Relational Contracts, Procurement Competition, and Supplier Collusion*

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Abstract

We study the tension between competitive screening, contract enforcement and supplier collusion where a buyer trades repeatedly with one among several suppliers, moral hazard and adverse selection coexist, and non-contractible dimensions are governed by relational contracting. With competing suppliers, open competition with discretion (on future participation or bonuses) is optimal when suppliers are few and heterogeneous, contract duration is low and non-contractible quality is not too important. Otherwise, the buyer optimally restricts competition to a subset of regular suppliers and may induce information sharing between them thus allowing for multilateral contracting. However, these policies facilitate collusion among suppliers, inducing a trade-off between relational contracting and collusion. Interestingly, this trade-off may disappear as collusion grants higher future rents to suppliers that allow the buyer to better manage their incentives and performance. These results shed light on a number of puzzling observations on well known cartels, such as the recent and worldwide "car parts cartel" investigation and its relationship with the "lean procurement" strategies that Toyota used to dominate the car industry in the last three decades.

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1 Introduction

The success of Toyota in the last half-century is widely attributed to its 'lean' management practices based on relational contracting.[1] In procurement, these imply long-term relations with a restricted group of dedicated suppliers to which most quality control activities are delegated instead of open competitive procurements with quality inspection by the buyer. Relational contracts have found their way even in the traditionally more rigid public procurement: since Steven Kelman became responsible for US public procurement under the Clinton administration a number of legal reforms took place intended at reducing reliance on open competitive auctions and leaving more scope to more flexible, restricted auctions with requests of quotations to a subset of potential suppliers strongly influenced by past performance and "the shadow of the future".

Relational contracts allow parties to govern sometimes crucial non-contractible dimensions of the supply relation through self-enforced cooperation. Cooperation incentives are typically stronger the larger the expected future payoffs at stake, so that relational enforcement may conflict with other important needs of a principal, in particular that of letting supplier compete to screen and select the more capable and least costly of them. In this paper we study this potential conflict in a model where a principal/buyer trades recurrently and sequentially with multiple competing suppliers and where non-contractible dimensions are important. We characterize the optimal relational contract, defined in the broad sense to include equilibrium choices on explicitly contracted features, on non-contractible dimensions, and on the competitive screening policy. We identify situations in which tension does arise between competition and enforcement, deriving the general implications of this trade off. We show that this tension can be so marked that actually negating competition and procuring with colluding suppliers may become optimal for a buyer in quest of the highest non-contractible enforcement.

By connecting relational management practices to cartels and collusion, our model helps to shed light on unexplored features of relational contracting in private and public procurement

[1] Helper and Henderson (2014) offers a brilliant account and a lot of references on this saga.

environments and on the relationship between these and the large set of recently discovered supplier cartels in the auto part industry, on trade policy frictions between the US and Japan in the 90s, and on the current debate on legal exception to antitrust enforcement against price-fixing agreements.

Outline of the model and results. In our setting an infinitely-lived principal (buyer) procures recurrently a task with an important non-contractible dimension from a population of heterogeneous and privately-informed infinitely-lived agents (suppliers). Both moral hazard (on non-contractible dimensions) and adverse selection (on suppliers' type/cost) are present, and when the principal designs the optimal relational contract he must choose: any explicit part of the contract enforceable by the court (contractible payments, auction format, contract duration, contractible performance standards); the implicit and self-enforcing incentives designed to govern costly non-contractible performance; and the screening policy, i.e. how and how often suppliers compete for procurement. These three aspects of the relationship are highly interdependent, and the optimal relational contract requires joint optimization of all three dimensions.

We first characterize the optimal relational contract when parties can exchange only contractible monetary transfers (e.g. payments related to suppliers' bids at a competitive auction), as is typically the case for accountability reasons in public procurement and large bureaucratic firms, and focus initially on bilateral relational contracts between the buyer and each individual supplier. We find (Proposition 1) that restricting competition to a stable pool of eligible, trusted suppliers under the threat of exclusion/replacement in case of under-performance on non-contractible quality, as typical of the "Toyota-way", may optimally solve the principal's problem. To enforce substantial levels of non-contractible quality, the buyer has to rely on promised large future rents by limiting future competition among those pre-selected suppliers, at the cost of lower efficiency and higher costs.

Investigating this first trade-off we show that restricted competition is more likely to be optimal (over open competition where all potential suppliers are invited to compete) (i) the more valuable is non-contractible quality; (ii) the larger is the number of potential suppliers in the market; (iii) the smaller suppliers' cost heterogeneity; and (iv) the smaller the common discount factor, which can be interpreted as lower frequency of interaction/longer contract duration.

These results are already consistent with the way Asanuma (1989), Aoki and Dore (1996) and Taylor and Wiggins (1997), among others, have related the "Toyota-way" to lean, relational procurement: requests for proposals (auctions) restricted to few –often two– loyal long-term suppliers;

small batches inducing high frequency of interaction; and ex-post quality evaluation rather that ex ante supply inspection. The comparative statics seem to fit well also with the switch to fewer, trusted suppliers observed in IT supply chains after globalization drastically increased the number of potential suppliers (Bakos and Brynjolfsson, 1993), and we will argue in the discussion may explain the difficulties faced by American auto parts producers in accessing Japanese markets in the 90s even after formal trade barriers were removed.

Although restriction to a smaller pool of eligible and regularly interacting suppliers facilitates cooperation between a buyer and his suppliers on non-contractible quality, at the same time it also facilitates suppliers' collusion against the principal. We therefore proceed to illustrate a second and rather general trade-off between relational enforcement and supplier collusion (Proposition 2) which disappointingly seems to denote limits on the possible remedies for non-contractible tasks. However, our analysis clarifies that collusion itself may interact directly with suppliers' incentives for non-contractible performance. In fact, by increasing the price, collusion clearly increases suppliers' gains from future trade with the principal which, as usual, can also be seen as the cost of being excluded for poor non-contractible performance. Hence, we show that there are circumstances in which the trade-off between non-contractible performance and collusion is only apparent (Proposition 3). When non-contractible dimensions are very important and negotiation with a single supplier is not allowed, or is too risky for the danger of unexpected disruption in the procurement flow, it may actually be optimal for the principal to induce the few trusted suppliers to fix supply price.[2]

Our results are consistent with recent evidence on the use of restricted auctions in public procurement.[3] They also shed light on the *Kansei-Dango* practice in Japan, where according to the Japan Fair Trade Commission,[4] public buyers coordinated bid rigging among suppliers –even in the absence of corruption– to avoid that price competition could disrupt quality of procured goods and services and the analogous tendency of public procurers to soften price competition allowing for consortia and restricted procedures when procurement is complex and non-contractible aspects crucial. (Of course, the relational contract ends up often involving corruption, besides

[2]From the procurement view point this result is provocative in that it implies that a buyer is not necessarily concerned by suppliers' collusion. Yet we explain why cooperation among suppliers – common in procurement within consortia, joint-ventures and other joint bidding agreements – is indeed likely in some circumstances to result in higher performance, thus benefitting the buyer.

[3]See Coviello et al. (2016) and references therein.

[4]General Secretariat, Japan Fair Trade Commission, 2015, "Towards the Prevention of Bid-Rigging", p. 68.

collusion, but the recent work of Troya-Martinez and Lewis (2016) suggests this may further increase efficiency).

In private procurement these forces are ubiquitous but discretionary transfers are typically allowed. Therefore, we generalize the model allowing parties to also exchange other contractible monetary transfers - like wages and participation fees - as well as non-contractible ones, like discretionary performance bonds and bonuses. Discretionary transfers may in principle allow a buyer to govern non-contractible dimensions without relying on rents to the suppliers thus pushing towards a more extensive use of open competition. However, the principal's temptation to renege on a promised bonus (or to withhold a bond) after the supplier performed, together with the possibility to exclude the betrayed performing supplier, limits the use of such discretionary transfers. Taking this incentive problem into account, we find that when suppliers compete and discretionary transfers are available, the principal optimally chooses bonuses and open competition when there are fewer available suppliers in the market and non-contractible dimensions are not too important (Proposition 4). Interestingly, bonuses are quite an effective tool with competing suppliers. The buyer does not pay it in the end because competition induces suppliers to compete it away (reducing their bid in anticipation of the bonus), *de facto* transforming a discretionary bonus into a discretionary bond. Still, restricted competition, under which discretionary bonuses are not credible and cannot be used, is optimal when quality is important and there are many potential suppliers. Other comparative statics results described above are unchanged. These results are consistent with the observation that discretionary monetary bonuses or bonds are hardly ever observed in auto part relational procurement, where competition is typically restricted to two or three trusted suppliers.

The results on the trade off between relational enforcement and collusion and on the optimality of collusion for the buyer are relevant when quality is important and competition is restricted, and are therefore not qualitatively affected by the availability of monetary transfers (Proposition 5).

Overall, the result on the enforcement-collusion trade off is suggestive of why, just now that many car manufacturers have converged to a Toyota-style relational procurement, a large number of overlapping cartels among car part suppliers –most of which Toyota suppliers– have been recently uncovered by antitrust authorities.[5] This set of overlapping cartels, still in the middle of

[5]The Economist, "Cartelbusting - Boring can Still be Bad,", "Just One More Fix," March 29th 2014; "No truck with cartels" Jun 4th 2016; "Massive price-fixing among auto-parts manufacturers hurt U.S. car buyers," The Columbus Dispatch, Sunday March 22, 2015.

investigations, has already led to a record amount of fines and jail sentences, is emerging as the biggest antitrust investigation ever, but presents a number of puzzling aspects. In the discussion we will argue that our results on conditions under which price-fixing among suppliers may be optimal for the buyer offers a useful perspective to recompose the puzzles.

Finally, following Levin (2002), we consider the case of multilateral relational contracting, in light of Toyota's investment in creating and maintaining the Bluegrass Automotive Manufacturing Association (BAMA) and the regular information sharing meetings among buyer and suppliers it organized (Milgrom and Roberts, 1993). We assume that the principal may at some cost create an information sharing device (e.g. a supplier association with regular meetings, like the BAMA) that ensures that the level of non-contractible quality provided by a supplier and possible problems with the performance bonus become known to all suppliers in the pool.[6] This allows the principal and the associated suppliers to establish *multilateral relational contracts* where, if the principal reneges on a promise, all suppliers in the pool stop cooperating with him. We show that these arrangements are more effective in our sequential procurement environment than in Levin's employment model, because the higher loss from a coordinated punishment by all suppliers is not compensated by the gains from a simultaneous defection by the principal (impossible with sequential procurement). Multilateral relational contracts improve the principal's ability to commit not to renege on a promised bonus, ensuring that even higher non-contractible quality is sustainable with open competition. This further reduces the need to shift to a restricted competition regime and allows for bonuses to be credible even with restricted competition. Interestingly, communication and information sharing devices, like BAMA, are well known factors that facilitate collusion, hence they may also help suppliers to collude. For what discussed above, however, collusion may not be an issue for a buyer who cares a lot for non-contractible dimensions.

Related literature. Our paper contributes to the literature on efficiency wages and relational

Although economists are often accused of studying models with little predictive power, the first version of the present paper circulated in 2005 (e.g. World Congress Econometric Society, London), several years before the car part cartel was discovered. To avoid being sued for providing criminal inspiration to practitioners, we notice that most of those conspiracies started a few years before that and none of the authors ever worked for Toyota, other car manufacturers and any of their suppliers.

[6] Among other things, BAMA "...provides expanded opportunities for direct communications with Toyota executives and access to Toyota training programs, while giving members the opportunity to share best practices and collectively raise issues and communicate problems affecting the way we do business." (from http://www.bama-group.org/, October 7, 2013).

contracts that, from the pioneering contributions of Shapiro and Stiglitz (1984), Bull (1987), MacLeod and Malcomson (1989) and Baker, Gibbons and Murphy (1994) (see MacLeod 2007 and Malcomson 2012 for surveys). The work closest to our own is probably that of Levin (2003), who elegantly characterizes the optimal relational contract with moral hazard and adverse selection between a buyer and a single seller. A major difference is that we focus on competition among several agents and we are thus concerned by the trade-off between competitive screening and the incentives to deliver non-contractible performance. Our work is also close to MacLeod and Malcomson (1998), which posits relational contracts between a number of principals and a larger number of competing suppliers, although without adverse selection and screening. Taylor and Wiggins (1997) provided a first model of the Japanese style relational procurement focusing on the frequency of interaction between a buyer and a single supplier.

So far the literature has paid limited attention to the case of a relational contract between one principal and several privately-informed agents who compete recurrently to be selected for a procurement contract. Levin (2002) studies team production in relational environment where agents do not compete. A similar environment is that in Rayo (2007) who studies relational contracts with multiple suppliers, endogenously deriving the organizational structure, but again in a framework with team production and no competition.[7] Board (2011) obtains a result analogous to our Proposition 1 on the optimality of limiting the number of trading partners, but in a very different model where the focus is on dynamics, there is no need to competitively screen suppliers and contractible monetary transfers (e.g. wages, prices) as well as performance bonuses (or bonds) are not admitted. In the same vein, a recent paper by Andrews and Barron (2016) focuses on the dynamics of contracts allocation among multiple suppliers as a device to make the principal's promises of discretionary bonuses credible, but does not discuss supplier competition nor collusion among suppliers.

Our paper is also linked to the literature on the optimality of using open, competitive auctions. When contracts are complete and their enforcement costless, classic results on the optimality of open auctions apply (e.g. Bulow and Klemperer, 1996, 2009). When contracts are highly incomplete and costly to enforce, i.e. when non-contractible quality is important, open auctions may perform poorly in terms of purely economic outcomes. Focusing explicitly on construction

[7] Mukherjee and Vasconcelos (2011) compare individual task responsibility with team responsibility, and show that the teams soften the multi-tasking problem but weakens relational contracting. They do not consider competition nor collusion among agents though.

procurement, Spulber (1990) showed first how the interplay of incomplete contracting and auctions may intensify problems of moral hazard and ex post opportunism, leading to rather poor outcomes. Manelli and Vincent (1996) reached an even more extreme conclusion, showing that when the crucial dimension on which gains from trade are concentrated is not contractible, open auctions that induce bidders to compete on contractible dimensions (e.g. price) are the worst among conceivable procurement mechanisms, as they maximize the damages from adverse selection. Bajari and Tadelis (2001) showed that bilateral negotiations may be better than competition for highly complex projects.

Restricted auctions leaving the buyer some discretion on whether to invite or not some bidders can be seen as a compromise between open auctions and bilateral negotiations, as they may limit but not eliminate supplier competition. In a dynamic framework, auctions with a choice of participant depending on past performance may allow the buyer to take into account reputational forces and establish long term relationships that may improve performance (Kim 1988, Doni 2006). Our paper shows how discretion to restrict competition may allow a buyer to sustain relational contracts that enforce non-contractible quality, but also that this solution inevitably facilitates collusion among suppliers, which can have positive or negative effects on procurement outcomes.

In this sense, our analysis is also relevant to the literature on reputation and markets, starting with the seminal work of Klein and Leffler (1981) and Shapiro (1983). These early analyses were concerned with the compatibility of "performance-assuring" reputational equilibria with free entry. Stiglitz (1989) raised the question of how reputation could be compatible with perfect competition, which should eliminate all future supracompetitive gains (see also Kranton 2003 and Bar-Isaac 2005). Hörner (2002) offered an elegant answer to Stiglitz's question. In his model with heterogeneous consumers and firms, adverse selection (time-persistent costs) and moral hazard (goods' quality), high prices signal high quality and make competition compatible with reputational forces. In our environment signalling would not work because of time-varying costs and since prices are set in a competitive auction (or, in negotiations, they are determined by the buyer). On the other hand, our analysis shows that when the number of potential competitors is limited and they are sufficiently heterogeneous, open competitive auctions coupled with a performance bonus and/or the threat to exclude a poorly performing suppliers may well guarantee a sufficient level of non-contractible quality to a buyer, while restricting competition to enforce quality increases the risk of collusion among suppliers.

The rest of the paper is organized as follows. Section 2 describes the model. Section 3

studies the optimality of open and restricted competition with competing suppliers and contractible transfers. Section 4 discusses the risk and consequences of suppliers' collusion. Section 5 allows the principal to use discretionary transfers as well. Section 6 studies multilateral contracting. Section 7 relates our results to some stylized facts from the car parts cartel and the US-Japan trade relationships. Section 8 discusses some robustness and extensions and concludes.

2 The base model

Environment. At any period $t = 0, 1, 2, ...$ a principal (a buyer) needs a task to be performed by one among $N > 1$ suppliers (the firms). The principal's per-period value of the task $v(q_t)$ is increasing and concave in a costly decision q_t (≥ 0) taken by the supplier supplying in t, i.e. the *supplier*. The per-period cost for supplier i is $\theta_{it} + \psi(q_t)$ with $\psi(q_t)$ increasing, differentiable, strictly convex and $\psi(0) = \psi'(0) = 0$. The value of trade in period t with supplier i is $s(q_t) - \theta_{it}$ where $s(q_t) \equiv v(q_t) - \psi(q_t)$. Selecting an adequate measure for q_t and appropriately scaling ψ, we set $v(q_t) = vq_t + v_0$ with $v > 0$ and $v_0 \geq 0$. The time horizon is infinite, all players are risk-neutral and have a constant and common discount factor $\delta \leq 1$.

Although q_t is observable to the principal and the supplier, it is not verifiable to third parties, which makes it not-contractible. For example, q_t may be the costly effort (or specific investment) provided by an expert or an employee, or a quality feature of the procured service that cannot be specified. In the reminder we will refer to q_t as non-contractible "quality". In Section 8 we will partially relax the assumption on non-verifiability allowing it to be observed by some third parties.

In this set up supply can be seen as an indivisible multi-tasking activity which contemplates a contractible decision taken by the supplier at cost θ_{it} that is worth v_0 to the principal and generates value $v_0 - \theta_{it}$, and a non-contractible valuable decision q_t. To avoid uninteresting cases we assume $v_0 > \theta_{it}$ for any θ_{it}, so that the principal never wants to discontinue supply.

The suppliers' outside option is $\underline{u} = 0$ and the principal one's $\underline{v} \geq 0$.

As in Levin (2003), we assume that $\theta_{it} \in \Theta \equiv [\underline{\theta}, \overline{\theta}]$ is independently and identically distributed with density $f(\theta_{it})(> 0)$ and $\theta_e \equiv E(\theta)$ (see Section 6 for a discussion on IID costs) and all this is common knowledge. In any period, the principal is uninformed about θ_{it} and, to simplify exposition, we assume suppliers are instead fully informed, as it is often the case in environments with frequently interacting suppliers that know each other well (a common circumstance in pro-

curement or among colleagues in a firm). This assumption is immaterial except for the results on collusion, in which case we show that the trade-offs underlying our results persist qualitatively even with asymmetrically informed suppliers.

Since the principal is uninformed about θ_{it}, in any t he uses a competitive screening device, an auction with its rules A_t, that awards an (explicit) contract requiring the winning supplier to provide the specified supply for one period. To fix ideas we refer explicitly to first price auctions, but other standard auction formats would do for our analysis as well.[8] The auction rules contemplate the price paid to the auction winner for supplying, i.e. the lowest winning bid b'_t and, in some cases, also a reservation price r. In addition to these "interim" verifiable monetary transfers, in Section 5 we will allow for transfers exchanged ex-ante, i.e. before suppliers learn their cost and compete (like wages or participation fees, denoted by w_t), and for ex-post discretionary transfers paid after the execution of the contract (such as bonuses and bonds B_t).

Explicit and Relational Contracts. Although quality is not contractible, principal and suppliers may still profit from ongoing interactions and reach an implicit agreement, or "*relational contract*", on how they are going to behave in the future, on and off equilibrium. A relational contract is self-enforcing if it describes a perfect public equilibrium of the repeated game (Fudenberg, Levine and Maskin, 1994). In the following we refer simply as the "*contract*" to the explicit court-enforced contract awarded at the auction stage and regulating the verifiable dimensions of the exchange (i.e. the price of supply b'_t established at the auction, the basic task/provision with value v_0 and the auction rule A_t itself).[9] We thus distinguish the contract from the implicit self-enforcing part of the relational contract.

We will first focus on "bilateral relational contracts" defined as complete and independent contingent plans of action for the principal and supplier i as in MacLeod and Malcomson (1989), denoted by C_i. Upon a deviation at date t, either by the date-t supplier or by the principal, the bilateral relational contract C_i prescribes how parties will behave in the future on and off the

[8] Agents may compete announcing a quality and an associated price, with the principal ranking offers by a scoring rule. This is irrelevant in our setup because of the same cost of quality for all agents. Furthermore, it would not be viable since the assignment of the contract (a contractible dimension) would be based on non-contractible dimensions (the promised quality).

[9] Although not explicitly modelled here, the principal could offer contracts that last for more than one period (or renew current ones). This is here captured with an increase of the discount factor δ. See Calzolari and Spagnolo (2009) for an explicit modelization of contract duration.

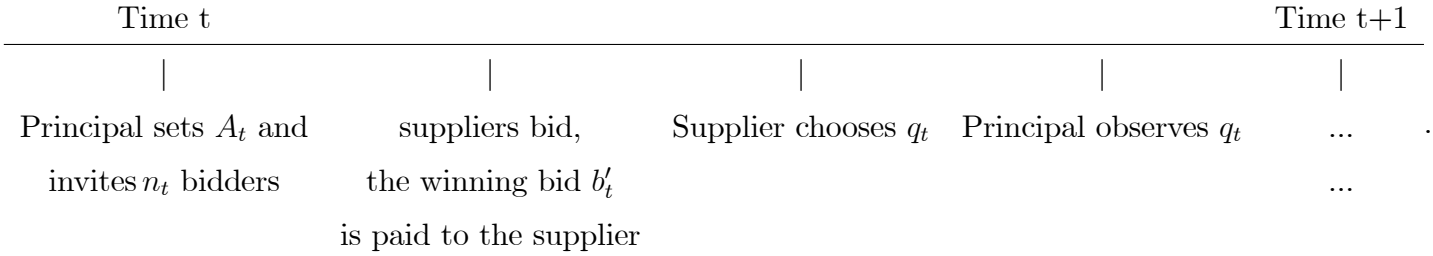
equilibrium path. In the present set up when a deviation occurs in the relational contract C_i, none of the other players knows that the deviation took place, nor can they ascertain the identity of the deviator if they become aware that a deviation took place. This assumption will be relaxed in Section 8 when we will let the suppliers who participated in the auction to share some information, extending the analysis to multilateral (interdependent) relational contracts (as in Levin, 2002).

Screening modes. As we will illustrate in the sequel, in this environment the principal may gain by restricting participation, in which case he forms *a pool of* n_t $(\leq N)$ *suppliers invited to compete* at the auction at date t (we will discuss the selection process of invited suppliers). We accordingly define the following.

Definition 1 (Screening modes) *With* open competition *the principal allows all suppliers to participate in the auction and sets* $n_t = N$. *With* restricted competition *the principal restricts participation to* $n_t < N$ *invited suppliers, which also includes the limit case of (bilateral)* negotiation *when* $n_t = 1$.

The number of invited suppliers, whether it is N or smaller, is observable by invited suppliers but not verifiable, thus being part of the relational contract.[10]

Summarizing, the time line of decisions in each period t is as follows:



To simplify notation in the remainder of the paper we will drop the time index when variables are time-invariant, as is the case with stationary contracts.

2.1 Benchmarks

Contractible quality. Let us temporarily assume that quality is verifiable and can be contracted upon. Since the environment is stationary, optimal procurement is so.[11] The principal optimally

[10] Although not always realistic, assuming n_t explicitly contractible would strengthen our results. Also, as we will explain in the sequel, assuming that agents observe n_t only after bidding would not affect our results.

[11] The proof of this standard result is, for example, in Laffont and Tirole (1994) pages 103-105, with a very similar environment.

sets q_{FB} that maximizes the surplus $s(q)$ and suppliers compete for the contract that contemplates procurement of such quality. With $n > 1$ competing suppliers and given a realization of the costs $\theta_t = (\theta_{1t}, ..., \theta_{nt})$, the most efficient supplier wins bidding a price b' which corresponds to the total cost of procuring q_{FB} by the second most efficient supplier. Hence, at any auction each of the n invited suppliers expects to earn a profit $\beta(n)\pi(n)$ where $\pi(n)$ is supplier's expected *informational rent* $\pi(n) \equiv \theta(n) - \theta'(n)$, with $\theta(n)$ and $\theta'(n)$ being respectively the expected cost of the second and of the first most efficient supplier out of n suppliers, and $\beta(n) = \Pr[\theta_{it} = \theta'(n)] = 1/n$ is the probability of being the most efficient one.[12] Since the expected total cost $\theta(n) + \psi(q_{FB})$ of procuring is decreasing in n, the principal prefers open competition and invites all N suppliers to bid. Hence, with contractible quality the procurement contract C_{FB} attains the efficient with $q = q_{FB}$ and $n = N$ at any t and, after substituting for the winning bids, the associated principal's (expected) payoff is

$$V_{FB} = [s(q_{FB}) - \theta(N)]\frac{1}{1-\delta}.$$

If the principal was also fully informed on suppliers' costs, she could directly contract with the most efficient supplier in any period with a take-it-or-leave-it offer. The only difference would then be a lower procurement cost $\theta'(N) + \psi(q_{FB})$ and nil informational rent.

"Zero-quality" equilibria. Back to non contractible quality and as usual in relational contracting, there always exist equilibria in which the principal expects $q_t = 0$ and suppliers indeed procure zero quality. Also in this case the principal would not gain from limiting competition and thus optimally sets $n_t = N$ in any period with an associated payoff

$$V_0^* = [v_0 - \theta(N)]\frac{1}{1-\delta}$$

(the per-period cost would be $\theta'(N)$ if she was fully informed).

3 On the optimality of restricted competition

We now study under what conditions equilibria emerge that allow the principal to implement strictly positive non-contractible quality. We will focus on stationary relational contracts that specify the same auction rules A, non-contractible quality q and pool of invited suppliers n at

[12] To simplify notation, but without loss of generality, we will proceed as if the event that two or more agents have exactly the same cost has zero measure at any t.

any period on the equilibrium path. The stationary equilibria we characterize correspond to the long-run steady state equilibrium paths that follow any possibly non-stationary initial phase, like that studied in Board (2011) where the n invited suppliers are selected sequentially.[13]

When a relational contract prescribes a strictly positive non-contractible quality q, suppliers may be tempted to cheat and save on quality costs with two types of deviation. First, the supplier that has won an auction may decide to deliver zero quality on the current contract. Second, anticipating that he will cheat on quality in case of being awarded the contract, an supplier may bid aggressively (also at a price lower than his costs), and win the contract even if it is not the most efficient.

The only way in which the principal can control and obtain (positive) quality in the current set up is by rewarding suppliers with the expected rent from participating to future auctions and punishing deviating suppliers by excluding them from such a rent. In particular, the principal may establish with each supplier i a bilateral relational contract C_i^n that contemplates: (i) no more than n suppliers invited to compete, (ii) a winning supplier must provide non-contractible quality $q > 0$, (iii) the principal will continue inviting him at future auctions when the quality he actually provided is at least q, (iv) if instead a winning supplier deviates ("cheats") providing lower quality, then he will be excluded from the pool for at least one period and possibly replaced by a newly invited supplier if $n < N$.[14]

We *temporarily* assume that the principal can commit to (the actions prescribed in) a set C^n of n bilateral relational contracts C_i^n.

Lemma 1 (Agents' incentives) *Assume the principal can commit to a relational contract. A relational contract induces the n suppliers in the pool to participate, bid with the intention of delivering q and then actually deliver q upon winning an auction, if and only if*

$$\beta(n)\pi(n)\frac{\delta}{1-\delta} \geq \psi(q). \tag{1}$$

[13]Board's model is different since it considers non-contractible transfers only, there is no competitive bidding and the principal is fully informed. In Board's preliminary non-stationary phase, insiders are treated differently than other agents, a discriminatory treatment unfeasible in most public or regulated procurement, where accountability requires equal treatment of all bids. A buyer facing these restrictions would optimally "jump" to the stationary our steady state directly.

[14]There may be milder forms of punishments such as threatening to handicap in future auctions a cheating supplier in future auctions, exclusion being an extreme form of handicap. Since we are mainly interested in cases in which the buyer wants to procure significantly large non contractible quality, those milder punishments tend to be dominated and will not be considered.

Condition (1) guarantees that no supplier has incentive to deviate by providing a quality lower than q. This is the case both for the most efficient supplier at any t and for any other supplier who may conceive to outbid the most efficient one and subsequently cheat on quality. Indeed the condition guarantees that what any supplier loses in the future by being excluded (the l.h.s. of (1)) is higher that what he can save by supplying but not providing the quality today (the cost in the r.h.s.). suppliers anticipate that if they cheat they sacrifice the present value of *any* expected future profits since the first supplier who deviates is excluded for at least one period but in fact remains out of the pool forever after. Indeed, any supplier knows that being excluded even for a single period, he cannot hope to come back into the pool since he cannot expect a deviation by any of the other suppliers currently admitted in the pool. This establishes sufficiency. For each of the n suppliers, the strategy profiles described above constitute an optimal penal code in the sense of Abreu (1988), so that no higher quality can be sustained than the highest one satisfying condition (1) as equality for any n. This establishes necessity.

From inequality (1), any q is *enforceable* (i.e. it is incentive compatible and guarantees suppliers' participation) if and only if $q \leq q(n)$ where

$$q(n) = \psi^{-1}[\beta(n)\pi(n)\frac{\delta}{1-\delta}] \tag{2}$$

is defined as the *maximum enforceable quality* that the principal can procure for any n.Notice that since both $\beta(n)$ and $\pi(n)$ are decreasing in n, the maximal enforceable quality $q(n)$ decreases with n.

The principal's program with commitment can then be written as

$$(\mathcal{P}_c) \quad \begin{array}{l} \max\limits_{N \geq n,\, q \geq 0} \quad V(n,q) \\ st.\ q \leq q(n) \end{array}$$

where

$$V(n,q) = [s(q) - \theta\,(n)]\frac{1}{1-\delta}, \tag{3}$$

and we will denote with n^* and q^* the solution to this program $(\mathcal{P}_c)$ with commitment.

Consider now *the principal's incentives* thus abandoning the assumption of commitment. Since in our environment the Nash equilibrium of a first price auction leads to the best possible outcome for the principal (for given q and n), there is no way she can gain by modifying the rules of the auction A. Similarly, the principal cannot gain by replacing an supplier who did not cheat in the

pool with a new one if available (i.e. when $n < N$), because suppliers are ex-ante identical. If $n < N$, the principal could gain increasing n so as to improve competitive screening and reduce the expected price paid and cost $\theta(n)$. However, any such deviation would be observed and met in the same period by the suppliers who could then begin procuring no quality, i.e. $q = 0$. Finally, the principal may prefer not to exclude a supplier who procured quality lower than q (i.e. differently from what prescribed in the relational contract C_i^n).

We shall say that a relational contract C^n with n suppliers is *incentive compatible* if it is so for the suppliers *and* the principal.

Lemma 2 (Incentive compatible relational contracts) *Any relational contract that contemplates restricted competition, strictly positive quality and that solves the principal's program with commitment* $(\mathcal{P}_c)$ *is* incentive compatible.

With open competition, contract C^N *with quality* q *is incentive compatible if and only if* $q \leq q(N)$ and

$$s(q^*) - \theta(n^*) \geq s(q) - \theta(N) - \frac{1}{N}vq, \tag{4}$$

where q^* *and* n^* *solve* $(\mathcal{P}_c)$ *with the additional constraint* $n^* < N$.

With restricted competition, i.e. $n < N$, the principal can always credibly substitute a deviating supplier at no cost, with one of the $N - n$ suppliers initially excluded from the pool. Furthermore, when n and q are the maximizers q^*, n^* of the principal's program with commitment $(\mathcal{P}_c)$, deviating to a different n (e.g. $n = N$) cannot be optimal either because the suppliers would then begin providing nil quality. Hence, when procuring with restricted competition, principal's incentive compatibility is always satisfied and optimal procurement is simply the solution of $(\mathcal{P}_c)$ (with the additional constraint $n < N$).

When instead procuring with open competition, i.e. $n = N$, constraint (4) guarantees that the principal is credible in excluding a cheating supplier. By keeping a supplier who cheated, she will continue procuring with N suppliers and a per-period payoff

$$s(q) - \theta(N) - \frac{1}{N}vq,$$

which accounts for the fact that in any future period, with probability $1/N$ the auction winner is precisely that supplier and the quality will be nil. By excluding a supplier who cheated instead, the principal will obtain a per-period payoff associated with the solution of problem $(\mathcal{P}_c)$ with

restricted competition, i.e. $s(q^*) - \theta(n^*)$.[15] Recall in fact that contracting is bilateral. Once excluding a deviating supplier, procurement will take place under restricted competition, from the point of view of all other suppliers. When there exist no q that satisfies (4) and (1), with open competition the principal can only procure nil quality. We will see in Section 5 that allowing the principal to use bonuses allows to implement positive quality even if (4) is violated.

For what stated so far, the principal's optimal relational contracts must solve the following optimization program

$$(\mathcal{P}) \quad \begin{array}{l} \max\limits_{N \geq n,\, q \geq 0} V(n,q) \\ \text{st. (1), and (4) when } n = N. \end{array}$$

Notice that the principal can always guarantee herself the payoff V_0^* of the zero quality equilibrium which is in fact equal to $V(N,0)$ with $q = 0$ trivially satisfying all constraints. The principal can obtain some positive quality with open competition as long as he can exclude from future auctions an supplier who fails to deliver the expected quality. He can further increase the level of procured q by restricting competition to a smaller pool of suppliers $n < N$ from the very beginning, i.e. adopting restricted competition. Indeed reducing competition increases suppliers' expected rent in two complementary ways: by increasing the informational rent from winning (because $\pi(n)$ is decreasing in n) and by increasing the probability/frequency of winning (because pool membership does not change in time and $\beta(n)$ is decreasing in n). The cost of restricted competition is that the price paid and the associated cost $\theta(n)$ faced by the principal are increased with a smaller n.

Program $(\mathcal{P})$ shows in fact a fundamental trade-off between quality and competition. Since the expected informational rent $\beta(n)\pi(n)$ is decreasing in n (both terms decrease with n) as well as the maximum enforceable quality $q(n)$, to increase q and at the same time ensure incentive compatibility, the principal may be obliged to further restrict the number of competing suppliers, with the highest enforceable quality obtained negotiating with a single supplier (i.e. $n = 1$). Put it differently, more intense competition (a larger n) allows to procure at a lower cost but at the same time it also reduces the non contractible quality q. The next proposition illustrates how to solve this fundamental trade-off.

Proposition 1 (Relational procurement) *There exist a function $\overline{v}(N) \geq 0$ decreasing in N and converging to 0 so that the principal's optimal relational procurement is as follows:*

[15] With open competition, temporary exclusion or handicapping at the auction stage may cost less to the buyer, with the drawback of providing less incentives to the supplier. Since we are interested in the implementation of significant levels of non contractible quality we disregard this possibility.

- *When quality is not very important for the principal, i.e.* $v < \overline{v}(N)$*, open competition is optimal and contemplates a strictly positive quality equal to* $\{q_{FB}, q(N)\}$ *if and only if (4) is satisfied.*

- *When quality is important for the principal, i.e.* $v \geq \overline{v}(N)$*, restricted competition is optimal. If* $v < \overline{v}(N-1)$ *then excluding one supplier is enough, i.e.* $n^* = N-1$*, and* $q^* = \min\{q_{FB}, q(N-1)\}$*, otherwise for* $v \geq \overline{v}(N-1)$ *the optimal quality is* $q = q(n^*)$ *and the number of competing supplier is* $n^* = n(v) < N-1$ *with* $n(v)$ *weakly decreasing in* v*.*

When the value of quality is limited, i.e. $v < \overline{v}(N)$, then there is no reason to restrict competition which would be meaningful for the principal only to possibly increase quality. In this case, open competition is optimal. This procurement then delivers either a positive quality if it is incentive compatible (satisfying both and (4) and (1)), or the principal prefers to procure with maximal (open) competition but nil quality.

When instead quality matters, i.e. $v \geq \overline{v}(N)$, the suppliers in the pool of n actual competitors must be restricted otherwise the procured quality would be too downward distorted. Under restricted competition the relational contract always contemplates two types of distortions: screening efficiency is reduced ($n < N$) to provide incentives for the competing suppliers, and the principal optimally lowers the quality demanded to the supplier to limit the inefficiency in screening ($q(n) < q_{FB}$). How much the principal wants to restrict competition depends on the trade-off on n and the associated value for quality v. The larger is v the more this trade-off is resolved sacrificing competition to increase procured quality and this is why the optimal number of competing suppliers is overall decreasing in v.[16]

Notice that if the number of potential suppliers is very limited, i.e. N very small, then open competition may still be optimal even if the principal values quality (indeed the function $\overline{v}(N)$ is decreasing in N). This is because the procurement cost increase $\theta(N-1) - \theta(N)$ caused by excluding even just one supplier can be very large when N is small.[17]

[16] The principal may guarantee future rents and thus high quality, using a minimum price. However, a minimum price is suboptimal to guarantee future rents because inefficient firms may at times win, obtaining small rents and reducing procurement efficiency.

[17] When the buyer can use discretionary bonuses (Section 5), she can rely more on open competition because she controls quality with the threat of non paying bonuses. Interestingly we will show that bonuses cost nothing to the buyer because they are competed away at the auction stage, so that the buyer actually never disburses the amount.

At the cost of reducing suppliers' rent and the implementable quality, the principal may setup a relational contract with restricted competition similar to ours that always treats all suppliers equally, also upon a deviation of one of them. If the supplier cheats, the principal re-draws the n ($< N$) invited suppliers among the N available ones, with equal probability. The punishment of the deviator is still present since he risks not being part of the new pool, although it is less severe because with some probability he will still be part of it. Although we do not explicitly follow this possibility, we notice that when restricted competition is optimal to sustain a large quality, this policy calls for even smaller pool of n invited suppliers (the risk to be excluded for a cheating supplier increases with lower n).[18]

The proposition is reminiscent of the efficiency wage models and related applications to procurement (Shapiro and Stiglitz 1984, Kim 1998, Board 2011). However, it differs from them substantially as it also suggests that restricting competition –with the cost-efficiency loss it entails– is not always necessary to obtain (positive) non-contractible quality. This is indeed the case when the value of quality v for the principal is intermediate and the number of potentially competing suppliers N is also not too large (recall that the threshold $\overline{v}(N)$ decreases with N). As long as some discretion is present, involving the possibility to switch to restricted competition, positive levels of non contractible quality can be elicited with open competition, and when quality is not too important this may suffice.

Summarizing, due to incentive compatibility constraints, restricted competition is more likely to be optimal for the principal, the more valuable is non contractible quality (the higher v), the larger the number of potential suppliers (the larger N), the smaller cost heterogeneity across suppliers (hence, the informational rent $\pi(n)$); and the smaller the discount factor δ.

That open competition is used for standardized and easy to contract transactions (where v is nil or small), whilst restricted procedures or negotiations are used for core supplies and complex services is common practice in private procurement. Public procurement laws also *typically* admit restricted procedures and negotiations when the object of the transaction is complex or difficult to contract upon.

That a large number of suppliers in the market (N) and a decrease in their cost heterogeneity should ceteris paribus induce more use of restricted competition has strong cross-industry implications. The conclusion appears also to be consistent with what has been observed in the last

[18]This policy would respect non discriminatory regulations present in some countries, such as the EU. Other mechanisms, such as handicapping the deviating supplier would not.

decades with IT procurement practices. Globalization involved a drastic fall of trade barriers and increased the number (N) of suppliers around the world that each buyer could access. At the same time, the increase of competition also associated with globalization drove out of business the most inefficient suppliers, containing or even reducing market heterogeneity in terms of cost. In the light of our previous results it easier to understand why many buyers reacted to this process by restricting attention to smaller networks of regular suppliers (see for example Bakos and Brynjolfsson, 1993).

The last comparative statics on δ can be interpreted in terms of contract duration and implied frequency of interaction.[19] A more intense use of restricted competition should be observed in environments where the average (explicit) contract duration is long, implying a low frequency of interaction between buyer and sellers (when the unitary time interval is long, frequency of interaction is low making the discount factor δ small).

4 Optimal procurement with collusion "risk"

When a group of suppliers repeatedly interact, as in teams of an organization or in procurement relationships, there is the risk that they end up colluding against the principal. As illustrated in the Introduction, far from being just a possibility we acknowledge hundreds of reported cartels and probably much more unreported ones.

Proposition 1 shows that where quality is important for the principal (i.e. $v \geq \overline{v}(N)$), limited enforcement may require reducing the number n of suppliers competing and this is more so the higher is v (i.e. $n(v)$ is decreasing in n). However, it is well known that repeated interaction between a restricted number of long-lived suppliers tends to foster collusion among them (as well as increasing the frequency of interaction which here can be interpreted with an "endogenous" reduction of δ). This means that a principal relying on restricted competition to control non-contractible quality may risk inducing suppliers to collude. We investigate this possibility and assume in this section that open competition is dominated, i.e. $v \geq \overline{v}(N)$.

We consider the possibility of suppliers's collusion in the simplest way and assume that when a cartel forms, the most efficient supplier is awarded the contract each period at the reservation price r and all the others in the pool of n invited suppliers either refrain from bidding or submit

[19] In Calzolari and Spagnolo (2009) we explicitely considered contract duration and showed that there are complementarities between shortening existing contract duration and reducing the number of invited agents.

losing bids; that is, collusion takes the form of a "stochastic" bid rotation driven by the efficiency cost parameters θ.[20]

Enforcement and Collusion: a trade-off. Let $\tilde{\pi}(n)$ denote supplier i's expected rent when a cartel among the n suppliers is in place, he is the most efficient cartel member and chooses not to deviate, i.e. $\tilde{\pi}(n) = r - \theta'(n)$. For collusion to be sustainable at any auction, the second most efficient supplier (i.e. the one with the greatest incentive to deviate) must not prefer to undercut the most efficient one. If this supplier does not deviate, he can expect the future collusive profits. Otherwise, by deviating he gets an immediate gain that we indicate with $D(n) \geq 0$ (which may depend on n as discussed below) but then collusion breaks down and all suppliers will compete from then on. This deviation is dominated if the following holds,

$$\beta(n)\tilde{\pi}(n)\frac{\delta}{1-\delta} \geq D(n) + \beta(n)\pi(n)\frac{\delta}{1-\delta}.$$

Clearly, an supplier who deviates from the collusive agreement may also consider the possibility of cheating with a nil quality instead of the requested quality q. Such a deviation is dominated if

$$\beta(n)\tilde{\pi}(n)\frac{\delta}{1-\delta} \geq \psi(q). \tag{5}$$

Hence, collusion is viable if the following incentive compatibility constraint is verified,

$$\beta(n)\tilde{\pi}(n)\frac{\delta}{1-\delta} \geq D(n) + \max\{\beta(n)\pi(n)\frac{\delta}{1-\delta}, \psi(q)\}. \tag{6}$$

What is the effect of a smaller number n of suppliers in the pool on cartel stability? First note that, for a given collusive bid, a smaller n reduces $D(n)$, since the second most efficient supplier (the one with the strongest temptation to deviate) becomes on average less efficient and his gains from deviation are thus smaller. Second, although both the l.h.s. and the second term in the r.h.s. of (6) decrease with n, the first falls more than the second. This is immediate if the deviating supplier also cheats on quality (i.e. when the max in r.h.s. of (6) is $\psi(q)$ which does not depend on n). When this is not the case, the cartel stability condition (6) becomes instead

$$\beta(n)[\tilde{\pi}(n) - \pi(n)]\frac{\delta}{1-\delta} \geq D(n),$$

[20] We do not consider partial collusion involving fewer than n agents. To simplify exposition, we also assume the cartel can implement high winning price for any realization of costs. Alternatively, for a sufficiently low realization of costs, the cartel may contemplate temporary reversion to competitive bids (as in Rotemberg and Saloner, 1986). This possibility would not qualitatively alter our results.

where the left hand side increases in n. In fact, a smaller size n of the pool of competing suppliers increases both the probability for each of them of being the most efficient $\beta(n)$ and also the difference $\tilde{\pi}(n) - \pi(n)$ (which is in fact equal to $r - \theta(n)$). This reasoning immediately leads to the following.

Proposition 2 (Enforcement vs. collusion) *There is a trade-off between enforcement and collusion: setting n lower in order to increase non contractible quality q (and/or increasing frequency of interactions), the principal may facilitate collusion among suppliers.*

This is a quite general trade-off that is clearly relevant in many other frameworks that share the ingredients of potential competition among suppliers and the need to give them the incentives to perform non-contractible tasks.

The trade-off is general also because it evidently applies to other factors that tend to facilitate cooperation besides the number of suppliers. For example, a shorter contractual duration facilitates the enforcement of quality by increasing the frequency of interaction (hence the speed with which a non-performing supplier can be punished), but it also facilitate collusion between suppliers (by increasing the speed with which a defection from a cartel agreement can be met by a punishment from competitors).

Optimal relational contracts with collusion. How does the principal address this trade-off between enforcing non-contractible quality and supplier collusion? The following Lemma provides a first important result.

Lemma 3 (Quality with collusion) *Any level of non contractible quality q that is enforceable with competing suppliers, is enforceable with colluding suppliers as well.*

This is a simple consequence of the fact that stability of collusion (i.e. constraint (6)) implies that the expected (present value of) profits with collusion is greater than with competition. Quality q is enforceable with collusion if $\beta(n)\tilde{\pi}(n)\frac{\delta}{1-\delta} \geq \psi(q)$. This condition is implied by q being enforceable with competition, i.e. $\beta(n)\pi(n)\frac{\delta}{1-\delta} \geq \psi(q)$, because a necessary condition for collusion to be viable is $\tilde{\pi}(n) \geq \pi(n)$. Hence, any supplier when deciding whether or not to deliver q knows that the cost of cheating on quality is greater than under competition, because the profits at stake are larger.

We can now state the following.

Proposition 3 (Optimality of collusion) *When quality is sufficiently important for the principal, optimal procurement involves "few" colluding suppliers or negotiation.*

When quality is important to the principal, limiting competition may become desirable above and beyond the principles of Proposition 1. Not only may the principal optimally want to restrict the number of competing suppliers: he can improve quality further by inducing suppliers to cooperate in consortia or cartels, because with collusion the suppliers' expected profits increase, which ultimately makes better quality attainable.[21]

Clearly, if the principal can restrict competition to the case of single-party negotiation, and this is optimal (i.e. $n^* = n(v) = 1$, see Proposition 1 and the program for negotiation (14) in the Appendix), the distinction between competition and collusion vanishes. Actually, the principal may be able to obtain even larger quality simply negotiating with a single supplier. However, we know that there are cases in which a principal cannot restrict attention to a single supplier (this is often the case in public procurement).[22] In these cases where quality is important enough, inducing suppliers to collude turns out to be the optimal way to procure.

There are other factors that may make procurement with colluding suppliers the best way to procure when quality matters. Although not explicitly accounted in the model, the principal may have a general concern for efficiency in production (it is often the case in public procurement). Since negotiating with a single supplier delivers the lowest possible (expected) efficiency, the case in favor of colluding suppliers is further strengthened.[23]

Alternatively, the supplier may be subject to unexpected inability to deliver during the period, a fact that exposes the principal to the risk of (possibly costly) unplanned halt in procurement, whenever she negotiates with a single supplier. To reduce or eliminate this risk the principal can assure supply by relying on second-sourcing. Assume that the adverse event (is observable and) takes place with some probability α, in which case the unique supplier would be (completely) unable to procure. Facing this risk of no procurement—the costs of which is at least v_0—the principal may allocate two contracts. The first-source contract is as in the previous analysis and contemplates the possibility that, with probability α, the supplier cannot procure. The second-

[21] We take the view according to which collusion takes place whenever it is viable.

[22] In most countries' small-scale public procurement and that of international organizations like the United Nations, accountability rules require getting competitive offers from some minimum number of potential suppliers.

[23] This effect in favor of collusion naturally emerges in the case of procurement with ex ante and ex post transfers of the next Section 5.

source contract is only executed with probability $1-\alpha$, when the first supplier cannot procure. Since the principal will never allocate the two contracts to the same supplier (to avoid exposing herself again to the risk of no procurement), dual-sourcing corresponds to a multi-unit auction where suppliers are not allowed to win both contracts.[24] The cost of second-sourcing for the principal is that the winning bids tend to be higher (because of the multi-units). On the other hand, second-sourcing guarantees procurement even in the case the adverse event realizes, which would not be the case with negotiation. When the cost of no procurement is large enough, and quality matters, optimal procurement involves colluding suppliers.

It is important to reiterate that, as stated in the Introduction, what we here call "collusion" can be also taken to stand as any cooperative and self-sustaining agreement among suppliers such consortia and other forms of joint bidding like joint ventures. In this case, the principal de facto deals with a single consortium whose stability is guaranteed by the incentive compatibility constraint (6), regardless of any legal obligation among agreeing supplier. Notice that the fact that the consortium is stable is important here because, the consortium itself relies on non contractible dimensions that cannot be dealt with explicit contracting. Our analysis illustrates some benefits of consortia and joint bidding among otherwise rival suppliers (in terms of enforceable quality), but also their possible limitations by accounting explicitly for the requirement that they be self-enforcing. In cases in which consortia are barred by law, inducing suppliers to collude implicitly is indeed a way to go around the prohibition and recover the benefits of supplier cooperation and higher quality. In other cases, consortia are admissible and do not need to be self-enforcing (in that they are governed by explicit contracts). If this is the case and collusion among suppliers is optimal in terms of our previous analysis, a consortium is then better still, since it guarantees higher rents to the firms and equal efficiency with collusion.[25]

5 Procurement with ex-ante and discretionary transfers

So far we have assumed that the only admissible transfer is that governed by the (explicit) contract attributed with the auctions, i.e. the payment to the winning bidder. This is a framework

[24] With at least three competing suppliers, the buyer's selection mechanism can be a uniform-price auction which is efficient in this environment and involves truthful bidding.

[25] Of course, when negotiations with a single agent and consortia are forbidden for a good reason, for example maintaining accountability and avoiding corruption, a buyer inducing collusion between suppliers may harm society on that ground even if quality is extremely valuable to her.

typical of public procurement and large bureaucratic organizations, where accountability reasons tend to restrict the type of admissible transfers –particularly discretional ones like bonuses and bonds conditional on non contractible performance–. In private procurement and employment relationships, instead, these restrictions are often less relevant. Here we investigate if and how enriching the set of transfers affects our previous results. We initially disregard the possibility that suppliers collude.

With respect to a date t, transfers can be paid *ex-ante* (before suppliers learn their cost and bid), *interim* (such as the payment to the auction winner), and *ex-post* (after delivery of procured goods or services). An *ex-ante transfer* $w \in \Re$ could be seen as a fee $w > 0$ for participating the selection process or a fixed wage $w < 0$ to compensate suppliers for being available to the principal. At the end of a contract, the principal and the supplying supplier may also exchange an *ex-post transfer* $B \in \Re$ which can be a bonus $B > 0$ that the principal may discretionary pay or a performance bond $B < 0$ posted by the supplier at the beginning of the contract that the principal may decide discretionally not to return.[26]

The principal can now manage suppliers' rents in two different ways: (i) with participation through a transfer w paid to all suppliers invited in the pool of n competitors and (ii) with the auctions and the associated informational rent $\pi(n)$. In addition, to enforce non-contractible quality the principal can now condition the ex-post discretionary transfer B on performance. The possibility to rely on competing suppliers brings about some interesting features of ex-ante and ex-post transfers in relational contracting that significantly stand out with respect to the case of a single available supplier i.e. $N = 1$ analyzed in the literature.

Several papers have illustrated the desirability of discretionary ex-post payments as disciplining device when a single supplier is available (e.g. MacLeod and Malcomson, 1989 and Baker et al., 1994). Interestingly, with competition any bonus is "competed out" at the auction stage even if it is paid ex-post. Any ex-post transfer (discretionary or not) that the principal announces to pay to the winner after the auction, induce suppliers to reduce their bid by an amount exactly equal to that transfer, and the winning bid becomes

$$b' = \theta(n) + \psi(q) - B.$$

In the end, the principal does not pay B and the bonus *de facto* becomes a bond in the hands of the

[26] Bonuses and bonds exchanged between the principal and an agent that is not the current supplier are irrelevant in the present environment.

buyer which the latter can decide to withhold discretionally. Bonuses/bonds become an effective and inexpensive out-of-equilibrium threat to the current supplier, when suppliers compete. This is not the case, of course, for ex-ante transfers w. Although they cannot be used as threat, they allow the principal to discipline suppliers by increasing their expected rents that are now $w+\beta(n)\pi(n)$. Suppliers' incentive compatibility constraint with these transfers then becomes

$$[w+\beta(n)\pi(n)]\,\frac{\delta}{1-\delta}\geq\psi(q)-B. \tag{7}$$

Ex-ante and ex-post transfers have however drawbacks with competing suppliers and limits. The ex-ante transfer w is expensive for the principal (when positive) since she must pay it to all the n suppliers in the pool of competitors, with a cost $n\times w$. This implies that the principal will set these transfers at its minimum and the suppliers' incentive compatibility constraint (7) is optimally set as an equality (similarly, when $w<0$, a participation fee, the principal wants w as large as possible, in absolute value, so that (7) binds).

Ex-post discretionary payments cannot be used instead with restricted competition. Since procured quality is observable in the principal-supplier dyad only, when $n<N$ the principal can renege on a bonus claiming the supplier under-performed and replace him at no cost with another supplier among those $N-n$ outside the pool.[27] When the principal chooses to procure with open competition, i.e. $n=N$, a discretionary payment conditional on quality may become credible. By reneging the bonus the principal will face the cost of contracting with fewer $N-1$ suppliers in the future. Formally, for a bonus of size B to be credible, it must be that it is lower in size than the reduction of procurement value to the principal if he decides to renege the bonus, i.e.

$$[V(n,q)-\underline{V}]\,\delta\geq B, \tag{8}$$

where

$$V(n,q)=[s(q)-\theta\,(n)-wn]\frac{1}{1-\delta}$$

and $\underline{V}$ is his continuation payoff when the current supplier cannot be employed anymore because the principal has reneged the bonus. Clearly, when $n<N$ we have $\underline{V}=V(n,q)$ and no strictly positive bonus is credible. When instead $n=N$ then the l.h.s. of (8) is positive and represents the upper-bound for a credible bonus. Furthermore, since a bonus is never actually paid with

[27] This observation is related to efficiency-wage equilibria in the labor market where workers (in our model, agents) on the "long side" and firms (in our model, the principal) are on the "short side" of the market (see for example MacLeod and Malcomson, 1998). In these cases too, bonuses are not credible.

competing suppliers, with open competition the principal will use it to directly control quality, i.e. optimally setting $B = \psi(q)$.

We can then state the following.

Proposition 4 (Procuring with ex-ante and ex-post transfers) *When ex-ante and ex-post transfers are available relational contracting is such that,*

- ***with open competition:*** $B^* = \psi(q^*)$, $q^* = q^{FB}$ *if* N *is small, otherwise* q^* *is bounded from above by*

$$\psi^{-1}\left[\left[\theta'(N-1) - \theta'(N)\right]\frac{\delta}{1-\delta}\right] > q^*, \tag{9}$$

and $w^* < 0$ *(a "participation fee").*

- ***with restricted competition:*** $B^* = 0$, n^* *and* q^* *maximize*

$$[s(q) - \theta'(n)]\frac{1}{1-\delta} - \frac{n}{\delta}\psi(q) \tag{10}$$

The optimal transfer w^* *may be negative ("participation fee") for relatively low* v *or positive ("availability wage") for large* v*.*

As with interim transfers only (Section 3), open competition turns out to be optimal and fully efficient when the number of competing suppliers N is relatively small. It is also interesting to notice that in this case any supplier in the pool of competitors must pay a participation fee $w^* < 0$. This is the case because suppliers' incentives (7) are entirely governed by the bonus (the principal optimally setting $B^* = \psi(q^*)$) so that quality is at its first-best level, and ex-ante transfer w allows to extract suppliers' expected informational rents.

However, if N is large, relying on open competition requires a reduction in quality which is now dictated by the principal's incentive compatibility constraint (8) where $B^* = \psi(q^*)$. This drop in quality can be substantial because the difference of expected procurement costs $\theta'(N-1) - \theta'(N)$ in (9) (which is a re-writing of (8)) tends to zero for N large. Restricting competition then becomes preferable.

With restricted competition, however, a bonus is not credible and n and q are determined maximizing (10) where the term $-n\psi(q)/\delta$ is the rent that the buyer must pay to all competing suppliers. When quality is very valuable and large, the r.h.s. in (7) is large as well and the principal sets a positive w^*, as with an employment contract between the principal and the n competing suppliers.

5.1 Collusion "risk"

Can collusion be optimal as illustrated in Section 4 even if the principal uses ex-ante and ex-post transfers?

As shown above, with an optimal bonus $B = \psi(q)$ the principal fully controls supplier's incentives. Since the benefit of colluding suppliers is the higher rents they can obtain and the associated larger implementable quality, with collusion the principal would only induce higher procurement costs with no effect on implementable quality. Procuring with colluding suppliers is thus not a good idea when the principal uses bonuses.

However, we already know that when the value of quality is large for the principal, she tends to restrict competition and we also know that collusion, if desirable, it is so because of the larger quality. Hence, it is natural to investigate collusions with restricted competition, in which case the bonus must be nil and different effects kick-in.

Proposition 5 *If the buyer can use ex-ante transfers and provided that the principal wants to implement significantly large quality, procurement with colluding suppliers can be optimal and strictly better than negotiation.*

The detailed analysis is in the Appendix. Here it suffices to notice a few facts.

First, collusion grants higher rents to the suppliers which allows the principal to implement higher quality, independently of the type of available transfers. Hence, for the same reason discussed with interim transfers only, if the principal very much cares for quality, collusion is preferable to competition.

Second, and differently from the case of interim transfers only, collusion may now dominate negotiation. The reason is that with ex-ante transfers the principal now appropriates the suppliers' surplus and internalizes the actual cost of production. Since negotiation is associated with the highest expected cost, collusion may be preferable because it grants high quality with relatively low cost of production.

Finally, as discussed in Section 4, procurement with collusion may be best for the principal also because it limits the risk of ending up with a single supplier who is unable to procure in the current period.

6 Multilateral contracting

As in MacLeod and Malcomson (1998), we have assumed that when a deviation occurs, either by the principal (reneging on B) or by a supplier (not providing the agreed upon level of q), none of the other players learns the identity of the deviator. This assumption is consistent with q being non-contractible, in the usual sense of being only observable by the two parties involved in the specific relationship, but not by third parties (such as other suppliers or a court), as otherwise these third parties could help enforce an explicit contract on q.

However, when discretional monetary payments are allowed, as typical for private sector procurement, other assumptions are of interest. An alternative assumption we consider here is that, although courts are not able to observe q, other suppliers who participated in the auction can. This means extending our analysis to multilateral (and interdependent) relational contracts, as analyzed in Levin (2002). We are also interested to see how the possibility that suppliers collude affect the differences between bilateral and multilateral contracting.

In an employment environment suppliers work simultaneously and possibly in team, as in Levin (2002). They can observe pretty well each other's behavior and can condition their strategies on the choices of the principal and of other suppliers, thus relying on multilateral relational contracting. Procurement or consulting is different since suppliers rarely work simultaneously, rather supplying in turn and sequentially. The possibility to observe other suppliers' behavior in past periods is thus limited, unless the principal plays an active role in inducing information sharing. To explore this possibility we now assume that, at some cost and irreversibly, the principal can form and maintain information sharing among suppliers so that the quality effectively procured by each supplier becomes common knowledge among all the n suppliers (and the principal).[28] This assumption squares well, for example, with Toyota's choice to invest considerable resources to create and maintain an organized supplier network, the BAMA as discussed in the Introduction, to facilitate information sharing with and among suppliers.[29]

Consider first the simpler case of *open competition* with $n = N$. Information sharing and

[28] For simplicity we assume that the cost of sharing information is a one-off set up cost, and consider how our game is affected after this cost is undertaken (being sunk, the cost itself will not affect the continuation game) The possibility to endogenously affect observability in relational contracts has been recently explored by Kvaloy and Olsen (2009).

[29] This network is considered an important tool to maintain the high level of coordination essential to the Just-In-Time production system, to elicit innovative ideas and to manage changes (Milgrom Roberts, 1993).

multilateral contracting only affect suppliers' out of equilibrium behavior: a multilateral relational contract C^N_{mult} now prescribes that all the N suppliers start punishing the principal as soon as he deviates against any of them. The coordinated punishment substantially reduces the continuation payoff of the principal after his deviation. As a consequence the upper-limit for an implementable bonus B can be increased (see (8)) and a higher level of q can be sustained.

Lemma 4 *With open competition and discretionary transfers, multilateral relational contracting increases the level of implementable quality with respect to bilateral contracting.*

Note that the principal's benefit from introducing multilateral contracting and obtaining higher quality are in principle larger in our sequential supply environment than in a simultaneous employment context as in Levin (2002). The reason is that when all suppliers act simultaneously, bonuses to all suppliers are paid at the same time each period and the tougher punishment phase induced by a multilateral contracting is partly offset by the principal's ability to (optimally) deviate simultaneously, reneging on *all* suppliers' bonuses at once.[30] In our set up, instead, supply is sequential, so that while the multilateral contract strengthens the punishment phase for a deviating principal, with open competition it does not affect the principal's maximal gains from an optimal deviation in any way.

When the principal relies on *restricted competition*, the effect of multilateral relational contracting is less immediate. The principal may find it impossible to costlessly replace a supplier after reneging the bonus, as other suppliers observe her deviation, and this may make bonuses credible also with restricted competition. However, one should check whether such punishment strategies are robust to replacement of all the suppliers in the pool (or a subset of them) with outsiders, which may in turn depend on the number of outsiders $N - n$ and on their beliefs. To restrict the number of possibilities to consider, we assume that as long as one insider remains in the pool after a first deviation by the principal, information concerning the principal's deviation will be shared and the new suppliers will continue punishing the principal.

When $N - n$ is large, i.e. larger than n, a principal who reneges on the promised B thus prefers to replace the n suppliers with a new pool of outsiders. The possibility to replace all the n

[30] This is similar to collusion with multimarket contact. The net gain from multilateral contracting emerges from smoothing asymmetries, i.e. from pooling the incentive constraints of the different bilateral relations into a single joint constraint that optimally reallocates scarce enforcement power across them. In a simultaneous environment gains from a multilateral contract may also come from payoff interdependence, for example generated by technological externalities (Levin 2002, Spagnolo 1999), which are less relevant in our sequential supply environment.

suppliers with outsiders (or with a subset of them) after reneging on the bonus makes the bonus not credible, as with bilateral contracting.

When instead $N-n$ is small, i.e. smaller than n, after a deviation the principal will replace the n suppliers with those in the smaller pool composed by all $N-n$ outsiders. The principal is then able to credibly commit to pay the bonus because the reduction of procuring suppliers from n to $N-n$ is now costly for the principal. This is in fact the same mechanism at play with bilateral contracting and open competition, with the difference that here the reduction in the available suppliers is not of just one of them but it is of the same size n of the pool. However, if the principal finds it optimal to pay a bonus, in principle now possible with restricted competition as well, then restricted competition is suboptimal. To see this notice that the cost for the principal of reneging the bonus is increasing in n (because fewer $N-n$ suppliers would be left available for future procurement) which implies that a larger bonus can be implemented with a larger n. Moreover, as we have shown with bilateral contracting, when the bonus is credible the principal optimally sets $B=\psi(q)$ so that the supplier's incentives are managed and completely guaranteed by the bonus.

We can thus conclude the following.

Proposition 6 (Multilateral contracting) *With multilateral contracting the scope for open competition (i.e. $n=N$) is strengthened with respect to bilateral contracting. Multilateral contracting is of no value for a principal who procures with restricted competition.*

Interestingly, the previous results holds independently of the particular beliefs assigned to outsiders. We have so far implicitly assumed that outsiders have "passive beliefs". Alternatively, when outsiders observe a principal replacing all his n suppliers at once, they may believe that the principal is trying to escape a multilateral punishment for a deviation and cannot be trusted in the future. Under this alternative assumption the principal's continuation payoff after a deviation is further reduced by having multilateral contracting. Therefore, an even larger bonus and implementable quality become available with open competition.

It should be also kept in mind that inducing suppliers to share information (so that multilateral contracting becomes viable) may be costly (as it is the Toyota's supplier network example). The principal may thus prefer to rely on bilateral contracting, investigated so far, whenever the cost of maintaining a network of well informed suppliers becomes prohibitive.

Finally, an information-sharing device that helps suppliers cooperate in punishing a principal's deviation will typically also help suppliers cooperate against the principal, i.e. to collude, when there was no deviation. Although multilateral contracting has an impact insofar the buyer procures with open competition and the bonus, conditions that may make collusion less desirable, it makes collusion even more stable.

7 Discussion

Over the last couple of years, competition authorities from 15 separate jurisdictions including Europe, the US, and Asia have undertaken over 30 investigations into anticompetitive conduct in the automotive parts sector. The United States Department of Justice (DoJ) has described its investigation into price-fixing in the automotive products industry as "the largest criminal investigation the Antitrust Division has ever pursued," both in terms of its scope and the potential volume of commerce affected by the alleged illegal conduct (Goldfein and Keyte, 2014). Apparently, it all started in February 2010, when Sumitomo, a Japanese supplier producing wire harnesses applied for a marker under the Notice on immunity from fines and reduction of fines in cartel cases, so called Leniency Note. According to Brent Snyder, who heads its criminal-enforcement efforts at the Department of Justice, the DoJ began raiding the companies in 2010 following he leniency application. Companies used code names, met in remote locations to fix the prices of starter motors, seat belts, radiators and more, and followed up with each other "to make sure the collusive agreements were being adhered to," the DoJ alleges. Twenty-six firms, many of them Japanese, have already pleaded guilty and agreed to $2 billion in fines. In 2014 two dozen people had been charged, and much more is under way. At the time, cases brought involved about 30 parts, but the DoJ believes the prices of 100-150 may have been manipulated.

The focus of the investigations has mainly been on Japanese automakers and suppliers, and many casual observers seem to understand that in Japan there is a prevalent cultural history and business tradition of making business in ways that may be conducive to collusion. Cartels are estimated to have started at the beginning of 2000, and to have lasted periods ranging from 5 to 14 years.

The auto parts cartels present some puzzling features if compared to the other cartel stories. A first puzzling aspect is that automakers are very large, few in number, traditionally tough, sophisticated, and very well informed buyers, all conditions that make life very hard for secret

cartels among suppliers and a long duration of such cartels very unlikely. The second is that these cartels seem to have had unusually long duration. A third puzzling feature is that many of the suppliers at the core of these cartels were nearly controlled by their buyers, and in particular by Toyota. A fourth puzzling feature is that there seem to be no sign of these cartels harming performance of Japanese automakers. To check for this, we downloaded all the decisions available from the homepage of the Antitrust Division of the Department of Justice relative to 21 auto part suppliers. It is interesting to note that all the 21 firms happened to be regular suppliers of Toyota. Only 12 of them have been suppliers for Honda and Nissan, 6 have been suppliers for Ford, and only 1 of them seem to have been suppliers for most other auto manufacturers. Figures 1 plots the profitability of large car manufacturers, including Toyota. During the alleged cart part cartels have been active, Toyota seem to have had the best performance of the market. This suggests that these cartels did not significantly hinder the appeal of Toyota cars to consumers and its profitability, although we do not have the counterfactual of what would have happened in the absence of such cartels. A fifth puzzling observation is that among car manufacturers, only Ford sued some of the convicted suppliers for damages.

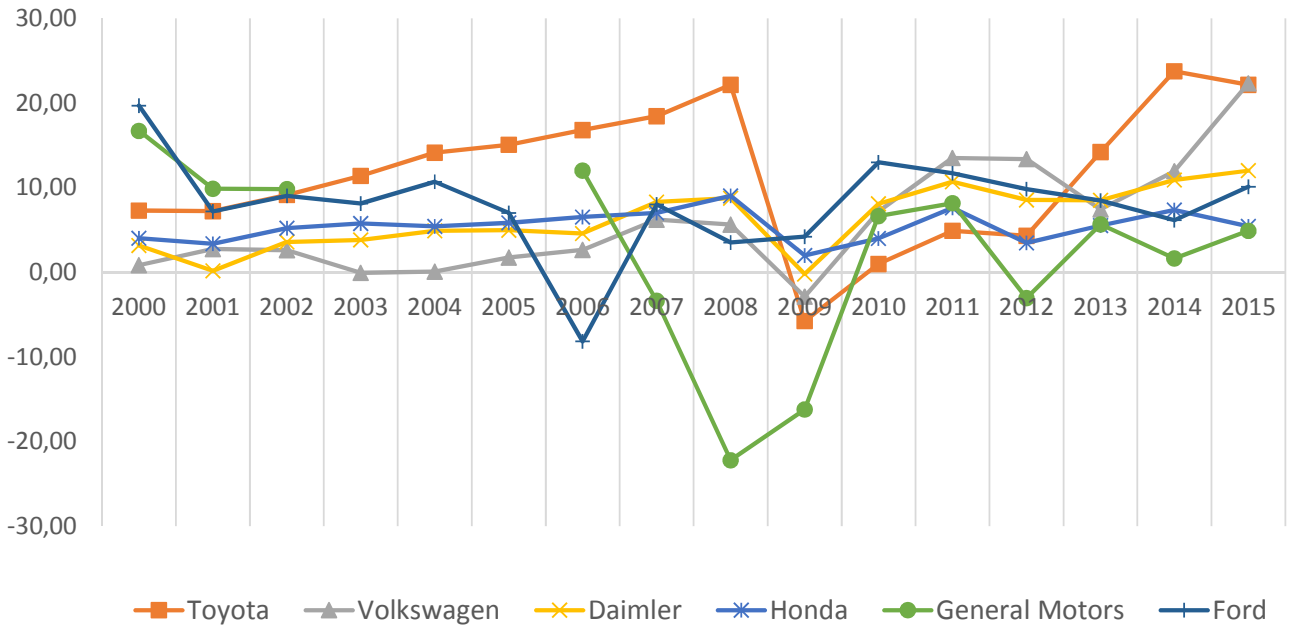


Figure 1: Operating income of large automakers (Billions of $)

In light of these puzzles, inevitable questions emerge. Were these cartels really harming automakers? Were they harming consumers? Were automakers really unaware of these concerted practices? Or were they part of the "managed competition" style of the "Toyota-way", that inspired the huge management literature (and consulting cottage industry) on "lean production"? Our model and results seem to suggest consistent answers to all these questions. Propositions 2-5 suggest that indeed these collusive practices were likely to be known, tolerated, and even encouraged by Toyota as instrument to ensure quality of car parts supply. They also suggest that these vertical arrangements, while certainly exclusionary for outsider (e.g. US) car part producers, may have benefitted consumers, who have continued to favor the high quality Toyota cars.

Although it is difficult to imagine a horizontal agreement larger and broader in scope than the one on car parts, it is certainly not the unique case where cartels were following up an attempt by buyers to stop a competitive race to the bottom on non-contractible dimensions. For example, in the UK Steel Tank Cartel case the cartel initiated after competitors were asked to meet up by buyers' industry body to discuss minimum safety standards following many complaint and a period of price wars (Stephan, 2016). The defendants have been arguing forcefully that the main raison d'être of the cartel was safeguarding safety standards upon request from the buyers. In Holland, there is currently a heated policy debate on the need to introduce minimum prices at industry association level and forbid price competition below that level, to allow the ministry of agriculture to enforce environmentally sustainable quality standards on food production.[31]

More broadly, our results should be taken into account in the current debate on exceptions from antitrust enforcement against horizontal agreements. This is not the only case where limits to competition in the intermediate markets are adopted to improve the final product. Vertical integration is an extreme, contractual version of this practice, and it may improve final output when crucial non-contractible dimensions are hard to govern (e.g. Economides 1999).

Interestingly, our results and the above discussion also help clarify part of the disagreement between the US and Japanese authorities during the sometimes heated debate on the US-Japan trade imbalance in the 80s and 90s (see Cooper, 2014, for a retrospective). The large and growing

[31]The Duch Competition Authority has been itself supporting these arguments and in 2014, the Dutch Ministry of Economic Affairs issued a policy rule that: "In the application of Article 6(3) of the competition law [the Dutch equivalent of Article 101(3) TFEU] the ACM considers in its assessment of the conditions whether [. . .] in agreements that restrict competition made in order to enhance sustainability, a fair share of the improvements benefits "users" in the long run." Netherlands Minister of Economic Affairs (2014), Article 2.

trade deficit of the US toward Japan in many industries, and in particular in the automobiles and car parts industries, translated in forceful political pressure from the US, up to threatening defence agreements, and led Japan to remove most of the state-sponsored formal and informal trade barriers that appear to have protected Japanese markets. Our model clarifies how long term relational contracts with few and regular trusted suppliers had an exclusionary effects on potential entrants, even after Japan's trade barriers were lifted. Collusion among suppliers, likely to be present already at that time according to our Propositions 2-4, could only reinforce this exclusionary effect. In some documents circulating at the time, the fact that supply relations in Keiretsus like Toyota were dominated by cartels among suppliers was almost given for granted (e.g. Morita 1993). The pressure from the US was then directed also to increase the independence and activity of the Japanese Competition Authority, seen as strongly subject to the influence of the MITI and of the government, in turn influenced by the big Keiretsus. The Authority had the power to exempt horizontal agreements from antitrust prosecution and used that power generously with Keiretsus like Toyota, under the political pressure of the government. With this respect, the surprise of several observers when the auto parts cartel investigation finally started in 2010 is puzzling and confirms the need of more research on the interaction between managerial practices, competition policy and international trade, in the spirit of the pioneering work of Antras and Helpman (2004).

Our results and the above discussion shed light on several recent issues in public procurement as well. In Europe, where concerns for openness and European market integration led legislators to restrict as much as possible the use of flexible procedures in favor of open auctions, there has been a hot debate with many calling for the use of simpler procedures, like restricted auctions, that allow to take past performance into account and to build relationships. Recent evidence shows that the ability to use restricted auctions with invited bidders is often associated with better performance (See e.g. Coviello et al. forthcoming and Chever et al. 2013). In the US, the reforms started under Kelman and the 1994 Procurement Streamlining Act has led to an increase use of flexible procedures with limited competition, and a smaller reliance on open auctions, leaving some observers concerned about their abuse (Yukins, 2008). The only study we are aware of about US data are Gil and Marion (2011) and Kang and Miller (2016) who point at positive effects of relationships and restricting competition. Of course, the discretion linked to procedures with restricted participation can be abused and used for relational contracts whose object are bribes rather than quality. As mentioned in the introduction, in Japan for many years public buyers

have been centrally organizing cartels among potential suppliers, a practice called *Kansei-Dango* (Hayashi, 2016). This practice has been tolerated by Japanese public procurement regulators and antitrust authorities, even though it was known to come often along with bribes and related corrupt practices, because it was explicitly considered the way to enforce quality of public procurement, much like suggested by our Proposition 3.

8 Conclusion

We have shown how a principal optimally procures non contractible quality in a recurrent environment when several suppliers are available. Optimal procurement requires restricting competition to a smaller set of suppliers when the principal has a strong preference for quality and open competition among all available suppliers otherwise. This pattern applies, with some qualifications, when the principal can or cannot employ ex-ante and ex-post transfers with the suppliers. Restricting competition (as well as reducing the length of the contracts) exposes the principal to the risk of collusion. We show that, unexpectedly, collusion may well be desirable for the principal under some conditions and in particular when quality matters or the principal wants to avoid the risk of interruption of procurement. Keeping the suppliers well informed, as it happens with a cohesive network of suppliers and multilateral contracting, may be desirable particularly with restricted competition.

Although we assumed fully informed suppliers, the drivers of our results also hold qualitatively in a more complex environment with privately-informed suppliers. The analysis of competing suppliers can be extended to asymmetric information almost without modification (applying the revenue equivalence theorem all standard auction formats would remain equivalent for the principal). With colluding suppliers, significant complexities emerge, as discussed in the literature on collusion with repeated auctions (see Skrzypacz and Hopenhayn 2004 and Blume and Heidhues 2006). As the cartel members are privately-informed, the efficiency properties of the cartel would be weakened. However, what matters for our results on collusion is the fact that the latter is incentive-compatible. Since this necessarily implies that (equilibrium) expected profits with collusion are greater than with competition, ultimately, enforceable performance is higher than with competing suppliers. Furthermore, the comparison between procuring with colluding suppliers and negotiations is also qualitatively unaffected. On average, the supplier selected out of the many (colluding) suppliers is more efficient than the single supplier with negotiation.

In our analysis we followed Levin (2003) and other previous work on relational contracts with asymmetric information in assuming that suppliers' efficiency is IID. This is a simplification and an interesting avenue for future research is introducing cost persistency. In this case, the principal would learn from auctions and the cost of dismissing a cheating but efficient supplier would be higher than in our environment. Setting aside the complications of such a model, in this case exclusion could be less of a deterrent for efficient suppliers suggesting an intrinsic trade-off between efficiency and performance. On one hand, less efficient suppliers would be aware that they can be readily discarded and replaced and this provides the right incentives. On the other hand, more efficient suppliers know that the principal would be reluctant to discard them and so will be less disciplined in providing high non-contractible performance. We leave this novel and interesting trade-off (that requires considering non-stationary relational contracts) for future work.

Recent theoretical papers on relational contracts with subjective performance measures (Levin 2003, MacLeod 2003 and Fuchs 2007) emphasized that the realized performance observed by the principal may be subject to noise, so that the principal and the supplier have private information on what they observe. A common theme in this environment is that in order to induce the principal to report perceived performance truthfully, the optimal contract must make the principal indifferent between reporting different performance levels. In relationships with a single supplier, this tends to induce inefficiencies and the optimal relational contract requires "money burning" which is used by the principal to penalize a non performing supplier without gaining anything itself. Interestingly, with multiple suppliers, as in our environment, when restricted competition emerges the principal can punish a non performing supplier by replacing and, what is more, with no direct gain (because suppliers are all ex-ante equal and the gain goes instead to another supplier). This maintains incentives for truthful performance reporting on the side of the principal and we expect that had we assumed a subjective performance assessment, we would have found analogous results in the cases of restricted competition.[32] We leave the analysis of procurement with competing suppliers and subjective evaluation for future work.

[32] See Malcomson (1984) and Fuchs (2007, online appendix) for related points developed in somewhat different environments.

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Appendix

Proof of Lemma 1. Sufficiency. Consider first the case with $n < N$ and an auction taking place at t. The relational contract C^n described in the text before the Lemma guarantees sufficiency. In fact, if any supplier prefers to bid and deliver q if it wins, he will prefer to do so at any future auction in $t' > t$. The most efficient supplier in t wins the auction and, by providing quality q, obtains the expected payoff

$$b' - \theta'(n) - \psi(q) + \beta(n)\pi(n)\frac{\delta}{1-\delta}.$$

If he instead cheats, then he sets $q = 0$ (cheating to other qualities is dominated), is replaced by some other supplier in the group of $N-n$ initially excluded suppliers and gets $b'-\theta'(n)$ since with none of the other suppliers deviating, he will be then excluded forever. Hence, if the inequality (1) is satisfied the supplier has no incentive to cheat on q. Also any supplier i who is not the most efficient in t may bid planning to cheat on quality. Incentives to deviate are strongest in this case for the second most efficient supplier who could bid $b' - \varepsilon$ with ε small and positive and set $q = 0$. If he instead bids planning not to cheat, he will not win in t, but can still expect the positive future profits. Hence, he will prefer to bid not planning to cheat if

$$\beta(n)\pi(n)\frac{\delta}{1-\delta} \geq b' - \theta\,(n) \tag{11}$$

which is equivalent to (1) since $b' = \theta\,(n) + \psi(q)$.

Consider now the case with $n = N$ and the following relational contract C^N. If an supplier i deviates by not providing the required q, according to C_i he is excluded from future auctions and the principal and the remaining suppliers switch to restricted competition with $n = N - 1$ and to relational contracts in C^{N-1} that are identical to those in C^N for each supplier except for the excluded supplier i. If any of the remaining $N - 1$ suppliers in the pool deviates in the future, he is replaced by the supplier that was not in the pool in the last period. Anticipating that the other

suppliers do not deviate, any supplier knows that being excluded one period implies exclusion forever and then (1) is again sufficient to induce the most efficient and also all other suppliers not to deviate.

Finally notice that in both cases for n, suppliers' participation is satisfied since the l.h.s. of (1) is their expected payoff from participating and the r.h.s. is non-negative.

Necessity. Consider any relational contract $\tilde{C}^n$ that contemplates $q > 0$. It must be that (1) is satisfied for $\tilde{C}^n$. Indeed, suppose instead that (1) does not hold. It is immediate that the most efficient and, similarly also, the second most efficient supplier have an incentive to deviate. ■

Proof of Lemma 2. The first part of the Lemma is immediate. Since with restricted competition the principal can always exclude a cheating supplier at no cost, the only constraint granting incentive compatibility is that of the suppliers (1).

With $n = N$ this is not the case because by excluding one supplier the principal may face a reduction of payoff. In particular when excluding the supplier the principal's payoff is

$$V_{DE} = [vq + v_0 - \psi(q) - \theta(N-1)] \frac{1}{1-\delta}$$

and

$$V_{DD} = \left[\frac{N-1}{N}[vq + v_0 - \psi(q) - \theta(N)] + \frac{1}{N}[v_0 - \psi(q) - \theta(N)]\right] \frac{1}{1-\delta}.$$

when instead she prefers not to exclude, where the term multiplied by $1/N$ accounts for the fact that the supplier who cheated will never provide quality and win the auction with probability $1/N$.

Notice that the cheating supplier may win more often anticipating that he will not face the cost of quality, contrary to his competitors. However, by doing so the other suppliers would learn that the principal did not punish a cheating supplier and they would then stop procuring the positive quality themselves. This would cancel the advantage of the cheating supplier: he would still win with probability $1/N$ obtaining the same information rent $\pi(N)$, but he would not obtain the extra payoff associated with quality cost saving $\psi(q)$ since none of the others would provide quality either. Hence, the cheating supplier always prefers to mimic the others, only winning an auction when he is actually the most efficient firm.

When $V_{DE} \geq V_{DD}$, which corresponds to (4), exclusion is credible and C^N thus incentive compatible. ■

Proof of Proposition 1.

Consider first the case of optimal procurement with restricted competition, i.e. $n \leq N-1$.

Let the efficient quality q_{FB} implicitly defined by $q_{FB} = \psi'^{-1}(v)$. If the following is satisfied

$$\frac{\theta(N-1) - \theta'(N-1)}{N-1} \frac{\delta}{1-\delta} \geq \psi(q_{FB})$$

then the solution of the principal's program is simply $n^* = N-1$ and $q^* = q_{FB}$. From the previous inequality it follows $q(N-1) \geq q_{FB}$ and

$$v < \underline{v}(N) \equiv \psi'(q(N-1)).$$

Now, assume instead $v - \psi'(q(N-1)) > 0$ or, equivalently, $v > \underline{v}(N)$. At the optimum, the constraint $q \leq q(N-1)$ must be binding so that the program becomes

$$\max_{N-1 \geq n} \quad \{s[q(n)] - \theta(n)\} \frac{1}{1-\delta}. \tag{12}$$

If the following holds

$$s[q(N-1)] - \theta(N-1) \geq s[q(N-2)] - \theta(N-2)$$

then it is optimal to set $n = N-1$. Since $N \in \Im_+$, linearizing and dividing by a unitary reduction in the number of competing suppliers, i.e. $\Delta n = N-1-(N-2)$, the previous inequality is proxied with

$$[v - \psi'(q(N-1))] \frac{\Delta q(N)}{\Delta n} - \frac{\Delta \theta(N)}{\Delta n} \geq 0$$

where $\Delta q(N) = q(N-1) - q(N-2) \leq 0$ and $\Delta \theta(N) = \theta(N-1) - \theta(N-2) \leq 0$, which can be equivalently rewritten as

$$v \leq \overline{v}(N) \equiv \psi'(q(N-1)) + \frac{\Delta \theta(N)}{\Delta q(N)}.$$

In this case the principal cannot set the first best quality but still prefers open competition.

When instead $v > \overline{v}(N)$, having $N-1$ competing suppliers is dominated by having only $n = N-2$ in the pool of competing suppliers. In this case the optimal number n^* of competing suppliers satisfies the following double inequality

$$[v - \psi'(q(n^*))] \frac{\Delta q(n^*)}{\Delta n} - \frac{\Delta \theta(n^*)}{\Delta n} \geq 0 \geq [v - \psi'(q(n^*))] \frac{\widetilde{\Delta} q(n^*)}{\Delta n} - \frac{\widetilde{\Delta} \theta(n^*)}{\Delta n}$$

where $\widetilde{\Delta} q(n^*) = q(n^*) - q(n^*+1) \geq 0$ and $\widetilde{\Delta} \theta(n^*) = \theta(n^*) - \theta(n^*+1) \geq 0$. The left inequality implies that having n^* suppliers is better for the principal than having $n^* - 1$ and the right one

that having n^* is also better than n^*+1. Since the left and the right inequalities are respectively decreasing and increasing in v, the comparative statics w.r.t. v follows.

Consider now optimal procurement with open competition $n = N$. For what stated above it must be $v \leq \overline{v}(N+1)$ otherwise restricted competition is optimal. However, Lemma 2 shows that one must also verify the principal's incentive constraint (4). Since we are considering $v \leq \overline{v}(N+1)$ and $\overline{v}(N+1) \leq \overline{v}(N)$ it is clearly the case that if a supplier deviates and is excluded, then the optimal procurement involves restricted competition and $n = N-1$ suppliers. ■

Proof of Proposition 2. The proof immediately follows from the argument in the text. ■

Proof of Lemma 3. The proof immediately follows from the argument in the text. ■

Proof of Proposition 3. We take the view according to which collusion realizes whenever it is viable. The cartel stability condition (6), written as

$$\beta(n)\tilde{\pi}(n)\frac{\delta}{1-\delta} = D(n) + \max\{\beta(n)\pi(n)\frac{\delta}{1-\delta}, \psi(q)\},$$

implicitly defines a threshold $\tilde{n}(q)$, decreasing in q, such that for any $n \leq \tilde{n}(q)$ collusion takes place.[33] Now consider any $v > \overline{v}(N)$ so that with competing suppliers optimal procurement contemplates restricted competition, i.e. $n^* = n(v) < N$ where, with a slight abuse of notation, $n(v)$ is implicitly defined by

$$\frac{dq(n)}{dn}\left[v - \psi'(q(n))\right] = \frac{d\theta(n)}{dn}.$$

For v sufficiently large, we necessarily have $n^* \leq \tilde{n}(q(n^*))$ and the principal's payoff shows a discontinuity at $\tilde{n}(q(n))$:

$$\begin{cases} [s(q(n)) - \theta(n)]\frac{1}{1-\delta} & \text{if } n > \tilde{n}(q(n)) \\ [s(\tilde{q}(n)) - r]\frac{1}{1-\delta} & \text{if } n \leq \tilde{n}(q(n)) \end{cases}$$

where $\tilde{q}(n)$ is the maximal enforceable quality with colluding firms, implicitly defined by $\psi(q) = \beta(n)\tilde{\pi}(n)\frac{\delta}{1-\delta}$. We now compare the values of the principal's payoff on the two branches at the discontinuity point $\tilde{n}$. Collusion is preferable as long as

$$s(\tilde{q}(\tilde{n})) - s(q(\tilde{n})) \geq r - \theta(\tilde{n}) \tag{13}$$

[33] To avoid extra notation this expression is written as if the principal kept the same n even if she realized that a cartel break down. Nothing would change in the arguments below considering a different off-equilibrium relational contract.

that is when the gain obtained with a higher quality (the l.h.s.) is larger than the higher cost of procuring (the r.h.s.). The former is increasing in v (recall $s(q) = vq - \psi(q)$) and the latter does not depend on it, so that for v large enough (13) is indeed verified. ■

Proof of Proposition 4. The principal's payoff with ex-ante and ex-post transfers is,

$$V(n,q) = [s(q) - nw - E(b^{'}) - B]\frac{1}{1-\delta}.$$

For what stated in the text, any relational contract C^n prescribing $q > 0$ with n competing suppliers is incentive compatible if and only if (7) and (8) are satisfied.

Since $V(n,q)$ is decreasing in w, this transfer is set such that (7) binds, i.e.

$$w = \frac{1-\delta}{\delta}\max\{\psi(q) - B, 0\} - \beta(n)\pi(n).$$

The principal then maximizes

$$V(n,q) = [s(q) - \theta'(n)]\frac{1}{1-\delta} - \frac{n}{\delta}\max\{\psi(q) - B, 0\},$$

subject to (8), i.e.

$$[s(q) - \theta'(n)]\frac{\delta}{1-\delta} - n\max\{\psi(q) - B, 0\} - \delta\underline{V} \geq B.$$

(The suppliers' participation constraint is always satisfied because the r.h.s. of (7) is positive.)

Now consider open competition. A larger B increases the objective function $V(n,q)$ and, substituting the previous expression for $V(n,q)$ into (8),

$$\left\{[s(q) - \theta'(n)]\frac{1}{1-\delta} - \frac{n}{\delta}\max\{\psi(q) - B, 0\} - \underline{V}\right\}\delta \geq B$$

we notice that, as long as $B \leq \psi(q)$, a larger B also helps satisfying (8). Indeed, the marginal effect of a larger B in the l.h.s. of (8) is $n \geq 1$, whilst that on the r.h.s. is simply 1. This shows that the principal optimally sets $B = \psi(q)$ (an even higher B has no effect on V_N and is "costly" in terms of constraint (8)).

Now notice that if the principal reneges the bonus, his outside option $\underline{V}$ is not smaller than the payoff she can get employing $N-1$ suppliers and requesting the same (possibly suboptimal with $N-1$ suppliers) quality q, i.e. $\underline{V} \geq V(N-1,q)$.[34] Since

$$V(N,q) - V(N-1,q) = [\theta'(N-1) - \theta'(N)]\frac{1}{1-\delta}$$

[34] None of the $N-1$ remaining agents is negatively affected by the principal's deviation. Also notice that beginning from a candidate optimal contract C^N, the possibility to revert to restricted competition with $n < N-1$ after a principal's deviation is dominated for the principal by contracting instead with all $N-1$ (residual) agents.

we obtain the condition (9) in the proposition.

Finally consider restricted competition. Since by replacing an supplier with any of those $N-n$ in the pool of excluded suppliers the principal gets $\underline{V}(N-1) = V(n,q)$, (8) implies $B = 0$ and the principal's objective becomes as in (10). Furthermore, the transfer $w = \frac{1-\delta}{\delta}\psi(q) - \beta(n)\pi(n)$ is positive if the optimal quality is high enough. ■

Proof of Proposition 5. The constraint for the suppliers is

$$w + [w + \beta(n)\tilde{\pi}(n)]\frac{\delta}{1-\delta} \geq w + r + \psi(q) - B - \theta'(n) - \psi(q) + B + [w + \beta(n)\pi(n)]\frac{\delta}{1-\delta}$$

which simplify to

$$[w + \beta(n)\tilde{\pi}(n)]\frac{\delta}{1-\delta} \geq r - \theta'(n) + [w + \beta(n)\pi(n)]\frac{\delta}{1-\delta}$$

or

$$[w + \beta(n)\tilde{\pi}(n)]\frac{\delta}{1-\delta} \geq r - \theta'(n) + \psi(q) - B.$$

Hence, the principal solves the following program,

$$\begin{aligned} & \max_{N\geq n,q,r,w,B} \quad [s(q) - r - B - wn]\frac{1}{1-\delta} \\ [w + \beta(n)(r - \theta'(n))]\frac{\delta}{1-\delta} \quad &\geq \quad \max\{D(n) + [w + \beta(n)(\theta(n) - \theta'(n))]\frac{\delta}{1-\delta}, \psi(q) - B\} \\ \left\{[s(q) - r - B - \psi(q) - wn]\frac{1}{1-\delta} - \underline{V}\right\}\delta \quad &\geq \quad B \end{aligned}$$

In particular, with restricted competition, as it is natural for collusion to exist, the program becomes

$$\begin{aligned} & \max_{N>n,q,r,w} \quad [s(q) - r - wn]\frac{1}{1-\delta} \\ [w + \beta(n)(r - \theta'(n))]\frac{\delta}{1-\delta} \quad &\geq \quad \max\{D(n) + [w^* + \beta(n^*)(\theta(n^*) - \theta'(n^*))]\frac{\delta}{1-\delta}, \psi(q)\} \end{aligned}$$

where n^* is the optimal number of competing suppliers with no collusion and w^* the associated transfer (restricted competition realizes in this case).[35] Since we know from previous analysis that

$$[w^* + \beta(n^*)(\theta(n^*) - \theta'(n^*))]\frac{\delta}{1-\delta} = \psi(q^*),$$

the constraint can be written as

$$[w + \beta(n)(r - \theta'(n))]\frac{\delta}{1-\delta} \geq \max\{D(n) + \psi(q^*), \psi(q)\}.$$

[35] We realistically assume that the principal notices if a cartel breaks down.

Now we need to consider two cases.

If

$$\psi(q) \geq D(n) + \psi(q^*)$$

then the constraint becomes

$$[w + \beta(n)(r - \theta'(n))] \frac{\delta}{1-\delta} \geq \psi(q)$$

which must bind at the optimum for the same arguments discussed in the case of no collusion with ex-ante and ex-post transfers. The program then becomes

$$\max_{N>n,q} \quad [s(q) - \theta'(n)] \frac{1}{1-\delta} - \frac{n}{\delta}\psi(q)$$

which is as with no collusion except for the fact that the principal now pays the lower cost $\theta'(n)$ of the most efficient supplier rather than $\theta(n)$, i.e. that of the second most efficient one. This immediately shows that when this cases realizes collusion is preferable for the principal. Furthermore, negotiation (i.e. $n = 1$) would lead to the program,

$$\begin{aligned} & \max_{q} \quad [s(q) - r] \frac{1}{1-\delta} \\ [r - \theta_e] \frac{\delta}{1-\delta} \quad & \geq \quad \psi(q) \end{aligned} \tag{14}$$

where θ_e ($\geq \theta(n)$) is the expected cost of a randomly selected supplier. Since the constraint must bind at the optimum, the program with negotiation becomes

$$\max_{q} \quad [s(q) - \theta_e] \frac{1}{1-\delta} - \frac{1}{\delta}\psi(q).$$

Comparing the two reduced programs, on one hand negotiation allows to obtain the highest quality even if at a very high cost θ_e. On the other hand, collusion allows to reduce production cost even if with a quality reduction. Which of the two effects prevails clearly depends on the specific expressions and parameters.

If instead

$$\psi(q) < D(n) + \psi(q^*)$$

then the constraint becomes

$$[w + \beta(n)(r - \theta'(n))] \frac{\delta}{1-\delta} \geq D(n) + \psi(q^*)$$

which must bind at the optimum. The program then becomes

$$\max_{N>n,q} \quad [s(q) - \theta'(n)]\frac{1}{1-\delta} - \frac{n}{\delta}[\psi(q^*) + D(n)].$$

The optimal quality of this program is the first best one, i.e. that maximizing $s(q)$ and the optimal number of competing suppliers is instead distorted, as usual, for incentive reasons. Hence, comparing this program with competition, it is immediate that if the principals cares for quality, inducing collusion is preferable again. Comparing with negotiation, we notice that since the optimal quality with collusion is the first best one, the trade-off between the two procurement may well induce the buyer to tilt towards collusion, in particular when quality is important. ■