# Coordinated Effects in Merger Review

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**Abstract**

Coordinated effects are merger-related harms that arise because a subset of postmerger firms modify their conduct to limit competition among themselves, particularly in ways other than explicit collusion. We provide a measure of the risk of such conduct by examining the individual rationality of participation by subsets of firms in market allocation schemes. This measure of risk for coordinated effects distinguishes markets that are at risk from those that are not and distinguishes mergers that increase risk from those that do not. A market's risk for market allocation by a subset of firms varies with the degree of outside competition, symmetry and strength of the subset of firms, buyers' power, and vertical integration. We make precise the widely used but rarely rigorously defined notion of a maverick firm and provide foundations for a maverick-based approach to coordinated effects. In addition, we identify previously unrecognized trade-offs between unilateral and coordinated effects.

## 1. Introduction

Competition authorities regularly review proposed mergers and oppose those deemed likely to have sufficiently detrimental effects, recognizing that one source of detrimental effects is that a merger can change "the nature of competition in such a way that firms that previously were not coordinating their behaviour, are now significantly more likely to coordinate and raise prices or otherwise harm

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effective competition" (Guidelines on the Assessment of Horizontal Mergers under the Council Regulation on the Control of Concentrations between Undertakings, 2004 O.J. [C 31] 5–18, para. 22[b]; hereafter, EC Guidelines).[1] Adverse competitive effects of mergers that arise in this way are referred to as coordinated effects and play a central role in antitrust thinking and practice.[2] Despite their prominence and in contrast to theories of harm based on unilateral effects, which are adverse competitive effects resulting from the elimination of competition between the merging parties (see, for example, US Department of Justice and Federal Trade Commission 2010) and are supported by a range of well-accepted tools for the quantification of harm (see, for example, Davis and Garcés 2010), theories of harm based on coordinated effects have proved difficult to formulate rigorously, and a methodology to quantify these harms has proved elusive.

Of course, a major obstacle to quantifying the effect of a merger on the risk of collusive conduct is that perfect collusion is always profitable, both before and after a merger. Consequently, any theory of harm based on coordinated effects must rely on a form of imperfectly collusive conduct. Of particular appeal to real-world agents and concern to competition authorities are market allocation schemes, whereby firms take turns in serving a given market.[3] The "phases of the moon" conspiracy that involved 29 suppliers of industrial electrical generators in the 1950s is a classic and colorful example of this notorious but popular (mal)practice (Asker 2018), and additional examples of allocation schemes are plentiful.[4]

In this paper, we provide a theory of collusive behavior based on market allocation schemes that permits us to quantify the extent to which a market is at risk for such conduct. The basic idea is that for participation in an allocation scheme to pay off, each participant has to be selected to be the active supplier with sufficiently high probability. Thus, any allocation scheme can be defined by a set of critical shares—the shares of the market that leave participants indifferent between participating in the allocation scheme and not participating. Of course, each supplier's critical share is strictly less than 1 because the allocation scheme

[1] Similarly, the US Horizontal Merger Guidelines (US Department of Justice and Federal Trade Commission 2010, p. 2; hereafter, US Guidelines) recognize that a merger "can enhance market power by increasing the risk of coordinated, accommodating, or interdependent behavior among rivals." Similar guidance is provided by the Australian Competition and Consumer Commission's Merger Guidelines.

[2] Coordinated-effects arguments played a central role in US merger cases such as Heinz/Beech-Nut, Anheuser-Busch InBev/Grupo Modelo, and H&R Block/TaxACT. For European cases, see Amelio et al. (2009) on *ABF/GBI Business,* Motta (2000) on Airtours/First Choice, and Aigner, Budzinski, and Christiansen (2006) on Sony/BMG and Impala and on the evolution of coordinated-effects assessment in the European Union.

[3] Bid rigging is one of the most common violations that the Department of Justice prosecutes. Four basic schemes are involved in most bid-rigging conspiracies, all of which involve one bidder being designated to represent the participating firms: bid suppression, complementary bidding, bid rotation, and customer or market allocation (US Department of Justice 2013).

[4] As described in the European Commission's decisions, allocation schemes were used by cartels in choline chloride, copper plumbing tubes, electrical and mechanical carbon and graphite products, food flavor enhancers, industrial and medical gases, industrial bags, industrial tubes, methylglucamine, monochloroacetic acid, and zinc phosphate (Marshall and Marx 2012, table 6.1).

suppresses competition and thereby increases the profits of the active supplier. However, for a market to be at risk for allocation by a given set of suppliers, the critical shares of those suppliers need to sum to less than 1. Because the scheme can be inefficient (for example, because the suppliers have different marginal costs or because the reaction of outsiders erodes the benefits accruing to insiders), there is no a priori reason for this sum of critical shares to be less than 1. Thus, for a given set of candidate participants, the sum of their critical shares provides a natural way to define whether a market is at risk for allocation by those firms—if the sum is less than 1, then it is at risk. This is the definition of being at risk for the suppression of rivalry by market allocation that we use in this paper. Notably, this framework for evaluating the risk for coordinated effects can be combined with whatever model of a market's price-formation process is most appropriate for the problem at hand, be that a model of oligopoly, procurement, Nash-in-Nash bargaining, or another bargaining model. Moreover, the theory provides the basis for a test of the extent to which a market is at risk and the extent to which this risk increases with a merger. Furthermore, the test is operational using data that are commonly available during merger review.

Our approach puts the participation constraints for collusion front and center.[5] This contrasts with the folk-theorem-based literature on collusion in repeated games, whose focus is on the incentive compatibility and sustainability of collusion and the calculation of critical discount factors. As emphasized by Farrell and Baker (2020, p. 4), the applicability of the traditional, repeated-game approach to coordinated effects is limited because subgame perfect equilibria abound, collusive subgame perfect equilibria exist both before and after a merger, and it fails to satisfy the "quantification-hungry" nature of the policy world.[6] In this sense, our paper is in line with the conclusion drawn by Farrell and Baker that approaches to coordinated effects should depart from repeated-game models in the direction of quantifiable models and measures.

Closely tied to the notion of coordinated effects, both in the literature and in practice, is the notion of a maverick firm.[7] Broadly and vaguely, a maverick is a

[5] Stigler (1964)—a seminal paper on collusion—takes as its starting point that oligopolists wish to collude to maximize profits but that collusion is much more effective in some circumstances than in others, even to the point that it may be impossible. Stigler (1964, p. 47) notes that "the conditions appropriate to the assignment of customers will exist in certain industries, and in particular the geographical division of the market has often been employed." Although Stigler's focus is on the issue of secret price cutting—that is, incentive-compatibility constraints—his point that conditions supporting an assignment of customers hold in some cases and not others continues to be true when one focuses, as we do, on the profitability of market allocations.

[6] "One particular problem is that neither the theoretical nor empirical literature tells us much at all about whether the disappearance of a single firm through merger will increase the likelihood of coordination, other than, perhaps, in the extreme case where a merger reduces the number of firms in a market from three to two" (Kolasky 2002, p. 7).

[7] The particular concerns raised by mergers involving mavericks are discussed in, for example, the US, EC, and Australian merger guidelines, and they arise in many merger cases. Examples include the proposed acquisition of maverick T-Mobile by AT&T, the acquisition of maverick Northwest Airlines by Delta Airlines, and the proposed acquisition of maverick baby food maker Beech-Nut by Heinz. On mavericks in EC merger decisions, see Bromfield and Olczak (2018).

firm whose acquisition will put a market at risk for allocation when the market is not at risk for allocation with the maverick firm present. Baker (2002, pp. 156, 197) argues for a "maverick-centered approach" to coordinated effects, stating that "the identification of a maverick who constrains more effective coordination is the key to explaining . . . which particular changes in market structure from merger or exclusion are troublesome, and why" and that "[i]n many settings, regulators reliably can identify an industry maverick that prevents or limits coordination." Kolasky (2002) argues that the elimination of a maverick may be necessary for coordinated effects.[8]

Because our framework allows us to quantify whether and the extent to which a market is at risk for the suppression of rivalry by various subsets of suppliers, we are able to offer a precise definition of a maverick firm. Relative to a given set of suppliers potentially engaged in suppression of rivalry, we say that some other firm $m$ outside this set is a maverick if the market is not at risk for allocation by these firms with $m$ present and is at risk for allocation without $m$. As we show, an approach to merger review that focuses on blocking mergers that involve mavericks makes sense for markets characterized by the Cournot model with constant marginal costs. However, in other instances, such as procurement markets, a merger involving a maverick need not put the market at risk because the acquisition of a supplier is not the same as eliminating its productive assets.

Consistent with agencies' concerns related to coordinated effects, we find that market allocation schemes reduce expected surplus to the buyer (or consumer) and social surplus. However, for a variety of widely used models of the price-formation process, we also show that by our measure of being at risk for coordinated effects, some, but not all, markets are at risk and some, but not all, mergers put markets at risk. While a maverick-based approach has a foundation in the Cournot model, in general a more nuanced approach to mavericks is required. We show that a market's risk varies with the degree of outside competition, symmetry and strength of participating firms, buyers' power, and vertical integration of buyers. We identify trade-offs between unilateral and coordinated effects, including that structural remedies based on divestitures may not be able to simultaneously address concerns related to unilateral and coordinated effects.

There is a large legal and economics literature on coordinated effects and the intertwined notion of maverick firms. Baker (2002, 2010a, 2010b), Kaplow (2011), and Harrington (2013) provide overviews of the legal literature, with Kaplow (2013) providing an in-depth discussion; Ivaldi et al. (2007), Porter (2020),

[8] Antitrust officials have described a maverick as "a firm that declines to follow the industry consensus and thereby constrains effective coordination" (Kolasky 2002, p. 7), while the US Guidelines (US Department of Justice and Federal Trade Commission 2010, p. 4) describe a maverick as "a firm that has often resisted otherwise prevailing industry norms to cooperate on price setting or other terms of competition." Ivaldi et al. (2007, pp. 224, 228) define a maverick as "a firm that has a drastically different cost structure, production capacity or product quality, or that is affected by different factors than the other market participants" and "is thus unwilling to participate to a collusive action." Kwoka (1989, p. 410) identifies a maverick as the relatively "more rivalrous" firm, and Ivaldi and Lagos (2017) take the view that a maverick is a small firm, while in de Roos and Smirnov (2019) a maverick is a fringe firm that disrupts coordination.

and Farrell and Baker (2020) provide overviews of the economics literature. With the notable exceptions of Kwoka (1989) and Miller and Weinberg (2017), who analyze coordinated effects in static models by incorporating conjectural variation and a behavioral common-ownership parameter, respectively, most of the coordinated-effects literature has taken a repeated-game approach. Theoretical contributions along these lines include Compte, Jenny, and Rey (2002), Vasconcelos (2005), and Bos and Harrington (2010). The first two papers analyze all-inclusive collusion with price-setting and quantity-setting firms, respectively. The last paper analyzes non-all-inclusive collusion with price-setting firms.[9] Rotemberg and Saloner (1990) provide a model in which price leadership facilitates collusion, with the leader earning higher profits, which raises the possibility that coordinated effects could arise as a result of a subset of large firms allocating the right to act as the leader among themselves. Empirical work includes Igami and Sugaya (2019) on the vitamin industry and Miller, Sheu, and Weinberg (2019), which finds that Grupo Modelo acted as a maverick that constrained interdependent pricing between ABI and MillerCoors in the beer industry. Ivaldi and Lagos (2017) provide simulation-based results.

Our paper shares with the repeated-game approach the quantitative interpretation of a market being more at risk when, in our setup, the coordinated-effects index is larger and, in the repeated-game framework, the critical discount factor is smaller.[10] A key distinguishing feature of our approach is that it naturally gives rise to a threshold that distinguishes markets that are at risk from those that are not and therefore allows one to hone in on mergers that would transform a market from not being at risk to being at risk. It is this threshold that also allows us to define mavericks, test for whether a firm is a maverick, and clarify the value of maverick-based merger policies.

The remainder of the paper is organized as follows. In Section 2, we present our approach, first without imposing assumptions about the price-formation process and then using a model of differentiated-products price competition to fix ideas. In Section 3, we examine procurement markets. Section 4 provides a discussion of policy implications, including a microfoundation for a maverick-based approach to merger review and an analysis of trade-offs between unilateral and coordinated effects. Section 5 concludes the paper. Longer proofs are in the Appendix, and the Online Appendix provides an application and extensions.

[9] In an alternative approach, Kovacic et al. (2007b, 2009) and Gayle et al. (2011) view coordinated effects as analogous to incremental mergers among postmerger firms and propose quantifying coordinated effects by using existing merger simulation tools to model coordinated effects as incremental mergers.

[10] Details of the repeated-game approach can be found in, for example, Ivaldi et al. (2007). In this context, the effects on collusion of having multiple markets, which could be allocated along similar lines to the allocation scheme that we consider, are explored by, for example, Bernheim and Whinston (1990), Belleflamme and Bloch (2008), and Byford and Gans (2014).

## 2. Risk for Market Allocation

We denote by $N \equiv \{1, \ldots, n\}$, with $n \geq 2$, the set of all suppliers, such as the firms in an oligopoly model, and we consider the possibility that the suppliers in a subset $K \subseteq N$ engage in market allocation, where $K$ contains $k \geq 2$ suppliers. An allocation scheme among suppliers in $K$ is an arrangement in which each supplier $i \in K$ is designated to be the active member of $K$ with some probability $s_i$, in which case all other members of $K$ are inactive. In a merger review context, competition authorities may have reason to focus on specific subsets of suppliers on the basis of historical conduct or other evidence; as we illustrate in the Online Appendix, one can use the framework developed here to identify which subsets of suppliers, if any, pose a concern.

Let $\Pi_i$ denote supplier $i$'s payoff when there is no market allocation. Given a market allocation among suppliers in $K$, we denote $\Pi_i(K)$ the payoff of supplier $i \in K$ when it is the only supplier from $K$ that is active in the market, which occurs when the other suppliers in $K$ are not active in that market.

A supplier's decision to participate in a market allocation depends on its expected payoff when it participates and what happens if the supplier declines to participate. Because a market allocation among a subset $K$ of suppliers provides a public good to suppliers outside $K$, the conservative approach is to assume that the failure of any one of the suppliers in $K$ to participate in the allocation scheme results in there being no market allocation by suppliers in $K$. If a market is not at risk for allocation by suppliers in $K$ under this assumption, then it is also not at risk for allocation by suppliers in $K$ under alternative assumptions regarding continued market allocation by subsets of $K$ when a supplier in $K$ declines to participate. This is the approach that we take.

In this setup, participation by supplier $i \in K$ in a market allocation with the other suppliers in $K$ is profitable for supplier $i$ if and only if supplier $i$'s expected payoff under the market allocation is greater than its payoff when there is no market allocation.[11] This occurs if and only if the market is allocated to supplier $i$ with a sufficiently high probability (or supplier $i$ is allocated a sufficiently large share of the geographic areas, products, or customers). Specifically, participation by supplier $i \in K$ in a market allocation scheme among suppliers in $K$ is individually rational for supplier $i$ if and only if the market is allocated to supplier $i$ with a probability greater than supplier $i$'s critical share $s_i(K)$ defined by

$$s_i(K) \equiv \frac{\Pi_i}{\Pi_i(K)}.$$

Of course, the market allocation is feasible only if it is profitable for all suppliers in $K$. This means that each supplier in $K$ needs to have the market allocated to it

[11] Under the interpretation that an allocation scheme allocates one market to each supplier in $K$ with some probability, it is the expected payoff from participation that is relevant. Under the alternative interpretation that a supplier is allocated a share of a large number of individual geographic areas, products, or customers, then there is no uncertainty regarding the allocation, and so one need not take expectations for complete-information models.

with a probability greater than its critical share. Because the probabilities that define the allocation scheme must sum to 1, the participation constraints can be satisfied for all suppliers in $K$ only if those suppliers' critical shares sum to less than 1. This naturally leads to the coordinated-effects index:

$$\mathcal{I}(K) \equiv 1 - \sum_{i \in K} s_i(K).$$

If $\mathcal{I}(K) > 0$, then shares exist for the suppliers in $K$ such that each of them finds it profitable to participate in the market allocation. In that case, we say that the market is at risk for allocation by the suppliers in $K$. In contrast, if $\mathcal{I}(K) \leq 0$, then no such shares exist, and we say that the market is not at risk for allocation by the suppliers in $K$. Given a positive index, a further increase in the index allows greater scope for an allocation scheme to operate in the sense that some inefficiencies or imperfections can then be accommodated. In the extreme, as the index approaches 1, a market allocation can be sustained by selecting each participating supplier with an equal probability (or dividing geographic areas, products, or customers evenly among the participating suppliers).

Because the coordinated-effects index focuses on a necessary condition for market allocation, it is biased in the direction of overestimating the gains from market allocation. It thus provides a screen that allows one to dismiss concerns of coordinated effects as unlikely whenever the index is nonpositive. In this case, a market allocation without communication or transfers is not profitable for the suppliers in $K$. If the index is positive, an allocation scheme may be profitable depending on the challenges of implementation, including the issue of inducing compliance from suppliers that are designated to be inactive.[12] Importantly, the coordinated-effects index is operational for practical purposes—indeed, the model of the premerger price-formation process that is required to calculate $\Pi_i$ and $\Pi_i(K)$ is something that is currently typically constructed using premerger data for the purpose of unilateral-effects analysis.[13]

As discussed in Section 1, the notion of a maverick firm is prominent in coordinated-effects analyses but lacks a precise definition. Our approach allows us to make headway on this topic. We define a maverick with respect to a set of suppliers $K$ to be a supplier whose presence prevents the premerger market from being at risk for a market allocation by suppliers in $K$; that is, the market is not at risk for allocation by suppliers in $K$ when the maverick is in the market but is at risk when the maverick is not in the market. In formal terms, writing $\mathcal{I}(K; N)$ to denote the coordinated-effects index for the subset $K$ of $N$ suppliers, supplier $m \in N \setminus K$ is a maverick if

$$\mathcal{I}(K; N) \leq 0 \quad \text{and} \quad \mathcal{I}(K; N \setminus \{m\}) > 0.$$

[12] One might expect that repeated interaction could resolve compliance concerns, although that is outside the model that we consider.

[13] "In modern economic terms [analyzing unilateral effects] typically means analyzing static Nash equilibria of the oligopoly game" (Farrell and Baker 2020, p. 4).

This definition of a maverick captures the view that a maverick firm stands separate from its rivals and interferes with its rivals' ability to enhance their profits by dividing the market (or geographic areas, products, or customers) among themselves. The definition allows the possibility that there is no maverick as well as the possibility that more than one supplier in a market could be a maverick with respect to a particular set $K$ of suppliers.[14]

The conditions for a market to be at risk or for structural changes, such as the acquisition of a maverick, to put a market at risk naturally depend on the specifics of the price-formation process. Thus, the implementation of this approach requires a model of the price-formation process.

To illustrate, suppose that we have a market with $n$ suppliers engaged in differentiated-products price competition, where supplier $i$'s cost function is $C_i$ and demand for supplier $i$'s product given price vector $\boldsymbol{p}$ is $D_i(\boldsymbol{p})$. Then supplier $i$'s payoff given price vector $\boldsymbol{p}$ is

$$\pi_i(\boldsymbol{p}) \equiv p_i D_i(\boldsymbol{p}) - C_i(D_i(\boldsymbol{p})).$$

Letting $\boldsymbol{p}^*(X)$ denote the vector of Nash equilibrium prices for the game in which suppliers in $X \subseteq N$ choose their prices to maximize their profits and the suppliers in $N \setminus X$ choose their prices so that their equilibrium quantities are 0, we have

$$\Pi_i = \pi_i(\boldsymbol{p}^*(N)) \quad \text{and} \quad \Pi_i(K) = \pi_i(\boldsymbol{p}^*((N \setminus K) \cup \{i\})).$$

For example, in the symmetric differentiated Bertrand model of Singh and Vives (1984) with inverse demand $P_i(\boldsymbol{q}) = 1 - q_i - s\sum_{j \neq i} q_j$ and marginal costs of 0, where $s \in (0, 1)$ is a substitution parameter, the coordinated-effects indices for subsets of $k = 2$ of $n$ suppliers are shown in Figure 1*A* as a function of the substitution parameter.

As Figure 1*A* illustrates, whether a market is at risk for market allocation by pairs of suppliers depends on the total number of suppliers in the market and the substitutability between the suppliers' products. As shown, a market with more suppliers is less at risk because $\mathcal{I}(K)$ decreases with $n$, and greater substitutability among products increases the risk because $\mathcal{I}(K)$ increases with $s$. These comparative statics align well with traditional thinking about which markets pose the greatest risk for coordinated effects.

Figure 1*B* shows the effects of a merger on the risk of market allocation by $k = 2$ suppliers, one of which being the merged entity, when there are $n = 5$ symmetric firms before the merger. A merger by two firms is modeled as creating a new firm that chooses prices to maximize the joint profit from the sale of both of its products. As Figure 1*B* shows, the merger increases the risk of allocation, and for products that are sufficiently strong substitutes, the merger causes a market that was not at risk for pairwise market allocation to become at risk.

[14] We provide additional discussion and examples in Section 1. The notion of multiple mavericks arises in practice, for example, in the US mobile communications market. Prior to T-Mobile's acquisition of MetroPCS, both were considered "'mavericks' with a history of disrupting the industry" (*Kansas City Star* 2017).

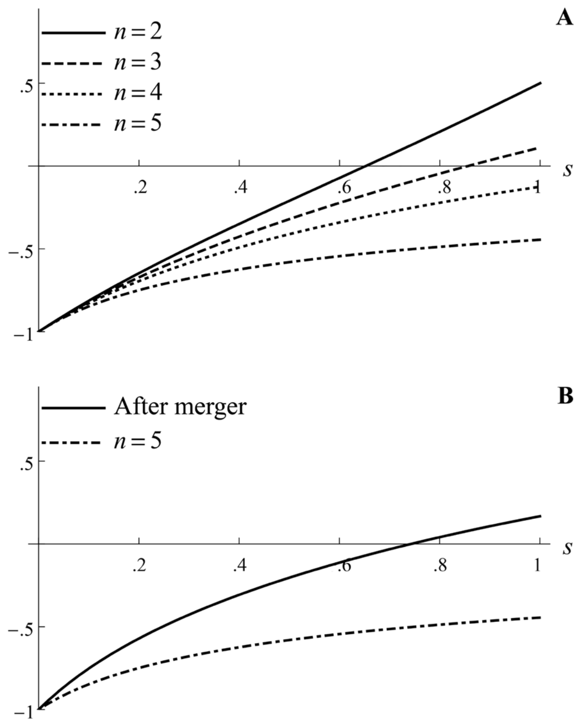


**Figure 1.** Coordinated-effects index for coordination by two firms. *A,* For varying total number of symmetric firms**;** *B,* before and after merger for five premerger firms.

## 3. Procurement Markets

The importance of business-to-business (or business-to-government) transactions, in which prices are typically determined through competitive procurements,[15] and the regularity of antitrust concerns related to collusion and supplier mergers in this sphere mean that a key application of coordinated-effects analysis is to procurement markets.[16] Thus, we turn our attention to procurement markets.

### *3.1. Procurement Market Setup*

We consider a standard procurement model in which a buyer with value $v$ for a single unit of a good can potentially purchase the good from any of $n$ suppliers. Each supplier $i$ independently draws its cost of producing a unit, which is its pri-

[15] Business-to-business wholesale and distribution in the United States was $8 trillion in 2018 (Mohammad 2018). Government procurement accounts for a double-digit share of gross domestic product in most developed economies (Kutlina-Dimitrova 2018).

[16] The US Department of Justice (2020) recently increased by more than 60 percent the size of its Procurement Collusion Strike Force, which is committed to “combatting collusion, antitrust crimes and related fraudulent schemes, which undermine competition in government procurement, grant and program funding.”

vate information, from a distribution $G_i$ with support $[\underline{c}, \overline{c}]$ and bounded density $g_i$ that is positive on $(\underline{c}, \overline{c})$. To focus on the case in which gains from trade are possible, we assume that $\underline{c} < v$. Symmetry among a set of suppliers means that the suppliers in that set draw their costs from the same distribution: $G_i = G$ for all $i$ in the set.

To model mergers, we assume, as do Farrell and Shapiro (1990), that merging suppliers rationalize production by producing at the lower of their two costs (see also Salant, Switzer, and Reynolds 1983; Perry and Porter 1985; Waehrer 1999; Dalkir, Logan, and Masson 2000; Loertscher and Marx 2019a). Thus, a merged entity that combines suppliers $i$ and $j$ has a cost distribution that is the distribution of the minimum cost of the two premerger suppliers, in which case the merged entity's cost distribution is $\hat{G}(c) \equiv 1 - [1 - G_i(c)][1 - G_j(c)]$. It follows that the productivity of the merged entity is enhanced relative to that of either of the individual merging suppliers.[17]

At the time when the suppliers in $K$ must decide whether to participate in a market allocation, all distributions, which characterize the firms' production technologies, are commonly known, but the suppliers' costs—their opportunity costs of using these technologies to serve the buyer—have not been realized. These costs are realized after the participation decisions are made but prior to bidding in the procurement.[18] Thus, the relevant payoffs associated with joining an allocation scheme are the suppliers' ex ante expected payoffs, with the expectation taken over all cost realizations and the allocation probabilities. We assume that the suppliers in $K$ participate in an allocation scheme on the basis of allocation probabilities $(s_i)_{i \in K}$. The timing is thus as follows: First, one of the suppliers in $K$ is selected to bid according to the probabilities $(s_i)_{i \in K}$. Second, costs are realized for the supplier in $K$ to whom the procurement is allocated and for the suppliers outside $K$, with those costs remaining the private information of the individual suppliers. Third, procurement occurs, with the designated supplier from $K$ competing against suppliers outside $K$. Finally, the winner is determined according to the procurement rules, and payoffs are realized. A key assumption is that the suppliers in $K$ other than the one to whom the procurement is allocated do not submit bids.

For some results, it is useful to parameterize the suppliers' cost distributions as $G_i(c) = 1 - (1 - c)^{\alpha_i}$ with $\alpha_i > 0$ and support $[\underline{c}, \overline{c}] = [0, 1]$, which we refer to as the power-based parameterization.[19] We refer to $\alpha_i$ as supplier $i$'s strength parameter because under efficient procurement, in a market with set $N$ of competing suppliers, supplier $i$'s market share is $\alpha_i / \sum_{j \in N} \alpha_j$. This parameterization allows us to talk about suppliers with larger values of $\alpha_i$ as being larger or stronger.

[17] For future research, one could incorporate additional merger-related cost synergies into the merged entity's distribution along the lines laid out in Loertscher and Marx (2019a).

[18] Whether the costs are realized before or after the designated bidder is selected in a market allocation is immaterial as long as the selection is independent of the realized costs.

[19] In this case, $G_i$ is the beta distribution with parameters $(1, \alpha_i)$.

### *3.2. Efficient Procurement Markets*

To model an efficient procurement market, we assume that the buyer uses a second-price procurement with reserve $r \equiv \min\{v, \overline{c}\}$, which, together with the assumption that suppliers follow their weakly dominant strategies of bidding truthfully, ensures that the procurement is efficient. We let $\mathcal{I}^S(K)$, with S for second price, denote the coordinated-effects index for efficient procurement markets.

A market allocation suppresses competition from one or more suppliers, and with positive probability the participation of the lowest-cost supplier is suppressed. Thus, a market allocation increases the expected cost conditional on trade and also reduces the probability of trade if the buyer's reserve binds with positive probability. As a result, a market allocation reduces expected social surplus. In addition, the elimination of bids as a result of a market allocation results in a higher expected price, which harms the buyer. Thus, we have the following result:

**Proposition 1.** In an efficient procurement market, market allocation reduces buyers' expected surplus and expected social surplus.

Proposition 1 provides a foundation for competition authorities' concerns about coordinated effects in procurement markets. Furthermore, if we view the buyer's purchase as an input to production for downstream consumers, and if a failure to purchase translates into a higher marginal cost or lower quality, then market allocation harms downstream consumers when $v < \overline{c}$ because it reduces the probability of trade. Using the notation $c_{(j:n)}$ to denote the $j$th lowest-order statistic of $n$ independent draws from a common cost distribution, we have the following result:

**Proposition 2.** In an efficient procurement market with symmetric suppliers with cost distribution $G$ and $v \geq \overline{c}$, the market is at risk for an all-inclusive market allocation, $\mathcal{I}^S(N) > 0$, if and only if

$$\mathbb{E}_{\boldsymbol{c}}[c_{(2:n)} - c_{(1:n)}] < \overline{c} - \mathbb{E}_c[c]. \tag{1}$$

Furthermore, this condition holds if $G(c)/g(c)$ is increasing in $c$ for all $c \in [\underline{c}, \overline{c}]$.

Proposition 2 provides conditions under which an efficient procurement market with symmetric suppliers is at risk for an all-inclusive market allocation scheme and conditions under which it is not. In particular, inequality (1) fails to hold—which implies that the market is not at risk for all-inclusive allocation—for cost distributions with a long left tail, where the price paid to the winning supplier is likely to be close to the reserve under competition and the expected incremental payment under cooperation is small and outweighed by the loss associated with the possibility that the supplier is not selected to participate.[20]

[20] If $G$ is the beta distribution with parameters $(1, a)$, then $G(c)/g(c)$ is increasing in $c$ for all $c \in [\underline{c}, \overline{c}]$ if $a \geq 1$ and not if $a \in (0, 1)$. The market is not at risk, for example, when $n = 2$ and $G$ is the beta distribution with parameters (1, .3), in which case the distribution $G_{(1)}$ of $c_{(1:n)}$ is the beta

It follows that the coordinated-effects-index test has power: according to the index, some, but not all, markets are at risk for coordination. Using model specification to mean the buyer's value and suppliers' cost distributions, we have the following result:

**Corollary 1.** For an efficient procurement market, there exist $N$, $K \subseteq N$, and model specifications such that $\mathcal{I}^{S}(K) > 0$ and other $N$, $K \subseteq N$, and model specifications such that $\mathcal{I}^{S}(K) \leq 0$.

### 3.2.1. Mergers and Mavericks

A merger raises concerns of coordinated effects if it enables or encourages postmerger coordinated interaction (US Department of Justice and Federal Trade Commission 2010, p. 24). A key scenario of concern is, therefore, a situation in which, on the basis of premerger data, the premerger market is characterized by $\mathcal{I}^{S}(K) \leq 0$ and, on the basis of the same data, the postmerger market would be characterized by $\mathcal{I}^{S}(K) > 0$. In that case, the data would be consistent with premerger competition and with the risk of postmerger market allocation. More generally, accounting for the inevitable uncertainty and imprecision, if a merger is expected to increase the coordinated-effects index, regardless of the sign of the index, it can be viewed as increasing the likelihood of a market allocation by the set of suppliers in $K$.

In another scenario, if one obtains $\mathcal{I}^{S}(K) > 0$ for the premerger market, then concerns that the merger could exacerbate coordinated effects are justified when the postmerger market has an even larger value of $\mathcal{I}^{S}(K)$ because this implies that a larger set of possibilities for allocation become available following the merger. Either scenario suggests potential for merger-specific harm based on coordinated effects.

An implication of proposition 2 is that even a three-to-two merger does not raise concerns of coordinated effects if the resulting duopoly is characterized by symmetric suppliers that draw their costs from a distribution that does not satisfy inequality (1). Thus, while it is possible to have a three-to-two merger that does not raise concerns of coordinated effects, such circumstances are limited, which is consistent with the view in practice that a three-to-two merger defines a significant, but not insurmountable, hurdle for antitrust approval.[21]

Next consider the effects of a merger among three or more suppliers in $K$ on the profitability of participation in a market allocation among them. In an efficient procurement market, the critical share for a supplier $i \in K$, $s_i(K)$, depends only on the distribution of the minimum cost of suppliers other than $i$ in $K$ and on the distribution of the minimum cost of suppliers outside $K$. Because a merger

distribution with parameters (1, .6), and we have $\mathbb{E}_{c:G}[c_{(2:n)} - c_{(1:n)}] = \mathbb{E}_{c:G_{(1)}}[G(c)/g(c)] \cong .2885$- and $1 - \mathbb{E}_c[c] = .3/(.3+1) \cong .2308$. Hence, inequality (1) is not satisfied.

[21] This is reflected in headlines such as "Is 4-3 the New 3-2? FTC Continues to Target Pharmaceutical Mergers" (Sokler and Kim 2014) and the analysis of antitrust enforcement trends (see, for example, Kovacic et al. 2007a; Hawkins and King-Kafsack 2014).

of two suppliers does not affect the distribution of the minimum cost of the two merging suppliers, it follows that in an efficient procurement market, a merger of two suppliers in $K$ does not affect the critical shares of the nonmerging firms in $K$. Thus, the change in $\mathcal{I}^S(K)$ as a result of the merger depends on how the critical share of the merged entity compares with the sum of the critical shares of two merging suppliers in the premerger market. Letting $\hat{N}$ denote the set of postmerger suppliers and $\hat{K}$ denote the postmerger suppliers in $K$ following the merger of suppliers $k$ and $\ell$ in $K$, and letting $\mu$ denote the merged entity, we have

$$\mathcal{I}^S(\hat{K};\,\hat{N}) - \mathcal{I}^S(K;\,N) = s_k(K;\,N) + s_\ell(K;\,N) - s_\mu(\hat{K};\,\hat{N}). \tag{2}$$

Lemma 1 follows immediately.

**Lemma 1.** For an efficient procurement market, a merger of suppliers in $K$ increases the coordinated-effects index if and only if the critical share of the merged entity is less than the sum of the premerger critical shares of the merging suppliers.

To see the forces at work, consider a merger of suppliers $k$ and $\ell$, both of which are members of $K$, and assume for purposes of illustration that $\Pi_k(K;\,N) = \Pi_\ell(K;\,N)$. Under this assumption, we have

$$s_k(K;\,N) + s_\ell(K;\,N) = \frac{\Pi_k + \Pi_\ell}{\Pi_k(K;\,N)}. \tag{3}$$

A merger of suppliers $k$ and $\ell$ is always profitable for those suppliers; that is, $\Pi_k + \Pi_\ell < \Pi_\mu$ (Loertscher and Marx 2019a, proposition 6), so the numerator in the merged entity's critical share, $\Pi_\mu$, is larger than the numerator in equation (3). At the same time, the denominator in the merged entity's critical share, $\Pi_\mu(\hat{K};\,\hat{N})$, is greater than the denominator in equation (3) because the merged entity draws its cost from a better distribution than does supplier $k$ or supplier $\ell$. Because either effect can dominate, the critical share of the merged entity can be greater than or less than the sum of the premerger critical shares of the merging suppliers, which implies that the coordinated-effects index can increase or decrease as a result of the merger.

In contrast to the case of a merger of suppliers in $K$, a merger of suppliers outside $K$ does not affect $\mathcal{I}^S(K)$ because $\mathcal{I}^S(K)$ depends only on suppliers outside $K$ through the distribution of the minimum of their costs, which is not affected by a merger. Thus, we have the following result:

**Proposition 3.** In an efficient procurement market, a merger of suppliers in $K$ can, but need not, cause a market not at risk for a market allocation by suppliers in $K$ to become at risk for a market allocation by the corresponding postmerger suppliers, and a merger of suppliers outside $K$ does not affect the risk for market allocation by suppliers in $K$.

An implication of the result in proposition 3 that a merger of outsiders does not affect the coordinated-effects index is that merging parties cannot reduce the perceived risk of a market allocation as a result of their merger by strategically varying the timing of their merger so that it falls either before or after a merger of outsiders. As we now show, the acquisition of a maverick can, but need not, put the market at risk. In a procurement market, the acquisition of a maverick is not the same as the elimination of the maverick's productive capability. Rather, it eliminates a bid in the procurement. Thus, if supplier $i \in K$ is the acquirer, then both $\Pi_i$ and $\Pi_i(K)$ increase after the acquisition, so the critical share $s_i(K)$ may well be larger after the acquisition than before it. For all other suppliers $j \in K \setminus \{i\}$, $\Pi_j(K)$ increases because the maverick has been eliminated as an outside supplier. In an efficient procurement, $\Pi_j$ is not affected, so $s_j(K)$ decreases. Consequently, in an efficient procurement market, the overall effect of the acquisition of a maverick with respect to $K$ on the coordinated-effects index depends on the details and can, as we show, go either way. Proposition 4 provides conditions under which the decrease in the critical share of the nonmerging supplier dominates if and only if the maverick is acquired by the smaller of two participating suppliers.

**Proposition 4.** For an efficient procurement market characterized by the power-based parameterization and $v \geq \overline{c}$, if $k = 2$, then the acquisition of a maverick by the weakly smaller supplier in $K$ puts the market at risk, whereas the acquisition by the larger supplier in $K$ does not if the weaker supplier is sufficiently small.

Proposition 4 implies that a maverick-based merger review that focuses on blocking mergers that involve the acquisition of a maverick can be misleading for efficient procurement markets. In addition, some other aspects of the perceived wisdom regarding mavericks are also not supported in our framework. In particular, one can easily construct examples in which the acquisition of a supplier that is not a maverick puts a market at risk. Thus, it is not the case that the acquisition of a maverick is necessary for coordinated effects. Contrary to what has been suggested, it is also not the case that the presence of a maverick prevents coordinated effects from mergers not involving the maverick.[22]

Similar to the neutrality result of Nocke and Whinston (2010) showing that the order in which a competition authority addresses mergers does not matter for unilateral effects, we have a form of neutrality for coordinated effects because outside mergers do not affect the participation constraint for a market allocation. If $\mathcal{I}^S(K) > 0$, a merger of outsiders cannot stop the market from being at risk nor create a maverick with respect to $K$ because mergers among firms outside $K$ do not affect $\mathcal{I}^S(K)$, which depends on outsiders only through the distribution of the minimum of their costs. Thus, a competition authority cannot reduce the

[22] To see that this argument (for example, in Baker 2002, p. 180) does not apply for efficient procurement markets, consider a market with five firms drawing their cost types from the uniform distribution on [0, 1]. Then supplier 5 is a maverick with respect to participation in a market allocation by suppliers in {1, 2, 3}; that is, $\mathcal{I}^S(\{1, 2, 3\}; \{1, 2, 3, 4, 5\}) \leq 0$ and $\mathcal{I}^S(\{1, 2, 3\}; \{1, 2, 3, 4\}) > 0$. Following the merger of suppliers 1 and 2, the market is at risk for market allocation by the merged entity and supplier 3; that is, $\mathcal{I}^S(\{\mu, 3\}; \{\mu, 3, 4, 5\}) > 0$, where $\mu$ is the merged entity.

risk of coordinated effects among one set of firms by first approving balancing mergers among outsiders. However, if $\mathcal{I}^{S}(K) < 0,$ then a merger of outsiders could create a maverick, which would then be a potential acquisition target for suppliers in $K$. For example, suppose that there are two suppliers outside $K$ and that $\mathcal{I}^{S}(K) < 0.$ If neither of the outsiders is a maverick, but if they are jointly a maverick in the sense that if both outsiders were eliminated the market would be at risk for a market allocation by $K$, then a merger of those outsiders creates a maverick.

The merger of US telecom firms Sprint and T-Mobile raised the question of whether the merger of two mavericks might create a super maverick, with former Federal Communications Commission chair Robert McDowell stating, "Verizon and AT&T have nearly 70 percent market share and 93 percent of the industry cash flow. Combining T-Mobile and Sprint will create a supercharged maverick, which will still be only Number Three. This newly invigorated third carrier will be better able to compete against the larger two" (McDowell 2019).[23] In our model, a merger involving a maverick with respect to $K$ and another supplier outside $K$ does not affect $\mathcal{I}^{S}(K;\ N)$ and increases $\mathcal{I}^{S}(K;\ N \setminus \{\hat{m}\}),$ where $\hat{m}$ denotes the merged entity formed by the maverick and the other outside supplier. As a result of such a merger, there continues to be a maverick with respect to $K$, and the difference between the coordinated-effects index with and without the maverick is increased.[24] Thus, there is a sense in which the merger of two mavericks could indeed be described as creating a super maverick.

### 3.2.2. Characteristics of the Market and Suppliers

We now show that the effects of the characteristics of the market and suppliers on the risk of market allocation in our model are broadly consistent with the perceived wisdom and the prior literature. In particular, we discuss the effects of outside competition, suppliers' strength, and symmetry among the participating suppliers on the coordinated-effects index.

A natural conjecture is that a market allocation by a given set of suppliers is more challenging when those suppliers face more outside competition. Although an increase in the number of (symmetric) outside suppliers decreases their payoffs in $K$ both with and without a market allocation, one can show that, for symmetric suppliers, the decrease in payoffs under market allocation is larger, so critical shares increase, and the market becomes less at risk for market allocation.

**Proposition 5.** In an efficient procurement market with symmetric suppliers,

[23] See also Deutsche Telekom chief executive officer Tim Hoettges's statement that he was "intrigued by the idea of having a combination with Sprint and being the 'super-maverick' in the market" (Bunton 2015).

[24] This suggests that one could quantify the extent of the maverickness by the difference in the coordinated-effects index with and without the maverick; that is, one could measure the strength of a maverick $m$ by $\mathcal{I}^{S}(K;\ N \setminus \{m\}) - \mathcal{I}^{S}(K;\ N)$. As an example, in the power-based parameterization with $n = 4$, $\alpha_1 = 2$, $\alpha_2 = 2$, $\alpha_3 = 1$, and $\alpha_4 = 1:$ supplier 2 is a maverick for $K = \{1, 3\}$ and more of a maverick after supplier 2 merges with supplier 4.

given $K$ with $k \geq 2$ members, the market is not at risk if $n$ is sufficiently large: $\lim_{n\to\infty} \mathcal{I}(K) = 1 - k < 0$.

The intuition is simple. As mentioned, a market allocation provides a public good whose costs are borne by the insiders and whose benefits accrue to all active suppliers, which include the designated supplier among the insiders and all outsiders. For a market allocation to pay off, it must be the case that the insiders internalize enough of the benefits that their conduct generates, which requires that the outside competition be limited.

Interestingly, the effect of the degree of outside competition on the incentives for a subset of suppliers to participate in a market allocation may make such conduct contagious in the following sense: Suppose that if the suppliers in some set $K_1$ do not coordinate, then $\mathcal{I}^S(K_2)$ is negative for some disjoint set of suppliers $K_2$. If the suppliers in $K_1$ coordinate, which implies that the lowest-cost supplier in $K_1$ is not active with positive probability,[25] this is as if the outside competition for the suppliers in $K_2$ has weakened and makes it possible that once the suppliers in $K_1$ coordinate, $\mathcal{I}^S(K_2)$ becomes positive. Of course, because the same logic applies to the suppliers in $K_1$, it is possible that each set of suppliers finds it beneficial to coordinate only if the other set coordinates as well.

Next we consider the effect of increases in the strength of the participating suppliers. We focus on the power-based parameterization, in which an increase in strength corresponds to an increase in the distributional parameter and to a first-order stochastically dominated shift in the cost distribution.

**Proposition 6.** For the power-based parameterization and $v \geq \overline{c}$,

*a*) if suppliers in $K$ have strength $\alpha$, then $\lim_{\alpha\to 0} \mathcal{I}^S(K) < 0$ and $\lim_{\alpha\to\infty} \mathcal{I}^S(K) > 0$;

*b*) index $\mathcal{I}^S(K)$ is largest, conditional on $|K| = k$ if $K$ includes the $k$ strongest suppliers; and

*c*) given $\boldsymbol{\alpha} = (\alpha_i)_{i\in N}$ and $\boldsymbol{\beta} = (\beta_i)_{i\in N}$ satisfying $\sum_{i\in N} \alpha_i = \sum_{i\in N} \beta_i$, and adding the distributional parameters as an argument to $\mathcal{I}^S$, we have

$$\mathcal{I}^S(K;\, \boldsymbol{\alpha}) < \mathcal{I}^S(K;\, \boldsymbol{\beta})$$

if $\alpha_i \leq \beta_i$ for all $i \in K$, with a strict inequality for at least one $i \in K$.

For the power-based parameterization, by proposition 6.*a*, efficient procurement markets are not at risk when the participants in the allocation scheme are sufficiently weak and are at risk when the participants are sufficiently strong. Intuitively, participating in a market allocation with a stronger supplier is more profitable because the bid suppression by that supplier is more likely to affect the outcome of the procurement. Furthermore, by proposition 6.*b*, market allocations in efficient procurement markets are characterized by positive assortative matching insofar as the coordinated-effects index for a set of $k$ suppliers is great-

[25] The contagion effect would not be present if the conduct were efficient, as might be the case with explicit collusion involving the communication of private information and transfers.

est when the set contains the $k$ strongest suppliers. Moreover, by proposition 6.*c*, the coordinated effects for a given set of suppliers $K$ increase as the suppliers become stronger while keeping fixed the distribution of the lowest cost draw in the market. Proposition 6.*b* implies that an efficient procurement market is most at risk for the allocation that is most problematic for buyers, namely, a market allocation involving the large suppliers. This is consistent with the prevailing view that a competition authority should be most concerned about a market allocation among the largest suppliers in a market.

We now turn our attention to the effects of asymmetries among participants in an allocation scheme. The literature argues that asymmetries make it more difficult for firms to agree to a common pricing policy and that incentive compatibility may be difficult to satisfy for low-cost firms that face relatively large gains from deviations and small costs from punishment (see, for example, Compte, Jenny, and Rey 2002; Kühn 2004; Vasconcelos 2005; Ivaldi et al. 2007).[26] We now show that a similar effect arises in our context.

To consider the effects of asymmetries among suppliers in a market, we begin by defining a neutral for rivals spread (NR spread). We say that a change in the cost distributions for suppliers $i$ and $j$ from $(G_i, G_j)$ to $(H_i, H_j)$ is an NR spread if, for all $c \in [\underline{c}, \overline{c}]$,[27]

$$H_i(c) \leq G_i(c),\ G_j(c) \leq H_j(c), \tag{4}$$

with strict inequalities for costs in an open subset of $[\underline{c}, \min\{v, \overline{c}\}]$, and

$$[1 - G_i(c)][1 - G_j(c)] = [1 - H_i(c)][1 - H_j(c)]. \tag{5}$$

The inequalities in expression (4) represent the spread, while equation (5) captures neutrality for rivals because it means that the distribution of the minimum cost of suppliers $i$ and $j$ is the same under $(H_i, H_j)$ as under $(G_i, G_j)$.

As we now show, consistent with the evidence that collusion is harder to sustain among more asymmetric suppliers, we provide conditions under which an NR spread applied to two suppliers in $K$ reduces the coordinated-effects index.

**Proposition 7.** For the power-based parameterization and $v \geq \overline{c}$, an NR spread applied to two suppliers in $K$ reduces $\mathcal{I}^S(K)$.

Proposition 7 highlights the impact of asymmetries among suppliers on the risk for coordinated effects. Intuitively, when two suppliers are made less symmetric, their expected second-lowest cost increases, which increases the expected prices and profits in the absence of a market allocation and so decreases $\mathcal{I}^S(K)$. At the same time, expected profits in the presence of a market allocation decrease

[26] For the contrasting view that asymmetries can facilitate collusion in some settings, see Ganslandt, Persson, and Vasconcelos (2012). Miklós-Thal (2008, 2009) shows that cost asymmetries can facilitate collusion if transfer payments are feasible.

[27] A neutral for rivals spread (NR spread) applied to two suppliers in a market produces a market that is "more concentrated" according to Waehrer (2019, p. 12). For example, if $G(c; \alpha) \equiv 1 - (1 - c)\alpha$, we can construct an NR spread of $(G(c; \alpha_1), G(c; \alpha_2))$, where $\alpha_1, \alpha_2 > 0$, using $H_1(c) = G(c; \alpha_1 - \Delta)$ and $H_2(c) = G(c; \alpha_2 + \Delta)$ for $\Delta \in (0, \min\{\alpha_1, \alpha_2\}]$.

for the supplier made weaker and increase for the supplier made stronger, with an ambiguous effect on $\mathcal{I}^{S}(K)$. Combining these, in the case of the power-based parameterization, the overall effect is to reduce $\mathcal{I}^{S}(K)$.

### *3.3. First-Price Procurement Markets*

We now provide conditions under which buyers that employ first-price rather than second-price procurements are less vulnerable to coordinated effects. In first-price procurement auctions, the bidder with the lowest bid that is less than the reserve wins and is paid the amount of its bid. We further restrict attention to ex ante symmetry among bidders, namely, $G_i = G$ for all $i \in N$. In a first-price auction, a market allocation by suppliers in $K \subset N$ harms the buyer and reduces social surplus just like it does in a second-price auction. It does so because, first, the active supplier in $K$ increases its bid for any cost realization $c \in [\underline{c}, \overline{c})$ because it faces less competition, which results in a higher expected price for the buyer and inefficient production. Moreover, if the outsiders—that is, the suppliers that do not participate in the market allocation—are aware of the market allocation, then they also bid higher according to the unique Bayes Nash equilibrium bidding strategy (Lebrun 1999) of the procurement game in which $n - k + 1$ symmetric suppliers simultaneously submit bids. If the outsiders are not aware of the market allocation, then they bid according to the Bayes Nash equilibrium bidding strategy with $n$ suppliers, and the active supplier in $K$ best responds to these strategies.

To distinguish between the scenarios in which outsiders are and are not aware of the market allocation, we denote the coordinated-effects index $\mathcal{I}_1^{F}(K)$ when outsiders are aware of the market allocation and $\mathcal{I}_0^{F}(K)$ when they are not. Because of strategic complementarity, we have $\mathcal{I}_1^{F}(K) \geq \mathcal{I}_0^{F}(K)$. It will be useful in what follows to note that the payoff-equivalence theorem (see, for example, Myerson 1981; Krishna 2002; Börgers 2015) implies that, under symmetry, suppliers' competitive payoffs are the same under second-price and first-price procurements. If, in addition, the market allocation is observable, then the resulting payoffs are also the same under second-price and first-price procurements because then, letting $k$ be the number of participating suppliers, we simply have competition among $n - k + 1$ symmetric suppliers. Thus, for symmetric suppliers,

$$\mathcal{I}^{S}(K) = \mathcal{I}_1^{F}(K) \geq \mathcal{I}_0^{F}(K),$$

with a strict inequality if and only if $K \neq N$. This formalizes the commonly held notion that first-price procurements are less susceptible to collusive conduct than second-price procurements (see, for example, Marshall and Marx 2009; Kovacic et al. 2006).

**Proposition 8.** Given a procurement market with $n$ symmetric suppliers, if allocation schemes are not observable, then the market is at lower risk for allocation by a subset of $k < n$ suppliers when the procurement is first price rather than second price, but the risk is not affected by the auction format if the allocation scheme is observable or if it is all inclusive, namely, $k = n$.

While proposition 8 confirms the usual thinking that first-price procurements tend to be more resistant to anticompetitive conduct by bidders than second-price procurements, it also provides conditions under which a first-price procurement provides no additional protection from a market allocation relative to a second-price procurement. Thus, while a buyer's use of first-price procurements may mitigate concerns related to coordinated effects, it does not eliminate them.

### *3.4. Procurement Markets with Powerful Buyers*

An entire section of the US Guidelines is devoted to "powerful buyers," where it is argued that "the conduct or presence of large buyers" could "undermine[] coordinated effects" (US Department of Justice and Federal Trade Commission 2010, p. 27).[28] Indeed, for procurement markets, it is natural to consider the possibility that powerful buyers design their procurement mechanisms to maximize their expected payoffs. (In contrast, it is not clear how one would incorporate buyer power into standard oligopoly models, which assume price-taking buyers.) Intuitively, one expects buyer power to reduce the profitability of market allocation schemes because powerful buyers rely less on rivalry among bidders to police prices than do buyers without power. Yet, to our knowledge, there has been no formalization of this intuitive idea in the literature.

We follow Bulow and Klemperer (1996) and our earlier work (Loertscher and Marx 2019a) in modeling a powerful buyer as one that has the sophistication and commitment power to employ the optimal procurement mechanism, that is, the mechanism that maximizes the buyer's expected profit subject to suppliers' dominant-strategy incentive compatibility and individual rationality constraints. We assume that buyer power itself is not affected by mergers among suppliers, which is natural if it derives from the size and/or sophistication of the buyer, as suggested by the EC Guidelines (2004 O.J. [C 31] 5–18, para. 65), or from the ability to vertically integrate upstream or sponsor entry, as suggested by the US Guidelines (US Department of Justice and Federal Trade Commission 2010, p. 27),[29] and if the merger does not give suppliers the power to influence the procurement mechanism that is employed by the buyer.[30]

[28] The US Guidelines (US Department of Justice and Federal Trade Commission 2010, p. 27) state that the agencies "consider the possibility that powerful buyers may constrain the ability of the merging parties to raise prices. This can occur, for example, . . . if the conduct or presence of large buyers undermines coordinated effects." The US Guidelines also state, "In some cases, a large buyer may be able to strategically undermine coordinated conduct, at least as it pertains to that buyer's needs, by choosing to put up for bid a few large contracts rather than many smaller ones, and by making its procurement decisions opaque to suppliers" (US Department of Justice and Federal Trade Commission 2010, p. 27).

[29] In contrast, the EC Guidelines (2004 O.J. [C 31] 5–18, para. 67) raise the possibility that a merger could reduce buyer power "because a merger of two suppliers may reduce buyer power if it thereby removes a credible alternative."

[30] Elsewhere, we (Loertscher and Marx, forthcoming) provide a formalization of the countervailing-power argument that a merger between suppliers might shift power away from the buyer and toward suppliers (see, for example, EC Guidelines, 2004 O.J. [C 31] 5–18, para. 11; Australian Merger Guidelines [Australian Competition and Consumer Commission 2017, paras. 1.4, 5.3, 7.48]). A nuance on the view that mergers decrease buyer power is provided in Loertscher and Marx (2019a), which observes that, with symmetric suppliers, a merger increases the buyer's incentive to become powerful.

Buyer power consists of two components: the ability to discriminate between suppliers and the commitment to cancel a procurement even though it would be profitable, which may be called monopsony power (Loertscher and Marx 2019a). Whether the buyer optimally exerts one or both of these powers depends on the problem at hand.[31] When all suppliers are ex ante symmetric—that is, when $G_i = G$ for all $i \in N$—there is no discrimination because ranking the suppliers according to their virtual costs is the same as ranking them according to their costs; however, in the absence of ex ante symmetry, the buyer optimally uses its power to discriminate some of the time. The buyer optimally refrains from ever using its monopsony power if and only if $v \geq \min_{i \in N} \Gamma_i(\overline{c})$, where $\Gamma_i(c) \equiv c + G_i(c)/g_i(c)$ is supplier $i$'s virtual cost, which we assume is increasing in $c$.[32] In procurement markets with buyer power, as in the case of efficient procurement markets, the buyer is harmed by a market allocation, and some but not all markets are at risk for market allocation. Interestingly, with buyer power, a market allocation can increase social surplus for some type realizations. This occurs with ex ante heterogeneous suppliers when, absent a market allocation, the buyer does not purchase from the lowest-cost supplier because it discriminates between suppliers on the basis of their virtual costs and purchases from a supplier with a lower cost when there is a market allocation because the bid of the supplier it buys from in the absence of a market allocation is suppressed.

With buyer power, the result that markets with sufficient outside competition are not at risk for market allocation continues to hold. Assuming that premerger suppliers are ex ante symmetric, a decrease in the critical share of the merged entity relative to the sum of the premerger critical shares of the merging suppliers is sufficient but no longer necessary for the merger to increase the coordinated-effects index. Nevertheless, it remains the case that a merger can, but need not, cause a market not at risk to become so.

To examine how the coordinated-effects index is affected by buyer power in our framework, we focus on ex ante symmetric suppliers. In this case, a powerful buyer never uses its power to discriminate, so the sole effect of buyer power is to reduce the reserve price, which allows us to focus on the effects of a change in the reserve in a second-price procurement. To the best of our knowledge, proposition 9 is the first formal demonstration that, consistent with perceived wisdom, buyer power reduces concerns of coordinated effects.

**Proposition 9.** In a procurement market with symmetric suppliers, $\mathcal{I}^S(K)$ is increasing in the buyer's reserve price and thus decreases with buyer power.

[31] Asker, Collard-Wexler, and De Loecker (2019) quantify the contribution of market power to the misallocation induced by the Organization of the Petroleum Exporting Countries.

[32] Because we allow the possibility that the densities are 0 at $\underline{c}$ (and also possibly at $\overline{c}$), define $\Gamma_i(\underline{c}) = \lim_{c \to \underline{c}} \Gamma_i(c) = \underline{c}$. For $x > \Gamma_i(\overline{c})$, we define $\Gamma_i^{-1}(x) \equiv \overline{c}$. An intuitive interpretation of the virtual cost function and an understanding of the role of its monotonicity can be developed using standard monopsony pricing. Consider a buyer with value $v \leq \overline{c}$ that faces a single supplier $i$ that draws its cost from the distribution $G_i$. The buyer's pricing problem is $\max_p (v - p)G_i(p)$, the first-order condition for which is $0 = g_i(p)[v - \Gamma_i(p)]$. If $\Gamma_i$ is increasing, then the second-order condition is satisfied if the first-order condition is satisfied (that is, the problem is quasi-concave).

Let us now turn to a merger. With buyer power, and regardless of whether suppliers are ex ante symmetric, a merger of two suppliers in $K$ increases the payoff of the other suppliers in $K$ when there is no market allocation as a result of the buyer's more aggressive discrimination against the merged entity. However, a merger between two suppliers in $K$ does not affect the payoff of a nonmerging supplier in $K$ under a market allocation. Thus, we have the following result.

**Proposition 10.** In a procurement market with buyer power, a merger of two suppliers in $K$ increases the critical shares of the nonmerging suppliers in $K$.

Proposition 10 implies that, with buyer power, a merger of two suppliers in $K$ constrains the profitability of a market allocation by increasing the critical shares of the nonmerging suppliers in $K$. Propositions 9 and 10 provide a foundation for the view that coordinated effects from a merger are less of a concern in the face of powerful buyers.[33]

### *3.5. Vertically Integrated Buyer*

Another question of concurrent interest concerns the effects of vertical integration on market outcomes (US Department of Justice and Federal Trade Commission 2020). To shed light on this question, we return to a second-price procurement without buyer power and stipulate that there are $n \geq 3$ ex ante symmetric suppliers and a buyer with willingness to pay $v \geq \overline{c}$ in the absence of integration. This implies that, prior to integration, the reserve price in the second-price auction is $\overline{c}$. The exposition simplifies by assuming that $G$ is such that for any $a \in [0, 1]$, both $\Gamma(c; a) \equiv c + aG(c)/g(c)$ and $\Phi(c; a) \equiv c - a[1 - G(c)]/g(c)$ are increasing in $c$, a sufficient condition for which is that $\Gamma(c; 1)$ and $\Phi(c; 1)$ are increasing in $c$.

Without loss of generality, assume that the buyer integrates with supplier 1. This implies that, after integration, the buyer's willingness to pay for the service or product of the independent suppliers is $c_1$, which implies that the postintegration market has two-sided private information. By a straightforward extension of the impossibility theorem of Myerson and Satterthwaite (1983) (see also, for example, Gresik and Satterthwaite 1989; Delacrétaz et al. 2019), this implies that postintegration ex post efficient trade is impossible without running a deficit.[34] For the postintegration market, it is then natural to focus on the second-best mechanism that maximizes ex ante expected social surplus subject to incentive compatibility, individual rationality, and budget constraints. As is well known (see, again, for example, Gresik and Satterthwaite 1989), this mechanism is characterized by an allocation rule that induces trade from the lowest-cost independent supplier $i$ to the integrated firm if and only if $\Phi(c_1; a^*) \geq \Gamma(c_i; a^*)$, where $\alpha^*$

[33] In the Online Appendix, we demonstrate the tractability of the analysis of markets with buyer power through an application to the oil-field services market.

[34] See Loertscher and Marx (forthcoming) for a more detailed analysis of vertical integration and the efficiency of the price-formation process.

$\in (0, 1)$.[35] For any $K \subset N \setminus \{1\}$, denote $\mathcal{I}^{S}(K)$ and $\mathcal{I}^{S}_{VI}(K)$ the coordinated-effects index before and after integration, respectively.

Intuitively, vertical integration has no effect on the efficient quantities under the assumptions that we stipulate in the sense that, under ex post efficiency, for any given cost realization, it is the same supplier that produces. Hence, if the quantities were still efficient following integration, then vertical integration would have no impact on the coordinated-effects index. However, because vertical integration induces a Myerson-Satterthwaite problem, the allocation following integration is no longer efficient. Qualitatively, the second-best mechanism has the same effects as endowing the buyer with buyer power. To see this, notice that any allocation rule according to which trade occurs between the integrated firm and the independent supplier with the lowest cost if and only if $\Phi(c_i; a) \geq \Gamma(c_i; a)$ is implementable via a second-price auction in which the integrated buyer sets the reserve $p(c_1; a) \equiv \Gamma^{-1}(\Phi(c; a); a)$, which is decreasing in $a$ and satisfies $p(c_1; 0) = c_1$. Thus, for a given realization of $c_1$, vertical integration has the same effect as having the buyer set a more aggressive reserve. As we know from proposition 9, buyer power reduces the risk for allocation among symmetric suppliers. Hence, from proposition 9 follows corollary 2.

**Corollary 2.** Vertical integration decreases the risk for allocation by any subset of independent, symmetric suppliers in the sense that for symmetric suppliers and $v \geq \bar{c}$, if $\Phi(c; 1)$ and $\Gamma(c; 1)$ are increasing in $c$ and $K \subset N \setminus \{1\}$, then $\mathcal{I}^{S}(K) > \mathcal{I}^{S}_{VI}(K)$.

To our knowledge, corollary 2 is the first instance of a formal connection between buyer power and vertical integration. Merger guidelines customarily refer to vertical integration as a source of buyer power.[36] Although in the independent private-values framework that underlies our setup there is no connection between the designer's type (that is, its realized willingness to pay) and its ability to use the profit-maximizing mechanism, vertical integration in this setting has qualitatively the same effect as endowing the buyer with buyer power, as the above shows.

## 4. Discussion

In this section, we discuss microfoundations for a maverick-based approach to coordinated effects. In addition, we examine the trade-offs between coordinated effects and unilateral effects.

[35] For our purposes, the derivation of $a^*$ and its precise size, above and beyond $a^* > 0$, does not matter. It is the smallest number $a \in [0, 1]$ such that an incentive-compatible and individually rational mechanism that is based on the allocation rule that induces trade between the lowest-cost independent supplier $i$ and the integrated firm if and only if $\Phi(c_1; a) \geq \Gamma(c_i; a)$ does not run a deficit.

[36] For example, the US Guidelines describe the "ability and incentive to vertically integrate upstream" as a possible source of buyer power (US Department of Justice and Federal Trade Commission 2010, p. 27).

### *4.1. Microfoundation for a Maverick-Based Approach*

We now show that the Cournot model provides a theoretical foundation for a maverick-based approach to coordinated effects. For this purpose, consider a Cournot model in which the inverse demand function for aggregate quantity $Q \in [0, 1]$ is $P(Q) = 1 - Q$ and suppliers have constant marginal costs $(c_1, \ldots, c_n)$ that are common knowledge.[37] We assume that costs are such that all suppliers are active in equilibrium in the absence of a market allocation.[38] To model a market allocation, we assume that $\Pi_i(K)$ is equal to supplier $i$'s Cournot payoff when only supplier $i$ and suppliers in $N \setminus K$ are present in the market. An immediate result is that a market allocation, which suppresses competition from one or more suppliers, reduces total output and so reduces consumer surplus and social surplus. Thus, the concerns of competition authorities related to coordinated effects apply to Cournot markets.

In the Cournot model, we model mergers as resulting in the elimination of the merging supplier with the higher cost or simply one of the suppliers if their costs are the same. This means that the effect of a merger in the Cournot model is the elimination of the productive assets of the weakly less efficient merging supplier, which leaves the productivity of the merged entity the same as that of the weakly more efficient merging supplier.[39] This immediately implies that a merger between a maverick and a lower-cost supplier eliminates the maverick and so, by the definition of a maverick, puts the market at risk.

Furthermore, as we now show, in the Cournot model the only way a merger can cause a market that is not at risk to become at risk for allocation by a subset of symmetric suppliers is if the merger involves a maverick. For the result in proposition 11, we assume that when a supplier $i \in K$ merges with a supplier outside $K$, the merged entity takes the place of supplier $i$ as a member of $K$ in the postmerger market. Because the proof is relatively short and straightforward, we include it here.

**Proposition 11.** In the Cournot model, a merger between a maverick with respect to $K$ and a weakly lower cost supplier puts the market at risk for market allocation by suppliers in $K$; moreover, the only merger that can cause a market that is not at risk for allocation by a subset $K$ of symmetric suppliers to become at risk is a merger involving a maverick with respect to $K$.

[37] For the relevance of the linear-demand, constant-marginal-cost Cournot setup in an empirical context, see, for example, Igami and Sugaya (2019).

[38] Farrell and Shapiro (1990) consider unilateral effects of mergers in a Cournot setup and provide conditions, which are satisfied in our Cournot setup with linear demand and constant marginal cost, under which a merger that involves no synergies must increase the price.

[39] The role the assumption of constant marginal costs plays for this result is worth mentioning. As noted in McAfee and Williams (1992), in the Cournot model a merger would no longer amount to the elimination of a supplier if, for example, supplier $i$'s cost function for producing quantity $q_i$ were $q_i^2/\kappa_i$, where $\kappa_i$ is $i$'s capacity. It that case, a merger of suppliers $i$ and $j$ would result in a supplier whose cost was only $q_i^2/(\kappa_i + \kappa_j)$. Related to this model of costs in a Cournot setup, see also Perry and Porter (1985), Farrell and Shapiro (1990), and Whinston (2006).

***Proof.*** The first part follows by the definition of a maverick and the assumption that a merger in the Cournot model eliminates the higher-cost supplier. Turning to the second part, we see that letting $q_i^{\mathrm{C}}(X)$ denote the Cournot quantity of supplier $i$ when suppliers in $X$ participate in the market gives

$$q_i^{\mathrm{C}}(X) = \frac{1 + C_X - (|X| + 1)c_i}{|X| + 1},$$

where $C_X \equiv \sum_{i \in X} c_i$. Because supplier $i$'s Cournot profit is the square of its quantity, the index for the Cournot model is $\mathcal{I}^{\mathrm{C}}(K) = 1 - \sum_{i \in K} [q_i^{\mathrm{C}}(N)/q_i^{\mathrm{C}}(N \backslash K \cup \{i\})]^2$, which for symmetric suppliers in $K$ becomes

$$\mathcal{I}^{\mathrm{C}}(K) = 1 - k\left(\frac{n - k + 2}{n + 1}\right)^2. \tag{6}$$

Given symmetric suppliers in $K$, if for all $i \in K$ $\mathcal{I}^{\mathrm{C}}(K; N) \leq 0$ implies $\mathcal{I}^{\mathrm{C}}(K \backslash \{i\}; N \backslash \{i\}) < 0$, then a merger between firms in $K$ does not put the market at risk. Thus, the only mergers that could put the market at risk involve either two firms outside $K$, where the weakly higher cost firm is a maverick with respect to $K$, or one supplier inside $K$ and one outside supplier that is a maverick with respect to $K$. Q.E.D.

As proposition 11 shows, the mergers that raise concerns of coordinated effects in the Cournot model correspond closely to those that involve a maverick, which provides a foundation for maverick-based merger review. Moreover, consistent with the results of Salant, Switzer, and Reynolds (1983) and Perry and Porter (1985), a market allocation by two symmetric firms in the Cournot model pays off only if the allocation scheme is all-inclusive, that is, if there are only two firms. However, if $K$ contains more than two firms, a non-all-inclusive allocation scheme can be profitable.

### *4.2. Trade-offs between Unilateral Effects and Coordinated Effects*

Our definition and measure of a market being at risk for coordinated effects brings to light trade-offs between unilateral effects and coordinated effects. To see this, reconsider the efficient procurement market. Because an NR spread results in a spread of the affected suppliers' market shares without changing their total market share, an NR spread increases the Herfindahl-Hirschman index (HHI), defined as the sum of the squared market shares, which is a widely used measure of merger effects.

As shown in proposition 7, for the power-based parameterization, an NR spread applied to two firms in $K$ decreases $\mathcal{I}^{\mathrm{S}}(K)$. In this sense, an NR spread is good medicine because it decreases the risk of allocation. At the same time, an NR spread implies that $H_i H_j < G_i G_j$;[40] that is, the distribution of the higher of the two

[40] Indeed, the result that $H_i H_j < G_i G_j$ is implied by any symmetry-reducing change, where a change in distributions for suppliers 1 and 2 from $(F_1, F_2)$ to $(H_1, H_2)$ is symmetry reducing if, for all $c \in [\underline{c}, \overline{c}]$, we have $\max_i\{H_i(c)\} \geq \max_i\{F_i(c)\}$ and $\min_i\{H_i(c)\} \leq \min_i\{F_i(c)\}$, with strict inequalities for costs in an open subset of $[\underline{c}, \min\{v, \overline{c}\}]$.

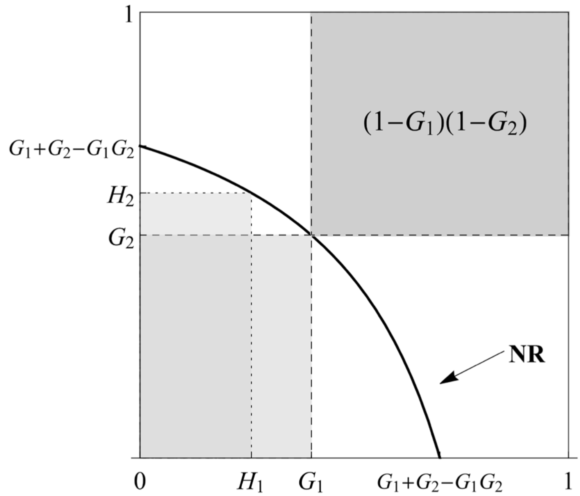


**Figure 2.** Symmetry-reducing neutral-for-rivals change from $(G_1, G_2)$ to $(H_1, H_2)$

cost draws after the spread first-order stochastically dominates the distribution of the higher of the two cost draws before the spread. This is shown in Figure 2, which has a symmetry-reducing NR change from $(G_1, G_2)$ to $(H_1, H_2)$. The shaded rectangles below the NR curve show that for any symmetry-reducing NR change, $H_1H_2 < G_1G_2$. This means that the buyer's expected price increases, and the more so the larger is the spread, where we say that $(\hat{H}_1, \hat{H}_2)$ is a larger NR spread from $(G_1, G_2)$ than $(H_1, H_2)$ if $(\hat{H}_1, \hat{H}_2)$ is an NR spread of $(H_1, H_2)$. Thus, an NR spread is bad medicine if the firms bid competitively because it harms the buyer. We summarize these results in proposition 12.

**Proposition 12.** An NR spread has the unilateral effect of increasing the HHI and the buyer's expected price, with a larger NR spread resulting in both a larger increase in the HHI and a larger increase in the expected price.

Proposition 12 resonates with the idea that the presence of a supplier with a "dominant position" harms buyers and that greater dominance results in greater harm.[41] It is noteworthy that the buyer's harm from a decrease in symmetry identified in proposition 12 arises irrespective of the sizes of the suppliers under consideration relative to their rivals—any NR spread increases the expected price.

Interestingly, while proposition 12 shows that an NR spread increases the HHI, proposition 7 shows that, for the power-based parameterization, an NR spread applied to suppliers in $K$ reduces $\mathcal{I}^S(K)$. In contrast to the positive and reaffirming news from proposition 12 for the use of the HHI as an indicator of unilateral effects, the fact that an NR spread applied to two suppliers can decrease

[41] Regarding the possibility of a "significant impediment to effective competition," the EC Guidelines (2004 O.J. [C 31] 5–18, para. 2) state, "The creation or the strengthening of a dominant position is a primary form of such competitive harm." See also Compte, Jenny, and Rey (2002).

the coordinated-effects index implies that a larger change in the HHI need not be indicative of an increase in risk for allocation as measured by the coordinated-effects index.[42] In other words, the HHI is not a reliable indicator of coordinated effects, except inversely so for some efficient procurement markets. This raises concerns given competition authorities' historical reliance on the HHI as an indicator of coordinated effects (see, for example, US Department of Justice and Federal Trade Commission 2006).

The contrast between unilateral effects and the risk for coordinated effects extends to dynamic considerations. For example, Nocke and Whinston (2013) raise the question of whether in a dynamic setting a competition authority might have an incentive to block a merger with a large supplier to induce a merger with a smaller supplier that is less harmful in terms of unilateral effects. Our results show that when considering the risk of coordinated effects, a competition authority might have an incentive to block a large firm from acquiring a smaller firm to induce it to instead acquire a larger firm, with a resulting lower coordinated-effects index.

The inherent conflict between unilateral and coordinated effects is particularly salient in the context of merger remedies. For example, a competition authority considering requiring a divestiture as a condition for merger approval faces the dilemma that a divestiture that results in relatively more symmetric postmerger suppliers reduces concerns of unilateral effects but increases concerns of coordinated effects, and the converse is the case for a divestiture that results in relatively less symmetric postmerger suppliers (for further analysis, see Cabral 2003; Vergé 2010; Vasconcelos 2010; Loertscher and Marx 2019b). If we define a merger plus divestiture to be a transaction that takes two suppliers and reorganize them to create two different suppliers, we have corollary 3.

**Corollary 3.** A merger plus divestiture involving suppliers in $K$ that results in an NR spread increases the HHI, but in an efficient procurement market characterized by the power-based parameterization and $v \geq \overline{c}$, it decreases $\mathcal{I}^S(K)$.

This raises the interesting point that although suppliers contemplating a merger might have an incentive to manipulate their market shares (for example, by shifting sales from one merging party to the other) in hopes of improving their chances of surviving a merger review, a manipulation that reduces concerns of unilateral effects based on the HHI could increase concerns of coordinated effects based on the coordinated-effects index.

## 5. Conclusion

Modeling coordinated effects as a market allocation scheme among a subset of suppliers, where only one of the suppliers in the subset is designated to be active in the market, we provide a framework that allows one to define and

[42] Igami and Sugaya (2019) show that when one measures coordinated effects on the basis of the incentive-compatibility constraint, it is again possible for the Herfindahl-Hirschman index and the incentive to collude to go in opposite directions.

measure when a market is at risk for market allocation and to define mavericks. This analysis provides guidance for competition authorities regarding whether a merger raises concerns of coordinated effects. Mergers that create a symmetric set of large suppliers in a market with limited outside competition and buyers that lack significant buyer power and are not vertically integrated are of particular concern for putting markets at risk for allocation schemes. We show that the Cournot model provides a foundation for a maverick-based approach to mergers. This contrasts with procurement markets in which a merger involving a maverick need not put a market at risk because the acquisition of a supplier does not correspond to eliminating its productive assets.

The framework of this paper allows one to see where prior thinking related to coordinated effects was sound and where it was muddled because it was, without being explicit about it, switching between different models of the price-formation process. For example, merger guidelines promote the idea that buyer power lessens concerns of coordinated effects, and our framework concurs but with the clarification that this is grounded in procurement-based thinking. At the same time, there is a view that mavericks play a critical role, but, as we show, that is grounded in Cournot-based thinking. Thus, another key contribution of our paper is to separate the overall framework for analyzing coordinated effects, which is general, from the model of the price-formation process, which is specific to a market.

## Appendix

### Proofs

*Proof of Proposition 2*

Under symmetry and $v \geq \overline{c}$, we have $r = \overline{c}$, and the definition of $\Pi_i(N)$ implies that

$$\Pi_i(N) = \mathbb{E}_c[\overline{c} - c],$$

and the definition of $\Pi_i$ (and the payoff-equivalence theorem) implies that

$$\Pi_i = \frac{1}{n}\mathbb{E}_{\boldsymbol{c}}[c_{(2:n)} - c_{(1:n)}].$$

Under symmetry, the market is at risk for all-inclusive allocation if and only if allocation based on symmetric selection probabilities increases the expected surplus for all suppliers—that is, for all $i \in N$, $(1/n)\Pi_i(N) > \Pi_i$—which holds if and only if

$$\mathbb{E}_c[\overline{c} - c] > \mathbb{E}_{\boldsymbol{c}}[c_{(2:n)} - c_{(1:n)}],$$

which establishes inequality (1).

Turning to the claim that inequality (1) is satisfied if $G(c)/g(c)$ is increasing, we note that

$$\mathbb{E}_c[\overline{c} - c] = \int_0^1 (1-c)g(c)dc = \int_0^1 G(c)dc = \int_0^1 \frac{G(c)}{g(c)}dG(c) = \mathbb{E}_{c:G}\left[\frac{G(c)}{g(c)}\right],$$

and using $G_{(1)}(c) \equiv 1 - [1 - G(c)]^n$ and $G_{(2)}(y) \equiv 1 - [1 - G(y)]^n - nG(y)[1 - G(y)]^{n-1}$,

$$\begin{aligned}\mathbb{E}_{\boldsymbol{c}}[c_{(2:n)} - c_{(1:n)}] &= \int_0^1 c\frac{dG_{(2)}(c)}{dc} - \int_0^1 c\frac{dG_{(1)}(c)}{dc} \\ &= \int_0^1 [G_{(2)}(c) - G_{(1)}(c)]dc \\ &= \int_0^1 nG(c)[1-G(c)]^{n-1}dc \\ &= \int_0^1 \frac{G(c)}{g(c)}dG_{(1)}(c) \\ &= \mathbb{E}_{c:G_{(1:n)}}\left[\frac{G(c)}{g(c)}\right].\end{aligned}$$

Because $G_{(1:n)}$ is first-order stochastically dominated by $G$, it follows that if $G(c)/g(c)$ is increasing, then

$$\mathbb{E}_{c:G_{(1:n)}}\left[\frac{G(c)}{g(c)}\right] < \mathbb{E}_{c:G}\left[\frac{G(c)}{g(c)}\right],$$

and so inequality (1) holds. Q.E.D.

*Proof of Proposition 4*

We begin by stating and proving lemma A.1, in which we let $A \equiv \sum_{j\in N}\alpha_j$ and $A_{-X} \equiv \sum_{j\in N\setminus X}\alpha_j$.

**Lemma A1.** For an efficient procurement market characterized by the power-based parameterization and $v \geq \bar{c}$,

$$\mathcal{I}^{\mathrm{S}}(K) = 1 - \sum_{i\in K}\frac{(1+\alpha_i + A_{-K})(1+A_{-K})}{(1+A_{-\{i\}})(1+A)}.$$

***Proof.*** It is straightforward to show that for $i \in K$,

$$\Pi_i = \frac{\alpha_i}{(1+A_{-\{1\}})(1+A)} \quad \text{and} \quad \Pi_i(K) = \frac{\alpha_i}{(1+\alpha_i + A_{-K})(1+A_{-K})},$$

and thus

$$s_i(K) = \frac{(1+\alpha_i + A_{-K})(1+A_{-K})}{(1+A_{-\{i\}})(1+A)}.$$

The expression for $\mathcal{I}^{\mathrm{S}}(K)$ then follows. Q.E.D.

Using lemma A.1, in the power-based parameterization,

$$s_i(K;\ N) = \frac{(1+\alpha_i + A_{-K})(1+A_{-K})}{(1+A_{-\{i\}})(1+A)},$$

where we augment the arguments of the critical share to include the set of all suppliers. Let $N = \{1, \ldots, n\}$ for some $n \in \{3, 4, \ldots\}$. Let $K = \{1, 2\}$ and assume that supplier $m \in \{3, \ldots, n\}$ is a maverick with respect to $K$. Define $X \equiv \sum_{i \in N \setminus \{1,2,m\}} \alpha_i$. By the definition of a maverick, $1 - \sum_{i \in K} s_i(K; N \setminus \{m\}) > 0$, which can be written as

$$\sum_{i \in \{1,2\}} \frac{(1+\alpha_i+X)(1+X)}{(1+\alpha_1+\alpha_2-\alpha_i+X)(1+\alpha_1+\alpha_2+X)} - 1 < 0. \tag{A1}$$

Following the merger of suppliers 1 and $m$, the coordinated-effects index for suppliers in $\hat{K} \equiv \{\mu_{1,m}, 2\}$, where $\mu_{1,m}$ denotes the merged entity, is

$$\mathcal{I}^S(\hat{K}) = 1 - \frac{(1+\alpha_1+X+\alpha_m)(1+X)}{(1+\alpha_2+X)(1+\alpha_1+\alpha_2+X+\alpha_m)} - \frac{(1+\alpha_2+X)(1+X)}{(1+\alpha_1+X+\alpha_m)(1+\alpha_1+\alpha_2+X+\alpha_m)}.$$

It follows that

$$\lim_{\alpha_2 \to 0} \mathcal{I}^S(\hat{K}) = 1 - 1 - \frac{(1+X)^2}{(1+\alpha_1+X+\alpha_m)^2} < 0,$$

which proves the second part of the proposition.

Using the above expression for $\mathcal{I}^S(\hat{K})$ and adding the expression on the left-hand side of the inequality in inequality (A1), which is negative, we have

$$\begin{aligned}\mathcal{I}^S(\hat{K}) > &-\frac{(1+\alpha_1+X+\alpha_m)(1+X)}{(1+\alpha_2+X)(1+\alpha_1+\alpha_2+X+\alpha_m)} \\ &- \frac{(1+\alpha_2+X)(1+X)}{(1+\alpha_1+X+\alpha_m)(1+\alpha_1+\alpha_2+X+\alpha_m)} \\ &+ \frac{(1+\alpha_1+X)(1+X)}{(1+\alpha_2+X)(1+\alpha_1+\alpha_2+X)} \\ &+ \frac{(1+\alpha_2+X)(1+X)}{(1+\alpha_1+X)(1+\alpha_1+\alpha_2+X)} \\ &\equiv (1+X) f(\alpha_1, \alpha_2, \alpha_m, X),\end{aligned}$$

where we factor out $(1 + X)$ and define $f(\alpha_1, \alpha_2, \alpha_m, X)$ to be equal to the remainder. Thus, $\mathcal{I}^S(\hat{K}) > 0$ if $f(\alpha_1, \alpha_2, \alpha_m, X) > 0$. When we collect the terms in $f(\alpha_1, \alpha_2, \alpha_m, X)$ over the common denominator of

$$(1+\alpha_1+X)(1+\alpha_2+X)(1+\alpha_1+\alpha_2+X+\alpha_m)(1+\alpha_1+X+\alpha_m)(1+\alpha_1+\alpha_2+X),$$

it follows that $\mathcal{I}^S(\hat{K}) > 0$ if the associated numerator,

$$\begin{aligned}\hat{f}(\alpha_1, \alpha_2, \alpha_m, X) \equiv & -(1+\alpha_1+X)(1+\alpha_1+X+\alpha_m)^2(1+\alpha_1+\alpha_2+X)\\ & +(1+\alpha_1+X+\alpha_m)(1+\alpha_1+\alpha_2+X+\alpha_m)(1+\alpha_1+X)^2\\ & -(1+\alpha_2+X)^2(1+\alpha_1+X)(1+\alpha_1+\alpha_2+X)\\ & +(1+\alpha_1+\alpha_2+X+\alpha_m)(1+\alpha_2+X)^2(1+\alpha_1+X+\alpha_m),\end{aligned}$$

is positive. Differentiating with respect to $X$, we see that it is straightforward to show that $\hat{f}(\alpha_1, \alpha_2, \alpha_m, X)$ is convex in $X$ and increasing at $X = 0$, which implies that for all $X \geq 0$, $\hat{f}(\alpha_1, \alpha_2, \alpha_m, X) \geq \hat{f}(\alpha_1, \alpha_2, \alpha_m, 0)$. Thus, it is sufficient to show that $\hat{f}(\alpha_1, \alpha_2, \alpha_m, 0) > 0$. Straightforward calculations show that $\hat{f}(\alpha_1, \alpha_2, \alpha_m, 0)$ is convex in $\alpha_2$ and is positive and increasing in $\alpha_2$ at $\alpha_2 = \alpha_1$, which implies that $\hat{f}(\alpha_1, \alpha_2, \alpha_m, 0) > 0$ for all $\alpha_2 \geq \alpha_1$, that is, as long as the acquiring supplier has the weakly smaller distributional parameter. That completes the proof of the proposition. Q.E.D.

*Proof of Proposition 5*

In the limit as $n$ grows large, with a probability of 1, both the lowest-order and the second-lowest-order statistics are less than the reserve $r$. Thus, we can focus on the scenario in which the reserve does not bind, in which case $\Pi_i = (1/n)\mathbb{E}[c_{(2:n)} - c_{(1:n)}]$ and $\Pi_i(K) = 1/(n-k+1)\mathbb{E}[c_{(2:n-k+1)} - c_{(1:n-k+1)}]$. Then we have

$$\mathcal{I}(K) = 1 - k\frac{\Pi_i}{\Pi_i(K)} = 1 - kA_n,$$

where

$$A_n \equiv \frac{n-k+1}{n}\frac{\mathbb{E}[c_{(2:n)} - c_{(1:n)}]}{\mathbb{E}[c_{(2:n-k+1)} - c_{(1:n-k+1)}]}.$$

To complete the proof, we show that $\lim_{n\to\infty} A_n = 1$.

First, note that (as shown in Loertscher and Marx, forthcoming, lemma 1)

$$j\mathbb{E}[c_{(j+1:n)} - c_{(j:n)}] = \mathbb{E}\left[\frac{G(c_{(j:n)})}{g(c_{(j:n)})}\right],$$

which, using $\mathbb{E}[G(c_{(1:\ell)})/g(c_{(1:\ell)})] = \int_{\underline{c}}^{\overline{c}} \ell G(x)[1-G(x)]^{\ell-1}dx$, implies that

$$A_n = \frac{\int_{\underline{c}}^{\overline{c}} G(x)[1-G(x)]^{n-1}dx}{\int_{\underline{c}}^{\overline{c}} G(x)[1-G(x)]^{n-k}dx} \leq 1. \tag{A2}$$

The denominator in the center expression in display (A2) satisfies

$$\begin{aligned}\int_{\underline{c}}^{\overline{c}} G(x)[1-G(x)]^{n-k}dx &= \int_{\underline{c}}^{\overline{c}} (G(x)[1-G(x)]^{n-1})^{(n-k)/(n-1)} G(x)^{(k-1)/(n-1)}dx \\ &\leq \left(\int_{\underline{c}}^{\overline{c}} G(x)[1-G(x)]^{n-1}dx\right)^{(n-k)/(n-1)} \left(\int_{\underline{c}}^{\overline{c}} G(x)dx\right)^{(k-1)/(n-1)}, \end{aligned} \tag{A3}$$

where the inequality uses Hölder's inequality.[43] Using displays (A2) and (A3), we have

$$A_n \geq \left(\frac{\int_{\underline{c}}^{\overline{c}} G(x)[1-G(x)]^{n-1}dx}{\int_{\underline{c}}^{\overline{c}} G(x)dx}\right)^{(k-1)/(n-1)}.$$

Letting $C \equiv 1/\max_{x\in[\underline{c},\overline{c}]} g(x) > 0$, where the inequality uses the assumption that $g$ is bounded, we then have

$$\begin{aligned}\int_{\underline{c}}^{\overline{c}} G(x)[1-G(x)]^{n-1}dx &= \int_0^1 u(1-u)^{n-1}\frac{1}{g(G^{-1}(u))}du \\ &\geq \int_0^{\frac{1}{n-1}} u(1-u)^{n-1}\frac{1}{g(G^{-1}(u))}du \\ &\geq \int_0^{\frac{1}{n-1}} u[1-(n-1)u]\frac{1}{g(G^{-1}(u))}du \\ &\geq \int_0^{\frac{1}{n-1}} u[1-(n-1)u]Cdu \\ &= \frac{C}{6(n-1)^2},\end{aligned}$$

where the first equality uses the change of variables $u = G(x)$, the first inequality reduces the upper bound of integration, the second inequality uses $(1 - u)^{n-1} \geq 1 - (n - 1)u$ for all $n \geq 1$ and $u \in [0, 1]$, the third inequality uses the definition of $C$, and the final equality integrates. Putting these together, and using $\lim_{n\to\infty}(n - 1)^{1/(n-1)} = 1$, we have

$$\begin{aligned}1 \geq A_n &\geq \left(\frac{\int_{\underline{c}}^{\overline{c}} G(x)[1-G(x)]^{n-1}dx}{\int_{\underline{c}}^{\overline{c}} G(x)dx}\right)^{(k-1)/(n-1)} \geq \left(\frac{1}{\int_{\underline{c}}^{\overline{c}} G(x)dx}\frac{C}{6(n-1)^2}\right)^{(k-1)/(n-1)} \\ &= \left(\frac{C}{6\int_{\underline{c}}^{\overline{c}} G(x)dx}\right)^{(k-1)/(n-1)} \left(\frac{1}{(n-1)^{\frac{1}{n-1}}}\right)^{2k-2} \underset{n\to\infty}{\longrightarrow} 1,\end{aligned}$$

[43] See Grout and Sonderegger (2005) on the implications of buyer power for the ability of suppliers to sustain collusion. See Green, Marshall, and Marx (2015), which illustrates how explicit collusion can defeat the buyer power of even a small number of large strategic buyers.

and so by the sandwich theorem $\lim_{n\to\infty} A_n = 1$, which completes the proof. Q.E.D.

*Proof of Proposition 6*

The proof of proposition 6.*a* follows straightforwardly from lemma A.1. Considering proposition 6.*b*, we see that if $n = k$, then the result holds trivially, so we assume that $n > k$. Without loss of generality, assume that $K = \{1, \ldots, k\}$. Using lemma A1, we have

$$\sum_{i\in K} s_i(K) = \sum_{i\in K} \frac{(1+\alpha_i + A_{-K})(1+A_{-K})}{(1+A-\alpha_i)(1+A)}.$$

Because we assume that $1 \in K$, we can rewrite this as

$$\sum_{i\in K} s_i(K) = \sum_{i\in K\setminus\{1\}} \frac{(1+\alpha_i + A_{-K})(1+A_{-K})}{(1+A-\alpha_i)(1+A)} + \frac{(1+\alpha_1 + A_{-K})(1+A_{-K})}{(1+A-\alpha_1)(1+A)}.$$

Suppose we deduct $\varepsilon \in (0, \alpha_n)$ from $\alpha_n$ and add $\varepsilon$ to $\alpha_1$. Then the sum of all suppliers' strength parameters $A$ remains unchanged, and we have

$$\begin{aligned}
&\mathcal{I}^S(K; \alpha_1 + \varepsilon, \alpha_2, \ldots, \alpha_{n-1}, \alpha_n - \varepsilon) \\
&= 1 - \left[\sum_{i\in K\setminus\{1\}} \frac{(1+\alpha_i + A_{-K} - \varepsilon)(1+A_{-K} - \varepsilon)}{(1+A-\alpha_i)(1+A)} \right. \\
&\quad \left. + \frac{(1+\alpha_1 + A_{-K})(1+A_{-K} - \varepsilon)}{(1+A-\alpha_1 - \varepsilon)(1+A)}\right].
\end{aligned}$$

Differentiating with respect to $\varepsilon$, we have

$$-\frac{1}{1+A}\left[\sum_{i\in K\setminus\{1\}} \frac{-(1+A_{-K}-\varepsilon) - (1+\alpha_i + A_{-K} - \varepsilon)}{1+A-\alpha_i} - \frac{(1+\alpha_1 + A_{-K})(A-\alpha_1 - A_{-K})}{(1+A-\alpha_1-\varepsilon)^2}\right],$$

which is positive. Thus, for all $\varepsilon \in (0, \alpha_n)$,

$$\mathcal{I}^S(K; \alpha_1 + \varepsilon, \alpha_2, \ldots, \alpha_{n-1}, \alpha_n - \varepsilon) > \mathcal{I}^S(K; \alpha_1, \alpha_2, \ldots, \alpha_{n-1}, \alpha_n). \quad \text{(A4)}$$

It follows that $\mathcal{I}^S(K)$ increases when a member of $K$ is replaced with a member of $N \setminus K$ with a larger distributional parameter and that $\mathcal{I}^S(K)$ is maximized when its members are the set $K$ of suppliers with the largest distributional parameters. This completes the proof of proposition 6.*b*.

Turning to proposition 6.*c*, we let $\beta$ be as given in the statement of the proposition. Because $\mathcal{I}^S(K)$ relies on the strength parameters of suppliers in $N \setminus K$ only through the sum of those parameters, we have

$$\begin{aligned}
&\mathcal{I}^S(K; \alpha_1, \ldots, \alpha_k, \alpha_{k+1}, \ldots, \alpha_n) \\
&= \mathcal{I}^S(K; \alpha_1, \ldots, \alpha_k, \beta_{k+1}, \ldots, \beta_{n-1}, A_{-K} - \sum_{i=k+1}^{n-1} \beta_i),
\end{aligned}$$

where $A_{-K} - \sum_{i=k+1}^{n-1} \beta_i > 0$ by the assumptions on $\boldsymbol{\beta}$. But then letting $\varepsilon_i \equiv \beta_i - \alpha_i \geq 0$ for $i \in K$, we have

$$\begin{aligned}
&\mathcal{I}^{S}(K;\, \alpha_1, \ldots, \alpha_k, \beta_{k+1}, \ldots \beta_{n-1}, A_{-K} - \sum_{i=k+1}^{n-1} \beta_i) \\
&< \mathcal{I}^{S}(K;\, \alpha_1 + \varepsilon_1, \ldots, \alpha_k + \varepsilon_k, \beta_{k+1}, \ldots \beta_{n-1}, A_{-K} - \sum_{i=k+1}^{n-1} \beta_i - \sum_{i=1}^{k} \varepsilon_i) \\
&= \mathcal{I}^{S}(K;\, \beta_1, \ldots, \beta_k, \beta_{k+1}, \ldots \beta_{n-1}, \beta_n),
\end{aligned}$$

where the inequality uses the repeated application of inequality (A4) and the assumption that $\varepsilon_i$ is strictly positive for at least one $i \in K$ and where the final inequality uses the definition of $\varepsilon_i$ and the assumption that $\sum_{i \in N} \beta_i = A$. This completes the proof. Q.E.D.

*Proof of Proposition 7*

Denote the two suppliers experiencing the NR spread as 1 and 2, with $\{1, 2\} \subseteq K$. Let $F_1$ and $F_2$ be their distributions prior to the spread, with parameters $f_1$ and $f_2$, and let $H_1$ and $H_2$ be their distributions after the spread, with parameters $h_1$ and $h_2$. Note that we abuse notation by using, for $i \in \{1, 2\}$, $f_i$ and $h_i$ to denote the parameters of the distributions $F_i$ and $H_i$ rather than their probability density functions. Denote the parameters of suppliers other than 1 and 2 by $\alpha_j$ for $j \in \{3, \ldots, n\}$.

An NR spread in the power-based parameterization implies the existence of $a > 0$ such that

$$h_1 > f_1 \geq a \geq f_2 > h_2$$

and

$$h_1 + h_2 = 2a = f_1 + f_2.$$

Thus, $h_2 = 2a - h_1$ and $f_2 = 2a - f_1$. Let $s_i(K)$ be the critical share for supplier $i \in K$ under $(F_1, F_2)$, and let $\hat{s}_i(K)$ be the critical share for supplier $i \in K$ under $(H_1, H_2)$. By lemma 1, the shift from $(F_1, F_2)$ to $(H_1, H_2)$ decreases $\mathcal{I}^{S}(K)$ if and only if it increases the sum of the critical shares of suppliers 1 and 2. In what follows, we show that $\hat{s}_1(K) + \hat{s}_2(K) - s_1(K) - s_2(K) > 0$.

Using lemma A.1 and letting $A \equiv 2a + \sum_{i \in \{3,\ldots,n\}} \alpha_i$,

$$s_i(K) = \frac{(1 + f_i + A_{-K})(1 + A_{-K})}{(1 + A - f_i)(1 + A)} \quad \text{and} \quad \hat{s}_i(K) = \frac{(1 + h_i + A_{-K})(1 + A_{-K})}{(1 + A - h_i)(1 + A)}.$$

Consequently, the sign of $\hat{s}_i(K) + \hat{s}_2(K) - s_1(K) - s_2(K)$ is equal to the sign of

$$\frac{(1 + h_1 + A_{-K})}{(1 + A - h_1)} + \frac{(1 + h_2 + A_{-K})}{(1 + A - h_2)} - \frac{(1 + f_1 + A_{-K})}{(1 + A - f_1)} - \frac{(1 + f_2 + A_{-K})}{(1 + A - f_2)}.$$

Substituting $2a - h_1$ for $h_2$ and $2a - f_1$ for $f_2$ and collecting terms, we get

$$\frac{2(f_1 - h_1 - 2a)(h_1 - f_1)(1 + a + X)(2 + 2a + X)}{(1 + 2a - f_1 + X)(1 + f_1 + X)(1 + 2a - h_1 + X)(1 + h_1 + X)},$$

where $X \equiv A_{-\{1,2\}} + A_{-K}$, which is positive. Q.E.D.

*Proof of Proposition 9*

From Myerson (1981), it is well known that in the optimal procurement, the buyer applies a supplier-specific reserve price to the supplier with the lowest virtual cost, where the reserve price applied to supplier $i$ is $\hat{r}_i \equiv \Gamma_i^{-1}(v)$. Because $\Gamma_i(c) > c$ for $c > \underline{c}$, it follows that $\hat{r}_i < v$. The assumption that suppliers follow their weakly dominant strategies of reporting truthfully implies that if supplier $i$ has the lowest virtual cost, then supplier $i$ wins if $c_i \leq \hat{r}_i$ and is paid (in the dominant strategy implementation) its threshold type of $\min_{j\in N\setminus\{i\}}\{\hat{r}_i, \Gamma_i^{-1}(\Gamma_j(c_j))\}$. Otherwise, there is no trade. Consequently, when the buyer is powerful,

$$\Pi_i = \mathbb{E}_{\boldsymbol{c}}[\max\{0, \min_{j\in N\setminus\{i\}}\{\hat{r}_i, \Gamma_i^{-1}(\Gamma_j(c_j))\} - c_i\} \cdot \mathbf{1}_{\Gamma_i(c_i)\leq \min_{j\in N\setminus\{i\}}\Gamma_j(c_j)}]$$

and

$$\Pi_i(K) = \mathbb{E}_{\boldsymbol{c}}[\max\{0, \min_{j\in N\setminus K}\{\hat{r}_i, \Gamma_i^{-1}(\Gamma_j(c_j))\} - c_i\} \cdot \mathbf{1}_{\Gamma_i(c_i)\leq \min_{j\in N\setminus K}\Gamma_j(c_j)}].$$

The definitions of critical shares and of the coordinated-effects index are then the same as in the case without buyer power.

With buyer power and symmetric suppliers, and with $L_X(c)$ denoting the distribution of the lowest cost among suppliers in $X$, that is, $L_X(c) = 1 - [1 - G(c)]^{|X|}$, for all $i \in K$,

$$s_i(K) = \frac{\int_{\underline{c}}^{\hat{r}}[1 - L_{N\setminus\{i\}}(c)]G(c)dc}{\int_{\underline{c}}^{\hat{r}}[1 - L_{N\setminus K}(c)]G(c)dc}. \tag{A5}$$

If $v \geq \Gamma(\overline{c})$, then $\hat{r} = \overline{c}$, and so the critical shares are not affected by buyer power. Focusing on the case with $\hat{r} < \overline{c}$ and differentiating the expression in equation (A5) with respect to $\hat{r}$, we get an expression with a sign equal to the sign of

$$\begin{aligned}
&[1 - L_{N\setminus\{i\}}(\hat{r})]\int_{\underline{c}}^{\hat{r}}[1 - L_{N\setminus K}(c)]G(c)c - [1 - L_{N\setminus K}(\hat{r})]\int_{\underline{c}}^{\hat{r}}[1 - L_{N\setminus\{i\}}(c)]G(c)dc \\
&= [1 - G(\hat{r})]^{n-1}\int_{\underline{c}}^{\hat{r}}[1 - G(c)]^{n-k}G(c)dc - [1 - G(\hat{r})]^{n-k}\int_{\underline{c}}^{\hat{r}}[1 - G(c)]^{n-1}G(c)dc \\
&= [1 - G(\hat{r})]^{2n-1-k}\int_{\underline{c}}^{\hat{r}}\left(\left[\frac{1 - G(c)}{1 - G(\hat{r})}\right]^{n-k} - \left[\frac{1 - G(c)}{1 - G(\hat{r})}\right]^{n-1}\right)G(c)dc.
\end{aligned}$$

Because $[1 - G(c)]/[1 - G(\hat{r})] > 1$ for $c < \hat{r}$ and because $k \geq 2$, which implies $n - k$

$< n - 1$, it follows that the equation above is negative. Thus, critical shares are weakly decreasing in buyer power, and strictly so for $v < \Gamma(\overline{c})$, which completes the proof. Q.E.D.

*Proof of Proposition 12*

Suppose we have an NR spread for suppliers 1 and 2 causing their distributions to change from $(G_1, G_2)$ to $(H_1, H_2)$, which satisfies expressions (4) and (5) for $i = 1, j = 2$, and all $c \in [\underline{c}, \overline{c}]$, with the inequalities in display (4) satisfied with strict inequalities for costs in an open subset of $[\underline{c}, \min\{v, \overline{c}\}]$. Letting $p_1$ and $p_2$ be the probabilities of trade for suppliers 1 and 2, respectively, prior to the NR spread and $\hat{p}_1$ and $\hat{p}_2$ be their probabilities after the NR spread, then $\hat{p}_1 < \min\{p_1, p_2\} \leq \max\{p_1, p_2\} < \hat{p}_2$. Because an NR spread affects neither the overall probability of trade nor the probability of trade of suppliers other than 1 and 2, we have $p_1 + p_2 = \hat{p}_1 + \hat{p}_2$. Letting $\Delta \equiv \min\{p_1, p_2\} - \hat{p}_1 > 0$, we see that the change in HHI as a result of the NR spread is

$$\begin{aligned}\hat{p}_1^2 + \hat{p}_2^2 - p_1^2 - p_2^2 &= (\min\{p_1, p_2\} - \Delta)^2 + [p_1 + p_2 - (\min\{p_1, p_2\} - \Delta)]^2 - p_1^2 - p_2^2 \\ &= 2\Delta(\max\{p_1, p_2\} - \min\{p_1, p_2\}),\end{aligned}$$

which is positive and increasing in $\Delta$.

An NR spread affects the price that the buyer pays only in the event that one of suppliers 1 and 2 has the lowest cost and the other one has the second-lowest cost. Because the distribution of their lowest cost is by construction not affected by the NR spread, all that is left to do is to compare the distribution of their second-lowest draw, which is $G_1(c)G_2(c)$ without the spread and $H_1(c)H_2(c)$ after the spread.

Take as given a $c \in (\underline{c}, \overline{c})$ in the open subset of $[\underline{c}, \min\{v, \overline{c}\}]$ such that the inequalities in display (4) are satisfied with strict inequalities. Let $A = 1 - H_1(c)$, $B = 1 - H_2(c)$, $C = 1 - F_1(c)$, and $D = 1 - F_2(c)$. Then we have (i) $AB = CD$ and (ii) $1 - A \geq 1 - C$, $1 - D \geq 1 - B$, with $A, B, C, D \in (0, 1)$. Consider the problem

$$\max_{(A,B)\in[0,1]^2} (1 - A)(1 - B) \quad \text{such that } AB = CD. \tag{A6}$$

Noting that $(1 - A)(1 - B) = (1 - \sqrt{AB})^2 - (\sqrt{A} - \sqrt{B})^2$, we can rewrite the problem as

$$\max_{(A,\, B)\in[0,1]^2} (1 - \sqrt{CD}) - (\sqrt{A} - \sqrt{B})^2 \quad \text{such that } AB = CD.$$

Because the maximand is less than or equal to $1 - \sqrt{CD}$ and equal to $1 - \sqrt{CD}$ if and only if $A = B$, we conclude that the unique solution to the problem in display (A6) is $A = B = \sqrt{CD}$. Thus, for any $A$ and $B$ satisfying i and ii with $B \neq \sqrt{CD}$, we have $(1 - A)(1 - B) < (1 - \sqrt{CD})^2$, which we can write as (dropping the argument $c$):

$$H_1H_2 < \left[1 - \sqrt{(1 - G_1)(1 - G_2)}\right]^2 = G_1G_2 - G_1 - G_2 - 2\sqrt{(1 - G_1)(1 - G_2)} < G_1G_2.$$

This establishes that the distribution of the second-lowest cost after the NR spread first-order stochastically dominates the distribution of the second-lowest cost prior to the spread, for all $c \in [\underline{c}, \overline{c}]$, $H_1H_2 \leq G_1G_2$, with a strict inequality for costs in an open subset of $[\underline{c}, \min\{v, \overline{c}\}]$. Because the second-lowest cost determines the buyer's price, this implies that the buyer's expected price is higher under $(H_1, H_2)$ than under $(G_1, G_2)$.

Furthermore, a larger NR spread—that is, a change from $(G_1, G_2)$ to $(\hat{H}_1, \hat{H}_2)$, where $(\hat{H}_1, \hat{H}_2)$ is an NR spread of $(H_1, H_2)$—implies a larger $\Delta$, and so a larger increase in the HHI, and also implies an increase in the buyer's expected price relative to $(H_1, H_2)$. Q.E.D.

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