly) the role of one of three firms: Firm A, Firm B or Firm C. Firms A and B will participate in all three auctions comprising the round. Firm C, on the other hand, can participate in the third auction if they choose to do so, but cannot participate in the first two auctions. Firm C must wait for Firms A and B to complete the first two auctions. The institution that conducts the auctions and that acquires the good or service produced by the firms is the computer.

<u>Auction 1</u>

At the beginning of the first auction Firms A and B submit a bid, i.e. the price in return for which they are willing to produce the good requested by the purchaser, bearing in mind that the maximum allowable bid is 4.5:

- The firm that submits the lowest bid (i.e., that offers to produce the good or service for the lowest price) wins the auction.
- If both firms submit the same bid, the winning firm will be selected randomly.

The winning firm must also make a production decision: which quality level to produce. For Firm A and Firm B it is possible to produce a high quality good/service at a cost of 2, or to produce low quality at a cost of 1.5. An auction is over when all the participating firms have submitted their bids and the winning firm has made its production decision.

The earnings for the winning firm from the first auction will be the winning firm's bid minus the cost of production. If, for example, the winning firm submitted a bid of 3 and decided to produce high quality at a cost of 2, then this firm's profit will be 3 – 2 = 1. The firm that did not win the auction (submitted a bid higher than 3) will earn a profit of 0 from this auction.

The buyer prefers high quality to low quality and, as explained in more detail below, rewards in the subsequent auction firms with a good reputation—i.e., those that in the previous period produced high quality—with a bonus on their bid when they win.

At the end of each auction, including this first auction, all three firms will be shown all submitted bids and the quality level which the winning firm decided to produce.

Auction 2

As in the first auction, only Firm A and Firm B participate in Auction 2. Both Firms A and B must submit a bid keeping in mind that the maximum possible bid is 4.5:

- The firm that submits the lowest bid (i.e., that offers to produce the good or service for the lowest price) wins the auction.
- If both firms submit the same bid, the winning firm will be selected randomly.

The firm that won Auction 1, if they produced high quality in that auction, has a good reputation in this second auction. What this means is that if this same firm wins Auction 2 they will be given a bonus equal to 100% of their winning bid. For example, if the bid submitted by a firm with good reputation is 2 and this bid wins Auction 2 (e.g., because the other firm submitted a bid larger than 2) the bonus paid to the winning firm with good reputation will be 100% of 2, i.e., 2, and the price paid to this winning firm for producing by the purchaser will be 2 + 2 = 4.

The firm winning Auction 2 must choose whether to produce high quality, at a cost of 2, or to produce low quality at a cost of 1.5, exactly as in Auction 1. The winning firm's profit from this second auction will be the price offered plus the bonus (if the winning firm has a good reputation, i.e. had won auction 1 and produced high quality there), minus the cost of production. Continuing with the previous example: if the firm with good reputation wins Auction 2 with a bid of 2, it receives its bid plus the bonus of 2, for a total revenue of 2 + 2 = 4. It must then decide whether to produce high or low quality in this second auction. If it decides to produce high quality also in this second race, its profit will be equal to the price with the bonus, minus the cost of producing high quality, that is, 4-2 = 2, and it will also have good reputation in the subsequent, third, auction. If it decides instead to produce low quality following Auction 2, it will now have a profit of 4 - 1.5 = 2.5, but will not have a good reputation (nor a bonus) in the third auction.

If the winning firm in Auction 2 does not have a good reputation (because it did not win the first auction or because it did not produce high quality there) it will not receive a bonus. In this case, its profit from the second auction will be its winning bid minus the cost of production. For example, if its winning bid was 2 and it decides to produce low quality, it will earn a profit of 2 - 1.5 = 0.5 and will not have a good reputation in Auction 3. On the other hand, if it decides to produce high quality its profit in the second auction will be 2 - 2 = 0, but it will have a good reputation in the third auction.

Consequently, if neither Firm A nor Firm B has a good reputation at the beginning Auction 2, they will compete on equal footing. If one of them has a good reputation, however, the firm with a good reputation will have an advantage: getting a bonus if it wins this second period.

At the end of the second auction, all firms will be able to see all bids submitted, which firm won the auction and the quality level the winning firm chose to produce.

<u>Auction 3</u>

At the start of the third auction, having observed what happened in the two previous races, Firm C must decide whether to participate in Auction 3 along with Firms A and B. If Firm C decides to participate, it will receive a bonus equal to [100%, 50%, 0%] of its bid if it wins the auction. For example, if Firm C submits a bid of 2 and wins Auction 3, its bonus will be [2,1, 0], and it will be paid 2 +[2, 1, 0] = [4, 3, 2] by the purchaser. Firm C's profit from this third race will be [4, 3, 2] minus the cost of production which, as will be explained below, may be different from the production costs of Firms A and B. If, instead, Firm C decides to not participate in Auction 3, it will earn 1 euro. If Firm C decides to participate in Auction 3 it will have to submit a bid in the same manner as Firms A and B with a maximum possible bid of 4.5.

In this third auction:

- The firm submitting the lowest bid (i.e., has offered to produce the good or service at the lowest price) wins.
- If more than one firm submits the same lowest bid, the winner will be randomly selected among these firms.

The winning firm must decide the quality level at which to produce. If Firm C is the winning firm, it costs of production are as follows:

- Producing low quality entails a production cost of 0.125
- Producing high quality entails a production cost of 2.

If either Firm A or Firm B win the third auction, its production costs are as before: producing high quality costs the firm 2, while the cost of producing low quality is 1.5.

Total earnings

At the end of today's session, one of the [12, 15] rounds will be randomly selected and each participant will be paid their overall earnings from all three auctions comprising this randomly chosen round. Participants assigned the role of Firm A or B will be paid the total euros earned in the three auctions. Participants assigned the role of Firm C will be paid 1 euro for each of the first two auctions plus 1 euro for the third auction if he/she decided not to participate. If he/she did participate in Auction 3, his or her earnings from this third auction will be either 0 if he or she did not win, or his or her bid plus the bonus minus the costs of production.

In addition to the earnings in the randomly selected round, all participants will be paid 5 euros as compensation for participation.

INSTRUCTIONS FOR FIRMS A AND B

You are Firm A or Firm B. In this experiment you will take part in a series of auctions to award the production of a good or a service. The experiment consists of [12, 15] rounds. In each round you will participate in three auctions taking place one after the other. At the start of the first auction you must submit a bid—the price for which you will produce a good or service. When both you and the other firm have submitted your bids:

- The company submitting the lowest bid (i.e., has offered to produce the good or service at the lowest price) wins the auction.
- If both firms submit the same bid, one firm will be randomly selected to win the auction.

If you are the firm that wins, you must make a production decision. You can either produce a high level of quality at a cost of 2, or you can produce a low quality good or service at a cost of 1.5.

When all bids are submitted and production decisions are made, the auction is over and all firms will learn all bids that were submitted as well as the quality level production decision of the winning firm.

You will then begin the second auction. Again, in Auction 2 only Firms A and B participate. As in the first auction, you submit a bid. If the firm that won the first auction produced high quality in Auction 1, in this second auction it will have a good reputation. This good reputation gives the firm a bonus of 100% of its (winning) bid, if it wins Auction 2. For example, if the bid submitted by a firm with good reputation in the second auction is 2, and this bid wins the auction, the bonus will also be 2 and the amount that this firm will be paid by the purchaser is 4. Its profit will be its bid plus the bonus minus the cost of production.

If the firm that won the first auction did not produce high quality, it will not have a good reputation in Auction 2 and it will not receive a bonus for winning, i.e., Firms A and B will participate on equal footing in the second auction.

When both you and the other firm have submitted your bids:

- The company submitting the lowest bid (i.e., has offered to produce the good or service at the lowest price) wins the auction.
- If both firms submit the same bid, one firm will be randomly selected to win the auction.

If you are the firm that wins, you must make a production decision. You can either produce a high level of quality at a cost of 2, or you can produce a low quality good or service at a cost of 1.5.

When all bids are submitted and production decisions are made, the auction is over and all firms will learn all bids that were submitted as well as the quality level production decision of the winning firm.

At the start of the third auction, Firm C must decide whether or not to participate. If Firm C decides to participate, you will have two competitors in Auction 3. In the third auction, you submit a bid (as before):

- The company submitting the lowest bid (i.e., has offered to produce the good or service at the lowest price) wins the auction.
- If more than one firm submits the same lowest bid, one firm will be randomly selected from among those submitting the lowest bid to win the auction.

If you win this third auction and you also won the second auction and produced high quality there, you have good reputation. You will be paid the bonus for good reputation, as described above, in addition to your winning bid by the purchaser.

Your earnings in a round are the sum of what you earned over all three auctions comprising a round.

In summary, if you win the first auction your earnings from Auction 1 will be your bid minus the cost of production. If you choose to produce with high quality in Auction 1, in the subsequent auction (Auction 2) you will have a good reputation and will be given a bonus if you win: your earnings in Auction 2 will be your winning bid plus the bonus minus the cost of production. If you choose to produce low quality in Auction 1, in the subsequent auction (Auction 2) you will not have a good reputation and will receive no bonus for winning the second auction. If you win the second auction and choose to produce high quality there, you will have a good reputation in the third auction and again receive a bonus for winning Auction 3. If, however, you win Auction 2 and produce low quality, you will not have good reputation in Auction 3, and so receive no bonus for winning the third auction.

INSTRUCTIONS FOR FIRM C

You are Firm C. In this experiment you will take part in a series of auctions to award the production of a good or a service. The experiment consists of [12, 15] rounds. Since you are Firm C you cannot participate in the first two auctions of each round but will earn 1 euro for each of these auctions. You can, however, participate in the third auction if you choose to.

If you decide not to participate in the third auction, you will earn an additional 1 euro. If you decide to participate in Auction 3, you forgo this 1 euro and must submit a bid. If your bid is the lowest of the three bids made (yours and those of Firms A and B), you win the auction and will be paid your winning bid plus a bonus equal to [100%, 50%, 0%] of your bid. For example, if your winning bid is 2, 2 + [2, 1 , 0] = [4, 3, 2] will be the amount you are paid by the purchaser.

If you are the winning firm, you must decide the level of quality to produce. You face the following production costs:

- Producing low quality costs 0.125.
- Producing high quality costs 2.

Your earnings in a round will be: 1 euro for the first auction, 1 euro for the second auction. For Auction 3, if you decide not to participate you will again earn 1 euro for the third auction. If, however, you participate in the third auction, your earnings from Auction 3 will be either: 0, if you lose; or your bid plus the bonus minus the cost of production if you win.

B. Individual Screens

[Screen 1A: shown to Incumbent firms only]:

- You have been assigned the role of [Firm A, Firm B]
- Click "Proceed" to begin

[Screen 1B: shown to Entrant firms only]:

- You have been assigned the role of Firm C.
- You can only participate in the third auction.
- Click "Proceed," then please wait patiently for the first two auctions to conclude.
- You will be informed when the third auction is about to begin.

[Screen 2: Auction 1 bid submission screen]:

- Please enter your bid below.
- Then, click "Submit bid."

Your bid: ___

[Screen 3: Auction 1 waiting screen, shown to losing Incumbent firm only]

- You did not win the auction.
- Please click "Proceed" and wait while the winning firm makes its production decision.

[Screen 4: shown to winning firm only]

- You won the auction.
- Please select which quality level to produce below.
- Then, click "Proceed."

Produce:

[order of options randomized]

  - High quality
  - Low quality

[Screen 5: Auction 1 summary, shown to all three firms]

Results of Auction 1

- Firm A bid: __
- Firm B bid: __
- The winning firm was [Firm A, Firm B]
- The winning firm produced [low quality, high quality]

[Screen 7]: Auction 2 bid screen, shown to Incumbent firms only]

- You [have, do not have] reputation.
- Please enter your bid below
- Then, click “Submit bid.”

Your bid: ___

[Screen 8]: Auction 2 waiting screen, shown to losing Incumbent firm only]

- You did not win the auction.
- Please click "Proceed" and wait while the winning firm makes its production decision.

[Screen 9]: shown to winning firm only]

- You won the auction.
- Please select which quality level to produce below.
- Then, click “Proceed.”

Produce:

[order of options randomized]

- o High quality
- o Low quality

[Screen 10]: Auction 2 summary, shown to all three firms]

Results of Auction 2

- Firm A bid: __
- Firm B bid: __

- The winning firm was [Firm A, Firm B]
- The winning firm produced [low quality, high quality]

[Screen 11: Auction 3 Entry decision screen, shown only to Entrant firm]

- Auction 3 is now about to take place.
- Please choose whether you will enter auction 3 below.
- After you have chosen, please click "Proceed."

[order of options randomized]

  - o Do not enter
  - o Enter the auction

[Screen 12: Auction 3 Entry decision announcement, shown to all three firms]

- Firm C decided [not to enter, to enter] the auction.
- Please click "Proceed."

[Screen 13A: Entrant firm Auction 3 bid submission screen, shown only to Entrant firm]

- Your entrant multiplier is __.
- Please enter your bid below.
- Then, click Submit bid.

Your bid: ___

[Screen 13B: Incumbent firm Auction 3 bid submission screen, shown only to Incumbent firms]

- Your entrant multiplier is __.
- Please enter your bid below.
- Then, click Submit bid.

Your bid: ___

[Screen 14]: Auction 3 summary, shown to all three firms]

Results of Auction 3

- Firm A bid __
- Firm B bid __
- Firm C [entered / did not enter]
- The winning firm was [Firm A, Firm B, Firm C]
- The winning firm produced [low quality, high quality]

[Screen 15]: Profit summary over all three auctions, shown to all three firms]

- If this round is selected, you will earn __ euro
- You earned __ from auction 1
- You earned __ from auction 2
- You earned __ from auction 3

- Please click "Proceed" and wait for the next round to begin.

[Screen 16]: Profit summary waiting screen, shown to all three firms]

- Please wait for all other participants to view their potential profits for this round. The next round will automatically start when everyone has clicked "Proceed."

Robustness Appendix

Not For Publication

Section A: Pairwise Mann-Whitney tests

Table A1: Mann-Whitney tests on quality provision

Pairwise comparison	Obs		Period 1	Period 2	Period 3
BA vs LM	360	*z-stat*	-14.118	-11.839	-3.099
	168	*Prob>|z|*	0.000	0.000	0.002
LM vs. MM	168	*z-stat*	1.061	1.601	-0.862
	264	*Prob>|z|*	0.289	0.109	0.389
MM vs. HM	264	*z-stat*	-0.212	-2.319	2.639
	219	*Prob>|z|*	0.832	0.020	0.008
BA vs. MM	360	*z-stat*	-14.897	-11.150	-4.477
	264	*Prob>|z|*	0.000	0.000	0.000
BA vs. HM	360	*z-stat*	-14.393	-13.010	-1.358
	219	*Prob>|z|*	0.000	0.000	0.174
LM vs. HM	168	*z-stat*	0.837	-0.529	1.581
	219	*Prob>|z|*	0.402	0.597	0.114

Notes: [1] Pairwise Mann-Whitney tests reported, using the following labelling conventions: BA = "Baseline" treatment; LM = "Low Multiplier Bonus" treatment; MM = "Medium Multiplier Bonus" treatment; HM = "High Multiplier Bonus" Treatment.

Table A2: Mann-Whitney tests on entry

Pairwise comparison	Obs	Non-par test (z, p)
BA vs LM	360	3.991
	168	0.000
LM vs. MM	168	-5.481
	264	0.000
MM vs. HM	264	0.426
	219	0.670
BA vs. MM	360	-2.086
	264	0.037
BA vs. HM	360	-1.521
	219	0.128
LM vs. HM	168	-4.881
	219	0.000

Notes: Pairwise Mann-Whitney tests reported, using the following labeling conventions: BA = "Baseline" treatment; LM = "Low Multiplier Bonus" treatment; MM = "Medium Multiplier Bonus" treatment; HM = "High Multiplier Bonus" Treatment.

Table A3: Mann-Whitney tests on buyers' transfers

Pairwise comparison	Obs		Period 1	Period 2	Period 3	Average Periods 1-3
BA vs LM	360	*z-stat*	7.58	-2.91	-5.10	-3.20
	168	*Prob*>|*z*|	0.000	0.004	0.000	0.001
LM vs. MM	168	*z-stat*	4.01	0.03	-0.16	1.40
	264	*Prob*>|*z*|	0.000	0.980	0.875	0.161
MM vs. HM	264	*z-stat*	-5.49	-0.09	-3.30	-2.96
	219	*Prob*>|*z*|	0.000	0.928	0.001	0.003
BA vs. MM	360	*z-stat*	12.26	-2.98	-7.23	-2.38
	264	*Prob*>|*z*|	0.000	0.003	0.000	0.017
BA vs. HM	360	*z-stat*	7.32	-3.70	-9.83	-5.68
	219	*Prob*>|*z*|	0.000	0.000	0.000	0.000
LM vs. HM	168	*z-stat*	-1.29	0.08	-2.57	-1.24
	219	*Prob*>|*z*|	0.199	0.933	0.010	0.215

Notes: [1] Pairwise Mann-Whitney tests reported, using the following labeling conventions: BA = "Baseline" treatment; LM = "Low Multiplier Bonus" treatment; MM = "Medium Multiplier Bonus" treatment; HM = "High Multiplier Bonus" Treatment.

Table A4: Mann-Whitney tests on profits, pooling over roles

	Including *w*				Excluding *w*			
Pairwise comparison	Period 1	Period 2	Period 3	All 3 periods	Period 1	Period 2	Period 3	All 3 periods
BA vs LM	7.180	-0.518	-2.590	2.234	11.837	2.989	-0.425	5.703
	(0.000)	(0.604)	(0.010)	(0.026)	(0.000)	(0.003)	(0.671)	(0.000)
LM vs. MM	1.307	-0.137	3.111	1.447	2.203	-0.207	0.929	0.162
	(0.191)	(0.891)	(0.002)	(0.148)	(0.028)	(0.836)	(0.353)	(0.871)
MM vs. HM	-1.558	0.384	-1.191	-1.234	-2.274	0.961	-1.002	-1.431
	(0.119)	(0.701)	(0.234)	(0.217)	(0.023)	(0.337)	(0.317)	(0.153)
BA vs. MM	9.396	-0.693	1.103	4.234	15.779	3.273	0.655	6.058
	(0.000)	(0.488)	(0.270)	(0.000)	(0.000)	(0.001)	(0.513)	(0.000)
BA vs. HM	7.686	-0.420	-0.106	2.670	13.035	3.922	-0.277	4.252
	(0.000)	(0.675)	(0.915)	(0.008)	(0.000)	(0.000)	(0.782)	(0.000)
LM vs. HM	-0.171	0.242	1.985	0.463	0.039	0.696	0.126	-0.900
	(0.864)	(0.809)	(0.047)	(0.644)	(0.969)	(0.487)	(0.900)	(0.368)

Notes: [1] Pairwise Mann-Whitney tests reported, using the following labeling conventions: Ba = "Baseline" treatment; LM = "Low Multiplier Bonus" treatment; MM = "Medium Multiplier Bonus" treatment; HM = "High Multiplier Bonus" Treatment. [2] z-scores from Mann-Whitney tests reported; Prob > |z| appears in parentheses.

Table A5: Mann-Whitney tests on buyers' empirical welfare

		α = γ = δ= 1/3			α = γ = ½; δ = 0		
Pairwise comparison	Obs	Mean	Std dev	z-score (p)	Mean	Std dev	z-score (p)
BA vs LM	360	0.432	0.185	-3.475	0.344	0.125	-13.630
	168	0.490	0.180	(0.001)	0.524	0.130	(0.000)
LM vs. MM	168	0.490	0.180	-4.626	0.524	0.130	0.539
	264	0.577	0.168	(0.000)	0.520	0.142	(0.590)
MM vs. HM	264	0.577	0.168	0.593	0.520	0.142	0.543
	219	0.562	0.174	(0.553)	0.508	0.134	(0.587)
BA vs. MM	360	0.432	0.185	-9.896	0.344	0.125	-14.719
	264	0.577	0.168	(0.000)	0.520	0.142	(0.000)
BA vs. HM	360	0.432	0.185	-8.457	0.344	0.125	-13.389
	219	0.562	0.174	(0.000)	0.508	0.134	(0.000)
LM vs. HM	168	0.490	0.180	-3.821	0.524	0.130	0.954
	219	0.562	0.174	(0.000)	0.508	0.134	(0.340)

Notes: [1] Pairwise Mann-Whitney tests reported, using the following labeling conventions: BA = "Baseline" treatment; LM = "Low Multiplier Bonus" treatment; MM = "Medium Multiplier Bonus" treatment; HM = "High Multiplier Bonus" Treatment.

Section B: Dynamic trends in our main variables, allowing for non-linear variation

Table B1: Quality provision

	Period 1	Period 2	Period 3	All Periods
LM	0.51***	0.56***	0.10*	0.72***
	(0.045)	(0.065)	(0.061)	(0.109)
MM	0.54***	0.52***	0.14**	0.69***
	(0.053)	(0.074)	(0.059)	(0.114)
HM	0.52***	0.60***	0.04	0.69***
	(0.052)	(0.060)	(0.065)	(0.110)
Round 2 (dummy)	-0.23***	-0.23***	-0.06***	-0.26***
	(0.079)	(0.034)	(0.018)	(0.062)
Round 3 (dummy)	-0.26***	-0.25***	-0.06***	-0.29***
	(0.096)	(0.052)	(0.019)	(0.070)
Round 4 (dummy)	-0.35***	-0.26***	-0.08***	-0.37***
	(0.075)	(0.047)	(0.022)	(0.073)
Round 5 (dummy)	-0.23***	-0.29***	-0.10***	-0.36***
	(0.062)	(0.039)	(0.020)	(0.066)
Round 6 (dummy)	-0.36***	-0.29***	-0.09***	-0.41***
	(0.060)	(0.039)	(0.019)	(0.076)
Round 7 (dummy)	-0.34***	-0.28***	-0.08***	-0.39***
	(0.069)	(0.032)	(0.015)	(0.075)
Round 8 (dummy)	-0.25***	-0.21***	-0.09***	-0.30***
	(0.070)	(0.051)	(0.022)	(0.068)
Round 9 (dummy)	-0.31***	-0.26***	-0.08***	-0.36***
	(0.071)	(0.053)	(0.019)	(0.082)
Round 10 (dummy)	-0.28***	-0.24***	-0.07***	-0.31***
	(0.094)	(0.039)	(0.017)	(0.080)

Round 11 (dummy)	-0.33***	-0.25***	-0.07***	-0.35***
	(0.075)	(0.040)	(0.018)	(0.078)
Round 12 (dummy)	-0.26***	-0.25***	-0.07***	-0.32***
	(0.089)	(0.024)	(0.012)	(0.061)
Round 13 (dummy)	-0.29*	-0.30***	-0.07***	-0.39***
	(0.169)	(0.033)	(0.022)	(0.077)
Round 14 (dummy)	-0.18	-0.30***	-0.09***	-0.37***
	(0.167)	(0.056)	(0.017)	(0.127)
Round 15 (dummy)	-0.42***	-0.33***	-0.09***	-0.58***
	(0.086)	(0.027)	(0.017)	(0.117)
Observations	1,011	1,011	1,011	1,011

Notes: [1] Columns 1-3 present the marginal effects from an estimated probit model using as the dependent variable winning firms' (binary) decision to provide high quality. [2] The fourth column presents results of a tobit regression in which the dependent variable is the n. of times high quality has been produced by the winning firm standardized by the n. of periods. [3] Robust standard errors, clustered by session, appear in parentheses. [4] *** p<0.01, ** p<0.05, * p<0.1

Table B2: Entry decision

	Period 3
LM	-0.19
	(0.126)
MM	0.09**
	(0.044)
HM	0.07**
	(0.033)
Round 2 (dummy)	-0.13**
	(0.057)
Round 3 (dummy)	-0.17***
	(0.036)
Round 4 (dummy)	-0.15**
	(0.065)
Round 5 (dummy)	-0.27***
	(0.040)
Round 6 (dummy)	-0.25***
	(0.046)
Round 7 (dummy)	-0.24***
	(0.057)
Round 8 (dummy)	-0.34***
	(0.063)
Round 9 (dummy)	-0.33***
	(0.052)
Round 10 (dummy)	-0.31***
	(0.059)
Round 11 (dummy)	-0.35***
	(0.054)
Round 12 (dummy)	-0.34***
	(0.076)
Round 13 (dummy)	-0.15***
	(0.048)
Round 14 (dummy)	-0.25***
	(0.083)
Round 15 (dummy)	-0.49***
	(0.026)
Observations	1,011

Notes: [1] Each column presents the marginal effects from an estimated probit model using as the dependent variable Entrant firms' (binary) decisions to enter Period 3. [2] Robust standard errors, clustered by session, appear in parentheses. [3] *** p<0.01, ** p<0.05, * p<0.1

Table B3: Buyers' total transfers

	Period 1	Period 2	Period3	Average Over All Periods
LM	-0.28**	0.41***	0.40**	0.18*
	(0.112)	(0.128)	(0.158)	(0.085)
MM	-0.47***	0.36***	0.34**	0.07
	(0.098)	(0.111)	(0.145)	(0.107)
HM	-0.24**	0.41***	0.53***	0.23**
	(0.104)	(0.100)	(0.113)	(0.101)
Round 2 (dummy)	-0.23***	-0.19	-0.26***	-0.23***
	(0.056)	(0.122)	(0.079)	(0.046)
Round 3 (dummy)	-0.43***	-0.44***	-0.54***	-0.47***
	(0.064)	(0.106)	(0.053)	(0.056)
Round 4 (dummy)	-0.43***	-0.59***	-0.54***	-0.52***
	(0.075)	(0.141)	(0.069)	(0.077)
Round 5 (dummy)	-0.45***	-0.63***	-0.63***	-0.57***
	(0.077)	(0.137)	(0.082)	(0.074)
Round 6 (dummy)	-0.42***	-0.57***	-0.64***	-0.54***
	(0.093)	(0.180)	(0.085)	(0.107)
Round 7 (dummy)	-0.44***	-0.55***	-0.66***	-0.55***
	(0.083)	(0.160)	(0.090)	(0.088)
Round 8 (dummy)	-0.42***	-0.50***	-0.63***	-0.52***
	(0.091)	(0.159)	(0.082)	(0.095)
Round 9 (dummy)	-0.40***	-0.59***	-0.56***	-0.52***
	(0.074)	(0.122)	(0.091)	(0.064)
Round 10 (dummy)	-0.45***	-0.56***	-0.61***	-0.54***
	(0.081)	(0.155)	(0.056)	(0.079)
Round 11 (dummy)	-0.43***	-0.55***	-0.57***	-0.51***
	(0.083)	(0.133)	(0.087)	(0.077)
Round 12 (dummy)	-0.47***	-0.53***	-0.65***	-0.55***
	(0.069)	(0.147)	(0.109)	(0.086)
Round 13 (dummy)	-0.30***	-0.26*	-0.23	-0.26**
	(0.086)	(0.122)	(0.234)	(0.092)
Round 14 (dummy)	-0.35***	-0.57**	-0.57***	-0.50***
	(0.099)	(0.260)	(0.082)	(0.124)
Round 15 (dummy)	-0.38***	-0.57***	-0.42***	-0.45***
	(0.096)	(0.090)	(0.119)	(0.065)
Constant	2.52***	2.45***	2.10***	2.36***
	(0.106)	(0.146)	(0.109)	(0.109)
Observations	1,011	1,011	1,011	1,011
R-squared	0.245	0.076	0.086	0.151

Notes: [1] Columns 1-3 present simple OLS estimates using as the dependent variable buyers' total payments (transfers) to winning firms in period in the column heading. [2] The fourth column presents a similar OLS estimate, but using average buyers' transfer across all three periods as the dependent variable. [3] Robust standard errors, clustered by session, appear in parentheses. [4] *** p<0.01, ** p<0.05, * p<0.1

Table B4: Firms' profits

	Including w				Excluding w			
	Period 1	Period 2	Period 3	All Periods	Period 1	Period 2	Period 3	All Periods
LM	-0.20***	0.06	0.10	-0.02	-0.20***	0.06	0.04	-0.04
	(0.040)	(0.050)	(0.068)	(0.035)	(0.040)	(0.050)	(0.046)	(0.039)
MM	-0.26***	0.05	0.03	-0.06	-0.26***	0.05	0.06	-0.05
	(0.037)	(0.040)	(0.055)	(0.042)	(0.037)	(0.040)	(0.055)	(0.042)
HM	-0.18***	0.05	0.13**	0.00	-0.18***	0.05	0.15**	0.01
	(0.040)	(0.038)	(0.053)	(0.041)	(0.040)	(0.038)	(0.051)	(0.039)
Round 2 (dummy)	-0.05**	-0.02	0.02	-0.02	-0.05**	-0.02	-0.02	-0.03*
	(0.020)	(0.044)	(0.041)	(0.017)	(0.020)	(0.044)	(0.041)	(0.016)
Round 3 (dummy)	-0.12***	-0.11**	-0.06	-0.09***	-0.12***	-0.11**	-0.11**	-0.11***
	(0.021)	(0.037)	(0.038)	(0.021)	(0.021)	(0.037)	(0.035)	(0.020)
Round 4 (dummy)	-0.10***	-0.15***	-0.03	-0.10***	-0.10***	-0.15***	-0.07	-0.11***
	(0.024)	(0.044)	(0.038)	(0.026)	(0.024)	(0.044)	(0.044)	(0.024)
Round 5 (dummy)	-0.13***	-0.16***	-0.09*	-0.12***	-0.13***	-0.16***	-0.16***	-0.15***
	(0.027)	(0.042)	(0.046)	(0.032)	(0.027)	(0.042)	(0.042)	(0.030)
Round 6 (dummy)	-0.10**	-0.14**	-0.09**	-0.11**	-0.10**	-0.14**	-0.16***	-0.13***
	(0.033)	(0.059)	(0.034)	(0.037)	(0.033)	(0.059)	(0.033)	(0.035)
Round 7 (dummy)	-0.11***	-0.13**	-0.06	-0.10**	-0.11***	-0.13**	-0.12**	-0.12***
	(0.032)	(0.052)	(0.051)	(0.035)	(0.032)	(0.052)	(0.050)	(0.037)
Round 8 (dummy)	-0.11***	-0.13**	-0.04	-0.10**	-0.11***	-0.13**	-0.14***	-0.13***
	(0.032)	(0.054)	(0.035)	(0.032)	(0.032)	(0.054)	(0.037)	(0.034)
Round 9 (dummy)	-0.10***	-0.15***	-0.04	-0.10***	-0.10***	-0.15***	-0.14***	-0.13***
	(0.030)	(0.047)	(0.036)	(0.024)	(0.030)	(0.047)	(0.029)	(0.026)
Round 10 (dummy)	-0.12***	-0.15**	-0.03	-0.10**	-0.12***	-0.15**	-0.12**	-0.13***
	(0.033)	(0.055)	(0.050)	(0.034)	(0.033)	(0.055)	(0.056)	(0.039)
Round 11 (dummy)	-0.11***	-0.14**	-0.05	-0.10**	-0.11***	-0.14**	-0.15**	-0.13***
	(0.031)	(0.048)	(0.053)	(0.034)	(0.031)	(0.048)	(0.053)	(0.037)
Round 12 (dummy)	-0.13***	-0.14**	-0.13**	-0.13***	-0.13***	-0.14**	-0.23***	-0.16***
	(0.025)	(0.054)	(0.056)	(0.030)	(0.025)	(0.054)	(0.044)	(0.030)
Round 13 (dummy)	-0.07**	-0.02	-0.05	-0.05	-0.07**	-0.02	-0.09	-0.06
	(0.023)	(0.036)	(0.091)	(0.040)	(0.023)	(0.036)	(0.083)	(0.038)
Round 14 (dummy)	-0.10*	-0.12	-0.15*	-0.12	-0.10*	-0.12	-0.22***	-0.15*
	(0.047)	(0.117)	(0.077)	(0.076)	(0.047)	(0.117)	(0.057)	(0.069)
Round 15 (dummy)	-0.07	-0.10***	-0.01	-0.06**	-0.07	-0.10***	-0.18***	-0.11***
	(0.049)	(0.029)	(0.038)	(0.026)	(0.049)	(0.029)	(0.036)	(0.025)
Constant	0.62***	0.59***	0.36***	0.52***	0.28***	0.26***	0.30***	0.28***
	(0.039)	(0.054)	(0.056)	(0.046)	(0.039)	(0.054)	(0.054)	(0.045)
Observations	3,033	3,033	3,033	3,033	3,033	3,033	3,033	3,033
R-squared	0.042	0.008	0.008	0.008	0.119	0.011	0.015	0.027

Notes: [1] Each column presents a simple OLS regression using as the dependent variable firms' profits. [2] The first four columns include in this calculation Entrant firms' reservation wage, w = 1, in Periods 1 and 2. The last four columns exclude the reservation wage from profit calculations. [3] Robust standard errors, clustered by session, appear in parentheses. [4] *** p<0.01, ** p<0.05, * p<0.1

Table B5: Quality provision over 2-round bins

	High Quality (Total Over Periods 1-3)					
	Rounds					
	1 - 2	3 - 4	5 - 6	7 - 8	9 - 10	> 10
LM	1.10***	0.86***	0.98***	1.20***	1.64***	1.41***
	(0.297)	(0.098)	(0.195)	(0.089)	(0.096)	(0.251)
MM	1.01***	1.21***	1.11***	1.34***	1.12***	0.98***
	(0.177)	(0.120)	(0.164)	(0.126)	(0.093)	(0.223)
HM	1.08***	1.18***	0.94***	1.12***	1.38***	1.16***
	(0.180)	(0.162)	(0.143)	(0.080)	(0.126)	(0.176)
Constant	0.72***	0.32***	0.27***	0.23***	0.18*	0.27
	(0.175)	(0.094)	(0.056)	(0.071)	(0.093)	(0.168)
Observations	162	162	162	162	162	201
R-squared	0.25	0.32	0.31	0.42	0.48	0.31

Notes: [1] Each column presents a simple OLS regression restricting observations to the rounds mentioned in the column heading. [2] Robust standard errors, clustered by session, appear in parentheses. [3] ***p<0.01, **p<0.05, *p<0.1. [4] The dependent variable in each column is the number of periods in which high quality was produced, which can take values from 0 to 3.

Table B6: Entry over 2-round bins

	Entry between Periods 2 and 3					
	Rounds					
	1 - 2	3 - 4	5 - 6	7 - 8	9 - 10	> 10
LM	-0.16	-0.01	-0.07	-0.19	-0.35**	-0.33***
	(0.108)	(0.086)	(0.161)	(0.273)	(0.139)	(0.040)
MM	0.09	0.16*	0.08	0.15	0.07	-0.01
	(0.054)	(0.083)	(0.051)	(0.131)	(0.097)	(0.048)
HM	0.18***	0.18**	0.11	0.07	-0.10	-0.01
	(0.041)	(0.078)	(0.101)	(0.077)	(0.059)	(0.105)
Constant	0.73***	0.62***	0.57***	0.55***	0.60***	0.58***
	(0.019)	(0.031)	(0.023)	(0.062)	(0.039)	(0.030)
Observations	162	162	162	162	162	201
R-squared	0.07	0.03	0.02	0.05	0.08	0.05

Notes: [1] Each column presents a simple OLS regression restricting observations to the rounds mentioned in the column heading. [2] Robust standard errors, clustered by session, appear in parentheses. [3] ***p<0.01, **p<0.05, *p<0.1. [4] The dependent variable in each column is a dummy for the Entrant's choice to enter the Period 3 auction, which takes the value of 1 if *E=in* and zero otherwise.

Table B7: Average total buyers' transfers over 2-round bins

	Average Buyers' Transfers (Periods 1-3)					
	Rounds					
	1 – 2	3 - 4	5 - 6	7 – 8	9 - 10	> 10
LM	0.41***	0.21**	0.08	-0.00	0.21*	0.16*
	(0.115)	(0.074)	(0.101)	(0.097)	(0.099)	(0.090)
MM	0.12	0.06	-0.02	0.07	0.03	0.19*
	(0.120)	(0.097)	(0.157)	(0.162)	(0.135)	(0.095)
HM	0.52***	0.33***	0.07	0.14	0.21	0.20***
	(0.141)	(0.098)	(0.120)	(0.143)	(0.142)	(0.056)
Constant	2.13***	1.84***	1.88***	1.88***	1.84***	1.82***
	(0.114)	(0.074)	(0.101)	(0.094)	(0.094)	(0.045)
Observations	162	162	162	162	162	201
R-squared	0.14	0.09	0.01	0.02	0.06	0.04

Notes: [1] Each column presents a simple OLS regression restricting observations to the rounds mentioned in the column heading. [2] Robust standard errors, clustered by session, appear in parentheses. [3] ***p<0.01, **p<0.05, *p<0.1. [4] The dependent variable in each column is the buyers' transfers, averaged over all three auctions of our game.

Section C: Behavior by period and treatment

Table C1: Bids, quality and entry by treatment and period

	BASELINE	LM	MM	HM
Average Winning Bid (Period 1)	2.14	1.87	1.67	1.91
Average Winning Bid (Period 2)	1.97	1.60	1.57	1.58
Average Winning Bid (Period 3)	1.57	1.41	1.24	1.22
Proportion of High Quality (Period 1)	0.18	0.82	0.77	0.78
Proportion of High Quality (Period 2)	0.09	0.57	0.49	0.60
Proportion of High Quality (Period 3)	0.06	0.14	0.17	0.09
Proportion of Entrants in Period 3	0.61	0.42	0.69	0.67

Table C2: Average buyer's transfer, by period and treatment

	(1) Period 1	(2) Period 2	(3) Period 3
Risk aversion	0.01	0.00	0.01
	(0.005)	(0.005)	(0.004)
LM	-0.27**	-0.37***	-0.16
	(0.113)	(0.096)	(0.101)
MM	-0.47***	-0.39***	-0.32**
	(0.099)	(0.096)	(0.127)
HM	-0.23**	-0.38***	-0.34***
	(0.097)	(0.098)	(0.102)
Round	-0.02***	-0.03***	-0.03***
	(0.006)	(0.006)	(0.005)

Observations	1,007	1,007	1,007
R-squared	0.195	0.253	0.186

Notes: [1] Each column presents a simple OLS regression using as the dependent variable winning bids in the relevant period (column heading). [2] Robust standard errors, clustered by session, appear in parentheses. [3] ***p<0.01, **p<0.05, *p<0.1.[4] The dependent variable in this table is the average buyer costs (transfers) over the tree periods.

Table C3: Quality provision, by period and treatment

	(1)	(2)	(3)
VARIABLES	Period 1	Period 2	Period 3
Risk aversion	-0.01***	-0.01**	-0.00
	(0.005)	(0.004)	(0.004)
LM	0.51***	0.55***	0.10
	(0.041)	(0.062)	(0.061)
MM	0.54***	0.51***	0.14**
	(0.047)	(0.067)	(0.056)
HM	0.52***	0.58***	0.04
	(0.045)	(0.055)	(0.064)
Round	-0.01*	-0.01**	-0.01**
	(0.006)	(0.006)	(0.003)
Observations	1,007	1,007	1,007

Notes: [1] Columns 1-3 present marginal effects estimates from a (separate) probit model, using as a dependent variable a dummy taking the value one whenever the winning firm produced high quality in the relevant period (column heading). [2] Robust standard errors, clustered by session, appear in parentheses. [3] *** p<0.01, ** p<0.05, * p<0.1

Table C4: Quality provision, by period and treatment

	(1)	(2)	(3)
VARIABLES	Period 1	Period 2	Period 3
Risk aversion	-0.01***	-0.01**	-0.00
	(0.005)	(0.004)	(0.004)
Winning Bid (Period 1)	0.06 (0.055)		
Winning Bid (Period 2)		-0.10** (0.052)	
Winning Bid (Period 3)			-0.08*** (0.030)
LM	0.51***	0.52***	0.09*
	(0.046)	(0.059)	(0.051)
MM	0.56***	0.48***	0.11**
	(0.056)	(0.072)	(0.052)
HM	0.53***	0.56***	0.01
	(0.050)	(0.056)	(0.054)
Round	-0.01	-0.02***	-0.01***
	(0.006)	(0.006)	(0.003)

Observations	1,007	1,007	1,007

Notes: [1] Columns 1-3 present marginal effects estimates from a (separate) probit model, using as a dependent variable a dummy taking the value one whenever the winning firm produced high quality in the relevant period (column heading). [2] Robust standard errors, clustered by session, appear in parentheses. [3] *** p<0.01, ** p<0.05, * p<0.1

Section D: Additional parametric and non-parametric tests accounting for behavioral spillovers within sessions

Table D1: Mann-Whitney tests on quality provision (first two rounds only)

Pairwise comparison	Obs		Period 1	Period 2	Period 3
BA vs LM	60	*z-stat*	-4.551	-3.656	-1.953
	28	*Prob>|z|*	0.000	0.000	0.051
LM vs. MM	28	*z-stat*	-0.536	0.656	0.565
	40	*Prob>|z|*	0.592	0.512	0.572
MM vs. HM	40	*z-stat*	0.952	-0.944	-0.394
	34	*Prob>|z|*	0.341	0.345	0.694
BA vs. MM	60	*z-stat*	-5.565	-3.317	-1.440
	40	*Prob>|z|*	0.000	0.001	0.150
BA vs. HM	60	*z-stat*	-4.554	-4.116	-1.825
	34	*Prob>|z|*	0.000	0.000	0.068
LM vs. HM	14	*z-stat*	0.355	-0.230	0.183
	17	*Prob>|z|*	0.722	0.818	0.855

Notes: [1] Pairwise Mann-Whitney tests reported, using the following labeling conventions: BA = “Baseline” treatment; LM = “Low Multiplier Bonus” treatment; MM = “Medium Multiplier Bonus” treatment; HM = “High Multiplier Bonus” Treatment.

Table D2: Mann-Whitney tests on entry (first two rounds only)

Pairwise comparison	Obs	Non-par test (z, p)
BA vs LM	60	1.510
	28	0.131
LM vs. MM	28	-2.277
	40	0.023
MM vs. HM	40	-1.080
	34	0.280
BA vs. MM	60	-1.062
	40	0.288
BA vs. HM	60	-2.059
	34	0.040
LM vs. HM	28	-3.089
	34	0.002

Notes: [1] Pairwise Mann-Whitney tests reported, using the following labeling conventions: BA = "Baseline" treatment; LM = "Low Multiplier Bonus" treatment; MM = "Medium Multiplier Bonus" treatment; HM = "High Multiplier Bonus" Treatment.

Table D3: Mann-Whitney tests on buyers' transfers (first two rounds only)

Pairwise comparison	Obs		Period 1	Period 2	Period 3	Average Periods 1-3
BA vs. LM	60	*z-stat*	0.92	-2.40	-2.20	-3.08
	28	*Prob>|z|*	0.358	0.017	0.028	0.002
LM vs. MM	28	*z-stat*	2.24	1.19	0.27	1.82
	40	*Prob>|z|*	0.025	0.263	0.789	0.069
MM vs. HM	40	*z-stat*	-1.86	-1.54	-2.85	-2.45
	34	*Prob>|z|*	0.064	0.124	0.004	0.014
BA vs. MM	60	*z-stat*	3.46	-1.65	-2.46	-1.52
	40	*Prob>|z|*	0.001	0.099	0.014	0.129
BA vs. HM	60	*z-stat*	1.12	-3.52	-5.43	-4.13
	34	*Prob>|z|*	0.262	0.000	0.000	0.000
LM vs. HM	28	*z-stat*	0.25	-0.11	-1.85	-0.57
	34	*Prob>|z|*	0.806	0.915	0.065	0.571

Notes: [1] Pairwise Mann-Whitney tests reported, using the following labeling conventions: BA = "Baseline" treatment; LM = "Low Multiplier Bonus" treatment; MM = "Medium Multiplier Bonus" treatment; HM = "High Multiplier Bonus" Treatment.

Table D4: Quality provision, by period and treatment (first two rounds only)

	(1)	(2)	(3)	(4)
VARIABLES	Period 1	Period 2	Period 3	All Periods
LM	0.36***	0.41***	0.20**	0.60***
	(0.052)	(0.149)	(0.084)	(0.172)
MM	0.43***	0.35***	0.13	0.55***
	(0.055)	(0.084)	(0.097)	(0.136)
HM	0.35***	0.43***	0.18	0.56***
	(0.054)	(0.075)	(0.128)	(0.137)
Round	-0.19***	-0.27***	-0.11**	-0.26***
	(0.072)	(0.055)	(0.048)	(0.062)
Observations	162	162	162	162

Notes: [1] Columns 1-3 present marginal effects estimates from a (separate) probit model, using as a dependent variable a dummy taking the value one whenever the winning firm produced high quality in the relevant period (column heading). [2] The fourth column presents results of a tobit regression in which the dependent variable is the n. of times high quality has been produced by the winning firm standardized by the n. of periods. [3] Robust standard errors, clustered by session, appear in parentheses. [4] *** p<0.01, ** p<0.05, * p<0.1

Table D5: Entry, by treatment (first two rounds only)

	Period 3
LM	-0.15
	(0.103)
MM	0.09*
	(0.048)
HM	0.18***
	(0.040)
Round	-0.10**
	(0.045)
Observations	162

Notes: [1] Reported values are marginal effects from a probit model, using as a dependent variable a dummy taking the value one whenever the Entrant firm entered the Period 3 auction rather than staying out. [2] Robust standard errors, clustered by session, appear in parentheses. [3] *** p<0.01, ** p<0.05, * p<0.1

Table D6: Average buyer's transfer, by period and treatment (first two rounds only)

	(1)	(2)	(3)	(4)
VARIABLES	Period 1	Period 2	Period 3	Average over Periods 1-3
LM	-0.07	0.76***	0.53**	0.41***
	(0.154)	(0.116)	(0.235)	(0.115)
MM	-0.39**	0.40**	0.36**	0.12
	(0.132)	(0.151)	(0.148)	(0.120)
HM	-0.10	0.78***	0.88***	0.52***
	(0.167)	(0.153)	(0.136)	(0.141)
Round	-0.23***	-0.19	-0.26***	-0.23***
	(0.056)	(0.123)	(0.080)	(0.046)
Constant	2.67***	2.48***	2.26***	2.47***
	(0.136)	(0.210)	(0.169)	(0.126)
Observations	162	162	162	162
R-squared	0.131	0.132	0.191	0.179

Notes: [1] Each column presents a simple OLS regression using as the dependent variable winning bids in the relevant period (column heading). [2] Robust standard errors, clustered by session, appear in parentheses. [3] ***p<0.01, **p<0.05, *p<0.1.[4] The dependent variable in this table is the average buyer costs (transfers) over the tree periods.

Table D7: Mann-Whitney tests on quality provision (group behavior, averaged across periods)

Pairwise comparison	Obs		Period 1	Period 2	Period 3
BA vs LM	30	*z-stat*	-5.34	-5.37	-3.28
	14	*Prob>|z|*	0.000	0.000	0.001
LM vs. MM	14	*z-stat*	1.01	1.18	-0.64
	20	*Prob>|z|*	0.311	0.237	0.521
MM vs. HM	20	*z-stat*	-0.12	-1.56	2.28
	17	*Prob>|z|*	0.902	0.120	0.023
BA vs. MM	30	*z-stat*	-5.97	-5.85	-3.46
	20	*Prob>|z|*	0.000	0.000	0.001
BA vs. HM	30	*z-stat*	-5.69	-5.72	-1.06
	17	*Prob>|z|*	0.000	0.000	0.289
LM vs. HM	14	*z-stat*	0.65	-0.57	1.96
	17	*Prob>|z|*	0.519	0.570	0.050

Notes: [1] Pairwise Mann-Whitney tests reported, using the following labeling conventions: BA = “Baseline” treatment; LM = “Low Multiplier Bonus” treatment; MM = “Medium Multiplier Bonus” treatment; HM = “High Multiplier Bonus” Treatment.

Table D8: Mann-Whitney tests on entry (group behavior, averaged across periods)

Pairwise comparison	Obs	Non-par test (z, p)
BA vs LM	30	2.88
	14	0.004
LM vs. MM	14	-3.58
	20	0.000
MM vs. HM	20	0.44
	17	0.657
BA vs. MM	30	-1.91
	20	0.056
BA vs. HM	30	-1.15
	17	0.248
LM vs. HM	14	-3.13
	17	0.002

Notes: [1] Pairwise Mann-Whitney tests reported, using the following labeling conventions: BA = “Baseline” treatment; LM = “Low Multiplier Bonus” treatment; MM = “Medium Multiplier Bonus” treatment; HM = “High Multiplier Bonus” Treatment.

Table D9: Mann-Whitney tests on buyers' transfers (group behavior, averaged across periods)

Pairwise comparison	Obs		Period 1	Period 2	Period 3	Average Periods 1-3
BA vs LM	30	*z-stat*	4.04	-4.11	-4.18	-2.90
	14	*Prob>/z/*	0.000	0.000	0.000	0.004
LM vs. MM	14	*z-stat*	3.34	0.28	0.82	1.50
	20	*Prob>/z/*	0.001	0.780	0.411	0.132
MM vs. HM	20	*z-stat*	-4.05	-0.76	-2.29	-2.77
	17	*Prob>/z/*	0.000	0.446	0.022	0.006
BA vs. MM	30	*z-stat*	5.62	-4.39	-3.74	-0.97
	20	*Prob>/z/*	0.000	0.000	0.000	0.332
BA vs. HM	30	*z-stat*	3.75	-4.34	-5.07	-3.83
	17	*Prob>/z/*	0.000	0.000	0.000	0.000
LM vs. HM	14	*z-stat*	-0.99	-0.71	-1.83	-1.35
	17	*Prob>/z/*	0.321	0.475	0.068	0.177

Notes: [1] Pairwise Mann-Whitney tests reported, using the following labeling conventions: BA = "Baseline" treatment; LM = "Low Multiplier Bonus" treatment; MM = "Medium Multiplier Bonus" treatment; HM = "High Multiplier Bonus" Treatment.

Table D10: Quality provision, by period and treatment (averaged across individuals)

	(1)	(2)	(3)	(4)
VARIABLES	Period 1	Period 2	Period 3	All Periods
LM	0.30***	0.28***	0.11*	0.17***
	(0.025)	(0.043)	(0.058)	(0.021)
MM	0.29***	0.25***	0.14**	0.16***
	(0.026)	(0.049)	(0.062)	(0.024)
HM	0.29***	0.28***	0.05	0.17***
	(0.028)	(0.040)	(0.085)	(0.021)
Observations	243	243	243	243

Notes: [1] Columns 1-3 present results from a (separate) tobit model, using as a dependent variable the number of times (averaged over all rounds) in which a winning firm produced high quality in the relevant period (column heading). [2] The fourth column presents results of a tobit regression in which the dependent variable is the n. of times high quality has been produced by the winning firm standardized by the n. of periods (averaged over all periods). [3] Robust standard errors, clustered by session, appear in parentheses. [4] *** p<0.01, ** p<0.05, * p<0.1

Table D11: Entry, by treatment (averaged across individuals)

	Period 3
LM	-0.19
	(0.120)
MM	0.09*
	(0.046)
HM	0.06*
	(0.035)
Observations	243

Notes: [1] Reported values are results from a tobit model, using as a dependent variable the fraction of times (averaged over all rounds) the Entrant firm entered Period 3 rather than staying out. [2] Robust standard errors, clustered by session, appear in parentheses. [3] *** p<0.01, ** p<0.05, * p<0.1

Table D12: Buyer's transfer, by period and treatment (averaged across individuals)

	(1)	(2)	(3)	(4)
VARIABLES	Period 1	Period 2	Period 3	Average over Periods 1-3
LM	-0.32***	0.30**	0.37*	0.11
	(0.103)	(0.128)	(0.176)	(0.076)
MM	-0.49***	0.32**	0.31**	0.03
	(0.078)	(0.124)	(0.129)	(0.100)
HM	-0.30***	0.41***	0.43***	0.16
	(0.096)	(0.130)	(0.122)	(0.114)
Constant	2.21***	2.01***	1.60***	1.96***
	(0.052)	(0.077)	(0.092)	(0.075)
Observations	238	241	234	243
R-squared	0.262	0.083	0.145	0.034

Notes: [1] Each column presents a simple OLS regression using as the dependent variable buyer's costs (transfers) in the relevant period (column heading). [2] Robust standard errors, clustered by session, appear in parentheses. [3] ***p<0.01, **p<0.05, *p<0.1.[4] The dependent variable in this table is the average buyer costs (transfers) over the tree periods.

Theoretical Appendix

1 Structure and Notation

The basic structure of the game consists of a sequence of three auctions. Two Incumbent firms enter and compete in all three auctions, while a third firm, the Entrant firm, may choose to enter and compete in only the third auction. In each of these auctions, all participating firms submit bids simultaneously. The firm submitting the lowest bid wins the auction and must produce at one of two quality levels, high or low. Ties are broken by uniformly randomly selecting the winner from among the set of firms submitting the lowest bid. Producing high quality is more costly than producing low quality. Bids are restricted to a discrete finite set, $\{0, 0.01, ..., \bar{b}\}$. We assume that any firm that loses a particular auction earns 0 from that auction and that Incumbents' earnings come solely from the auctions.

For ease of exposition, we will often omit the term "firm" and simply refer to players as Incumbent 1, Incumbent 2 and the Entrant. To facilitate comprehension, we describe the game as proceeding in stages. In Stages 1, 2 and 3, auctions occur. In Stages 1.5, 2.5 and 3.5, production quality decision are made before all bids as well as the winning firm's quality decision are subsequently revealed to all three firms. At Stage 2.6, the Entrant decides whether to participate in the Stage 3 Auction. This decision is revealed to both Incumbents at the beginning of Stage 3 before any bids are submitted. This timeline is summarized in Figure 1

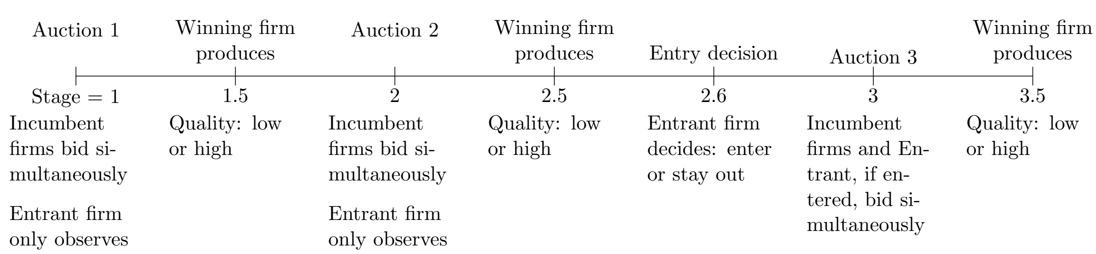

Figure 1: Timeline of Dynamic Procurement Auction Game

The Entrant observes all submitted bids and the production quality decisions of the winning firms for the first two auctions before making its decision about whether to enter Auction 3. For each of the first two auctions it earns an outside wage, w. If the Entrant decides to not participate in the Stage 3 auction at Stage 2.6, it also earns this outside wage w in Stage 3, for a total earnings of $3w$ from the game. If, on the other hand, the Entrant decides to enter the Stage 3 auction it forgoes the outside wage associated with Auction 3. Its total earnings from the game in this case are $2w$ plus whatever it earns from Auction 3.

To analyze the game, we first fix notation. Denote Player i's bid in Auction t by b_i^t, where $t \in \{\text{I}, \text{II}, \text{III}\}, i \in \{1, 2, e\}$. Subscripts $i = 1, 2$ refer to Incumbent 1 and

Incumbent 2, respectively, while the subscript $i = e$ refers to the Entrant. Label the quality production decision in Auction t by $Q_i^t \in \{H, L\}$, $i \in \{1, 2, e\}$, $t \in \{\mathrm{I}, \mathrm{II}, \mathrm{III}\}$, where H and L mean H(igh) and L(ow) quality, respectively. We include the Entrant to simplify notation, but note that it can only submit a bid or make a quality production decision in (at most) Auction 3. Denote by $E \in \{in, out\}$ the Entrant's decision at Stage 2.6 about whether to enter into and compete in Auction 3 ($E = in$) or to stay out of Auction 3 ($E = out$). While all of these actions can be conditioned on all prior information sets, for simplicity we suppress this dependence in our notation.

The primary parameters of interest that are common to all of our treatments are the (Incumbents') costs of producing high or low quality, c_H and c_L, respectively, and the Entrant's cost advantage for producing low quality, k. That is to say, the Entrant produces low quality at a cost of $c_L^e = c_L - k$ and high quality at the common cost c_H. We assume the cost of producing high quality is low enough to be profitable with the maximum allowable bid: $c_H < \bar{b}$. The parameters which we vary across our treatments are: B, the reimbursement multiplier enjoyed by an Incumbent in Auction t, t$\in \{2, 3\}$, conditional on winning Auctions t and t-1 and having produced high quality in Auction t-1; and β, the reimbursement multiplier enjoyed by the Entrant. Notice that situations in which an Incumbent or the Entrant has no reimbursement multiplier can also be described by $B = 1$ or $\beta = 1$, respectively.

To illustrate how the reimbursement multipliers work, we consider the case where Incumbent 1 wins Auction 1 outright with bid b_1^{I}, produces high quality at Stage 1.5 ($Q_1^{\mathrm{I}} = H$) and then goes on to win Auction 2 with a bid of b_1^{II} and produce low quality at Stage 2.5 ($Q_1^{\mathrm{II}} = L$). In this case, Incumbent 1's earnings from Auction 1 would be $b_1^{\mathrm{I}} - c_H$ while its Auction 2 earnings would be $Bb_1^{\mathrm{II}} - c_L$. Similarly, if the Entrant enters Auction 3, wins outright with bid b_e^{III} and produces low quality, its earnings from Auction 3 would be $\beta b_e^{\mathrm{III}} - (c_L - k)$, while its total earnings from the game would be $2w + \beta b_e^{\mathrm{III}} - (c_L - k)$. If it does not enter, its earnings from Auction 3 would be w, and its total earnings from the game would be $3w$.

2 Solution Concept

We use the solution concept Subgame Perfect Nash Equilibrium (SPNE) with the additional restriction that weakly dominated strategies not be played. To illustrate the type of behaviors our additional restriction rules out, consider the last auction stage of our game.

For simplicity, suppose that we are in a subgame following $E = out$ so that Auction 3 involves only the two Incumbents. Assume Incumbent 1 enters Auction 3 with a reimbursement multiplier, $B > 1$. Because our auctions involve simultaneous bid submission the bids $b_1^{\mathrm{III}} = \frac{c_L}{B}$ $b_2^{\mathrm{III}} = \frac{c_L}{B} + 0.01$ are admissible in SPNE because Incumbent 2 is indifferent between all of its bids which entail losing the auction. We consider this outcome to be unreasonable, as it suggests that even very large reimbursement multipliers do not necessarily confer a competitive advantage.

Forbidding weakly dominated strategies addresses this concern. To see that Incumbent 2's strategy is weakly dominated, consider the alternative strategy which replaces only its Auction 3 bid in the history h leading up to the subgame starting with Auction 3 under consideration. This alternative bid is $\hat{b}_2^{\text{III}} = c_L$. This strategy does at least as well as the original strategy no matter what the other players do and sometimes it does better. For example, in the subgame starting at Auction 3 being considered, it does as well as the original bid against Incumbent 1's bid—both lose the auction for Incumbent 2, resulting in zero additional profits. However, in the same subgame against the $b_1^{\text{III}} = \frac{c_L}{B} + 0.02$ it does strictly better, losing and returning zero additional profit. By contrast, the original Incumbent 2 bid would have won the auction and contributed strictly negative additional profits along the equilibrium path.

The key feature of the example above is that losing the auction is strictly preferable to winning with such a low bid. It is only the simultaneous-moves nature of the auction which preserves such non-credible threats in SPNE. Extending this logic, our restriction on weakly dominated strategies will also rule out submitting a bid at any auction stage for any history that would result in a negative total subsequent increment to profits conditional on winning the auction stage. This is a fact we will repeatedly make use of when characterizing equilibria below.

In the discussion that follows, we will often talk of "profits from a subgame." By this, we technically mean the additional profit consequences resulting only from actions taking place in the subgame. We may also need to refer to profits associated with one particular auction only, which we will denote by $\pi_i^t, i \in \{1, 2, e\}, t \in \{\text{I}, \text{II}, \text{III}\}$.

3 Equilibria in the game without reimbursement multipliers (Baseline)

To examine equilibria in our game we start from the simplest setting, our Baseline treatment, where $B = \beta = 1$. We start from the post-Auction 3 quality decision (Stage 3.5) and work backwards.

3.1 Stage 3.5: Post-Auction 3 quality decision

As these constitute the last decision nodes of the game, there is no monetary incentive to produce high quality at the cost $c_H > c_L > c_L - k$. Consequently, in any subgame equilibrium all firms choose to produce low quality conditional on winning Auction 3: $Q_i^{\text{III}} = L, i = 1, 2, e$.

3.2 Stage 3: Auction 3

There are two types of subgames to consider: either the Entrant has entered at Stage 2.6 ($E = in$) or not ($E = out$).

3.2.1 Subgames following $E = out$

In subgames starting from nodes in which $E = out$, Auction 3 involves only the two Incumbents. Since $B = 1$, symmetric (Bertrand) competition leads to bids inducing (approximately) zero profits for both firms. Since both firms choose to produce low quality following Auction 3, the set of bid pairs that constitute mutual best responses in Auction 3 consist of: $(b_1^{\text{III}}, b_2^{\text{III}}) \in \{(c_L, c_L), (c_L + 0.01, c_L + 0.01)\}$. The resulting expected profits are $(\pi_1^{\text{III}}, \pi_2^{\text{III}}, \pi_e^{\text{III}}) \in \{(0, 0, w), (0.005, 0.005, w)\}$. Here, "expected" accounts for the fact that ties are broken with a coin flip.

3.2.2 Subgames following $E = in$

We turn next to the type of subgame following entry ($E = in$). The Entrant always has a cost advantage, k, in producing low quality. In any SPNE of the game the Entrant firm can win the auction outright with the bid $b_e^{\text{III}} = c_L - 0.01$ since the lowest permissible bid for either Incumbent here is c_L. Assume Incumbent 1 submits the bid $b_1^{\text{III}} = c_L$, while Incumbent 2 submits any bid $b_2^{\text{III}} \geq c_L$. With the bid triple $(b_1^{\text{III}}, b_2^{\text{III}}, b_e^{\text{III}}) = (c_L, b_2^{\text{III}}, c_L - 0.01)$, the Entrant guarantees itself a profit of $(c_L - 0.01) - (c_L - k) = k - 0.01$. Assuming $k > 0.02$ rules out a strictly profitable deviation for the Entrant to $b_e^{\text{III}} = c_L$.[1] Bid triples of the form $(b_1^{\text{III}}, b_2^{\text{III}}, b_e^{\text{III}}) = (c_L + 0.01, b_2^{\text{III}} \geq c_L + 0.01, c_L)$ also constitute mutual best responses and yield the Entrant a profit of $(c_L) - (c_L - k) = k$. Consequently, along the equilibrium path Auction 3 profits in this type of subgame are in the set $(\pi_1^{\text{III}}, \pi_2^{\text{III}}, \pi_e^{\text{III}}) \in \{(0, 0, k - 0.01), (0, 0, k)\}$.

3.3 Stage 2.6: Entry decision

The Entrant's decision hinges on whether the profits it makes from the continuation game offset the loss of its outside wage. Consequently, the Entrant always chooses $E = in$ on the equilibrium path whenever $k - 0.01 > w$ and always chooses $E = out$ on the equilibrium path when $k < w$. When $k \in [w, w + 0.01]$, the Entrant's decision depends on the equilibrium being played, with either $E = in$ or $E = out$ being possible. For example, if $k = w$ then if the Entrant's profit from Auction 3 is exactly k on the equilibrium path, the Entrant is indifferent between entering or not, so that either decision can occur in equilibrium.

3.4 Stage 2.5: Post-Auction 2 quality decision

Because there is never strategic benefit to producing high quality but there is a cost ($c_H > c_L$), the winning Incumbent always chooses to produce low quality ($Q_i^{\text{II}} = L, i = 1, 2$).

[1] This profitable deviation is ruled out by the condition $k - 0.01 > \frac{1}{2}k$, where the right-hand side of this inequality is the largest expected profit the Entrant could receive from the deviation given our tie-breaking rule. This inequality is satisfied when $k > 0.02$.

3.5 Stage 2: Auction 2

Auction 2 involves only the two Incumbents. Symmetric (Bertrand) competition leads to bids inducing (approximately) zero profits for both firms. Since both firms choose to produce low quality following Auction 2, the set of bid pairs that constitute mutual best responses in Auction 2 consist of: $(b_1^{\text{II}}, b_2^{\text{II}}) \in \{(c_L, c_L), (c_L + 0.01, c_L + 0.01)\}$. Expected Auction 2 profits are therefore $(\pi_1^{\text{II}}, \pi_2^{\text{II}}) \in \{(0,0), (0.005, 0.005)\}$.

3.6 Stage 1.5: Post-Auction 1 quality decision

Again, because there is never strategic benefit to producing high quality but there is a cost ($c_H > c_L$), the winning firm always chooses to produce low quality ($Q_i^{\text{I}} = L, i = 1, 2$).

3.7 Stage 1: Auction 1

The analysis is similar to the discussion of Stage 2, above. Auction 1 involves only the two Incumbents so that symmetric (Bertrand) competition leads to bids inducing (approximately) zero profits for both firms. Expected profits from Auction 1 are, again, $(\pi_1^{\text{I}}, \pi_2^{\text{I}}) \in \{(0,0), (0.005, 0.005)\}$.

4 Equilibria in the game with reimbursement multipliers

In this section we characterize the equilibria of our game when Incumbents who previously produced high quality enjoy a reimbursement multiplier, $B > 1$. The Entrant may also enjoy a reimbursement multiplier ($\beta > 1$) or may not $\beta = 1$. Our analysis of the case without reimbursement multipliers makes clear that there are often essentially equivalent subgame equilibria involving bids which differ by ± 0.01. For ease of exposition, in this section we typically ignore this type of multiplicity of equilibrium bids. When Incumbents submit different bids, we generally assume it is Incumbent 1 that submits the lower bid. We also generally assume that Incumbent 1 has the reimbursement multiplier when discussing cases where one Incumbent has such a multiplier. As above, we proceed using backwards induction.

4.1 Stage 3.5: Post-Auction 3 quality decision

These constitute the last decision nodes of the game. Therefore, there is no monetary incentive to produce high quality at the cost $c_H > c_L > c_L - k$. Consequently, in all equilibria all firms choose to produce low quality conditional on winning Auction 3: $Q_i^{\text{III}} = L, i = 1, 2, e$.

4.2 Stage 3: Auction 3

There are two types of subgames to consider: either the Entrant has entered ($E = in$) or not ($E = out$).

4.2.1 Subgames following $E = out$

Subgames starting from nodes in which $E = out$ involve only the two Incumbents. If neither Incumbent enjoys a reimbursement multiplier symmetric (Bertrand) competition leads to bids that induce (approximately) zero profits for both Incumbents. Since both firms choose to produce low quality following Auction 3, the analysis here is identical to the simpler case without reimbursement multipliers above. Consequently, the bids $(b_1^{\text{III}}, b_2^{\text{III}}) = (c_L, c_L)$ constitute mutual best responses and characterize the sort of bids submitted in this type of subgame equilibrium. Profits from Auction 3 are therefore $(\pi_1^{\text{III}}, \pi_2^{\text{III}}, \pi_e^{\text{III}}) = (0, 0, w)$, subject to the maintained caveat of the existence of essentially equivalent subgame equilibria.

If, on the other hand, Incumbent 1 has a reimbursement multiplier $B > 1$, we assume that B is non-trivial in the sense that it confers some competitive advantage.[2] In (subgame) equilibrium, Incumbent 1 always wins the auction. The bid pair $(b_1^{\text{III}}, b_2^{\text{III}}) = (c_L, c_L + 0.01)$ characterizes bids submitted in this type of equilibrium, yielding Auction 3 profits of $(\pi_1^{\text{III}}, \pi_2^{\text{III}}, \pi_e^{\text{III}}) = (c_L(B-1), 0, w)$.

4.2.2 Subgames following $E = in$

We turn next to the type of subgame following entry ($E = in$). Here, we must also consider the same two broad cases: i) neither Incumbent enjoys a reimbursement multiplier; or ii) Incumbent 1 has a reimbursement multiplier, $B > 1$.

In the first case, since the Entrant always has a cost advantage k in producing low quality and low quality is always produced at Stage 3.5, the Entrant can always certainly win the auction with the bid $b_e^{\text{III}} = c_L$ against the bids $b_1^{\text{III}} = c_L + 0.01$ and $b_2^{\text{III}} \geq c_L + 0.01$. These bids are mutual best responses and thus can occur along the equilibrium path, provided the threshold condition $\beta > \frac{c_L - k}{c_L - 0.02}$ is satisfied.[3] Auction 3 profit resulting from this set of bid triples is $(\pi_1^{\text{III}}, \pi_2^{\text{III}}, \pi_e^{\text{III}}) = (0, 0, c_L(\beta - 1) + k)$.

In case ii), where Incumbent 1 has a reimbursement multiplier $B > 1$, the Entrant may or may not win the auction. To see this, notice that the Entrant's zero-profit bid

[2] The assumption is that $B(c_L - 0.01) - c_L > \frac{1}{2}(Bc_L - c_L)$, i.e., $B > \frac{c_L}{c_L - 0.02}$. This condition assures that Incumbent 1 strictly prefers to underbid Incumbent 2 and win Auction 3 with certainty, rather than just-matching Incumbent 2's bid and winning with probability $\frac{1}{2}$. The condition comes from the inequality $B(c_L - 0.01) - c_L > \frac{1}{2}(Bc_L - c_L)$, which rules out the possibility that just-matching Incumbent firm 2's bid of c_L is a profitable deviation. A similar calculation comparing Incumbent 1's profit of deviating from $b_1^{\text{III}} = c_L$ to just matching Incumbent 2's bid of $c_L + 0.01$ yields the threshold condition $B > \frac{c_L}{c_L - 0.01}$ which is obviously satisfied when $B > \frac{c_L}{c_L - 0.02} > \frac{c_L}{c_L - 0.01}$, so that $(b_1^{\text{III}}, b_2^{\text{III}}) = (c_L, c_L + 0.01)$ are also mutual best responses. This threshold on B can be thought of as a minimal condition under which the reimbursement multiplier conveys a competitive advantage, so that we assume it to be satisfied.

[3] Bid triples $(b_1^{\text{III}}, b_2^{\text{III}}, b_e^{\text{III}})$ in the set $\{(c_L, b_2^{\text{III}} \geq c_L, c_L - 0.01)\}$ also constitute mutual best responses and feature in essentially equivalent subgame equilibria. To rule out a potentially profitable deviation for the Entrant of bidding one cent higher and winning with probability (at most) one-half in both of these (essentially equivalent) sets of equilibria, we assume the threshold condition $\beta > \frac{c_L - k}{c_L - 0.02}$ is satisfied. The calculation is similar to the calculation in the previous footnote. For example, the Entrant's profit from winning outright with a bid of $c_L = 0.01$ is larger than the profit from tying with one Incumbent firm with a bid of c_L when the following inequality is satisfied: $\beta(c_L - 0.01) - (c_L - k) > \frac{1}{2}(\beta c_L - (c_L - k))$.

is governed by the inequality $b_e^{\mathrm{III}} = \frac{c_L - k}{\beta} \geq 0$, while Incumbent 1's zero-profit bid is governed by the inequality $b_1^{\mathrm{III}} = \frac{c_L}{B} \geq 0$. A larger cost advantage (k) or reimbursement multiplier (β) lowers the zero-profit bid for the Entrant, while a higher reimbursement multiplier, B, lowers the zero-profit bid for the Incumbent. Whenever $\frac{c_L - k}{\beta} > \frac{c_L}{B}$ is satisfied, the Entrant can win Auction 3 with the bid $b_e^{\mathrm{III}} = \frac{c_L}{B}$, or the bid closest to but still below this value on our discrete price grid. Assuming this value is in our discrete price grid, the Entrant's Aucion 3 profit will be $\pi_e^{\mathrm{III}} = \beta b_e^{\mathrm{III}} - (c_L - k) = \beta \frac{c_L}{B} - (c_L - k)$. If, instead, $\frac{c_L - k}{\beta} < \frac{c_L}{B}$, Incumbent 1 wins Auction 3 in equilibrium with the bid $b_1^{\mathrm{III}} = \frac{c_L - k}{\beta}$, again assuming this is a feasible bid, and secures a profit of $\pi_1^{\mathrm{III}} = B \frac{c_L - k}{\beta} - c_L$.

4.2.3 Summary of Stage 3

Summing up, to understand equilibria in the subgames starting from Stage 3, we broke the analysis into various types of subgames. We considered first the subgames following the Entrant's decision to stay out ($E = out$), and subdivided these subgames further depending on whether or not an Incumbent has a reimbursement multiplier, $B > 1$. If neither Incumbent has a reimbursement multiplier, then they both earn approximately zero profit from Auction 3 on the equilibrium path, submitting bid pairs $(b_1^{\mathrm{III}}, b_2^{\mathrm{III}}) \in \{(c_L, c_L), (c_L + 0.01, c_L + 0.01)\}$. If, on the other hand, Incumbent 1 has a reimbursement multiplier, then there is the possibility of a strictly positive profit from Auction 3 for Incumbent 1. The profit level will be determined by the magnitude of B. For example, in equilibria with $(b_1^{\mathrm{III}}, b_2^{\mathrm{III}}) = (c_L, c_L + 0.01)$, Incumbent 1's profit is $\pi_1^{\mathrm{III}} = Bc_L - c_L = c_L(B-1) > 0$.

We next considered subgames following entry ($E = in$), where the picture was slightly more complicated. There, equilibrium profits – including who wins the auction – depend on whether an Incumbent has a reimbursement multiplier as well as relationship between the magnitude of the Incumbent's reimbursement multiplier ($B > 1$), the magnitude of the Entrant's reimbursement multiplier ($\beta \geq 1$), and the size of the Entrant's cost advantage ($k > 0$). If neither Incumbent has a reimbursement multiplier, the Entrant always wins Auction 3 on the equilibrium path by, e.g., submitting $b_e^{\mathrm{III}} = c_L$ and earning profit $\pi_e^{\mathrm{III}} = c_L(\beta - 1) + k$. If Incumbent 1 has a reimbursement multiplier, the Entrant may still win. Specifically, whenever $\frac{c_L - k}{\beta} > \frac{c_L}{B}$, the Entrant wins Auction 3 in (subgame) equilibrium with the bid $b_e^{\mathrm{III}} = \frac{c_L}{B}$ and secures a profit of $\pi_e^{\mathrm{III}} = \beta b_e^{\mathrm{III}} - (c_L - k) = c_L(\frac{\beta}{B} - 1) + k$. When $\frac{c_L - k}{\beta} < \frac{c_L}{B}$, on the other hand, Incumbent 1 wins Auction 3 and earns a profit of $\pi_1^{\mathrm{III}} = B \frac{c_L - k}{\beta} - c_L$.

4.3 Stage 2.6: Entry decision

Moving one step backwards, the Entrant must decide whether to enter Auction 3 and forgo its outside wage, w, or to stay out of Auction 3. A necessary condition for entry is that the Entrant's expected profits from entering weakly exceed w. The Entrant's (expected) profits from winning, in turn, depend on whether an Incumbent will have a reimbursement multiplier as well as the magnitude of this reimbursement multiplier.

If neither Incumbent has a reimbursement multiplier, the Entrant can, given assumptions on the magnitude of β and k mentioned above, win Auction 3 with a bid of $b_e^{\mathrm{III}} = c_L$ against a minimum of the Incumbents' bids equal to $c_L + 0.01$, securing itself a profit of $\pi_e^{\mathrm{III}} = c_L(\beta - 1) + k$. Therefore, a necessary condition for choosing $E = in$ at Stage 2.6 in this case is: $c_L(\beta - 1) + k \geq w$. If, on the other hand, Incumbent 1 has a reimbursement multiplier $B > 1$, we characterized the Entrant's equilibrium Auction 3 profits in this type of subgame as $c_L(\frac{\beta}{B} - 1) + k$, yielding the necessary condition for entry: $c_L(\frac{\beta}{B} - 1) + k \geq w$.[4]

Comparing these two entry conditions, a couple of things are apparent: since $\frac{\beta}{B} < \beta$, entry is less likely if an Incumbent has a reimbursement multiplier; and conditional on entry, the Entrant's equilibrium profit is lower when an Incumbent has a reimbursement multiplier In these two entry conditions, therefore, we can explicitly see how the relative magnitude of an Incumbent's reimbursement multiplier affects entry. We can also see how an Incumbent choosing to produce low quality at Stage 2.5 "accomodates" the Entrant by permitting the Entrant to earn higher profits in equilibrium. Finally, we also see from these entry conditions how the negative implication of an Incumbent reimbursement multiplier on entry can be overcome by increasing the Entrant's reimbursement multiplier β, or by increasing the Entrant's cost advantage k.

4.4 Stage 2.5: Post-Auction 2 quality decision

Assume that Incumbent 1 has won Auction 2 and is deciding whether to incur the extra cost to produce high quality. The monetary benefit from producing high quality depends on whether the Entrant chooses to enter Auction 3 ($E = in$) or not ($E = out$) at Stage 2.6. We calculated above that in the case where an Incumbent has a reimbursement multiplier $B > 1$ the Entrant enters and wins Auction 3 ($E = in$) whenever $c_L(\frac{\beta}{B} - 1) + k) > w$. When this inequality is satisfied, therefore, both Incumbents earn zero profit from Auction 3 in equilibrium, implying there is no monetary benefit from producing high quality while there is a monetary cost. As a consequence, Incumbent 1 always chooses $Q_1^{\mathrm{II}} = L$ in this type of subgame equilibrium.

If, on the other hand, $\beta\frac{c_L}{B} - (c_L - k) < w$,[5] the Entrant always chooses $E = out$ at the next decision node along the equilibrium path. In subgames where Incumbent 1 chooses to produce low quality ($Q_1^{\mathrm{II}} = L$) and $E = out$, its subsequent Auction 3 profits are $\pi_1^{\mathrm{III}} = 0$,[6] while in subgames following $Q_1^{\mathrm{II}} = H$ and $E = out$, its subsequent Auction 3 profits are $\pi_1^{\mathrm{III}} = c_L(B - 1)$ – assuming B is large enough. Thus, Incumbent 1 decides to produce high quality at Stage 2.5 ($Q_1^{\mathrm{II}} = H$) in subgame equilibria featuring

[4]This assumes $\frac{c_L - k}{\beta} > \frac{c_L}{B}$. Otherwise, the Entrant loses Auction 3 and earns zero profit in this type of equilibrium.

[5]We ignore for the moment the knife-edge case where $\beta\frac{c_L}{B} - (c_L - k) = w$.

[6]Or, as we saw above, they may also be 0.005, depending on which specific subgame equilibrium is played.

$E = out$ if the increment to associated cost is less than the increment to associated monetary benefit. The parameter values for which this is true satisfy the inequality $c_H - c_L < c_L(B-1)$, or equivalently, $B > \frac{c_H}{c_L}$. If this inequality is not satisfied, the winning Incumbent chooses to produce low quality at Stage 2.5 ($Q_1^{\text{II}} = L$).

Overall, if $c_L(\frac{\beta}{B} - 1) + k) > w$, then along the equilibrium path $Q_1^{\text{II}} = L$. If $\beta\frac{c_L}{B} - (c_L - k) < w$, the winning Incumbent's quality production decision depends on the magnitude of the reimbursement multiplier relative to the ratio of the costs of producing high and low quality. If $B > \frac{c_H}{c_L}$, then $Q_1^{\text{II}} = H$ in all (subgame) equilibria. If, on the other hand, $B < \frac{c_H}{c_L}$, then $Q_1^{\text{II}} = L$ in all subgame equilibria.[7]

4.5 Stage 2: Auction 2

In Auction 2, Incumbents' bids depend on Auction 3 profits along the equilibrium path. Which type of equilibrium is being played depends on the parameters of the game. We consider three cases: i) $\beta\frac{c_L}{B} - (c_L - k) > w$; ii) $\beta\frac{c_L}{B} - (c_L - k) < w$ and $c_H < Bc_L$; and iii) $\beta\frac{c_L}{B} - (c_L - k) < w$ and $c_H > Bc_L$.

4.5.1 Case i): $\beta\frac{c_L}{B} - (c_L - k) > w$

The simplest case is case i, where $\beta\frac{c_L}{B} - (c_L - k) > w$. Here, the Entrant chooses $E = in$ at Stage 2.6 in all subgame equilibria implying that both Incumbents earn zero profit from Auction 3 and, knowing this, choose to produce low quality at Stage 2.5 ($Q_1^{\text{II}} = L$). If neither Incumbent enters Auction 2 with a reimbursement multiplier, the usual argument implies that the bid pair $(b_1^{\text{II}}, b_2^{\text{II}}) = (c_L, c_L)$ constitutes mutual best responses which yield zero Auction 2 profit ($\pi_1^{\text{II}} = \pi_2^{\text{II}} = 0$). If Incumbent 1 enters Auction 2 with a reimbursement multiplier, it wins the auction with certainty submitting the bid $b_1^{\text{II}} = c_L$ against the bid $b_2^{\text{II}} = c_L + 0.01$, yielding equilibrium profits in Auction 2 for Incumbent 1 of $\pi_1^{\text{II}} = c_L(B-1)$ and Auction 2 profits for Incumbent 2 equal to zero ($\pi_2^{\text{II}} = 0$). Since Auction 3 profits are zero for both Incumbents, Auction 2 profits in case i are also the continuation game profits.

4.5.2 Case ii): $\beta\frac{c_L}{B} - (c_L - k) < w$ and $B > \frac{c_H}{c_L}$

For these parameter values, as we saw above, the Entrant chooses $E = out$ in equilibrium at Stage 2.6, while Incumbent 1 wins Auction 2 and produces high quality at Stage 2.5 ($Q_1^{\text{II}} = H$), securing Auction 3 profits of $\pi_1^{\text{III}} = c_L(B-1)$. If neither Incumbent enters Auction 2 with a reimbursement multiplier, because their situation at Stage 2 is symmetric all subsequent profits are bid away in equilibrium. The zero-profit bid satisfies $b_i^{\text{II}} - (c_L(B-1) - c_H) = 0$. The bid pair $(b_1^{\text{II}}, b_2^{\text{II}}) = (c_L(B-1) - c_H, c_L(B-1) - c_H)$ therefore constitutes mutual best responses and features in this type of equilibrium.

If, on the other hand, Incumbent 1 enters Auction 2 with a reimbursement multiplier $B > 1$, then it wins Auction 2 outright in subgame equilibrium with the bid

[7] If $c_H = Bc_L$, then either $Q_1^{\text{II}} = H$ or $Q_1^{\text{II}} = L$ are possible along the equilibrium path.

$b_1^{\mathrm{II}} = c_L(B-1) - c_H$ against the bid $b_2^{\mathrm{II}} = c_L(B-1) - c_H + 0.01$. The resulting continuation game profit for Incumbent 1 would be $B[c_L(B-1) - c_H] - c_H + c_L(B-1)$, which is positive whenever $(Bc_L - c_H) \geq c_L$, or equivalently, whenever $B \geq \frac{c_L + c_H}{c_L}$. We assume for simplicity that this condition is satisfied, which implies that the bid pair constitutes mutual best responses and is played in subgame equilibrium.[8] Continuation game profits for Incumbent 2, who loses Auction 2 in this case, are zero.

4.5.3 Case iii): $\beta\frac{c_L}{B} - (c_L - k) < w$ and $B < \frac{c_H}{c_L}$

In all subgame equilibria with these parameter values the Entrant chooses $E = out$ at Stage 2.6 but the Incumbent winning Auction 2 does not produce high quality at Stage 2.5 ($Q_1^{\mathrm{II}} = L$). Because of this, subsequent (Auction 3) profits after winning Auction 2 are zero along the equilibrium path. Because there are no future profits to account for, if neither Incumbent enters Auction 2 with a reimbursement multiplier, the bid pair $(b_1^{\mathrm{II}}, b_2^{\mathrm{II}}) = (c_L, c_L)$ constitutes mutual best responses and is played in subgame equilibrium, yielding Auction 2 profits of $(\pi_1^{\mathrm{III}}, \pi_2^{\mathrm{III}}) = (0, 0)$. If, on the other hand, Incumbent 1 enters Auction 2 with a reimbursement multiplier, the bid pair $(b_1^{\mathrm{II}}, b_2^{\mathrm{II}}) = (c_L, c_L + 0.01)$ constitutes mutual best responses and is played in equilibrium, yielding Auction 2 profits of $(\pi_1^{\mathrm{III}}, \pi_2^{\mathrm{III}}) = (c_L(B-1), 0)$. Because the profits from Auction 3 for both Incumbents in case iii are zero, the Auction 2 profits are also the continuation game profits.

4.6 Summary of Stage 2

Summarizing the analysis of Stage 2, if the parameters of the game are such that the Entrant chooses to compete in Auction 3 in equilibrium ($\beta\frac{c_L}{B} - (c_L - k) > w$), then the combined profits from Auction 2 and 3 are either zero for both Incumbents – if neither incumbent enters Auction 2 with a reimbursement multiplier – or $c_L(B-1)$ for Incumbent 1 and zero for Incumbent 2 otherwise.

If the parameters are such that the Entrant stays out of Auction 3 ($\beta\frac{c_L}{B} - (c_L - k) < w$), then the picture is more complicated. The profits associated with entering Auction 2 with a reimbursement multiplier depend on the inequality $B > \frac{c_H}{c_L}$. When it is satisfied and, moreover, when $B \geq \frac{c_L + c_H}{c_L}$, then Incumbent 1 can earn a continuation game profit of $B[c_L(B-1) - c_H] - c_H + c_L(B-1)$ in subgame equilibrium when it has a reimbursement multiplier. If, on the other hand, $B < \frac{c_H}{c_L}$, then continuation game profits of $c_L(B-1)$ are possible in equilibrium for Incumbent 1 provided it enters Auction 2 with a reimbursement multiplier. Incumbents that enter Auction 2 without a reimbursement multiplier ensure themselves zero continuation game profits.

[8]If the condition is not satisfied, Incumbent 1 prefers to lose Auction 2 and earn zero subsequent profit over winning and earning negative subsequent profit. However, knowing this, Incumbent 1 would not have produced high quality at Stage 1.5. Consequently, when $B < \frac{c_L + c_H}{c_L}$ this type of subgame cannot be part of any equilibrium.

4.7 Stage 1.5: Post-Auction 1 quality decision

The considerations governing high quality production are by now familiar. If Incumbent 1 wins Auction 1 and produces low quality ($Q_1^{\mathrm{I}} = L$) at Stage 1.5, then it enters Auction 2 as a symmetric competitor, ensuring zero continuation game profit. If, on the other hand, it enters Auction 2 with a reimbursement multiplier by choosing ($Q_1^{\mathrm{I}} = H$) then, depending on the parameters of the game, it can secure continuation game profits of either $B[c_L(B-1) - c_H] - c_H + c_L(B-1)$ or $c_L(B-1)$ in (subgame) equilibrium. The decision to produce high quality will therefore be driven by the comparison between the increment in cost associated with doing so ($c_H - c_L$) and the increment to profit, either $B[c_L(B-1) - c_H] - c_H + c_L(B-1)$ or $c_L(B-1)$.

4.8 Stage 1: Auction 1

Since neither Incumbent enters Auction 1 with a reimbursement multiplier, symmetric Bertrand competition pushes bids low enough to ensure zero continuation game profit. The bids submitted in equilibrium therefore depend on the parameters of the game and the equilibrium being played.

4.9 Summary of equilibria with reimbursement multipliers

Of primary interest for our current study is the constellation of parameter values determining entry and quality provision. For ease of exposition, we will frequently omit the qualifier "in all subgame equilibria of this type," although this qualifier should be understood to apply.

4.9.1 Entry

For entry, the primary consideration is whether an Incumbent has a reimbursement multiplier at Stage 2.6, i.e., the decision node at which the Entrant must decide whether to enter or stay out. If neither Incumbent has a reimbursement multiplier, the decision is somewhat simple: if $c_L(\beta - 1) + k \geq w$, then entry can entry occur and definitely occurs if the inequality is strict; if the inequality is not satisfied, entry definitely does not occur. In our experiment, we fix some of these parameter values for all treatments: $k = 1.375$, $c_L = 1.5$, $w = 1$. Across treatments we vary primarily the Entrant's reimbursement multiplier, letting β take values in the set $\{1, 1.5, 2\}$. The inequality $c_L(\beta - 1) + k \geq w$ is strictly satisfied for all of these values of β given our choices for k, c_L, and w. Consequently, entry always occurs if the winning Incumbent produces low quality at Stage 2.5.

If, on the other hand, the winning Incumbent produces high quality at Stage 2.5, entry depends also on the magnitude of the Incumbent's reimbursement multiplier, B. In particular, entry can only occur if $c_L(\frac{\beta}{B} - 1) + k \geq w$. In all of our (non-baseline) treatments, we fix $B = 2$, so that the inequality becomes $c_L(\frac{\beta}{2} - 1) + k \geq w$. Plugging in the other (fixed) parameters, this reduces to $1.5(\frac{\beta}{2} - 1) + 1.375 \geq 1$. For $\beta = 1$ this inequality is strictly not satisfied, so that Entry never occurs if high quality is produced at Stage 2.5. When $\beta = 1.5$, the condition holds with equality, so entry is possible depending on the equilibrium being played. When $\beta = 2$, the inequality is strictly satisfied, implying that entry always occurs even if high quality is produced at Stage 2.5.

4.9.2 Quality

Quality provision is more complicated as it can occur at more than one decision. For illustration, we focus here on Stage 2.5, as this is the stage that (as we saw) also determines entry. In this discussion we assume that Incumbent 1 has won Auction 2 and must therefore decide between $Q_1^{\text{II}} = L$ and $Q_1^{\text{II}} = H$ At Stage 2.5.

We noticed above that whenever $E = in$ at the subsequent stage, Incumbent 1 will always choose $Q_1^{\text{II}} = L$. Given our choice of parameter values, when $\beta = 2$ entry occurs irrespective of whether the winning Incumbent produces high quality at Stage 2.5, implying that $Q_1^{\text{II}} = L$ is certain. When $\beta = 1$, the parameters we chose imply entry never occurs and, consequently, that high quality is always produced $Q_1^{\text{II}} = H$. In the intermediate case where $\beta = 1.5$, whether high quality is produced depends on whether entry occurs in the particular equilibrium being played. When $E = in$, $Q_1^{\text{II}} = L$ is certain, while $Q_1^{\text{II}} = H$ is certain if the equilibrium being played entails $E = out$.

In summary, when the Entrant effectively has no reimbursement multiplier ($\beta = 1$) so that it is treated like an Incumbent who (immediately) previously produced low quality, high quality provision is the most likely. High quality provision is the least likely when the Entrant enjoys a reimbursement multiplier equivalent to an Incumbent who immediately previously produced high quality ($\beta = 2$). For the intermediate case, $\beta = 1.5$, the likelihood of high quality provision is also intermediate – possible in some equilibria and impossible in others.