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Joint bidding and horizontal subcontracting

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ABSTRACT

This paper investigates joint bidding when firms have incentives to sign subcontracts with each other after competing in the bidding stage. A bidding consortium affects the horizontal subcontracting market and, through backward induction, alters firms' bids. Our findings challenge the current legal practice that consortia without efficiencies must pass the "no-solo-bidding test", requiring that its members could not bid stand-alone. Our framework predicts that the formation of a temporary consortium, which has the feature that it dissolves after submitting a losing bid, benefits the procurer. The winning bid is more competitive with a temporary as compared to a structural consortium.

1. Introduction

Joint bidding is common in procurement and refers to the practice where two or more firms submit a single bid. Also, winning and losing bidders often form contractor-subcontractor relations after the contract has been awarded in the bidding stage. Both practices can reduce costs by efficiently reallocating production across firms, for example when firms are subject to idiosyncratic cost shocks or capacity constraints. Accordingly, joint bidding and subcontracting are widespread in a diverse set of industries. For example, Hendricks and Porter (1992) report on joint bidding for outer continental shelf oil drilling leases in the U.S., an industry where subcontracting occurs (Hendricks et al., 2003 and Haile et al., 2010). Corwin and Schultz (2005) analyze the practice of loan syndication between banks to reduce the cost of issuing capital. Further, in military aircraft procurement, competing bidders often team up due to heterogeneous specializations (Miller, 2005). Marion (2015) studies subcontracting between competing firms in the California highway construction industry.

Competition authorities and courts rely mainly on the following two criteria to assess joint bidding. First, bidding consortia without efficiencies are only permitted if it is infeasible for their members to participate in the procurement on a stand-alone basis. They must pass what we refer to as the "no-solo-bidding test". The reasoning is that, when failing the test, the joint bidding arrangement reduces competition by lowering the number of bidders. This argument has already been used in 1975 by the US Congress to prohibit joint bidding arrangements between large oil companies for offshore oil leases

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Table 1
temporary versus structural consortium.

	Bidding	Contracting	Subcontracting
Temporary consortium	Joint	Joint	Solo
Structural consortium	Joint	Joint	Joint

(Hendricks and Porter, 1992). In Europe, the no-solo-bidding test has been prominently applied in several recent court cases. For example, joint bidding for patient transportation contracts was regarded by the Norwegian Supreme Court as a restriction of competition by object since parties could have bid solo.[1,2] As a second criterion, when failing the no-solo-bidding test, sufficient offsetting efficiencies are required, for example through organizational integration. In Italy, the competition authority recently accepted efficiency arguments to permit joint bidding by two competing pharmaceutical companies that could have bid solo.[3]

In this paper we highlight that joint bidding arrangements between competitors, although reducing the number of bidders, also reduce the demand for contracting. We develop a model which explicitly accounts for the effect of joint bidding on the terms of trade in the subcontracting market. The findings from the model challenge in several respects the standards against which joint bidding arrangements are currently assessed.

We capture the strategic interaction between firms by modeling a two-stage game, detailed in Section 2. In the first stage, firms submit bids and the contract is awarded to the lowest bidder. Nature then independently draws a zero or high cost for each individual firm. Stage two is the horizontal subcontracting market. There are incentives to form contractor-subcontractor relations when the winner draws a high cost and there is at least one losing firm drawing a zero cost. The distribution of surplus between the contractor and the subcontractor(s) is modelled in reduced form representation. By doing so, our model covers a range of subcontracting market conditions.

There exists a wide variety of bidding consortia in practice. To study their competitive effect, we argue that a key dimension along which consortia differ is whether they are temporary or structural in nature. Temporary consortia jointly bid and, when selected as winner, jointly contract. However, when losing, cooperation between its members breaks down. The decisions to act as subcontractor are then made solo by the original entities. Temporary consortia thus capture cooperation agreements that are *ad hoc* and dissolve if another firm submits the lowest bid. In contrast, a consortium is structural when it involves an agreement or joint venture which is longer-lasting and, for example, concerns multiple tenders. A structural consortium thus crucially differs from a temporary consortium because it continues to operate jointly regardless of the outcome of the bidding stage (joint contracting *and* joint subcontracting). Table 1 summarizes their distinction.

Empirical evidence suggests that both types of consortia are relevant, as illustrated by the following examples. In auctions for U.S. offshore oil and gas leases, “firms who bid jointly in one area of a sale will not necessarily do so in other areas or other sales” (Haile et al., 2010, p. 391). In this industry, for example, Exxon bids jointly only 13% of the time, reflecting *ad hoc* cooperation, whereas the consortia Kerr/Marathon/Felmont and LaLand/Hess/Cabot bid jointly over 90% of the time (Hendricks and Porter, 1992, p. 507). Another example of long-lasting cooperation is the Norwegian joint venture established by Ski Taxi and Follo Taxi, entrusted with submitting joint bids over the course of multiple years (Sanchez-Graells, 2018). Gugler et al. (2020), in their study of the Austrian construction sector, report that about two thirds of bidding consortia are formed only once and that other bidding consortia bid jointly up to thirty times.

A temporary consortium in our model corresponds to a “non-full-function joint venture” and would in Europe be assessed under TFEU 101 and the Guidelines on horizontal cooperation agreements. A structural consortium, in contrast, would be treated as a full-function joint venture and accordingly fall under the merger regulation. In the US, the standards used to determine whether joint bidding violates the antitrust laws are described in the Antitrust guidelines for collaborations among competitors (Federal Trade Commission, 2000, §3.37). The consortium, however, would be treated as a merger if appropriate when “the collaboration does not terminate within a sufficiently limited period by its own specific and express terms.” (Federal Trade Commission, 2000, §1.3).

Sections 3 and 4 present an analysis of solo bidding and joint bidding through a temporary consortium, respectively. We find that the formation of a temporary consortium between firms failing the no-solo-bidding test changes the terms of trade in the subcontracting market, to the benefit of the procurer. Specifically, joint contracting from losing rivals results in two distinct pro-competitive effects. First, it reduces the cost at which the consortium can contract inputs, thereby allowing it to submit a more competitive bid. Second, the consortium’s increased contracting power reduces subcontracting profits for outsiders. The outsiders thus forego a smaller amount of profits when winning, leading them to compete more fiercely as well. Our findings cast doubt on the economic rationale behind the no-solo-bidding test as a basis for assessing joint bidding in procurement industries with subcontracting.

[1] We refer to HR-2017-1229-A case no. 2015/203 (https://bit.ly/2AO8oPg) and the EFTA Court judgment of 22 December 2016.

[2] As another example, the Guidelines by the Danish Competition and Consumer Authority (2020) on joint bidding under competition law also apply the no-solo-bidding test.

[3] We refer to https://bit.ly/2FfXToU.

In our model, a temporary consortium reallocates production across its members. This approach captures joint bidding agreements between competitors that do not integrate their operations. In the U.S., these joint bidding arrangements are regarded as anti-competitive and therefore challenged as per se illegal Federal Trade Commission (2000). In a similar spirit, in the EU, a recent court case has judged such an arrangement as anti-competitive.[4] Our analysis yields that, even without integration of operations, a temporary consortium alters the terms of trade in the subcontracting market and benefits the procurer.

In Section 5, we consider a structural consortium. As with a temporary consortium, a structural consortium efficiently reallocates production and does not create additional synergies. We thus model the structural consortium with the presumption of no synergies. This presumption follows from current merger policy under which structural consortia are assessed. Moreover, it allows for a clean comparison between the two consortia types.

A structural consortium continues to operate jointly even if it loses in the bidding stage. There are two resulting anti-competitive effects. First, outsiders pay more to contract inputs, which weakens their ability to submit a competitive bid. Second, increased subcontracting power by the consortium makes it more attractive for the consortium to subcontract, and thereby reduces the consortium's incentives to submit a competitive bid. These two additional effects distinguish the structural consortium from the temporary consortium. We conclude that structural consortia should be assessed with more scrutiny than temporary consortia.

1.1. Related literature

The empirical and theoretical literature has treated joint bidding and subcontracting mainly separately. This is rather surprising since, as also observed by Branzoli and Decarolis (2015), both practices frequently occur together in procurement.

The existing literature on the competitive effects of joint bidding has not yet explored the role of a horizontal subcontracting market. Instead, it has focused on other elements, such as the number of bidders and their characteristics. In influential studies of the U.S. market for offshore oil leases, joint bidding has been documented to stifle competition when it reduces the number of bidders (Markham, 1970, Hendricks and Porter, 1992 and Haile et al., 2010). Other studies have highlighted that joint bidding can also invite entry through pooling of resources or information. For example, Moody and Kruvant (1988) report empirically that joint bidding enhances entry in the market for offshore oil leases. Joint bidding can also improve competition by reducing the winner's curse, even with fewer bidders, as shown by Krishna and Morgan (1997).[5] Estache and Iimi (2009) empirically study joint bidding in developing countries and find that joint bidding by local enterprises can be pro-competitive. Albano et al. (2009) survey the regulation of joint bidding in European public procurement. In a recent study of the Austrian construction sector, Gugler et al. (2020) find that banning joint bidding can lead to more entry by inefficient firms. Their empirical observations support that bids are more competitive when temporary bidding groups are allowed.[6] Finally, joint bidding through horizontal mergers has been studied in the context of auction design. We refer to Waehrer (1999) and Waehrer and Perry (2003) for theoretical analyses, Froeb and Shor (2005) for a survey, and Li and Zhang (2015) for an empirical application on timber auctions. Our work differs from the existing literature by demonstrating that a horizontal subcontracting market plays an important role in the competitive effects of joint bidding.

Previous work on horizontal subcontracting has not investigated the competitive effects of the common practice of joint bidding. Horizontal subcontracting occurs when the winning bidder (the contractor) outsources the production of goods or services to losing bidders (the subcontractors).[7] Kamien et al. (1989) is close to our paper by studying two price competing firms with convex costs engaging in ex post horizontal subcontracting. We develop a model with three or more firms suitable for analysing the competitive effects of joint bidding. We show how a bidding consortium affects the horizontal subcontracting market and thereby alters the strategic interaction in the bidding stage. Other studies in the horizontal subcontracting literature have focused on different aspects and have not investigated the effects of joint bidding. Spiegel (1993) studies horizontal subcontracting between quantity-competing firms. Gale et al. (2000) and Jeziorski and Krasnokutskaya (2016) study sequential procurement auctions with subcontracting. Haile (2001, 2003) offers empirical and theoretical studies of auctions with resale opportunities.[8] In Haile's studies bidders are uncertain about their costs, a feature that our model also adopts. Bouckaert and Van Moer (2017) investigate firms' incentives to invest in production capacity in the presence of a horizontal subcontracting market. We refer to Huff (2012), Lewis and Bajari (2014), and Marion (2015) for empirical analyses of horizontal subcontracting in the U.S. road construction sector, and to Marion (2009) and Moretti and Valbonesi (2015) for empirical analyses of vertical subcontracting.

[4] In the so-called road marking case, the Danish Supreme Court ruled in 2019 that the consortium between Eurostar and GVCO was a restriction of competition by object. The consortium agreement was regarded by the Court as a means to share the procured lots among the members and the Court concluded that the criteria for exemption under TFEU 101(3) were not met.

[5] Levin (2004) emphasizes a demand reduction effect from joint bidding in multi-unit auctions, which leads to less aggressive bidding.

[6] The authors study two extreme scenarios in their counterfactual analysis of prohibiting bidding consortia: (i) consortium members could not bid solo (strict interpretation of the current law) and (ii) consortium members could bid solo.

[7] Horizontal subcontracting should be distinguished from vertical subcontracting where the successful bidder contracts from firms that did not participate in the bidding stage.

[8] An alternative interpretation of our model is to regard the subcontracting market as a resale market. Haile's (2001) analysis of timber auctions, for example, also allows both interpretations.

Branzoli and Decarolis (2015) study Italian procurement and investigate empirically the effect of the auction format on strategic variables including joint bidding choices and subcontracting. They find evidence that first-price auctions (as opposed to average bid auctions) invite more joint bidding and decrease the prevalence of subcontracting. The contribution of our paper is to offer a competition analysis of joint bidding that accounts for the interaction with the horizontal subcontracting market. Camboni et al. (2020) empirically investigate the bidding behaviour of temporary consortia between firms short of necessary qualifications to perform the contract. Their findings indicate that such temporary consortia bid more competitively than firms outsourcing ex post. The authors argue that consortia improve investment incentives by mitigating hold-up.[9] Our analysis delineates how consortia affect bidding incentives by altering competition in the horizontal subcontracting market.

2. A model

Three risk-neutral, ex ante symmetric firms $i = 1, 2, 3$ can produce a homogeneous good for a procurer. In the first stage, they submit bids and the contract is allocated to the lowest bidder. Next, costs are realized, giving incentives for horizontal subcontracting in stage two, after which production occurs. In our triopoly model a joint bidding arrangement between two firms reduces the number of bids from three to two and hence fails the no-solo-bidding test. With this setup we capture the competitive effects of joint bidding most prominently and in their simplest form.[10] We proceed by detailing each stage.

2.1. Bidding stage

We normalize market demand to equal one unit. Firms compete by simultaneously handing in price bids. Denote the lowest submitted bid by b. The firm with the lowest bid wins and delivers the unit. When there is a tie, the winning firm is randomly selected.[11]

2.2. Subcontracting stage

In many industries, firms are uncertain about their unit cost due to a time lag between the contract award and its execution. This uncertainty offers incentives for ex post subcontracting to reduce costs.[12] We let nature reveal a (constant) unit cost for each firm. In particular, each firm independently draws a zero cost with probability q or a high cost $c > 0$ with the remaining probability $1 - q$.[13] Denote firm i's cost draw by $x_i = \{0, c\}$. We denote a state of nature as $\{x_1, x_2, x_3\}$. There is an incentive to sign a subcontract when the winner (contractor) draws a high cost and one or two losing firms (subcontractors) draw a zero cost. If so, subcontracting enables firms to reduce the production cost from c to zero.

We let firms take advantage of all potential surplus from subcontracting. In other words, they use subcontracts to allocate production cost-efficiently, so that production occurs at minimal cost ($\min\{x_1, x_2, x_3\}$).

If the winner draws a high cost and only *one* subcontractor has access to zero-cost production, the surplus division between the contractor and the subcontractor is determined by their bilateral bargaining positions. We denote the fraction of surplus that goes to the subcontractor by α_1 where $0 \leq \alpha_1 \leq 1$. The remaining fraction goes to the contractor. One interpretation is that α_1 represents the probability with which the subcontractor makes a take-it-or-leave-it offer and that with the remaining probability the contractor makes the offer.[14] As such, a higher α_1 corresponds to a higher degree of bargaining power for the monopolist subcontractor. When $\alpha_1 = 0.5$ there is symmetric Nash bargaining.

If the winner draws a high cost and the *two* subcontractors have access to zero-cost production, the surplus division is instead determined by the intensity of competition between the duopolistic subcontractors. The share of surplus appropriated by the subcontractors then equals α_2, i.e., each subcontractor receives share $0.5\alpha_2$, whereas the contractor receives $1 - \alpha_2$. Two possible interpretations are that each subcontractor serves half a unit, or each serves the unit with probability 0.5. We make the plausible assumption that $\alpha_1 \geq \alpha_2$, i.e. competition among subcontractors tends to erode their rents.

At one end of the competitive spectrum, when $\alpha_2 = 0$, rivalry between the two subcontractors is à la Bertrand and fully erodes their rents. Such a setting can reflect the presence of regulations intended to improve competition in the

[9] The authors do not consider consortia between firms capable of bidding solo.

[10] In subsection 6.1, we develop the analysis for more than three firms and demonstrate that our results continue to hold.

[11] The features fixed demand and a winner-take-all tie-breaking rule are common in practice. However, they do not affect our results, as detailed in subsection 6.2.

[12] Haile (2001) reports that contracts to harvest timber are typically executed at the end of the contract term, so that bidding firms are likely to be uncertain about their future cost when competing in the auction. Cost uncertainty is also important in other procurement industries. For example, large projects in the defense industry are characterized by a substantial timespan between contract award and execution (Miller, 2005). In the construction sector, one could interpret our model as capturing uncertainty about future backlog. In subsection 6.3, we analyse an alternative model with capacity constraints that upholds our results.

[13] Our results also hold for (imperfectly) correlated cost structures across firms. Such correlation may be important, for example, if all bidders are affected by a common business cycle. However, for expositional purposes, we make use of the binomial distribution throughout the analysis. Thomas (2004) presents a comparable approach.

[14] Kamien et al. (1989) investigate the two polar cases $\alpha_1 = \{0, 1\}$.

Table 2
direct cost under solo bidding.

States of nature	Probability	Direct cost
$\{c, c, c\}$	$(1-q)(1-q)^2$	c
$\{c, 0, c\} \cup \{c, c, 0\}$	$(1-q)2q(1-q)$	$\alpha_1 c$
$\{c, 0, 0\}$	$(1-q)q^2$	$\alpha_2 c$
$\{0, x_2, x_3\}$	q	0

Table 3
subcontracting profit under solo bidding.

States of nature	Probability	Subcontracting profit
$\{0, c, c\}$	$q(1-q)^2$	$\alpha_1 c$
$\{0, c, 0\}$	$q(1-q)q$	$0.5\alpha_2 c$
$\{c, x_2, x_3\} \cup \{x_1, 0, x_3\}$	remaining probability	0

subcontracting market. For example, the Federal Acquisition Regulation (FAR, 2005) requires prime contractors to carefully consider whether "adequate price competition [was] obtained or its absence properly justified" (FAR 44.202-2). At the other end, when $\alpha_2 = \alpha_1$, competition among the subcontractors is absent. For example, there can be search costs à la Diamond (1971) incurred by the contractor. Alternatively, subcontractors may collude in the subcontracting stage while competing in the bidding stage, i.e., a form of semi-collusion. A high α_2 can also capture regulatory frameworks hindering competition in the subcontracting market. For example, the California Subcontracting and Subletting Fair Practice Act prohibits the winner to call upon other subcontractors than those declared in its bid (Miller, 2014 and Marion, 2015). While such a prohibition may be useful to guarantee that the winner is able to deliver, it can also enable a hold-up strategy by the subcontractor.

In summary, we have developed an approach for modeling the subcontracting market which allows for any distribution of rents between the contractor and the subcontractor(s). Moreover, it also incorporates that the distribution depends on the market structure in the subcontracting stage (α_1 exceeds α_2). Our analysis, which we pursue in the next sections, therefore captures that joint bidding alters the terms of trade in the subcontracting stage.

3. Solo bidding benchmark

We solve the model according to the principle of backward induction.

3.1. Subcontracting stage

First, we will investigate a firm's direct cost for serving the procurer. Firm i's direct cost refers to its in-house production cost or the cost of contracting from a losing rival. It is an expectation and is denoted by DC_i. Second, we will investigate firm i's subcontracting profit if it loses. It is also an expectation and is denoted by SP_i.

Table 2 displays firm 1's direct cost in each state of nature. From ex ante symmetry, we do not lose generality by considering firm 1. We adopt the convention of writing the probability of a state of nature as the probability of firm 1's cost draw multiplied by the probability of firm 2's and firm 3's cost draw, respectively.

When all firms draw a high cost ($\{c, c, c\}$), there are no gains from contracting and the winner's direct cost equals c. In $\{c, 0, c\}$ and $\{c, c, 0\}$, the winner draws a high cost and only one subcontractor draws a zero cost. The winner's direct cost is then determined by the bargaining power of that subcontractor and equals $\alpha_1 c$. Next, in $\{c, 0, 0\}$, there are two zero-cost subcontractors that compete against each other and the winner's direct cost equals $\alpha_2 c$. Finally, when the winner has access to zero-cost production, its direct cost equals zero. We can summarize that firm i's direct cost equals

$$DC_i = (1-q)\left[(1-q)^2 c + 2q(1-q)\alpha_1 c + q^2 \alpha_2 c\right]. \tag{1}$$

We now investigate a firm's profit from subcontracting. In Table 3, without loss of generality, we consider firm 1's subcontracting profit when firm 2 wins.

When firm 1 is the only firm drawing a zero cost ($\{0, c, c\}$), its subcontracting profit is determined according to its bargaining power with respect to the winner and equals $\alpha_1 c$. Next, in $\{0, c, 0\}$, firm 1 and firm 3 draw a zero cost. Consequently, firm 1 earns $0.5\alpha_2 c$ which is half of the total rents going to the subcontractors. Finally, firm 1 cannot profit from subcontracting when it draws a high cost *or* the winner draws a zero cost. We can summarize that firm i's subcontracting profit equals

$$SP_i = q(1-q)[(1-q)\alpha_1 c + q0.5\alpha_2 c]. \tag{2}$$

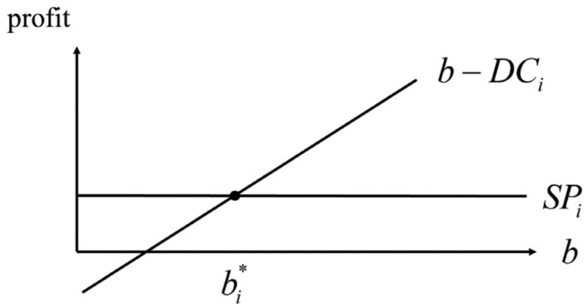

Fig. 1. solo bidding analysis.

3.2. Bidding stage

We now investigate at what bid levels firms prefer to win or lose against a competitor. Firm i's profit if it wins equals $b - DC_i$. If it loses, firm i earns SP_i. Fig. 1 depicts the equilibrium analysis of solo bidding.

In equilibrium, firms should be indifferent between winning and losing. The associated bid can be written as

$$b_i^* = DC_i + SP_i. \tag{3}$$

The following reasoning shows that b_i^*, the sum of the direct cost and the alternative profit from subcontracting, is the equilibrium bid. First, a higher bid cannot be an equilibrium because then the losing firms would have an incentive to undercut the winner. Second, a lower bid cannot be an equilibrium either because the winning firm would have an incentive to raise its bid and profit from subcontracting. When all firms bid b_i^*, there are no unilateral incentives to deviate.

From (1), (2), and (3), we find that the equilibrium bid increases with the bargaining power of a monopolist subcontractor (α_1) and with softer duopoly competition among subcontractors (α_2). There are two reasons for this finding. First, contracting is more costly, thereby increasing the direct cost of winning. Second, subcontracting is more attractive. As such, a winning firm foregoes higher profits from subcontracting. This increased opportunity cost also results in a higher equilibrium bid. The equilibrium bid is minimal when $\alpha_1 = \alpha_2 = 0$. The direct cost then equals c only in state $\{c, c, c\}$ and the subcontracting profit equals zero, resulting in an equilibrium bid $(1-q)^3 c$.

We next turn to firms' profits. Since in equilibrium firms are indifferent between winning and losing, each firm's profit equals SP_i and is increasing in α_1 and α_2. The model thus suggests that industry associations may have incentives to lobby for legal institutions that increase the share of rents going to the subcontractors (raise α_1 and α_2). By doing so, they increase the height of the winning bid.

Finally, in our model, demand is fixed and production is cost-efficient. Consequently, the bid price at which the unit is procured does not affect total welfare. It determines only the *distribution* of welfare between the procurer and the firms.

4. Temporary consortium

Without loss of generality, we consider a temporary consortium between firms 1 and 2. The temporary consortium, denoted by **TC**, jointly hands in a bid. Further, it jointly contracts when winning but dissolves when losing. The outsider to the consortium is denoted by $\backslash$**TC**.

No efficiencies. We rule out efficiencies such as, for example, scale economies, learning effects, or more efficient management, so that these do not interfere with our results. This approach captures bidding consortia without operational integration by their members. Formally, we model that the **TC** does not affect the production possibilities available in the market, or $x_{\mathbf{TC}} = \min\{x_1, x_2\}$. This definition corresponds to Farrell and Shapiro's (1990) terminology of no synergies.[15]

In our setting, firms reallocate production cost-efficiently using horizontal subcontracts. Consequently, the production cost equals $\min\{x_{\mathbf{TC}}, x_3\} = \min\{x_1, x_2, x_3\}$, the production cost incurred under solo bidding.

4.1. Subcontracting stage

We first investigate the scenario where the **TC** wins. This enables us to analyze the **TC**'s direct cost and the outsider's subcontracting profit.

Table 4
temporary consortium's direct cost.

States of nature	Probability	Direct cost
$\{x_{\mathbf{TC}} = c, c\}$	$(1-q)^2(1-q)$	c
$\{x_{\mathbf{TC}} = c, 0\}$	$(1-q)^2 q$	$\alpha_1 c$
$\{x_{\mathbf{TC}} = 0, x_3\}$	remaining probability	0

Table 5
outsider $\backslash$**TC**'s subcontracting profit.

States of nature	Probability	Subcontracting profit
$\{x_{\mathbf{TC}} = c, 0\}$	$(1-q)^2 q$	$\alpha_1 c$
$\{x_{\mathbf{TC}} = 0, x_3\}$	remaining probability	0

4.1.1. Temporary consortium's direct cost

Table 4 depicts the **TC**'s direct cost $DC_{\mathbf{TC}}$. For conciseness we denote the states of nature as $\{x_{\mathbf{TC}} = c, x_3\} \equiv \{c, c, x_3\}$ and $\{x_{\mathbf{TC}} = 0, x_3\} \equiv \{0, c, x_3\} \cup \{c, 0, x_3\} \cup \{0, 0, x_3\}$.

In state $\{x_{\mathbf{TC}} = c, c\}$, all cost draws are high and the **TC**'s direct cost equals c. Next, when the outsider is the only firm with a zero-cost draw ($\{x_{\mathbf{TC}} = c, 0\}$), contracting occurs through bilateral bargaining and the **TC** incurs a direct cost equal to $\alpha_1 c$. Finally, when at least one of the **TC**-members draws a zero cost, its direct cost equals zero. We can summarize that the **TC**'s direct cost equals

$$DC_{\mathbf{TC}} = (1-q)^2[(1-q)c + q\alpha_1 c]. \tag{4}$$

We are now ready to compare with solo bidding. From Table 2 and Table 4 we find that, when the **TC** wins, subcontracting happens with a lower probability. Our model thus explains that joint bidding partly substitutes for horizontal subcontracting.[16] Using (1) and (4), we obtain that the **TC**'s direct cost reduces by

$$DC_i - DC_{\mathbf{TC}} = (1-q)q(1-q)\alpha_1 c + (1-q)q^2\alpha_2 c. \tag{5}$$

The **TC** enjoys a reduced direct cost as compared to solo bidding. The first term reflects that when $\{c, 0, c\}$, forming the **TC** reduces the direct cost from $\alpha_1 c$ to zero. The second term captures that, when $\{c, 0, 0\}$, forming the **TC** reduces the direct cost from $\alpha_2 c$ to zero.

4.1.2. Outsider's subcontracting profit

Next, we analyze the outsider's subcontracting profit $SP_{\backslash\mathbf{TC}}$, depicted in Table 5. The outsider only earns a subcontracting profit if it is the only firm with a zero-cost draw ($\{x_{\mathbf{TC}} = c, 0\}$). In that event, the outsider earns a profit equal to $\alpha_1 c$, which is an increasing function of its bargaining power.

We can summarize that the outsider's subcontracting profit equals

$$SP_{\backslash\mathbf{TC}} = (1-q)^2 q\alpha_1 c. \tag{6}$$

We are now ready to compare with solo bidding. Using (2) and (6), we obtain that the **TC** reduces the outsider's subcontracting profit by

$$SP_i - SP_{\backslash\mathbf{TC}} = (1-q)q^2 0.5\alpha_2 c. \tag{7}$$

In $\{c, 0, 0\}$, the **TC** reduces the outsider's subcontracting profit from $0.5\alpha_2 c$ to zero. We interpret (7) as the **TC**'s *net gain in contracting power*. The following insight serves as the key ingredient for this section's main result.

Insight 1. *The temporary consortium enjoys a net gain in contracting power. It reduces the consortium's direct cost and decreases the outsider's subcontracting profit.*

Notice that the **TC**'s net gain in contracting power does not depend on the bargaining power of a monopolist subcontractor (α_1); there is no reduction in contracting cost when the outsider is the only firm with a zero-cost draw.

Next, we investigate what happens when the **TC** loses.

4.1.3. Outsider's direct cost

Since the **TC** dissolves after losing, the outsider's direct cost $DC_{\backslash\mathbf{TC}}$ is invariant to the presence of a **TC**, or

$$DC_{\backslash\mathbf{TC}} = DC_i. \tag{8}$$

[15] Farrell and Shapiro's (1990, p. 112) description of a merger M with no synergies is: "After the merger, the combined entity M can perhaps better allocate outputs across facilities ("rationalization") but M's production possibilities are no different from those of the insiders (jointly) before the merger. In this case we say that the merger "generates no synergies."" This also corresponds to Perry and Porter (1985), who vary the industry structure while fixing the industry supply curve.

[16] This result is consistent with Branzoli and Decarolis (2015) who empirically observe a negative association between temporary consortia and subcontracting.

4.1.4. Temporary consortium members' subcontracting profits

Likewise, the subcontracting profit of each consortium member is unaffected by the consortium. Both members' subcontracting profits are equal and sum up to

$$2SP_i. \tag{9}$$

4.2. Bidding stage

We subsequently analyze the **TC**'s and the outsider's bidding incentives.

4.2.1. Temporary consortium's bidding incentives

The bid at which the **TC** is indifferent between winning and losing equals

$$b^*_{\mathbf{TC}} = DC_{\mathbf{TC}} + 2SP_i. \tag{10}$$

We can now compare the **TC**'s bidding incentives to those of a solo bidder. Using (3) and (10), we write that the bid difference

$$b^*_{\mathbf{TC}} - b^*_i = \underbrace{DC_{\mathbf{TC}} - DC_i}_{\text{(-); direct cost decreases}} + \underbrace{SP_i}_{\text{(+); opportunity cost increases}}. \tag{11}$$

There are two countervailing forces. First, a direct cost reduction leads to more aggressive bidding. Second, the members of the **TC**, by winning, forego the *sum* of the separate entities' subcontracting profits under solo bidding. From (2) and (5) we obtain that

$$b^*_{\mathbf{TC}} - b^*_i = -(1-q)q^2 0.5\alpha_2 c. \tag{12}$$

We thus find that the consortium is willing to bid more competitively. The amount by which it is willing to lower its bid is equal to its net gain in contracting power.

4.2.2. Outsider's bidding incentives

The bid at which the outsider is indifferent between winning and losing equals

$$b^*_{\setminus\mathbf{TC}} = DC_{\setminus\mathbf{TC}} + SP_{\setminus\mathbf{TC}}. \tag{13}$$

From (3) and (13), and using (8), we obtain that the bid difference equals

$$b^*_{\setminus\mathbf{TC}} - b^*_i = \underbrace{SP_{\setminus\mathbf{TC}} - SP_i}_{\text{(-); opportunity cost decreases}}. \tag{14}$$

Using (7), we obtain

$$b^*_{\setminus\mathbf{TC}} - b^*_i = -(1-q)q^2 0.5\alpha_2 c. \tag{15}$$

The **TC** makes the outsider willing to bid more competitively. The amount by which the outsider is willing to lower its bid is equal to its loss in subcontracting profit (i.e., the **TC**'s net gain in contracting power).

The above analysis shows that the bidding incentives of the **TC** and the outsider are identical ($b^*_{\mathbf{TC}} = b^*_{\setminus\mathbf{TC}}$). By the same reasoning we used for solo bidding, we find that the equilibrium bid equals $b^*_{\mathbf{TC}} = b^*_{\setminus\mathbf{TC}}$. We are now ready to state Proposition 1.

Proposition 1. *In comparison to solo bidding, the formation of a temporary consortium benefits the procurer. The associated decrease in the winning bid equals* $(1-q)q^2 0.5\alpha_2 c$.

The **TC** enjoys a net gain in contracting power that makes bidding more aggressive by all bidders. This net gain is greater when duopoly competition among subcontractors is softer (high α_2). So, when competition in the subcontracting market is poor, a **TC** acts as an effective instrument to reduce the procurer's expenses.

Next, we report on the incentives to form the **TC**. Since the equilibrium bid equals $b^*_{\mathbf{TC}}$, the consortium earns equal profits if it wins or loses. To find the **TC**'s equilibrium profits, we can therefore consider what happens if it loses. The **TC** then dissolves and each of its members earns a profit as under solo bidding. This establishes that forming the **TC** is profit-neutral for its members. Intuitively, when the **TC** wins, the **TC**'s net gain in contracting power is fully passed on into the lower equilibrium bid. In Section 6 we demonstrate that, with $N \geq 4$ firms, forming the **TC** is strictly profitable.

Forming the **TC**, however, imposes a negative externality on the outsider. Specifically, the outsider suffers a profit loss equal to its decrease in subcontracting profit, given by (7). The decrease in equilibrium bid therefore benefits the procurer at the expense of the outsider. Finally, the **TC** does not affect total welfare, as in our model demand is fixed, production is efficient, and there are no efficiencies from forming the **TC**.

In summary, our analysis yields that the temporary consortium benefits the procurer. Current legal practice only permits bidding consortia failing the no-solo-bidding test when they are efficiency-enhancing. Our model without efficiencies predicts that this practice results in missed opportunities to reduce procurement expenses. We expect that the presence of efficiencies would strengthen this finding.

Table 6
outsider **SC**'s direct cost.

States of nature	Probability	Direct cost
$\{x_{\mathbf{SC}} = c, c\}$	$(1-q)^2(1-q)$	c
$\{x_{\mathbf{SC}} = 0, c\}$	$[1-(1-q)^2](1-q)$	$\alpha_1 c$
$\{x_{\mathbf{SC}} = \min\{x_1, x_2\}, 0\}$	remaining probability	0

Table 7
Structural consortium's subcontracting profit.

States of nature	Probability	Subcontracting profit
$\{x_{\mathbf{SC}} = 0, c\}$	$[1-(1-q)^2](1-q)$	$\alpha_1 c$
all other states	remaining probability	0

5. Structural consortium

This section studies a structural consortium **SC** between firms 1 and 2. The **SC** always acts jointly in the bidding stage as well as in the subcontracting stage. The outsider is denoted by **SC**. We model the **SC** with the presumption of no efficiencies, so that $x_{\mathbf{SC}} = \min\{x_1, x_2\}$.

5.1. Subcontracting stage

We start with the scenario where the **SC** wins.

5.1.1. Structural consortium's direct cost

The **SC**'s direct cost $DC_{\mathbf{SC}}$ equals the direct cost of a **TC**, or

$$DC_{\mathbf{SC}} = DC_{\mathbf{TC}}. \tag{16}$$

5.1.2. Outsider's subcontracting profit

Similarly, the outsider's subcontracting profit is equal to the subcontracting profit earned by the outsider to a **TC**, or

$$SP_{\backslash\mathbf{SC}} = SP_{\backslash\mathbf{TC}}. \tag{17}$$

The following insight is analogous to insight 1.

Insight 2. *The structural consortium enjoys a net gain in contracting power. It decreases the consortium's direct cost and the outsider's subcontracting profit.*

We next investigate what happens when the **SC** loses.

5.1.3. Outsider's direct cost

Table 6 depicts the outsider's direct cost.

When all firms draw a high cost, the outsider incurs a direct cost equal to c. Next, when at least one of the **SC**-members draws a zero cost and the outsider draws a high cost, the outsider's direct cost equals $\alpha_1 c$. Finally, when the outsider draws a zero cost, its direct cost equals zero. We can summarize that the outsider's direct cost equals

$$DC_{\backslash\mathbf{SC}} = (1-q)\left[(1-q)^2 c + \left[1-(1-q)^2\right]\alpha_1 c\right]. \tag{18}$$

We are now ready to compare with solo bidding. Using (1) and (18), we obtain

$$DC_{\backslash\mathbf{SC}} - DC_i = q^2(1-q)(\alpha_1 c - \alpha_2 c). \tag{19}$$

The **SC** increases the outsider's direct cost. The increase occurs when the winning outsider draws a high cost and the two **SC**-members each have favorable cost draws ($\{0, 0, c\}$). The outsider is then charged $\alpha_1 c$, whereas under solo bidding the **SC**-members would have competed against each other and the outsider would have been charged $\alpha_2 c$.

5.1.4. Structural consortium's subcontracting profit

Table 7 depicts the **SC**'s subcontracting profit. The **SC** only earns a subcontracting profit if it draws a zero cost and the outsider draws a high cost ($\{x_{\mathbf{SC}} = 0, c\}$). The **SC** then charges $\alpha_1 c$ for its subcontracted unit.

Summarizing, we can write that the **SC**'s subcontracting profit equals

$$SP_{\mathbf{SC}} = \left[1-(1-q)^2\right](1-q)\alpha_1 c. \tag{20}$$

Using (2), we can rewrite (20) as

$$SP_{\mathbf{SC}} = 2SP_i + q^2(1-q)(\alpha_1 c - \alpha_2 c). \tag{21}$$

The **SC**'s subcontracting profit exceeds the sum of the insiders' under solo bidding. The following insight is the key ingredient for this section's main result.

Insight 3. *The structural consortium enjoys more subcontracting power. It increases its subcontracting profit and the outsider's direct cost.*

Notice that, by (21), the increase in subcontracting power depends on *the difference in* profit that the consortium members earn by joining forces in the subcontracting market. The increase is largest when a monopolist subcontractor has much bargaining power (high α_1) and the prospect of duopoly competition in the subcontracting market is poor (low α_2). Our analysis thus reveals a qualitatively distinct role for α_1 and α_2 in the analysis of a structural consortium.

5.2. Bidding stage

5.2.1. Structural consortium's bidding incentives

The bid at which the **SC** is indifferent between winning and losing equals

$$b^*_{\mathbf{SC}} = DC_{\mathbf{SC}} + SP_{\mathbf{SC}}. \tag{22}$$

We can now compare the bidding incentives of the **SC** with those under solo bidding. Using (3) and (22), the bid difference equals

$$b^*_{\mathbf{SC}} - b^*_i = \underbrace{DC_{\mathbf{SC}} - DC_i}_{\text{(-); direct cost decreases}} + \underbrace{SP_{\mathbf{SC}} - SP_i}_{\text{(+); opportunity cost increases}}. \tag{23}$$

Using (2), (4), (16), and (21), we obtain

$$b^*_{\mathbf{SC}} - b^*_i = -(1-q)q^2 0.5\alpha_2 c + q^2(1-q)(\alpha_1 c - \alpha_2 c). \tag{24}$$

The amount by which the **SC** is willing to alter its bid is determined by its net gain in contracting power (first term) and subcontracting power (second term), as described in insights 2 and 3.

5.2.2. Outsider's bidding incentives

Finally, the bid at which the outsider is indifferent between winning and losing equals

$$b^*_{\backslash\mathbf{SC}} = DC_{\backslash\mathbf{SC}} + SP_{\backslash\mathbf{SC}}. \tag{25}$$

Using (3) and (25), we can write that the bid difference equals

$$b^*_{\backslash\mathbf{SC}} - b^*_i = \underbrace{DC_{\backslash\mathbf{SC}} - DC_i}_{\text{(+); direct cost increases}} + \underbrace{SP_{\backslash\mathbf{SC}} - SP_i}_{\text{(-); opportunity cost decreases}}. \tag{26}$$

Substituting (7), (17), and (19), yields

$$b^*_{\backslash\mathbf{SC}} - b^*_i = -(1-q)q^2 0.5\alpha_2 c + q^2(1-q)(\alpha_1 c - \alpha_2 c). \tag{27}$$

The outsider's bidding incentives are thus identically affected by the **SC**'s changes in contracting and subcontracting power, described in insights 2 and 3. We obtain that the equilibrium bid equals $b^*_{\mathbf{SC}} = b^*_{\backslash\mathbf{SC}}$ and arrive at the following Proposition.

Proposition 2. *In comparison to solo bidding, the formation of a structural consortium changes the winning bid by* $-(1-q)q^2 0.5\alpha_2 c + q^2(1-q)(\alpha_1 c - \alpha_2 c)$.

The first term captures that, when the **SC** enjoys a net gain in contracting power, the **SC** and the outsider bid *more* aggressively. The second term captures that, when $\alpha_1 > \alpha_2$, the **SC** enjoys increased subcontracting power which makes all bids *less* competitive. The formation of a structural consortium is prone to increasing the winning bid when a monopolist subcontractor enjoys much bargaining power (high α_1) and duopoly competition among subcontractors is fierce (low α_2). Conversely, when the value of α_2 is close to that of α_1, the model predicts that the structural consortium lowers the winning bid.

We next consider the profitability of forming the **SC**. Since the equilibrium bid equals $b^*_{\mathbf{SC}}$, the **SC** earns the same profits if it wins or loses. We can therefore consider what happens if it loses. From (21), the **SC** then earns a profit equal to $2SP_i + q^2(1-q)(\alpha_1 c - \alpha_2 c)$. The last term establishes that, when $\alpha_1 > \alpha_2$, forming the **SC** is strictly profitable.

The outsider is also indifferent between winning and losing. Consequently, its equilibrium profit equals its subcontracting profit, given by (6) and (17). Comparing with solo bidding, the outsider thus suffers a profit loss equal to the **SC**'s net gain in contracting power. We conclude that the outsider earns the same lowered profit with any consortium type as compared with solo bidding. Our model thus predicts an "outsider's offence" even when the consortium does not produce efficiencies. Finally, total welfare does not change with a **TC** or **SC**.

A simple comparison between the bid effect of a **TC** (Proposition 1) and the bid effect of an **SC** (Proposition 2) yields the following proposition.

Proposition 3. *The procurer prefers the formation of a temporary consortium to the formation of a structural consortium. The associated difference in the winning bid equals* $q^2(1-q)(\alpha_1 c - \alpha_2 c)$.

In summary, we have found that a structural consortium is distinct from a temporary consortium as it leads to increased subcontracting power. This effect increases the opportunity cost of the consortium members and the outsider's direct cost. Therefore, distinct from temporary consortia, our analysis does not recommend structural consortia without efficiencies. This finding is supportive of the current legal approach treating structural consortia as mergers.

6. Discussion and robustness

6.1. Oligopoly

In this subsection we analyze our model when the number of firms (N) equals four or more. We investigate the effects of a **TC** or **SC** with two members. Empirical studies report that a substantial fraction of consortia consists of only two members. Hendricks and Porter (1992), for example, observe that among large firms, two-firm bidding consortia occur with a much higher frequency than consortia with more firms. Similarly, Gugler et al. (2020) report that, in their dataset, the average number of members in a bidding consortium is 2.17 and there is an average number of 1.5 bidding consortia participating per auction where at least one consortium participates. There can be various reasons why bidding consortia typically form with relatively few members. First, having additional consortium members may increase the likelihood of failing the no-solo-bidding test. It would appear easier for a single firm to argue that it could not bid solo, as compared to two firms arguing that their joint resources are insufficient. Second, the structure of consortia is also determined by monitoring incentives and information asymmetries (Sufi, 2007). We expect that a model based on such transaction costs can explain why consortia tend to have relatively few members.[17]

Further, for simplicity, we make the reasonable assumption that competition between three or more subcontractors with a zero-cost draw, fully erodes their rents; i.e., $\alpha_3 = 0$, $\alpha_4 = 0$, and so on. One interpretation of this approach, offered by Federico et al. (2017) in their analysis of mergers and innovation, is that three or more firms cannot effectively coordinate their prices.

The analysis of the model is presented in the Appendix. A distinct feature of the model with $N \geq 4$ firms as compared to the basic model is that there are *multiple* outsiders to the consortium. Consequently, for both consortia types, we find that each outsider suffers a reduction in subcontracting profit which is only a fraction of the consortium's net gain in contracting power. Specifically, each outsider's reduction in subcontracting profit (opportunity cost) only equals fraction $1/(N-2)$ of the **TC**'s or **SC**'s net gain in contracting power. As a result, we find that outsiders bid less aggressively than the consortium. The consortium therefore has a margin to raise its bid before meeting the competitive constraint set by the outsiders. With this insight, the Appendix demonstrates that forming a consortium is *strictly* profitable regardless of whether the consortium is temporary or structural. In other words, the model predicts that joint bidding arrangements are formed in industries with horizontal subcontracting. The following two Propositions hold when the subcontracting market is not perfectly competitive ($\alpha_2 > 0$).

Proposition 4. *For* $N \geq 4$, *forming a temporary or a structural consortium is strictly profitable.*

We can also state the following summarizing proposition on how joint bidding affects procurer welfare.

Proposition 5. *For all* $N \geq 3$, *the procurer benefits from the formation of a temporary consortium and prefers it to the formation of a structural consortium.*

We refer to the Appendix for the general analysis and illustrate here the effects of a **TC** and **SC** using a parametric configuration. The configuration sets $q = 0.5$ and normalizes $c = 100$. With a monopolist subcontractor, the surplus is shared according to symmetric Nash bargaining ($\alpha_1 = 0.5$). To capture a range of competition intensities between two zero-cost subcontractors, a low and a high value of α_2 are considered ($\alpha_2 = 0.1$ and $\alpha_2 = 0.4$, respectively). For $N = 3$, the figures are constructed by substituting these parameter values into the analytical expressions obtained in the basic model. For $N \geq 4$, we use the analytical expressions obtained in the Appendix.

Fig. 2 depicts the change in equilibrium bid resulting from both consortium types. A **TC** decreases the equilibrium bid and the effect is stronger when α_2 is higher. When $N = 3$, an **SC** decreases the equilibrium bid for a high value of α_2 and increases it for a low value of α_2. This observation illustrates Proposition 2, reporting that the bid effect is an increasing function of $\alpha_1 - \alpha_2$, capturing the **SC**'s increase in subcontracting power. For large values of N, however, we find that the role of α_2 reverses, such that the bid effect of an **SC** is *increasing* with α_2. The reason for this finding relates to the scenario where a winning outsider draws cost c, both **SC**-members draw a zero cost, and one of the losing outsiders also draws a zero cost. The winning outsider then incurs cost $\alpha_2 c$ whereas under solo bidding the winning outsider would have incurred a direct cost equal to zero ($\alpha_3 c = 0$). In that scenario, a higher value of α_2 is thus associated with a higher direct cost for the winning outsider. It makes outsiders less aggressive, which explains the countervailing force. Remark that this effect does

[17] We refer to Hendricks and Porter (1992) for additional reasons why consortia have limited members.

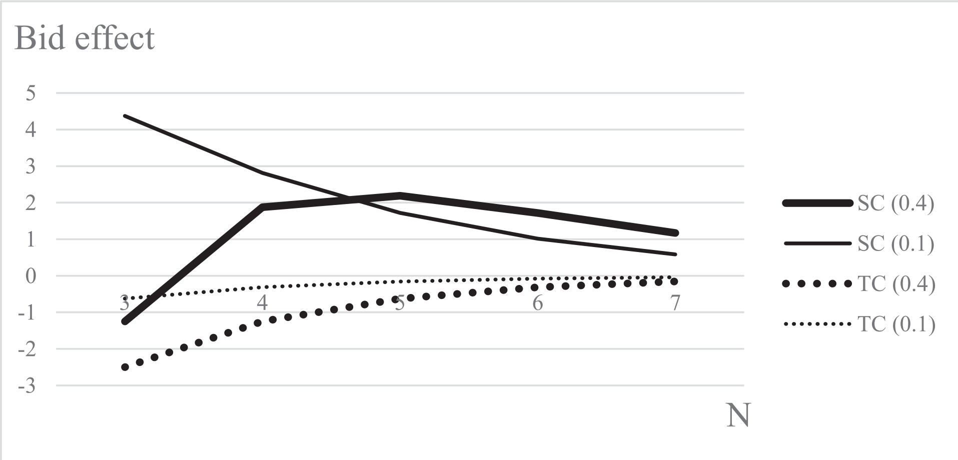

Fig. 2. The bid effect of a temporary and structural consortium.

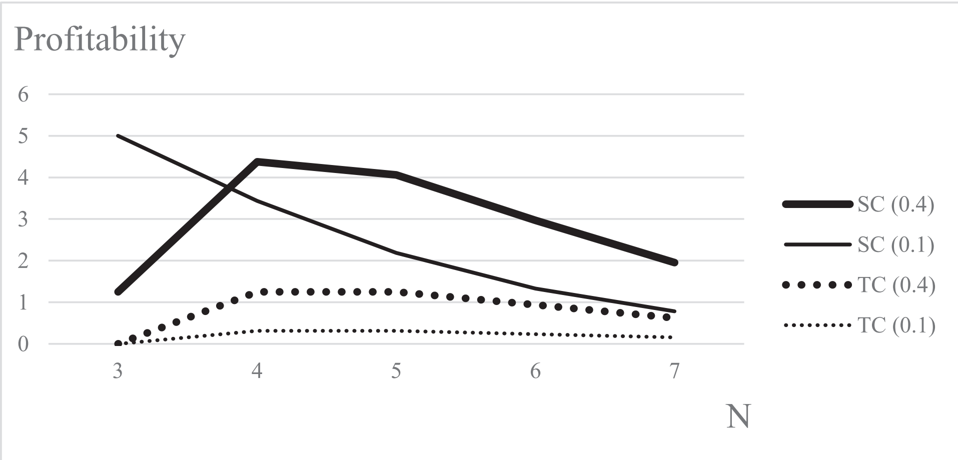

Fig. 3. The profitability of a temporary and structural consortium.

not arise in the basic model with $N = 3$ as the winning outsider can then only contract from a monopolist subcontractor (i.e. the **SC**). Next, Fig. 2 also visualizes Proposition 5, stating that from a procurer welfare perspective, a **TC** is preferred to an **SC**. Finally, as the number of firms becomes very large, there is a higher probability of having sufficiently many zero-cost draws to guarantee competition in the subcontracting market. Consequently, the bid effect weakens for large values of N.

Fig. 3 depicts the difference between the consortium's profits and the sum of the consortium members' profits under solo bidding, such that higher values correspond to more profitable consortia. Forming a **TC** is profit-neutral for $N = 3$. For $N \geq 4$, it is strictly profitable and its profitability increases with α_2. Forming an **SC** is always strictly profitable. For $N = 3$, it is more profitable when α_2 is low, as then the **SC** enjoys a large increase in subcontracting power. For larger values of N, the role of α_2 reverses. Specifically, an **SC** then becomes more profitable for large values of α_2. As detailed above, with $N \geq 4$, a higher value of α_2 can be associated with a higher direct cost for outsiders, which makes them less aggressive. Consequently, the **SC** enjoys more leeway to increase its bid. This effect makes it more profitable to form the **SC**. Next, Fig. 3 also visualizes that forming an **SC** is more profitable than forming a **TC**. Finally, as the number of firms grows large, there is an increased likelihood of competition between three or more zero-cost subcontractors, which weakens the profitability of forming a consortium.

6.2. Multiple lots

In the basic model, if bidding results in a tie, only one winner is selected to be responsible for delivering the contract. Our analysis, however, would be equivalent when alternatively the contract would be split into multiple lots. To illustrate, consider two firms with perfectly negatively correlated cost shocks. Under a winner-take-all tie breaking rule, there is a

0.5 probability that subcontracting is needed. If the contract is split into two equal lots, half a unit is subcontracted with certainty. The expected need for subcontracting is identical.

The possibility to have multiple winners allows to extend our analysis to address questions outside procurement. First, an analysis of price-elastic demand is feasible by working out the analysis at the unit level and then aggregating all units up to total demand. Second, it is possible to investigate other modes of competition in the bidding stage as well, such as for example price competition with product differentiation, where in equilibrium several firms would be responsible for serving different types of consumers.

6.3. Capacity constraints

This subsection shows that the insights generated by the basic model are also valid when subcontracting follows from capacity constraints.[18] To this end, we consider the following illustrative model.

Demand in the bidding stage is fixed and equals two units. There are three capacity-constrained firms that can only produce one unit each. The cost of producing that unit is normalized to zero. Bidding occurs as in the basic model: firms simultaneously submit bids and the firm submitting the lowest bid is selected as the winner.

The assumption of one unit capacity simplifies the analysis of the subcontracting market without losing the essentials. In particular, a winning consortium does not need a subcontractor, as it can produce both units in-house. This contrasts with a winning solo bidder that needs to contract one unit. The winner's direct cost then depends on the number of subcontractors. With a monopolist subcontractor, the winner pays $\alpha_1\bar{t}$, where $\bar{t}$ can be interpreted as the winner's damage payment for not delivering the second unit or its marginal cost of producing units beyond its efficient scale. With two competing subcontractors, the amount paid equals $\alpha_2\bar{t}$.

6.3.1. Solo bidding

Firm i's direct cost equals $DC_i = \alpha_2\bar{t}$, the cost of contracting the second unit, and firm i's subcontracting profit equals $SP_i = 0.5\alpha_2\bar{t}$. As in the basic model, the equilibrium bid is such that firms are indifferent between winning and losing. Consequently, we find that the equilibrium bid under solo bidding equals $b_i^* = 1.5\alpha_2\bar{t}$.

6.3.2. Temporary consortium

If the **TC** wins, it can produce both units in-house at zero cost, without relying on the subcontractor. Its direct cost thus equals $DC_{\mathbf{TC}} = 0$ and the outsider to the consortium earns zero subcontracting profits ($SP_{\backslash\mathbf{TC}} = 0$). The net gain in contracting power equals $0.5\alpha_2\bar{t}$.

If the **TC** loses, it dissolves back into its separate entities. Therefore, the outsider's direct cost equals DC_i and the **TC**-members' subcontracting profits are equal and sum up to $2SP_i$.

The equilibrium bids again follow from the condition that firms should be indifferent between winning and losing, and equal $b_{\mathbf{TC}}^* = b_{\backslash\mathbf{TC}}^* = \alpha_2\bar{t}$. Consistent with Proposition 1, the **TC** leads to more aggressive bidding. It is easily seen that, as in the basic model, forming the **TC** is profit-neutral.

6.3.3. Structural consortium

If the **SC** wins, the analysis is as described for the **TC**. If it loses, the **SC** enjoys a subcontracting power increase: the **SC** avoids competition between its members and can charge $\alpha_1\bar{t}$. We can write that the outsider's direct cost and the **SC**'s subcontracting profit equal $DC_{\backslash\mathbf{SC}} = SP_{\mathbf{SC}} = \alpha_1\bar{t}$. We find that the equilibrium bids equal $b_{\mathbf{SC}}^* = b_{\backslash\mathbf{SC}}^* = \alpha_1\bar{t}$. Consequently, the **SC** changes the winning bid by $\alpha_1\bar{t} - 1.5\alpha_2\bar{t}$, which can be written as $-0.5\alpha_2\bar{t} + (\alpha_1 - \alpha_2)\bar{t}$. The winning bid thus tends to decrease when the net gain in contracting power is substantial (first term) and tends to increase when the consortium's subcontracting power increase is large (second term). These insights uphold Proposition 2. Finally, the difference in procurer welfare between a **TC** and an **SC** equals $(\alpha_1 - \alpha_2)\bar{t}$, confirming Proposition 3. Notice also that, as in the basic model, forming the **SC** is strictly profitable.

Remark that, in this model with capacity constraints, the procurer could eliminate firms' need for contracting by splitting the contract into two equal lots. Altering the design of the procurement in this way alters the analysis and could be profitable for the procurer. In practice, the procurer would face a tradeoff. On the one hand, reducing the need for subcontracting can reduce the winning bid. On the other hand, procurers may rather coordinate with just one supplier to avoid moral hazard issues. For example, Sufi (2007) studies the syndicated loans market and reports that, for 69 % of loans in the sample, there is only one lead arranger on the loan.

7. Conclusions

Unless bidding consortia generate sufficient efficiencies through integration of operations, competition authorities and courts require that their members cannot bid stand-alone. The results of our paper challenge the economic rationale of such

[18] As an example, Jofre-Bonet and Pesendorfer (2003) highlight the importance of capacity constraints in the highway construction industry, a sector with joint bidding and horizontal subcontracting.

a "no-solo-bidding test". We present a framework where competing firms have incentives to sign subcontracts with each other after the winner of the bidding stage has been appointed. A bidding consortium either dissolves after losing in the bidding stage (temporary consortium) or not (structural consortium).

Our results find that temporary consortia benefit the procurer. Their pro-competitive effect follows from changes in terms of trade in the subcontracting market and does not require synergies through integration of operations. Firms that bid jointly depend less on subcontractors if they win. Such reduced dependence grants the consortium more contracting power. Consequently, the consortium can afford to compete more aggressively to win the procurement. Moreover, increased contracting power by the consortium also makes outsiders bid more aggressively. The reason is that, if they lose, they have a lower chance of acting as subcontractors. Accordingly, they forego less profits from winning. We conclude that a prohibition of temporary consortia that fail the no-solo-bidding test and that do not integrate their operations raises expenses for the procurer.

Structural consortia are distinct from temporary consortia as they do not dissolve when losing. Consequently, they enjoy increased subcontracting power vis-à-vis a winning outsider, yielding two additional effects that harm the procurer. First, it becomes more costly for the outsider to win, which raises its bid. Second, the consortium finds it more attractive to act as subcontractor, leading the consortium to raise its bid as well. Therefore, our recommendation for more leniency towards temporary consortia in industries with horizontal subcontracting does not extend to structural consortia.

Our analysis also calls for reflection on the no-solo-bidding test. In principle, all firms could bid solo if they have the possibility to hire subcontractors. We have shown that a framework where firms are too capacity-constrained to perform the entire contract in-house delivers the same insights as our basic model where firms are not capacity-constrained. So, the presence of a horizontal subcontracting market challenges the economic rationale of the no-solo-bidding test.

Finally, in highlighting these pro-competitive effects from temporary consortia, we do not wish to leave the impression that other competition considerations are only of secondary importance. For example, we have studied the effects of a consortium in an industry with symmetric firms. It goes without saying that caution is warranted when the consortium is formed between the two largest bidders in the industry. Also, an assessment of bid rigging should continue to be a crucial part of a competition investigation .

Credit author statement

All authors contributed equally to this manuscript.

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Appendix

The Appendix analyses the model for $N \geq 4$ firms.

Solo bidding benchmark

Subcontracting stage

Firm i's direct cost if it wins equals

$$DC_i = (1-q)\left[(1-q)^{N-1}c + (N-1)q(1-q)^{N-2}\alpha_1 c + \frac{(N-1)(N-2)}{2}q^2(1-q)^{N-3}\alpha_2 c\right]. \tag{A1}$$

Firm i draws cost c with probability $1-q$. The direct cost then depends on whether none, one, two, or more of the other firms draw a zero cost. The first term between the square brackets represents the direct cost when all other firms draw cost c as well. The second term shows the direct cost when one out of the $N-1$ subcontractors draws cost c, a scenario which happens with probability $(N-1)q(1-q)^{N-2}$ according to the binomial distribution.[19] The third term shows firm i's direct cost when it draws cost c and two subcontractors draw a zero cost (with probability $\frac{(N-1)(N-2)}{2}q^2(1-q)^{N-3}$). Finally, whenever three or more subcontractors draw a zero cost, competition between them fully erodes their rents and firm i's direct cost equals zero.

[19] The probability that exactly k out of m firms draw a zero cost is given by $\frac{m!}{(m-k)!k!}q^k(1-q)^{m-k}$.

Firm i's subcontracting profit equals

$$SP_i = q(1-q)\left[(1-q)^{N-2}\alpha_1 c + (N-2)q(1-q)^{N-3}0.5\alpha_2 c\right]. \tag{A2}$$

Firm i earns a positive subcontracting profit when it draws a zero cost (with probability q) and the winner draws cost c (with probability $1-q$). The size of the subcontracting profit then depends on whether none, one, or more of the other firms draw a zero cost.

Bidding stage

The bid b_i^* at which firm i is indifferent between winning and losing equals

$$b_i^* = DC_i + SP_i, \tag{A3}$$

where DC_i and SP_i are given by (A1) and (A2). As in the basic model, the equilibrium bid is increasing in α_1 and α_2.

Temporary consortium

Subcontracting stage

The scenarios a) and b) present the analysis when the **TC** wins.

a) Temporary consortium's direct cost

The **TC**'s direct cost equals

$$DC_{\mathbf{TC}} = (1-q)^2\left[(1-q)^{N-2}c + (N-2)q(1-q)^{N-3}\alpha_1 c + \frac{(N-2)(N-3)}{2}q^2(1-q)^{N-4}\alpha_2 c\right] \tag{A4}$$

and is positive when both **TC**-members draw cost c, and none, one, or two of the other firms have a zero-cost draw.

b) Outsider's subcontracting profit when the consortium wins.

An outsider's subcontracting profit when the consortium wins is denoted by $SP_{\backslash\mathbf{TC}-\mathbf{TC}}$. The subscript $\backslash\mathbf{TC}-\mathbf{TC}$ denotes whose subcontracting profit is considered (first part of the subscript) and the winner in the bidding stage (second part of the subscript). We can write that

$$SP_{\backslash\mathbf{TC}-\mathbf{TC}} = (1-q)^2 q\left[(1-q)^{N-3}\alpha_1 c + (N-3)q(1-q)^{N-4}0.5\alpha_2 c\right]. \tag{A5}$$

The outsider earns a positive subcontracting profit when the **TC**-members both draw cost c, the outsider draws a zero cost, and none or one of the other firms draws a zero cost.

Scenarios c), d) and e) describe what happens when an outsider wins.

c) Outsider's direct cost

When an outsider wins, the **TC** dissolves. Consequently, an outsider's direct cost is invariant to the **TC**, or

$$DC_{\backslash\mathbf{TC}} = DC_i. \tag{A6}$$

d) Temporary consortium members' subcontracting profits

Likewise, both **TC**-members' subcontracting profits sum up to

$$2SP_i. \tag{A7}$$

e) Outsider's subcontracting profit when another outsider wins.

Finally, we need to consider an outsider's subcontracting profit when another outsider wins, a scenario which could not arise in the basic model with only three firms. The outsider then earns the same profits as under solo bidding, or

$$SP_{\backslash\mathbf{TC}-\backslash\mathbf{TC}} = SP_i. \tag{A8}$$

Bidding stage

a) Temporary consortium's bidding incentives

The **TC** is indifferent between winning and losing when $b_{\mathbf{TC}}^* = DC_{\mathbf{TC}} + 2SP_i$. Comparing with solo bidding using (A3), we find that $b_{\mathbf{TC}}^* - b_i^* = DC_{\mathbf{TC}} - DC_i + SP_i$, which can be worked out using (A1), (A2), and (A4) to obtain

$$b_{\mathbf{TC}}^* - b_i^* = -(N-2)q^2(1-q)^{N-2}0.5\alpha_2 c. \tag{A9}$$

Eq. (A9) equals the **TC**'s net gain in contracting power, i.e., the extra rents the **TC** can extract from the outsiders if it wins.

b) Outsider's bidding incentives.

The bid at which an outsider is indifferent between winning and losing against the **TC** equals $b^*_{\backslash\mathbf{TC}-\mathbf{TC}} = DC_i + SP_{\backslash\mathbf{TC}-\mathbf{TC}}$ (from (A6)). We compare with solo bidding using (A2), (A3), and (A5), and obtain

$$b^*_{\backslash\mathbf{TC}-\mathbf{TC}} - b^*_i = -q^2(1-q)^{N-2}0.5\alpha_2 c. \tag{A10}$$

Eq. (A10) equals the reduction in subcontracting profit (i.e., opportunity cost) for an outsider when losing against the **TC**. Notice that the reduction of all the outsiders' subcontracting profits is obtained by multiplying (A10) with the number of outsiders $(N-2)$ and equals the **TC**'s net gain in contracting power given by (A9).

Finally, the bid at which an outsider is indifferent between winning and losing against another outsider follows from (A6) and (A8) and equals $b^*_{\backslash\mathbf{TC}-\backslash\mathbf{TC}} = b^*_i$. Consequently, we have that

$$b^*_{\backslash\mathbf{TC}-\backslash\mathbf{TC}} - b^*_i = 0. \tag{A11}$$

Comparing (A9), (A10), (A11) and using that $N \geq 4$, we find that $b^*_{\mathbf{TC}} \leq b^*_{\backslash\mathbf{TC}-\mathbf{TC}} \leq b^*_{\backslash\mathbf{TC}-\backslash\mathbf{TC}}$, with strict inequalities whenever $\alpha_2 > 0$. The **TC** is thus willing to bid more aggressively relative to the outsiders. This finding is explained as follows. The **TC**'s net gain in contracting power is given by (A9) and is fully passed through into the bid level at which the **TC** is indifferent between winning or losing. In contrast, the amount by which each outsider is willing to lower its bid is given by (A10) and measures the reduction in subcontracting profit suffered by each outsider. Specifically, each outsider's reduction in subcontracting profit equals the **TC**'s net gain in contracting power divided by the number of outsiders $(N-2)$. Since $N \geq 4$, there are multiple outsiders and the **TC** is willing to bid more aggressively than each of the outsiders. This feature differs from the basic model (with three firms) where we found that the **TC** and the outsider were willing to bid equally aggressively.

How do firms bid in equilibrium? The **TC** bids as a lowest-cost firm in a homogenous product Bertrand oligopoly: it bids (almost) up to the level at which the outsiders are indifferent between winning and losing. Intuitively, the **TC** has incentives to raise its bid as much as possible, while making sure the outsiders have no incentives to undercut.[20] The equilibrium bid thus equals $b^*_{\backslash\mathbf{TC}-\mathbf{TC}}$. Relation (A10) describes the decrease in equilibrium bid and establishes the first part of Proposition 5 for $N \geq 4$ firms.

Finally, we turn to the analysis of whether forming the **TC** is profitable. In this respect, the scenario where the **TC** loses serves as a benchmark. In that event, the **TC** dissolves and its members earn solo bidding profits. Forming the **TC** would thus be profit-neutral in the hypothetical scenario where the **TC** would indifferent between winning and losing (i.e., when the winning bid would equal $b^*_{\mathbf{TC}}$). However, we have demonstrated that the equilibrium bid amounts up to $b^*_{\backslash\mathbf{TC}-\mathbf{TC}}$, meaning that the **TC**'s net gain in contracting power is not fully passed on into a lower equilibrium bid. Consequently, forming the **TC** yields a profit bonus equal to $b^*_{\backslash\mathbf{TC}-\mathbf{TC}} - b^*_{\mathbf{TC}}$. Comparing (A9) and (A10) now establishes Proposition 4 for the **TC**.

Structural consortium

Subcontracting stage

a) Structural consortium's direct cost

When the **SC** wins, the analysis coincides with a **TC**. The **SC**'s direct cost equals

$$DC_{\mathbf{SC}} = DC_{\mathbf{TC}}. \tag{A12}$$

b) Outsider's subcontracting profit when the consortium wins

An outsider's subcontracting profit when the **SC** wins equals

$$SP_{\backslash\mathbf{SC}-\mathbf{SC}} = SP_{\backslash\mathbf{TC}-\mathbf{TC}}. \tag{A13}$$

c) Outsider's direct cost

Next, we investigate what happens when an outsider wins. The direct cost of a winning outsider equals

$$\begin{aligned} DC_{\backslash\mathbf{SC}} = {} & (1-q)^2(1-q)^{N-3}(1-q)c \\ & + \left[\left[1-(1-q)^2\right](1-q)^{N-3} + (1-q)^2(N-3)q(1-q)^{N-4}\right](1-q)\alpha_1 c \\ & + \left[\left[1-(1-q)^2\right](N-3)q(1-q)^{N-4} + (1-q)^2\frac{(N-3)(N-4)}{2}q^2(1-q)^{N-5}\right](1-q)\alpha_2 c. \end{aligned} \tag{A14}$$

The first line states that a winning outsider's direct cost equals c when the **SC**-members both draw cost c (with probability $(1-q)^2$), the other outsiders all draw cost c (with probability $(1-q)^{N-3}$), and the winning outsider draws cost c

[20] The detailed equilibrium analysis is standard and is omitted for the purpose of brevity. To deal with the open-set problem, one can assume that in case of a tie the consortium wins the unit with priority. There is then a Nash equilibrium when the consortium and the lowest-bidding outsider both submit bid b such that $b^*_{\mathbf{TC}} \leq b \leq b^*_{\backslash\mathbf{TC}-\mathbf{TC}}$. However, for $b < b^*_{\backslash\mathbf{TC}-\mathbf{TC}}$, the outsider would play a weakly dominated strategy. Ruling this out leaves $b^*_{\backslash\mathbf{TC}-\mathbf{TC}}$ as the winning bid.

(with probability $(1-q)$). The second line shows the scenario where the winning outsider faces a monopolist subcontractor. This happens when at least one of the **SC**-members draws a zero cost or when only one of the other, losing outsiders draws a zero cost. Finally, the third line represents the scenario with competition between two zero-cost subcontractors, which happens when the **SC** competes against one other outsider or when two other outsiders compete against each other. Notice that, when $N=4$, the scenarios with a winning outsider and two losing outsiders cannot arise (happen with zero probability).

d) Structural consortium's subcontracting profit

The **SC**'s subcontracting profit equals

$$SP_{\mathbf{SC}} = \left[1-(1-q)^2\right]\left[(1-q)^{N-3}\alpha_1 + (N-3)q(1-q)^{N-4}0.5\alpha_2\right](1-q)c. \tag{A15}$$

The subcontracting profit is positive when at least one of the **SC**-members draws a zero cost, none or one of the other outsiders draws a zero cost, and the winner draws cost c .

e) Outsider's subcontracting profit when another outsider wins

The subcontracting profit of an outsider when another outsider wins equals

$$\begin{aligned} SP_{\backslash\mathbf{SC}-\backslash\mathbf{SC}} = {} & (1-q)^2 q(1-q)^{N-4}(1-q)\alpha_1 c \\ & +\left[1-(1-q)^2\right]q(1-q)^{N-4}(1-q)0.5\alpha_2 c \\ & +(1-q)^2 q(N-4)q(1-q)^{N-5}(1-q)0.5\alpha_2 c. \end{aligned} \tag{A16}$$

The first line represents the subcontracting profit when the outsider is a monopolist subcontractor. This scenario happens when the **SC**-members both draw cost c, the outsider draws a zero cost, the other losing outsiders draw cost c, and the winning outsider draws cost c. The second line and third line capture the scenarios where the outsider is among two subcontractors with a zero cost. Specifically, the second line represents the subcontracting profit when the outsider competes against the **SC** in the subcontracting market. The third line shows the subcontracting profit when the outsider competes against another outsider in the subcontracting market. Notice that, with $N=4$, that scenario cannot arise; it then happens with zero probability.

Bidding stage

a) Structural consortium's bidding incentives

The **SC** is indifferent between winning and losing when the bid equals $b^*_{\mathbf{SC}} = DC_{\mathbf{SC}} + SP_{\mathbf{SC}}$. Comparing with solo bidding, and using (A12), we obtain $b^*_{\mathbf{SC}} - b^*_i = DC_{\mathbf{TC}} + SP_{\mathbf{SC}} - DC_i - SP_i$. An elaborate calculation using (A1), (A2), (A4) and (A15) yields

$$\begin{aligned} b^*_{\mathbf{SC}} - b^*_i = {} & -(N-2)q^2(1-q)^{N-2}0.5\alpha_2 c \\ & +q^2(1-q)^{N-2}[\alpha_1 c - \alpha_2 c] + q^2(N-3)q(1-q)^{N-3}0.5\alpha_2 c. \end{aligned} \tag{A17}$$

The first line represents the **SC**'s net gain in contracting power which is equivalent for a **TC** and an **SC**. The second line captures the **SC**'s increase in subcontracting profit and makes the **SC** bid less aggressively. The first term of the second line captures the state of nature where both consortium partners draw a zero cost and all other firms draw cost c. The **SC** then earns a subcontracting profit equal to $\alpha_1 c$ rather than $\alpha_2 c$, the profits both **SC**-members would have jointly earned under solo bidding in that state of nature. The second term of the second line captures the scenario where both **SC**-members draw a zero cost and one other losing outsider also draws a zero cost. In that event, the **SC** earns $0.5\alpha_2 c$, as opposed to earning zero under solo bidding.

b) Outsider's bidding incentives

The bid at which an outsider is indifferent between winning and losing against the **SC** equals $b^*_{\backslash\mathbf{SC}-\mathbf{SC}} = DC_{\backslash\mathbf{SC}} + SP_{\backslash\mathbf{SC}-\mathbf{SC}}$. Comparing with solo bidding and using (A3) and (A13), we obtain $b^*_{\backslash\mathbf{SC}-\mathbf{SC}} - b^*_i = DC_{\backslash\mathbf{SC}} + SP_{\backslash\mathbf{TC}-\mathbf{TC}} - DC_i - SP_i$. An elaborate calculation using (A1), (A2), (A5) and (A14) shows that

$$\begin{aligned} b^*_{\backslash\mathbf{SC}-\mathbf{SC}} - b^*_i = {} & -q^2(1-q)^{N-2}0.5\alpha_2 c \\ & +q^2(1-q)^{N-2}[\alpha_1 c - \alpha_2 c] + q^2(N-3)q(1-q)^{N-3}\alpha_2 c. \end{aligned} \tag{A18}$$

The first line equals the subcontracting profit reduction suffered by the outsider and is the same with a **TC** or **SC**. The second line equals the increase in direct cost. The first term captures the scenario where both **SC**-members draw a zero cost and all other firms draw cost c. The winning outsider then incurs cost $\alpha_1 c$ whereas it would have incurred $\alpha_2 c$ under solo bidding. The second term represents the scenario where both **SC**-members draw a zero cost, one of the losing outsiders also draws a zero cost, and the winning outsider draws cost c. The winning outsider then incurs cost $\alpha_2 c$ as opposed to incurring zero under solo bidding. That scenario does not arise in the basic model with three firms and makes the outsiders less aggressive.

The bid at which an outsider is indifferent between winning and losing against another outsider to the **SC** equals $b^*_{\backslash\mathbf{SC}-\backslash\mathbf{SC}} = DC_{\backslash\mathbf{SC}} + SP_{\backslash\mathbf{SC}-\backslash\mathbf{SC}}$. Comparing with solo bidding, we have $b^*_{\backslash\mathbf{SC}-\backslash\mathbf{SC}} - b^*_i = DC_{\backslash\mathbf{SC}} + SP_{\backslash\mathbf{SC}-\backslash\mathbf{SC}} - DC_i - SP_i$. Substituting (A1), (A2), (A14) and (A16), and simplifying, we find that

$$\begin{aligned} b^*_{\backslash\mathbf{SC}-\backslash\mathbf{SC}} - b^*_i &= q^3(1-q)^{N-3}0.5\alpha_2 c \\ &+q^2(1-q)^{N-2}[\alpha_1 c - \alpha_2 c] + q^2(N-3)q(1-q)^{N-3}\alpha_2 c. \end{aligned} \tag{A19}$$

The first line equals the increase in subcontracting profit and captures the scenario where both **SC**-members draw a zero cost, the outsider also draws a zero cost, and all other firms draw cost c. The outsider then earns $0.5\alpha_2 c$ with the **SC** rather than earning zero with solo bidding. The second line equals the increase in direct cost and we refer to (A18) for the explanation.

A comparison of (A17), (A18) and (A19) yields that $b^*_{\mathbf{SC}} \le b^*_{\backslash\mathbf{SC}-\mathbf{SC}} \le b^*_{\backslash\mathbf{SC}-\backslash\mathbf{SC}}$, with strict inequalities whenever $\alpha_2 > 0$. Consequently, the **SC** wins and bids up to the level at which the outsiders are indifferent between winning and losing ($b^*_{\backslash\mathbf{SC}-\mathbf{SC}}$). Relation (A18) thus states the bid effect of the **SC**.

Finally, we conduct a comparison between the **TC** and the **SC**. Comparing (A10) and (A18) we obtain

$$b^*_{\backslash\mathbf{SC}-\mathbf{SC}} - b^*_{\backslash\mathbf{TC}-\mathbf{TC}} = q^2(1-q)^{N-2}[\alpha_1 c - \alpha_2 c] + q^2(N-3)q(1-q)^{N-3}\alpha_2 c > 0. \tag{A20}$$

We find that the difference in equilibrium bid is positive, which establishes the second part of Proposition 5 for $N \ge 4$.

Finally, we turn to the question whether forming an **SC** is strictly profitable. The analysis of a **TC** serves as a benchmark in this respect. We know that both consortia types win in equilibrium and that the **SC**'s direct cost coincides with the direct cost of a **TC** (from (A12)). Consequently, the difference in profitability between an **SC** and a **TC** follows from the difference in equilibrium bid. That difference is given by (A20) and is positive. It follows that forming an **SC** is more profitable than forming a **TC**. Since the latter is strictly profitable, the former is strictly profitable as well. This finding completes the proof of Proposition 4.

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