Incomplete information bargaining with applications to mergers, investment, and vertical integration∗

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Abstract

We provide an incomplete information bargaining framework that captures the effects of differential bargaining power in markets with multiple buyers and multiple suppliers. The market is modeled as a mechanism that maximizes the expected weighted welfare of the agents, subject to the constraints of incentive compatibility, individual rationality, and no deficit. We show that, in this model, there is no basis for the presumption that vertical integration increases equally weighted social surplus, while it is possible that horizontal mergers that appropriately change bargaining weights increase social surplus. Moreover, efficient bargaining implies that in equilibrium noncontractible investments are efficient.

Keywords: bargaining power, countervailing power, vertical integration, investment

JEL Classification: D44, D82, L41

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1 Introduction

Bargaining has come to the forefront in industrial organization and antitrust and plays a prominent role in recent cases, including hospitals, insurers, telecommunications providers, and media companies. Common practice in modeling bargaining is to assume that the agents have complete information about each other’s values and costs to adhere to axiomatic approaches based on Nash bargaining or the Shapley value according to which the bargaining outcomes are efficient. Apart from bargaining losing “much of its interest” when information is complete (Fudenberg and Tirole 1991), the complete information approach has the downside that shifts of bargaining power, perhaps due to a merger, or more generally changes in market structure, only affect the distribution of surplus and not its size since bargaining is, by assumption, efficient. Of course, the popularity of the complete information bargaining approach is in no small part due to the perceived challenges associated with the alternative of incomplete information bargaining, such as a lack of tractability of extensive-form representations and the dependence of bargaining outcomes on higher-order beliefs and assumptions of common knowledge of type distributions.

In this paper, we develop an incomplete information bargaining framework that sidesteps the lack of tractability of extensive-form games by taking an “as-if” approach in which allocations and transfers are on the Pareto frontier achievable through mediated mechanisms. Specifically, we stipulate that there is a market mechanism that, for given bargaining weights, maximizes the weighted sum of the agents’ surplus, subject to the constraints that the mechanism is incentive compatible and individually rational and does not run a deficit. For the case of one buyer and one supplier with equal bargaining weights, our model specializes to the bilateral trade problem of Myerson and Satterthwaite (1983).

We apply this framework to analyze several long-standing questions in antitrust. We show that with incomplete information bargaining, there is no basis for a presumption that vertical integration increases social surplus. The intuition is simple and related to the fact that whether incomplete information bargaining is efficient is endogenous. In a nutshell, vertical integration can create a Myerson-Satterthwaite problem by rendering hitherto efficient bargaining inefficient. More generally, because changes in bargaining weights and market structures have direct effects on the social surplus resulting from incomplete information...

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1 The notion that vertical integration improves outcomes remains influential in antitrust. A case in point is the 2020 update of the U.S. DOJ and FTC’s Vertical Merger Guidelines, which after recognizing that “vertical mergers are not invariably innocuous” state that “vertical mergers often benefit consumers through the elimination of double marginalization, which tends to lessen the risks of competitive harm” and that “vertical mergers combine complementary economic functions and eliminate contracting frictions, and therefore have the capacity to create a range of potentially cognizable efficiencies that benefit competition and consumers” (U.S. DOJ and FTC, 2020, pp. 2, 11).
bargaining, the framework opens scope for a countervailing power defense of, say, horizontal mergers that appropriately shift bargaining powers, or more generally the analysis of policies that equalize bargaining powers. Although the concept of countervailing power has been controversial since its inception\(^2\) it has popular appeal and has influenced antitrust policies and regulation\(^3\). Our paper thus provides a framework that permits the evaluation of arguments based on countervailing power.

The incomplete information bargaining framework also has the feature that when agents make noncontractible and nonobservable investments that improve their own type distributions, efficient incomplete information bargaining implies efficient equilibrium investments. Thereby, the model sheds new light on ongoing debates in industrial organization and antitrust in the wake of the Dow-DuPont merger decision on the interaction between market structure and investments. It also epitomizes the contrast to complete information models, which with incomplete contracting obtain inefficient investments because of hold up. With incomplete information, incentive compatibility protects the agents from hold up, and if bargaining is efficient, it perfectly aligns individuals’ investment incentives with the planner’s objective.

Our framework uses the Myersonian mechanism design approach (Myerson, 1981) to elicit agents’ private information and determine prices and builds on the bilateral trade model of Myerson and Satterthwaite (1983), augmented by bargaining weights and multiple buyers and suppliers. Thereby, it combines elements of Myerson and Satterthwaite (1983), Williams (1987), and Gresik and Satterthwaite (1989). Specifically, our model allows for multiple buyers and multiple suppliers without imposing restrictions on the supports of the buyers’ values and the suppliers’ costs other than assuming that all buyers’ value distributions have the same support and all suppliers’ cost distributions have the same support.\(^4\) We generalize Williams’ approach of maximizing an objective that assigns differential weights in a bilateral trade problem by allowing for multiple agents. Put differently, our paper reinterprets Myerson and Satterthwaite (1983) as a bilateral monopoly problem, extends

\(^2\)Galbraith (1954, p. 1) saw it as a mitigant of economic power of “substantial, and perhaps central, importance,” while Stigler (1954, p. 13) lamented the lack of any explanation for “why bilateral oligopoly should in general eliminate, and not merely redistribute, monopoly gains.” The controversy arises in no small part because formalizing notions of countervailing power has proven challenging and because “it is difficult to model bilateral monopoly or oligopoly, and there exists no single canonical model” (Snyder, 2008, p. 1188).

\(^3\)For example, OECD (2011, pp. 50–51) and OECD (2007, pp. 58–59) raise the possible role of collective negotiation and group boycotts for counterbalancing market power by providers of payment card services. Potential benefits from allowing physician network joint ventures are recognized by the U.S. DOJ and FTC’s 1996 “Statement of Antitrust Enforcement Policy in Health Care.”

\(^4\)While Gresik and Satterthwaite (1989) also allow for multiple buyers, they restrict attention to identical cost distributions. In that regard, our setup thus shares similarities with the optimal auction setting of Myerson (1981), with the important difference that our setup has two-sided private information.
it to allow for bargaining weights and multiple agents on both sides of the market, and shows that it is tractable and has all the required features.\footnote{For experimental results consistent with the incomplete information bargaining, see \cite{Valley2002} Fig. 3.A). See \cite{Larsen2020} on the first-best and second-best frontiers for wholesale used cars.} In particular, inherent to the independent private values setting is the key economic tradeoff between rent extraction and social surplus. We defer further discussion of the literature to Section 8.

While our paper does, of course, not resolve the deep problems related to agents’ higher-order beliefs and common knowledge assumptions in economics, it seems fair to deflect criticism of incomplete information bargaining models based on these concerns by noting that assuming common knowledge of distributions is weaker than the assumption of complete information models that there is common knowledge of values and costs.

The remainder of the paper is structured as follows. Section 2 introduces the setup. In Section 3, we provide a model of incomplete information bargaining. Section 4 derives results pertaining to horizontal mergers, and Section 5 derives results for vertical integration. Section 6 analyzes investment incentives. In Section 7, we briefly discuss extensions that are provided in the online appendix. In Section 8, we discuss related literature. Section 9 concludes the paper. Formal mechanism design results and longer proofs are relegated to appendices.

2 Setup

We consider a pre-merger market with \(n^S\) suppliers with \(\mathcal{N}^S \equiv \{1, \ldots, n^S\}\) and \(n^B\) buyers with \(\mathcal{N}^B \equiv \{1, \ldots, n^B\}\). Each supplier \(j\) has the capacity to produce \(k_j^S\) units of a good at a constant marginal cost, and each buyer \(i\) has constant marginal value for up to \(k_i^B\) units of the good, where \(k_j^S\) and \(k_i^B\) are positive integers. Total demand is \(K^B \equiv \sum_{i \in \mathcal{N}^B} k_i^B\), and total supply is \(K^S \equiv \sum_{j \in \mathcal{N}^S} k_j^S\), and we define \(K \equiv \min\{K^B, K^S\}\).

Supplier \(j\) draws its constant marginal cost \(c_j\) independently from distribution \(G_j\) with support \([\underline{c}, \bar{c}]\) and density \(g_j\) that is positive on the interior of the support. Buyer \(i\) draws its constant marginal value \(v_i\) independently from distribution \(F_i\) with support \([\underline{v}, \bar{v}]\) and density \(f_i\) that is positive on the interior of the support. The problem is trivial if \(\bar{v} > \bar{c}\) because then it is never ex post efficient to have any trade. Therefore, we assume that \(\bar{v} > \bar{c}\). We assume that \(G_1, \ldots, G_{n^S}\) and \(F_1, \ldots, F_{n^B}\) and are common knowledge, while the realized costs and values are the private information of the individual suppliers and buyers. To save on notation, we ignore ties among the agents’ costs and values. While we adhere to a setup with constant marginal costs and values, with additional structure, one can allow for decreasing marginal values and increasing marginal costs.
The suppliers and buyers have quasilinear preferences. The payoff of supplier $j$ with type $c_j$ when producing $q \in \{0, \ldots, k^S_j\}$ units of the good and receiving the monetary transfer $m$ is $m - c_jq$. The payoff of buyer $i$ with type $v_i$ when receiving $q \in \{0, \ldots, k^B_i\}$ units of the good and making the monetary payment $m$ is $v_iq - m$.

Because both the buyers’ values and the suppliers’ costs are random variables whose realizations are the agents’ private information, the setup is symmetric with respect to the privacy of information, with the important consequence that ex post efficiency need not be possible. Indeed, our setup encompasses the classic Myerson-Satterthwaite (1983) setting, where, as they show, for $n^S = n^B = 1$, ex post efficient trade is impossible if and only if $v < \bar{c}$. We refer to the case with $v < \bar{c}$ as the case with overlapping supports and the case with $v \geq \bar{c}$ as the case of nonoverlapping supports. Thus, with one supplier and one buyer, incomplete information prevents ex post efficient trade in the case of overlapping supports, but not in the case of nonoverlapping supports.

We denote supplier $j$’s virtual cost and buyer $i$’s virtual value function by

$$\Gamma_j(c) \equiv c + \frac{G_j(c)}{g_j(c)} \quad \text{and} \quad \Phi_i(v) \equiv v - \frac{1 - F_i(v)}{f_i(v)},$$

which we assume to be increasing. For $a \in [0, 1]$, we define the $a$-weighted virtual cost functions and the $a$-weighted virtual value functions by

$$\Gamma^a_j(c) \equiv c + (1 - a)\frac{G_j(c)}{g_j(c)} \quad \text{and} \quad \Phi^a_i(v) \equiv v - (1 - a)\frac{1 - F_i(v)}{f_i(v)}.$$  

The monotonicity of $\Gamma_j(c)$ and $\Phi_i(v)$ implies that $\Gamma^a_j(c)$ and $\Phi^a_i(v)$ and are also monotone. As observed by Mussa and Rosen (1978), virtual value functions can be interpreted as marginal revenue functions and, analogously, virtual cost functions can be interpreted as marginal cost.

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To avoid informed-principal problems, we model the mechanism-design problem as one in which a third party without private information—such as a broker or “the market”—organizes the exchange. Although our setup has properties that are sufficient for the informed-principal problem to have no material consequences (see Mylovanov and Tröger, 2014), it seems wise to circumvent the associated technicalities. Of course, by giving all the bargaining power to one agent, we still obtain the optimal mechanism for that agent, just as one would if we assumed that the agent with all the bargaining power organizes the exchange.

If $g_j(c) = 0$, then define $\Gamma_j(c) \equiv \lim_{c \downarrow 0} \Gamma_j(c)$. If $g_j(\bar{c}) = 0$, then $\Gamma_j(\bar{c}) = \infty$. Likewise, if $f_i(v) = 0$, then $\Phi_i(v) = -\infty$. The assumption of increasing virtual type functions can be relaxed through the use of “ironing.”

This departs from the more standard notation in that the coefficient on the hazard rate term is $1 - a$ rather than $a$, but because we will be introducing bargaining weights, this modification is useful.
3 Incomplete information bargaining

At the heart of any economic model of exchange with transfers are assumptions that govern the price-formation process. For example, oligopoly models specify a mapping from firms’ actions to prices, and models based on Nash bargaining specify a mapping from preferences to trades and transfer payments. As mentioned in the introduction, we stay within this tradition by working with a given price-formation process, and we add to it by introducing an incomplete information bargaining model that allows for heterogeneous bargaining weights. It has neither the shortcoming of standard oligopoly models that buyers are price takers nor the problem of Nash bargaining that outcomes are efficient by assumption. For the exposition, it is useful to think of incomplete information bargaining as what the market does and to contrast it with what society, represented by a planner, would choose, with the planner facing the same constraints as the market—incentive compatibility, individual rationality and no deficit—while giving equal weight to all agents.

3.1 Market mechanism

We model incomplete information bargaining as a direct mechanism \(\langle Q, M \rangle\) operated by the market, where the allocation rule, \(Q = (Q^S, Q^B)\) with \(Q^S_j : [v, \tau]^n \times [c, \tau]^n \rightarrow \{0, \ldots, k^S_j\}\) and \(Q^B_i : [v, \tau]^n \times [c, \tau]^n \rightarrow \{0, \ldots, k^B_i\}\) maps the agents’ types to the quantities provided by the suppliers and the quantities received by the buyers, and the payment rule, \(M = (M^S, M^B)\) with \(M^S : [v, \tau]^n \times [c, \tau]^n \rightarrow \mathbb{R}^n\) and \(M^B : [v, \tau]^n \times [c, \tau]^n \rightarrow \mathbb{R}^n\) maps types to the payments to the suppliers and the payments from the buyers. Feasibility requires that for all type realizations, \(\sum_{j \in N^S} Q^S_j(v, c) \geq \sum_{i \in N^B} Q^B_i(v, c)\).

The mechanism is required to satisfy incentive compatibility, individual rationality, and no deficit. A direct mechanism is incentive compatible if it is in the best interest of every agent to report its type truthfully to the mechanism and is individually rational if each agent, for every possible type, is weakly better off participating in the mechanism than...
walking away, where we normalize the payoffs of not trading and of walking away—that is, the value of the outside option—to zero. A direct mechanism has no deficit if the sum of the expected payments from the buyers is greater than or equal to the sum of the expected payments to the suppliers. For formal definitions, see Appendix A.

Fixing a mechanism \( (Q, M) \), supplier \( j \)'s and buyer \( i \)'s ex post surpluses as a function of the type realizations are

\[
U_{j;Q,M}(v, c) \equiv M_j^S(v, c) - c_j Q_j^S(v, c),
\]

and

\[
U_{i;Q,M}(v, c) \equiv v_i Q_i^B(v, c) - M_i^B(v, c).
\]

The budget surplus generated by the mechanism is

\[
R_M(v, c) \equiv \sum_{i \in N^B} M_i^B(v, c) - \sum_{j \in N^S} M_j^S(v, c),
\]

and the welfare or social surplus generated by the mechanism is

\[
W_Q(v, c) \equiv \sum_{i \in N^B} v_i Q_i^B(v, c) - \sum_{j \in N^S} c_j Q_j^S(v, c).
\]

To capture bargaining power, we endow the agents with bargaining weights \( w = (w^S, w^B) \), where \( w_j^S \in [0, 1] \) is supplier \( j \)'s bargaining weight and \( w_i^B \in [0, 1] \) is buyer \( i \)'s bargaining weight. We assume that at least one agent’s bargaining weight is positive. We define weighted welfare with bargaining weights \( w \) to be

\[
W_{Q,M}^w(v, c) \equiv \sum_{i \in N^B} w_i^B U_{i;Q,M}^B(v, c) + \sum_{j \in N^S} w_j^S U_{j;Q,M}^S(v, c),
\]

and assume that the market maximizes \( \mathbb{E}_{v,c} [W_{Q,M}^w(v, c)] \), subject to incentive compatibility, individual rationality, and the constraint of no deficit:

\[
\mathbb{E}_{v,c} [R_M(v, c)] \geq 0.
\]

The payoff equivalence theorem (see, e.g., Myerson 1981; Krishna 2010; Börgers 2015)\footnote{In our independent private values setting, any Bayesian incentive compatible and interim individually rational mechanism can be implemented with dominant strategies and ex post individual rationality. By construction, it yields the same interim and hence ex ante expected payoffs and revenue. Thus, while we formally state our assumptions in Appendix A in terms of Bayesian incentive compatibility and interim individual rationality, one could also use the ex post versions of those constraints.}
implies that, given \((Q, M) \in M\), the expected payoff of an agent is pinned down by the allocation rule and incentive compatibility up to a constant that is equal to the interim expected payoff of the worst-off type for that agent, which by incentive compatibility is \(\bar{v}\) for a supplier and \(\bar{v}\) for a buyer (see Appendix [A]). Thus, we have

\[
\mathbb{E}_{v,c}[M_j^S(v, c)] = \mathbb{E}_{v,c} \left[ \Gamma_j(c_j)Q_j^S(v, c) \right] + \hat{u}_j^S(\bar{v}) \tag{3}
\]

and

\[
\mathbb{E}_{v,c}[M_i^B(v, c)] = \mathbb{E}_{v,c} \left[ \Phi_i(v_i)Q_i^B(v, c) \right] - \hat{u}_i^B(\bar{v}), \tag{4}
\]

where \(\hat{u}_j^S(c) \equiv \mathbb{E}_{v,c_j}[U_j^S(Q, M)(v, c)]\) and \(\hat{u}_i^B(v) \equiv \mathbb{E}_{v,-i,c}[U_i^B(Q, M)(v, c)]\).

It is possible that multiple agents have the maximum bargaining weight and that a mechanism exists that maximizes weighted welfare subject to incentive compatibility and individual rationality and satisfies the no-deficit constraint (2) with slack. If this is the case, then the bargaining weights pin down the allocation rule but not the payments because the expected budget surplus can be allocated among any of the agents with the maximum bargaining weight as lump sum payments without affecting the value of the objective or the incentive constraints. Because a complete specification of the outcome of incomplete information bargaining needs to account for these eventualities, we assume that there are tie-breaking shares \((\eta^S, \eta^B) \in [0, 1]^{n^S+n^B}\) satisfying \(\eta^x_i = 0\) if \(w^x_i < \max w\) and \(\sum_{j \in N^S} \eta^S_j + \sum_{i \in N^B} \eta^B_i = 1\). The market then selects the mechanism that, absent fixed payments to the agents, generates the maximum budget surplus and that distributes that surplus among the agents according to their tie-breaking shares.\(^{13}\)

Letting \(M\) be the set of incentive-compatible, individually-rational, no-deficit mechanisms, we define an incomplete information bargaining mechanism with bargaining weights \(w\) to be a mechanism in \(M\) that maximizes expected weighted welfare, \(\mathbb{E}_{v,c}[W_{Q, M}(v, c)]\). Notice that, because we evaluate outcomes according to expected welfare \(\mathbb{E}_{v,c}[W_{Q}(v, c)]\), the bargaining weights \(w\) are indeed only bargaining weights, that is, they do not affect how outcomes are evaluated, although they affect the distribution of social surplus and, as we will see, sometimes the size of social surplus.

An immediate implication of this approach is that with equal bargaining weights, incomplete information bargaining delivers the second-best allocation rule, which maximizes expected welfare subject to incentive compatibility, individual rationality, and no deficit. Depending on the specifics, the second-best allocation rule may differ from the first-best allocation rule that maximizes welfare ex post without accounting for the no-deficit con-

\(^{13}\)For example, one might apply equal sharing or distribute the surplus according to Nash bargaining weights. Like with Nash bargaining weights, the tie-breaking shares have no social surplus effects.
Another implication of our approach is that if a group of agents on one side of the market have all the bargaining power, e.g., each agent in the group has a bargaining weight of one while all other agents have a bargaining weight of zero, then the incomplete information bargaining outcome is the perfectly collusive outcome for the agents with all the bargaining weight. Although collusive outcomes are not necessarily inconsistent with large numbers of agents under the view that increasing competition on one side of the market reduces the bargaining power of those agents, one could, for example, fix a set of buyers with positive bargaining weight and assume that when there are \( n \) suppliers, each supplier has bargaining weight \( \frac{1}{n} \), in which case we get the “usual” result that supplier surplus goes to zero as the number of suppliers increases.

### 3.2 Allocation rule for incomplete information bargaining

The Lagrangian associated with maximizing expected weighted welfare \( W_{Q,M}(v,c) \) subject to the no-deficit constraint can be written as \( E_{v,c} \left[ W_{Q,M}(v,c) + \rho R_M(v,c) \right] \), where \( \rho \) is the Lagrange multiplier on the no-deficit constraint. Consequently, the Lagrangian can be rewritten as

\[
E_{v,c} \left[ \sum_{i \in N^B} w_i^B (v_i - \Phi_i(v_i)) Q_i^B(v,c) + \sum_{j \in N^S} w_j^S (\Gamma_j(c_j) - c_j) Q_j^S(v,c) \right] + \rho \left( \sum_{i \in N^B} \Phi_i(v_i) Q_i^B(v,c) - \sum_{j \in N^S} \Gamma_j(c_j) Q_j^S(v,c) \right)
\]

plus the term \( \sum_{i \in N^B} (w_i^B - \rho) \hat{u}_i^B(v) + \sum_{j \in N^S} (w_j^S - \rho) \hat{u}_j^S(c) \), which does not depend on the allocation rule. The buyer, supplier, and budget surpluses identified in (5) are the parts of the respective surpluses that vary with the allocation rule and exclude the fixed terms.

Given the Lagrange multiplier \( \rho \), the allocation rule that maximizes (5) can be defined pointwise. For the case of one supplier with cost \( c \) and one buyer with value \( v \), it is straightforward to show that the optimum has \( Q_i^S(v,c) = Q_i^B(v,c) = \min\{k_i^S, k_i^B\} \) if \( \Gamma_i^w(c) \leq \Phi_i^w(v) \), and \( Q_i^S(v,c) = Q_i^B(v,c) = 0 \) otherwise. For the general case, this basic

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14 The first-best allocation rule is monotone and hence permits incentive compatible implementation. Without the no-deficit constraint, individual rationality is trivial to satisfy.

15 Hatfield et al. (forth.) show that collusion in syndicated markets may become easier as market concentration falls, and that market entry may facilitate collusion because firms can sustain collusion by refusing to syndicate with any firm that undercuts the collusive price.
rule extends as one might expect, but requires some additional notation.

Let $\Gamma^a_j(c)$ denote the constant vector $(\Gamma^a_j(c), \ldots, \Gamma^a_j(c))$ with $k^S_j$ elements and denote by $\Gamma^a(c) \equiv (\Gamma^a_j(c_j))_{j \in N^S}$ the collection of these weighted virtual costs. Analogously, let $\Phi^a_i(v)$ denote the constant vector $(\Phi^a_i(v), \ldots, \Phi^a_i(v))$ with $k^B_i$ elements and denote by $\Phi^a(v) \equiv (\Phi^a_i(v_i))_{i \in N^B}$ the collection of these weighted virtual values. For a given type vector $(v, c)$, bargaining weight vector $w$, and Lagrange multiplier $\rho$, the objective in (5) is maximized when the quantity traded $q^*$ is the largest element of $\{0, 1, \ldots, K\}$ such that the $q^*$ lowest elements of $\Gamma^{w/\rho}(c)$ are less than or equal to the $q^*$ greatest elements of $\Phi^{w/\rho}(v)$.\footnote{We select, arbitrarily but without loss of generality, the largest quantity consistent with the virtual values associated with traded units being greater than or equal to the virtual costs associated with traded units.} Defining $\Gamma^*$ to be the $q^*$-th lowest element of $\Gamma^{w/\rho}(c)$ and $\Phi^*$ to be the $q^*$-th highest element of $\Phi^{w/\rho}(v)$, it follows that $\Gamma^* \leq \Phi^*$ and that $\Gamma^*$ and $\Phi^*$ are thresholds that separate, on each side of the market, the agents that trade from those that do not. We denote the set of inframarginal suppliers and buyers, respectively, by

$$
N^S_I \equiv \{j \in N^S \mid \Gamma^{w/\rho}_j(c_j) < \Gamma^*\} \quad \text{and} \quad N^B_I \equiv \{i \in N^B \mid \Phi^{w/\rho}_i(v_i) > \Phi^*\}.
$$

Observe that $q^*$, $\Gamma^*$, $\Phi^*$, $N^S_I$, and $N^B_I$ depend on $v$, $c$, $w$, and $\rho$, but to ease notation we do not make this dependence explicit.

With this in hand, we are in a position to describe the allocation rule for incomplete information bargaining. It induces each supplier $j \in N^S_I$ to produce $k^S_j$ and each buyer $i \in N^B_I$ to obtain $k^B_i$ units. Ignoring ties among the weighted virtual types of different agents at these threshold values, which occur with probability zero, the “residual” quantity $q^* - \sum_{j \in N^S_I} k^S_j$, is procured from the supplier whose weighted virtual cost is equal to $\Gamma^*$, and quantity $q^* - \sum_{i \in N^B_I} k^B_i$, is allocated to the buyer whose weighted virtual value is equal to $\Phi^*$.

Letting $\rho^w$ denote the smallest value of $\rho$ greater than or equal to $\max w$ such that the no-deficit constraint is satisfied for the allocation rule that maximizes (5) pointwise\footnote{This follows by the same arguments that were first developed in the working paper version of \cite{gresik1989} and that were first used in published form in \cite{myersonsatterthwaite1983}. Because any budget surplus can be reallocated to the agents through fixed payments, the shadow price of budget surplus, $\rho^w$, satisfies $\rho^w \geq \max w$. In addition, because a positive expected budget surplus is always possible given our assumption that $\bar{v} > c$, the shadow price is finite.} and evaluating all expressions at $\rho = \rho^w$, we have:

**Lemma 1.** The allocation rule for incomplete information bargaining with bargaining weights $w$, $Q^w$, is defined by
\[
Q^{w,S}_j(v, c) \equiv \begin{cases} 
  k^S_j & \text{if } \Gamma^{w,S}_j/\rho^w(c_j) < \Gamma^*, \\
  q^* - \sum_{i \in N^S_j} k^S_i & \text{if } \Gamma^{w,S}_j/\rho^w(c_j) = \Gamma^*,
\end{cases}
\]
and \(Q^{w,S}_j(v, c) \equiv 0\) otherwise, and
\[
Q^{w,B}_i(v, c) \equiv \begin{cases} 
  k^B_i & \text{if } \Phi^{w,B}_i/\rho^w(v_i) > \Phi^*, \\
  q^* - \sum_{\ell \in N^B_i} k^B_\ell & \text{if } \Phi^{w,B}_i/\rho^w(v_i) = \Phi^*,
\end{cases}
\]
and \(Q^{w,B}_i(v, c) \equiv 0\) otherwise.

**Proof.** See Appendix B.

An implication of Lemma 1 is that the probability of trade, and hence social surplus, are decreasing in \(\rho^w\).

### 3.3 Payoffs under incomplete information bargaining

We are left to augment the allocation rule of Lemma 1 with a consistent payment rule. As described above, based on the payoff equivalence theorem, all that remains to be done is to define the fixed payments to the agents’ worst-off types. Individual rationality is satisfied if and only if LSimon, is it ok to use “fixed payments” here? fixed payments to suppliers are nonnegative and from buyers are nonpositive. The optimization of the weighted objective requires that no money be left on the table. So, we first define the “money on the table” before fixed payments are made, i.e., the budget surplus under the mechanism of Lemma 1 not including the fixed payments, given by

\[
\pi^w = \mathbb{E}_{v,c} \left[ \sum_{i \in N^B} \Phi_i(v_i)Q^w_B(v, c) - \sum_{j \in N^S} \Gamma_j(c_j)Q^{w,S}_j(v, c) \right].
\]

Because all expected budget surplus is distributed to the agents, it follows that

\[
\pi^w = \sum_{j \in N^S} \hat{u}_j^S(v) + \sum_{i \in N^B} \hat{u}_i^B(v).
\]

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\(^{18}\)While we do not pursue it here, our approach generalizes directly to the requirement that the mechanism needs to generate a budget surplus of \(\kappa \in \mathbb{R}\), which is not more than the maximum budget surplus that any incentive-compatible, individually-rational mechanism can generate. The second-best mechanism that generates \(\kappa\), but otherwise maximizes the same objective, has an allocation rule as defined in Lemma 1 but with \(\rho^w\) replaced by \(\rho^w_\kappa\), which is an increasing function of \(\kappa\). Interpreted in this way, we have \(\rho^w = \rho^w_0\).
Of course, if $\rho^w > \max w$, then the no-deficit constraint binds, implying that $\pi^w = 0$ and that the question of how to allocate the budget surplus is moot. In contrast, if $\rho^w = \max w$, then $\pi^w \geq 0$. In this case, weighted welfare is maximized when $\pi^w$ is allocated among the suppliers and buyers with bargaining weights equal to $\max w$, which is accomplished by having interim expected payoffs to the agents’ worst-off types of

$$\hat{u}_j^S(c; w, \eta) = \eta_j^S \pi^w$$ and $$\hat{u}_i^B(v; w, \eta) = \eta_i^B \pi^w,$$

where, as defined above, $\eta_j^S = 0$ and $\eta_i^B = 0$ for any supplier $j$ and buyer $i$ that do not have the maximum bargaining weight.

The outcome of incomplete information bargaining with bargaining weights $w$ and tie-breaking shares $\eta$ is then given by the expected buyer and supplier payoffs implied by the allocation rule $Q^w$ given in Lemma 1 and interim expected payoffs to agents’ worst-off types given by (6). Thus, we have:

**Proposition 1.** Incomplete information bargaining with bargaining weights $w$ and shares $\eta$ generates expected supplier payoffs for $j \in N^S$ of

$$u_j^S(w, \eta) \equiv \eta_j^S \pi^w + \mathbb{E}_{v, c} \left[ (\Gamma_j(c_j) - c_j) Q_j^{w,S}(v, c) \right],$$

and expected buyer payoffs for $i \in N^B$ of

$$u_i^B(w, \eta) \equiv \eta_i^B \pi^w + \mathbb{E}_{v, c} \left[ (v_i - \Phi_i(v_i)) Q_i^{w,B}(v, c) \right].$$

The outcomes from incomplete information bargaining given in Proposition 1 coincide with the set of Pareto undominated payoffs associated with mechanisms in $\mathcal{M}$. To see this, take as given a vector of expected payoffs $\tilde{u}$ that is the outcome of $\langle \tilde{Q}, \tilde{M} \rangle \in \mathcal{M}$ and that is Pareto undominated in the set of expected payoff vectors that obtain from mechanisms in $\mathcal{M}$. Then there exist bargaining weights $w \in [0, 1]^{n^S + n^B}$ such that $Q^w$ is equal to $\tilde{Q}$ (as shown in the proof of Proposition 2, these weights are derived from the Lagrange multipliers on the constraints that agents’ payoffs be at least as great as in $\tilde{u}$). Further, there exist shares $\eta$ such that the agents’ expected payoffs are $\tilde{u}$ in incomplete information bargaining with bargaining weights $w$ and shares $\eta$. Conversely, because no money is left on the table, any expected payoffs from incomplete information bargaining are Pareto undominated among payoffs resulting from mechanisms in $\mathcal{M}$.

**Proposition 2.** Expected payoff vector $\tilde{u}$ associated with $\langle \tilde{Q}, \tilde{M} \rangle \in \mathcal{M}$ is Pareto undominated among expected payoff vectors for mechanisms in $\mathcal{M}$ if and only if there exist bargaining weights $w$ and shares $\eta$ such that $Q^w = \tilde{Q}$ and $(u^S(w, \eta), u^B(w, \eta)) = \tilde{u}$. 

11
As we show in Appendix C, incomplete information bargaining includes the $k$-double auction of Chatterjee and Samuelson (1983) as a special case (when $n^S = n^B = 1$ and agents draw their types from the uniform distribution). In incomplete information bargaining, just as in the $k$-double auction, equalization of bargaining power increases expected social surplus, which is what we turn to next.

3.4 Social-surplus-increasing equalization of bargaining weights

Despite the result of Proposition 2 that incomplete information bargaining is Pareto efficient, its outcome may differ from what the planner would choose. This creates potential for social-surplus-increasing equalization of bargaining power—by which we mean changing some asymmetric vector of bargaining weights $\mathbf{w}$ to $\mathbf{w} = (w, \ldots, w)$—and scope for countervailing power in the sense that the negative consequences of, say, a merger on social surplus might be reversed by an associated equalization of bargaining weights.

In particular, denoting by $W^* \equiv \mathbb{E}_{v,c}[W_{Q^*}(v, c)]$ the value of the planner’s objective under the planner’s optimal allocation rule, which we denote by $Q^*$, and by $W^w \equiv \mathbb{E}_{v,c}[W_{Q^w}(v, c)]$ the value of the planner’s objective under the allocation rule chosen by the market, denoted $Q^w$, we have $W^w \leq W^*$ because the allocation rule $Q^w$ is available when the planner chooses $Q^*$. Notice also that $Q^* = Q^{(w, \ldots, w)}$ for any $w \in (0, 1]$. Hence, for any $w \in (0, 1]$, we have $W^* = W^{(w, \ldots, w)}$.

Given a market with weights $w$, we say that the planner prefers an equalization of bargaining weights if $W^w < W^*$, or equivalently, $Q^w(v, c) \neq Q^*(v, c)$ for all $(v, c)$ in an open subset of $[v, \overline{v}]^{n^B} \times [c, \overline{c}]^{n^S}$. As stated in the next proposition, specific conditions are required for the planner not to prefer an equalization of bargaining weights. Of course, the question of equalization of bargaining weights is moot when if these weights are already all the same. But even when the weights differ, there may be no benefit to the planner if the market has full trade, that is,

$$\left( K\text{-th lowest of } \{\frac{\Gamma_j^{w^S}}{\rho^w}(\overline{c})\}_{j \in N^S} \right) \leq \left( K\text{-th highest of } \{\frac{\Phi_i^{w^B}}{\rho^w}(\overline{v})\}_{i \in N^B} \right),$$

which implies that $\rho^w = \max w$, and if there is sufficient symmetry among the agents that it is always the highest-value buyers and lowest-cost suppliers that trade. Specifically, the

\[19\]To see this, note that $W^{(w, \ldots, w)}_{Q^w}(v, c) = w(W_{Q}(v, c) - R_{\text{M}}(v, c))$, which is maximized, subject to no deficit, at $Q^*$. With symmetric bargaining weights, the weight $w$ has a multiplicative effect on the solution value of the Lagrange multiplier on the no-deficit constraint, but ultimately it has no effect on the allocation rule $Q^w$, which depends on $w$ divided by that multiplier.
suppliers must have equal bargaining weights and the buyers must have equal bargaining weights, and if one side of the market has a lower bargaining weight, i.e., does not have weight equal to max \( w \), then agents on that side must have symmetric distributions so that the ordering of virtual types matches the ordering of actual types.  

**Proposition 3.** In a market with asymmetric bargaining weights \( w \), the planner prefers an equalization of bargaining weights unless all of the following conditions are satisfied: 

(i) the full-trade condition \( \text{(i)} \) holds; 
(ii) for all \( j \in N^S \), \( w_j^S = w_j \), and for all \( i \in N^B \), \( w_i^B = w_i \); 
(iii) if \( w_j^S < w_j^B \), then for all \( j \in N^S \), \( G_j = G \); 
(iv) if \( w_j^B < w_j^S \), then for all \( i \in N^B \), \( F_i = F \).

*Proof. See Appendix B.*

Proposition 3 provides conditions on bargaining weights and primitives such that the planner does not benefit from an equalization of bargaining weights. That said, there exist asymmetric bargaining weights such that the planner benefits from an equalization of bargaining weights, i.e., there exist \( w \) such that \( W^w < W^* \), unless \( n^B = n^S = 1 \), \( \tau \leq \Phi_1(v) \), and \( v \geq \Gamma_1(c) \). This shows that, quite generally, equalization of bargaining power increases social surplus. Some of the benefits that the planner obtains from more equal bargaining weights stem from an equalization of bargaining weights among agents on the same side of the market, which eliminates socially wasteful discrimination among the agents based on differently weighted virtual types. While this effect is integral to the incomplete information bargaining model that we study here, equalization of bargaining power on one side of the market is arguably not what competition authorities and practitioners, or for that matter, John Galbraith, have in mind when speaking of countervailing power, which refers to an equalization of bargaining power across the two sides of the market. Adhering to this terminology, we say that there is scope for countervailing power in a market if the planner prefers an equalization of bargaining power across the two sides of the market.

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\(^{20}\)That ex ante symmetry among agents implies that there is no inefficiency in production when the production decision is based on (equally weighted) virtual types rather than actual types hinges on the assumption that the virtual type functions are increasing. Without that assumption, the weighted virtual type functions would have to be replaced by their “ironed” counterparts (see [Myerson 1981](#)), and the resulting allocation rules would induce inefficiency with positive probability because of random tie-breaking.

\(^{21}\)These distributional assumptions are restrictive in the sense that they are not satisfied if the supports of the buyer’s and suppliers’ type distributions overlap because \( \Phi_i(v) < v \) for any \( v < \tau \) and \( \Gamma_i(c) > c \) for any \( c > \zeta \). Further, the conditions fail in many cases even when there is no overlap—for example, if the supplier draws its cost from the uniform distribution on \([0, 1]\) and the buyer draws its value from the uniform distribution on \([v, v + 1]\), then the conditions hold if and only if \( v \geq 2 \). If \( \tau > \Phi_1(v) \), then giving the supplier all the bargaining power reduces welfare below \( W^* \), and if \( v < \Gamma_1(c) \), then giving the buyer all the bargaining power reduces welfare below \( W^* \).
To analyze the scope for countervailing power, we consider the bargaining frontier associated with shifts in bargaining weight between the buyer side and the supplier side of the market. Given bargaining weights \( \mathbf{w} = (\mathbf{w}^S, \mathbf{w}^B) \) defining the relative bargaining weights among buyers and, separately, among suppliers, and \( \Delta \in [0, 1] \), indicating bargaining differential between the buyer and supplier sides of the market, we define \( \tilde{\mathbf{w}}_{\mathbf{w}, \Delta} \equiv ((1 - \Delta)\mathbf{w}^S, \Delta \mathbf{w}^B) \). Further, let \( \tilde{\eta}_{\mathbf{w}} \) denote the tiebreaking shares that specify an equal division of any budget surplus among the agents with the maximum bargaining weight in \( \mathbf{w} \).

Then we can define \( \tilde{u}^S_i(\mathbf{w}, \Delta) \equiv u^S_i(\tilde{\mathbf{w}}_{\mathbf{w}, \Delta}, \tilde{\eta}_{\mathbf{w}, \Delta}) \) and \( \tilde{u}^B_i(\mathbf{w}, \Delta) \equiv u^B_i(\tilde{\mathbf{w}}_{\mathbf{w}, \Delta}, \tilde{\eta}_{\mathbf{w}, \Delta}) \). In honour of Williams (1987) who first analyzed problems of this kind in a bilateral trade setting, we call

\[
\mathcal{F}_{\mathbf{w}} \equiv \left\{ \left( \sum_{j \in \mathcal{N}^S} \tilde{u}^S_j(\mathbf{w}, \Delta), \sum_{i \in \mathcal{N}^B} \tilde{u}^B_i(\mathbf{w}, \Delta) \right) \mid \Delta \in (0, 1) \right\}
\]

the Williams frontier initialized at weights \( \mathbf{w} \).

**Proposition 4.** The Williams frontier is concave to the origin, and strictly concave if and only if its intersection with the first-best frontier contains at most one point.

**Proof.** See Appendix B.

As shown in Proposition 4, the Williams frontier is strictly concave if and only if it coincides with the first-best frontier at most at one point. This occurs, for example if the supports of the suppliers’ and buyers’ type distributions coincide, that is, if \( v = \tilde{v} \) and \( \tau = \tilde{\tau} \), because in that case first-best is not possible (see e.g. Williams 1999). In contrast, if the supports do not overlap, then the Williams frontier follows the first-best frontier for a range of bargaining weights that are sufficiently symmetric. Along that segment, it is only weakly concave. This is illustrated in Figure 1. As shown in panel (a), for the case of overlapping supports, the first-best cannot be achieved and the Williams frontier is strictly concave. In contrast, as shown in panel (b), with nonoverlapping supports, the first-best is achieved for a range of \( \Delta \) close to \( 1/2 \) and in that range the frontier is linear. The reasons for the concavity of the Williams are essentially the same as those invoked by Paul Samuelson to show that with constant returns to scale the production possibility frontier is concave: The convex combination between any two points on the frontier can be achieved by randomizing over the mechanisms associated with each of them. By re-optimizing, one may be able to do better. The linear segment of the frontier in panel (b) of Figure 1 is a case where

\[22\] If \( \mathbf{w}^S = \mathbf{0} \), then we restrict attention to \( \Delta \in (0, 1] \), and if \( \mathbf{w}^B = \mathbf{0} \), then we restrict attention to \( \Delta \in [0, 1) \) so as to avoid the case in which all agents have zero bargaining weight.

\[23\] That is, for \( x \in \{B, S\} \), if \( w^x_i \neq \max \mathbf{w} \), then \( \tilde{\eta}^x_{w, i} \equiv 0 \), and otherwise \( \tilde{\eta}^x_{w, i}(\mathbf{w}) \equiv 1/m \), where \( m \) is the number of elements of \( \mathbf{w} \) that are equal to \( \max \mathbf{w} \).
reoptimizing cannot improve outcomes because at both end points of that segments the mechanism is already first-best.

(a) Overlapping supports

\[ FB \prec SB \prec uS \]

\[FB\prec SB\prec uB\]

\[\Delta = 1\]

\[\Delta = 1/2\]

\[\Delta = 0\]

(b) Nonoverlapping supports

\[FB \prec uS \prec FB \]

\[FB \prec uB \prec FB\]

\[\Delta = 1\]

\[\Delta = 1/2\]

\[\Delta = 0\]

Figure 1: Williams frontier \(F_w\) for the case of 1 single-unit buyer and 1 single-unit supplier and \(w = (1, 1)\). \(FB\) denotes the first-best social surplus, and \(SB\) denotes the second-best social surplus. Panel (a) assumes that the buyer’s and supplier’s types are uniformly distributed on \([0, 1]\). Panel (b) assumes that the supplier’s cost is uniformly distributed on \([0, 1]\) and that the buyer’s value is uniformly distributed on \([1, 1, 2.1]\). In that case, the first-best and second-best total surplus is the same.

Building on Proposition 4 and letting \(W_w(\Delta) \equiv \sum_{j \in N_S} \bar{u}_j^S(w, \Delta) + \sum_{i \in N_B} \bar{u}_i^B(w, \Delta)\), the concavity of the Williams frontier has the following implication:

**Corollary 1.** Given symmetric \(w = (w, \ldots, w)\), movement towards the equalization of buyer-side and supplier-side bargaining weights weakly increases social surplus, i.e., if \(\Delta' < \Delta \leq 1/2\) or \(1/2 \leq \Delta < \Delta'\), then \(W_w(\Delta') \leq W_w(\Delta) \leq W_w(1/2)\).

Corollary 1 has policy implications for settings in which competition authorities could allow actions that equalize bargaining power. For example, allowing merchants that purchase payment card services from powerful suppliers (e.g., Visa, Mastercard) to engage in group boycotts might improve social surplus by equalizing bargaining power.\(^{24}\) Considering bargaining between powerful insurance companies and doctors for the supply of health services, allowing physician joint ventures might equalize bargaining power and improve social surplus.\(^{25}\)

\(^{24}\)See footnote 3.

\(^{25}\)For example, the U.S. DOJ and FTC (1996) state: “The Agencies will not challenge, absent extraordinary circumstances, a non-exclusive physician network joint venture whose physician participants share
An effect similar to that described in Corollary 1 arises in the partnership literature, where social surplus is increased by equalizing ownership shares rather than by equalizing bargaining weights. For example, as first observed by Cramton et al. (1987), when all agents draw their values independently from the same distribution, ex post efficient reallocation is possible if all agents have equal shares, and is impossible if one agent has full ownership. However, the paths through which these gains in social surplus are achieved, and the gains themselves, are different in the two approaches. In the partnership literature, the allocation rule is kept fixed at the ex post efficient one, but agents’ ownership shares are allowed to change. The revenue of the mechanism increases as ownership shares (or, more generally, agents’ worst-off types) become more similar, eventually permitting the first-best without running a deficit. In contrast, in incomplete information bargaining with bargaining weights, the worst-off types of all agents are always the same (the lowest type for a buyer and the highest type for a supplier), and so is the budget surplus of the mechanism, which is zero. What changes as the bargaining weights change is the allocation rule, which transitions from, say, the buyer-optimal one via the second-best to the one that is optimal for the suppliers. Moreover, because, for example with identical supports, the second-best is different from first-best in the model with bargaining weights, equalization of bargaining weights yields, in general, less social surplus than equalization of ownership shares (or worst-off types) in a partnership model.

4 Horizontal mergers

In this section, we analyze horizontal mergers. We evaluate outcomes, including the profitability of mergers, from an ex ante perspective, that is, before firms’ types are realized. We consider both the productive power effects of a merger and effects of changes in agents’ bargaining weights.

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*substantial financial risk and constitute 30 percent or less of the physicians in each physician specialty with active hospital staff privileges who practice in the relevant geographic market* (p. 65). While the guidelines do not allow simple group negotiations over price, without some form of financial integration, under the theory that group negotiation would tend to raise prices, Corollary 1 finds benefits to group negotiation that equalizes bargaining weights even in the absence of financial integration.

With identical distributions, equal shares imply equal worst-off types, which somewhat camouflages the point that the driving force for possibility is the equalization of worst-off types; see, for example, Che (2006) for a proof that with equal worst-off types, ex post efficiency is possible.
4.1 Effects of horizontal mergers

To model mergers within our constant-returns-to-scale setup, we assume that the merged entity draws its constant marginal type from a distribution that combines the distributions of the merging firms. Further, we assume that the capacity of the merged entity combines the capacities of the merging firms. For a merger of suppliers \(i\) and \(j\), we denote the merged entity’s cost distribution by \(G_{i,j}\) and its capacity by \(k_{i,j}^S\), and for a merger of buyers \(i\) and \(j\), we denote the merged entity’s value distribution by \(F_{i,j}\) and its capacity by \(k_{i,j}^B\).

To model a merger, one needs to describe how a merger transforms the two pre-merger firms’ distributions and capacities into the distribution and capacity of the merged entity. The natural mapping from pre-merger to post-merger firms is clear for a merger of firms whose capacities are sufficiently large that each could individually serve the entire other side of the market. For example, suppose that suppliers 1 and 2 merge, where \(k_1^S = k_2^S = K^B\). We model the merged entity as having a constant marginal cost for \(K^B\) units that is drawn from the distribution of the minimum of a cost drawn from \(G_1\) and a cost drawn from \(G_2\), i.e., \(G_{1,2}(c) = 1 - (1 - G_1(c))(1 - G_2(c))\). This has the natural interpretation of a merged entity that has two facilities, each with constant marginal cost for \(K^B\) units, where the merged entity rationalizes its production by using only the facility with the lower marginal cost. In other words, in line with Farrell and Shapiro (1990)\footnote{This is the approach also taken by, for example, Salant et al. (1983), Perry and Porter (1985), Waehrer (1999), Dalkir et al. (2000), and Loertscher and Marx (2019).},\footnote{Additional merger-related synergies can be incorporated along the lines laid out in Loertscher and Marx (2019).} we assume that there are no synergies associated with a merger beyond the ability to rationalize production or consumption between the component firms.\footnote{This is the approach also taken by, for example, Salant et al. (1983), Perry and Porter (1985), Waehrer (1999), Dalkir et al. (2000), and Loertscher and Marx (2019).} Analogously, the merged entity created from the merger of buyers 1 and 2 with \(k_1^B = k_2^B = K^S\) would draw its constant marginal cost for \(K^S\) units from \(F_{1,2}(v) = F_1(v)F_2(v)\).

Mergers that do not affect the bargaining weights and shares

As we now show, in the case of a merger of “large” firms described above, a merger that does not alter bargaining weights or shares weakly reduces expected weighted welfare, and strictly so if the merging firms do not have the maximum bargaining weight. In what follows, we provide conditions on the relation between the pre-merger and post-merger firms’ type distributions and capacities such that a merger weakly reduces expected weighted welfare. We say that a merger does not alter bargaining weights or shares if all nonmerging agents retain their pre-merger bargaining weights and shares in the post-merger market and the merging agents have the same bargaining weight in the pre-merger market, which is then
inherited by the merged entity, and the share of the merged entity is equal to the sum of the shares of the merging agents.

**Proposition 5.** A horizontal merger that does not alter bargaining weights or shares, and that involves suppliers $i$ and $j$ with $k_i^S = k_j^S = K^B$, weakly reduces expected weighted welfare (strictly if $w_{i,j} < \max w$; and with equality for all agents if $w_{-\{i,j\}} = 0$), and analogously for a merger of buyers $i$ and $j$ with $k_i^B = k_j^B = K^S$.

**Proof.** See Appendix B.

A number of results follow from Proposition 5. Proposition 5 implies that a horizontal merger involving agents with maximum capacity reduces social surplus when all agents have the same bargaining weight and harms any nonmerging agent that has all the bargaining power. Further, the proposition implies that two maximum capacity agents on the same side of the market that are the only agents with bargaining power have no incentive to merge, something that we see depicted in Figure 2 below. Proposition 5 generalizes the insights from Loertscher and Marx (2019) that a merger harms a powerful buyer to a setting in which incomplete information pertains to both sides of the market, multiple buyers and suppliers, multi-unit demand and supply, and bargaining power that is not restricted to be with the buyer.

In general, a merger affects the productive power of the merging agents by creating a merged entity that draws its type from a distribution that can differs from the distributions of the pre-merger firms. We now consider conditions on the merged entity’s type distribution that are sufficient for the result, as in Proposition 5 that a merger reduces expected weighted welfare.

To develop intuition, consider the case of a supplier merger in which, as in Proposition 5, the merged entity draws its constant marginal cost from the distribution of the minimum of the two merging suppliers’ marginal costs. Then one can essentially transfer to the pre-merger market the allocation rule of any incentive compatible post-merger mechanism by replacing the type of a merged entity that combines suppliers $i$ and $j$ with $\min\{c_i, c_j\}$ and allocating the merged entity’s quantity to the merging supplier $i$ or $j$ with the lower cost. Using threshold payments, the budget surplus, not accounting for fixed payments, is then greater in the pre-merger market because the competition between suppliers $i$ and $j$ reduces the threshold payments to those suppliers. This means that the post-merger incomplete information bargaining mechanism is feasible in the pre-merger market—indeed has strictly greater budget surplus not accounting for fixed payments. If it also gives (weakly) greater expected weighted welfare, then it follows by a form of revealed preference argument that
expected weighted welfare under the (optimized) pre-merger mechanism is (weakly) greater than under the post-merger mechanism.\footnote{If the merging suppliers do not have the maximum bargaining weight, then pre-merger expected weighted welfare can be increased by distributing the savings from reduced payments to the merging suppliers to agents with higher bargaining weights, giving the result that expected weighted welfare is greater pre-merger. If the merging suppliers have the maximum bargaining weight and all other agents have lower bargaining weights, then we can achieve the same expected weighted welfare in the pre-merger market, and potentially greater expected weighted welfare once the mechanism is optimized for the pre-merger market. If the merging suppliers have the maximum bargaining weight and all other agents have a bargaining weight of zero, then no further optimization is possible, and so the merger has no effect on expected weighted welfare.}

We provide general conditions for this argument to apply in the following lemma. As stated in the lemma, we require that the post-merger distribution, $G_{i,j}$ in the case of a supplier merger, is equal to the distribution of some nondecreasing function of $h$ the merging agents’ types, $c_i$ and $c_j$ for a supplier merger. The remaining conditions ensure that we can rank the threshold payments of the merging agents relative to the threshold payment of the merged entity.

**Lemma 2.** A merger of suppliers $i$ and $j$ that does not alter bargaining weights or shares weakly reduces expected weighted welfare if the merged entity’s cost distribution $G_{i,j}$ and capacity $k_{i,j}^S$ are such that there exists continuous, nondecreasing function $h : [\underline{c}, \overline{c}]^2 \rightarrow [\underline{c}, \overline{c}]$ satisfying: (i) for all $z \in [\underline{c}, \overline{c}]$,

$$\Pr_{c_i, c_j}(h(c_i, c_j) \leq z) = G_{i,j}(z),$$

(ii) $\min\{c_1, c_2\} \leq h(c_i, c_j)$, (iii) $k_i^S < k_{i,j}^S \Rightarrow c_j \leq h(c_i, c_j)$, and (iv) $k_j^S < k_{i,j}^S \Rightarrow c_i \leq h(c_i, c_j)$; and analogously for a merger of buyers.

**Proof.** See Appendix B.

Condition (i) in Lemma 2 is sufficient to permit the construction of a mechanism in the pre-merger market that has the same interim expected allocations for the nonmerging firms as the post-merger incomplete information bargaining mechanism. Then, as long as $h(c_i, c_j) \geq c_i$ whenever agent $i$ trades, the sum of the premerger agents’ threshold payments is no greater than the threshold payment of the merged entity in the post-merger market. Conditions (ii)–(iv) guarantee this. Thus, under the conditions of Lemma 2, one can construct a pre-merger mechanism that mimics the post-merger allocation and payments, but with weakly lower payments to merging suppliers (weakly higher payments to merging buyers), giving us an incentive compatible, individually rational, no-deficit mechanism for the pre-merger market that has the same or greater expected weighted welfare. Optimizing that mechanism for
the pre-merger market only reinforces the result that expected weighted welfare is greater pre-merger than post merger.

**Bargaining power effects of mergers**

In addition to changing the productive power of the merged entity compared to the merging firms, it is also conceivable that mergers alter firms’ bargaining powers. Indeed, the idea that a merger that somehow “levels the playing field” endows merging parties with *countervailing power* is based on this very conception.\(^{30}\) It finds support in the empirical literature (Ho and Lee, 2017; Bhattacharyya and Nain, 2011; Decarolis and Rovigatti, 2020) and features prominently in antitrust debates and cases. Nonetheless, a major obstacle to analyzing the effects of countervailing power in existing modeling approaches is that these take the efficiency of the price-formation process as given. This is true for all oligopoly models, in which agents on one side of the market (typically buyers) are assumed to be price-takers and also applies to randomized take-it-or-leave-it offers.

In contrast, as stated in Corollary 1, with incomplete information, a change in bargaining weights has an impact on social surplus because the efficiency of the mechanism varies with bargaining weights. Consequently, a merger that results in buyer-side and supplier-side bargaining power moving closer together increases social surplus if the bargaining-power effects outweigh the productive-power effects of consolidation. As an example, Figure 2(a) shows a case in which a merger of suppliers reduces social surplus if the buyer has all the bargaining power both before and after the merger, but a merger increases social surplus if the buyer and suppliers’ bargaining weights are equalized after the merger.\(^{31}\) Indeed, Figure 2(b) provides an example in which countervailing power restores the first-best in the post-merger market—specifically, if the buyer has all the bargaining weight prior to the merger, then the pre-merger outcome is not the first-best, but with symmetric bargaining weights in the post-merger market, the outcome is the first-best.

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\(^{30}\) As a case in point, the Australian government’s 1999 (now superseded) guidelines stated: “If pre-merger prices are distorted from competitive levels by market power on the opposite side of the market, a merger may actually move prices closer to competitive levels and increase market efficiency. For example, a merger of buyers in a market may create countervailing power which can push prices down closer to competitive levels” (ACCC, 1999, para. 5.131).

\(^{31}\) In the example of Figure 2(a), merger plus equalization of bargaining weights decreases buyer surplus by -0.028 and increases social surplus by 0.009, so for a competition authority to credit a countervailing power defense, it would need to place a weight of at least 75% on social surplus versus buyer surplus.
Figure 2: Williams frontier for the case of 1 pre-merger buyer and 2 symmetric pre-merger suppliers (blue), all with capacity of one, and the frontier following the merger of the two suppliers (orange). The pre-merger frontier is defined by \((w^S, w^B) = (1, 1, 1)\) and \(\Delta \in [0, 1]\), and the post-merger frontier is defined by \((\hat{w}^S, \hat{w}^B) = (1, 1)\) and \(\hat{\Delta} \in [0, 1]\). We assume equal tiebreaking shares among the agents with the maximum bargaining weight. Panel (a) assumes that the buyer’s and pre-merger suppliers’ types are uniformly distributed on \([0, 1]\). Panel (b) assumes that the pre-merger suppliers’ costs are uniformly distributed on \([0, 1]\) and that the buyer’s value is uniformly distributed on \([1, 2]\).

Transposing the roles of buyers and suppliers in Figure 2 provides an example of how consolidation among buyers that equalizes bargaining power between buyers and a dominant supplier can increase welfare. This is consistent with, for example, empirical analysis of Decarolis and Rovigatti (2020) showing that consolidation among online advertising intermediaries has increased their buyer power, countervailing Google’s significant market power in online search.\(^{32}\)

We summarize with the following result:

**Corollary 2.** A merger between two symmetric suppliers or two symmetric buyers that only has productive power effects and reduces social surplus is more harmful than a merger between the same two agents that equalizes the bargaining weights between the two sides of the market. Moreover, the effects of equalizing bargaining weights associated with a merger can be so strong that the first-best is possible after the merger when it was not possible before the merger.

Combining Corollary 2 and Proposition 8 allows us to connect investment with the equal-
ization of bargaining power. By Proposition 8, the equalization of bargaining power cannot
only increase social surplus, holding investments fixed, as stated in Corollary 2, but it can
also improve investments to the first-best level. Proposition 8 thus provides an additional
channel—investments—through which bargaining power changes can increase social surplus.

Corollary 2 demonstrates that there is the possibility of defending a merger on grounds
that it will equalize bargaining power. A merger that only involves productive power effects
reduces social surplus if the first-best is not possible post merger. In contrast, a merger that
causes bargaining weights to shift in favor of the merging parties may improve expected social
surplus despite the adverse productive power effects. Of course, a merger of, for example,
suppliers that also induces an increase in suppliers’ bargaining power is bad for the buyers
for two reasons: competition among suppliers is reduced and the remaining suppliers have
increased bargaining power. Thus, the review of a supplier merger based on a buyer-surplus
standard would never be swayed by claims of equalization of bargaining power. In contrast,
merger review based on a social-surplus standard may well be.

Our analysis allows us to identify necessary conditions for a merger defense based on the
equalization of bargaining power. First, as just mentioned, the objective of the merger review
would need to include the promotion of social surplus, and not just buyer surplus. Second, the
side of the market on which the merger occurs would need to have less bargaining power than
the other side, so that an increase in the merging parties’ bargaining power is a movement
towards the equalization of bargaining power. Third, the side opposite the merger would
need to retain at least some bargaining power following the merger—for example, following
a supplier merger, buyer power would need to diminish, but not vanish—so that society is
not simply trading dominant buyers for dominant suppliers, or vice versa.

This brings to mind the EC merger guidelines, which state that “it is not sufficient that
buyer power exists prior to the merger, it must also exist and remain effective following the
merger. This is because a merger of two suppliers may reduce buyer power if it thereby
removes a credible alternative” (EC Guidelines, para. 67). Our conclusions are consistent
with that view insofar as the buyer must have power before a supplier merger and retain
at least some power after the merger in order for a defense based on the equalization of
bargaining power to make economic sense.

33In the alternative, but analogous, setting of a sale auction, a merger of buyers harms the suppliers and
possibly benefits (all) buyers. This gives rise to the possibility of buyer-surplus-increasing mergers, which
might be viewed as procompetitive. To increase social surplus, the merger would have to reduce the suppliers’
bargaining power without eliminating it.

34The EC merger guidelines state, “Countervailing buyer power in this context should be understood as
the bargaining strength that the buyer has vis-à-vis the seller in commercial negotiations due to its size, its
commercial significance to the seller and its ability to switch to alternative suppliers” (EC Guidelines, para.
64).
The necessary conditions for a defense based on the equalization of bargaining power raise the question of how one would ascertain that an agent has bargaining power. For example, if a market is characterized as a $k$-double auction, then evidence of buyer power would be that transactions always occur at the buyer’s price.

For a procurement auction, evidence consistent with buyer power but inconsistent with the absence of buyer power includes:

(i) the buyer uses procurement methods that result in suppliers other than the lowest-cost supplier winning, such as handicaps or preferences;
(ii) the distribution of reserve prices is different across the markets if the buyer purchases in separate markets;
(iii) one observes with positive probability ties in procurement outcomes and randomization over winners.

Analogous conditions apply for an analysis of supply power.

5 Vertical integration

We now analyze vertical integration between a buyer and a supplier. We assume that after integration, the integrated entity can efficiently solve its internal agency problem, which is a standard assumption.

Consider vertical integration between buyer 1 and supplier 1 and focus on the case of single-unit buyers and suppliers. If there are external suppliers but no external buyers, then the vertically integrated firm acts as a buyer with value $y = \min\{v_1, c_1\}$, whose distribution we denote by $\tilde{F}(y) \equiv 1 - (1 - F_1(y))(1 - G_1(y))$, which we assume to exhibit increasing virtual value. If there is no trade between the vertically integrated firm and the nonintegrated suppliers, then the integrated firm’s payoff is equal to $\max\{0, v_1 - c_1\}$ due to internal sourcing, and the nonintegrated suppliers have payoffs of zero. Analogously, if there are external buyers but no external suppliers, then the vertically integrated firm acts as a supplier with cost $y = \max\{v_1, c_1\}$, whose distribution we denote by $\tilde{G}(y) \equiv F_1(y)G_1(y)$, which we assume to

---

35This property does not hinge on particular distributional assumptions. For $k = 1$, the buyer’s and supplier’s optimal bids are $\Gamma_1^{-1}(v)$ and $c$, respectively, while for $k = 0$, they are $v$ and $\Phi^{-1}(c_1)$. Hence, for $k = 1$ ($k = 0$) the $k$-double auction is the mechanism that is optimal for the buyer (supplier) for any distributions $F$ and $G_1$ with positive densities on their supports. (If $\Phi$ or $\Gamma_1$ is not monotone, one would replace the virtual type function with its ironed counterparts and the inverse with the generalized inverse (Myerson, 1981).)

36The background for these conditions is as follows. (i): A buyer with power discriminates among heterogeneous suppliers based on their virtual costs. (ii): A buyer without power would optimally set a reserve equal to its value, so even if suppliers in the different markets draw their types from different distributions, the distribution of reserves would be the same across the markets as long as the buyer’s values for the goods in the markets are drawn from the same distribution. (iii): For a buyer with power, this outcome arises when suppliers draw their costs from distributions that are identical but do not satisfy regularity, that is, their virtual costs are not monotone and so the optimal mechanism involves “ironing.” A buyer without power purchases from the lowest-cost supplier.

37This assumption can be rationalized, for example, on the grounds that integration slackens the individual rationality constraints within the integrated firm.
exhibit increasing virtual cost. If there are both external buyers and external suppliers, then the vertically integrated firm may act as either a buyer or a supplier depending on the type realizations, but requires a more detailed analysis. Here we show that it is straightforward to derive conditions for when vertical integration increases and when it decreases expected social surplus, while staying in the setup in which the vertically integrated firm is only a buyer or a supplier, but not both.

Consider first a bilateral trade setting with overlapping supports before integration (i.e., \( n_B = n_S = 1 \) and \( v < c \)). Because the first-best is impossible when the buyer and supplier are independent entities, it follows immediately from our assumption that the integrated entity can resolve the internal agency problem that vertical integration can increase social surplus:

**Proposition 6.** Assuming single-unit demand and supply, with bilateral trade and overlapping supports, vertical integration increases social surplus (to the first-best) regardless of bargaining weights.

By Proposition 6, vertical integration can increase social surplus and enable the first-best by essentially eliminating a Myerson-Satterthwaite problem. However, as we show next, it can also create one.

To this end, assume that the market has one-to-many trade in the sense that either \( n_B = 1 \) and \( n_S \geq 2 \) or \( n_S = 1 \) and \( n_B \geq 2 \), and consider the case with nonoverlapping supports. The latter assumption implies that prior to vertical integration, the first-best is possible and, indeed, occurs if the pre-integration bargaining weights are symmetric. Hence, vertical integration cannot possibly increase social surplus. This leaves the question of whether vertical integration could be neutral. The following proposition shows that the answer is negative.

**Proposition 7.** Assuming single-unit demand and supply, given a pre-integration market with one-to-many trade and nonoverlapping supports, vertical integration decreases social surplus whenever pre-integration bargaining weights are symmetric, regardless of post-integration bargaining weights.

**Proof.** See Appendix B.

Proposition 7 provides a clear-cut case in which vertical integration is harmful from the perspective of society. This result, as well as the result in Proposition 6, is robust in that it does not depend on specific assumptions about distributions or beliefs of agents. Indeed, because there is always a dominant strategy implementation of the price-formation mechanism, beliefs play no role. Moreover, we obtain social surplus decreasing vertical
integration without imposing any restrictions on the contracting space and without invoking exertion of market power by any player (above and beyond requiring individual-rationality and incentive-compatibility constraints to be satisfied). These are noticeable differences relative to the post-Chicago school literature on vertical contracting and integration, whose predictions rely on assumptions about beliefs, feasible contracts, and/or market power. Of course, our results do rely, inevitably, on support assumptions.

At the heart of both Propositions 6 and 7 is the fact that the efficiency of the price-formation process is endogenous in incomplete information bargaining. The elimination of a Myerson-Satterthwaite problem through vertical integration is the incomplete information analogue to the classic double mark-up problem. In contrast to the literature, however, there is now a new effect, namely that trade becomes less efficient for the nonintegrated agents. Further, it is possible for this latter effect to dominate so that the market as a whole is made less efficient as a result of vertical integration.

Connecting bargaining breakdown with vertical integration

A pervasive feature of real-world bargaining is that negotiations often break down. Anecdotal examples range from the U.S. government shut down, to the British coal miners’ and the U.S. air traffic controllers’ strikes in the 1980s, to failures to form coalition governments in countries with proportional representation, to, possibly, Brexit. Providing systematic evidence of bargaining breakdown, Backus et al. (2020) analyze a data set covering 25 million observations of bilateral negotiations on eBay and find a breakdown probability of roughly 55 percent.

In incomplete information bargaining, negotiations break down on the equilibrium path for three reasons. First, it may be that the buyer’s value is below the supplier’s cost, but because of private information, the two parties do not know this before they sit down at the negotiating table, so bargaining begins but then breaks down. Second, with unequal bargaining power, incentives for rent extraction may lead more powerful agents to impose sufficiently aggressive thresholds for trade that breakdown results. Third, by the Myerson-Satterthwaite theorem, even if the buyer’s value exceeds the supplier’s cost, the constraints imposed by incentive compatibility, individual rationality, and no deficit may prevent ex post surplus from decreasing. As described by Crawford (2014), there are regular blackouts of broadcast television stations on cable and satellite distribution platforms due to the breakdown of negotiations over the terms for retransmission of the broadcast signal.
efficient trade from taking place.

Assuming that real-world negotiations are appropriately captured by incomplete information bargaining, one can use observed frequencies of negotiation breakdowns to back out the parameters of the distributions from which the buyer and the supplier draw their types. For purpose of illustration, consider a market with one buyer and two suppliers, with types drawn from parameterized distributions

\[
  F(v) = 1 - (1 - v)^{1/\kappa} \quad \text{and} \quad G_j(c) = c^{1/\kappa_j},
\]

with support \([0, 1]\), where the parameters \(\kappa\) and \(\kappa_j\) are positive real numbers and have the interpretation of “capacities” insofar as larger values of \(\kappa\) and \(\kappa_j\) imply better distributions in the sense of first-order stochastic shifts. These distributions are analytically convenient because they imply linear virtual type functions. Rather than treating negotiation breakdowns as measurement error, which is difficult to justify if breakdown occurs more than fifty percent of the time in 25 million observations, the frequency of those breakdowns is valuable information that can be used for estimation in the incomplete information framework. Figure 3(a) provides an example of how the probability of bargaining breakdown can be used to calibrate the model with parameterized distributions. Then in Figure 3(b), we use the model to predict the change in social surplus as result of vertical integration. As shown, when the rate of bargaining breakdown in the pre-integration market is sufficiently low, i.e., the pre-integration market is sufficiently efficient, the change in social surplus from vertical integration is negative. In contrast, when the probability of breakdown is sufficiently high prior to integration, the increased efficiency associated with internal transactions dominates, and vertical integration increases social surplus.

6 Investment

We start by extending the setup to have investment and provide results. Then we connect the investment results with our results on vertical integration. Finally, we provide comparative statics related to investment.

6.1 Setup and results

Investment incentives feature prominently, and at times controversially, in concurrent policy debates\(^{41}\) and they have been at center stage in the theory of the firm since Grossman and

\[^{41}\text{For example, related to the 2017 Dow-DuPont merger, the U.S. DOJ’s “Competitive Impact Statement” identifies reduced innovation as a key concern (https://www.justice.gov/atr/case-}\]
Calibration of distributions to data

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<td>50-50</td>
<td>55%</td>
<td>(1, 1, 1)</td>
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Figure 3: Interaction between the pre-integration breakdown probability and the effect of vertical integration on social surplus. Panel (a): Calibration of distributional parameters based on market shares and breakdown probabilities assuming that \( n^B = 1 \) and \( n^S = 2 \) and that \( w \) and \( \eta \) are symmetric, \( F(v) \) and \( G_j(c) \) are given by (8), and \( (κ₁ + κ₂)/2 = 1 \). Panel (b): Change in expected social surplus due to vertical integration as the probability of breakdown in the pre-integration market, “pre-VI Pr(bd),” varies, based on the calibration of Panel (a).

Hart (1986) and Hart and Moore (1990) (G-H-M hereafter). To account for investment, we extend our model by adding investment as an action taken by each agent prior to the realization of private information, where investment improves an agent’s type distribution. We show that the results under incomplete information differ starkly from those obtained in the G-H-M literature. This literature stipulates complete information and efficient bargaining and, as a consequence, obtains hold-up and inefficient investment. In contrast, in our setting, incomplete information protects agents from hold-up, and investments are efficient if and, under additional assumptions, only if bargaining is efficient.

We extend the model to allow the suppliers and buyers to improve (or more generally change) their type distributions by investing. Supplier \( j \in N^S \) making investment \( e^S_j \) incurs cost \( \Psi^S_j(e^S_j) \), and buyer \( i \in N^B \) making investment \( e^B_i \) incurs cost \( \Psi^B_i(e^B_i) \). Consistent with G-H-M, we assume that investments are not contractible.\(^{42}\) Thus, bargaining only depends on equilibrium investments and does not vary with off-the-equilibrium-path investments. One implication of this is that the interim expected payments to the worst-off types of agents are not affected by actual investments. We assume that the buyers and suppliers first simultaneously make their investments and then bargaining takes place.

We first consider the planner’s problem of determining investments when the allocation rule is first-best. Denote the first-best allocation for a given realization of types by \( Q^{FB}(v, c) \). Then, for a given realization of types, first-best welfare is \( W^{FB}(v, c) \). Document/file/973951/download, pp. 2, 10, 15, 16).

\(^{42}\)This assumption also prevents the mechanism from using harsh punishments for deviations from any prescribed investment level.
\[ \sum_{i \in \mathcal{N}^B} v_i Q_{i}^{FB,B}(v, c) - \sum_{j \in \mathcal{N}^S} c_j Q_{j}^{FB,S}(v, c). \]

We let \( \bar{\mathcal{e}} \) denote first-best investments, which are a solution to the planner’s first-best investment problem, given by \( \max_{e} \mathbb{E}_{v,c|e} [W^{FB}(v, c)] - \sum_{i \in \mathcal{N}^B} \Psi_i^B(e_i^B) - \sum_{j \in \mathcal{N}^S} \Psi_j^S(e_j^S). \)

Now consider the agents’ incentives to invest when incomplete information bargaining is such that the first-best is possible (see, e.g., Proposition 3 for conditions under which this is the case without symmetric bargaining weights). By the payoff equivalence theorem, it follows that, up to a constant, any incentive compatible mechanism generates the same interim and consequently the same ex ante expected utility for every agent. Thus, for the case considered here in which the first-best is possible, we can, without loss of generality, focus on expected utilities for the Vickrey-Clarke-Groves (VCG) mechanism. Given a type realization \((v, c)\), supplier \(i\)’s VCG payoff is \(W^{FB}(v, c) - W^{FB}(v, \bar{c}, c_{-i})\), plus possibly a constant. Likewise, the buyer \(i\)’s payoff is \(W^{FB}(v, c) - W^{FB}(v, v_{-i}, c)\), plus possibly a constant.

Taking expectations over \((v, c)\), and noticing that \(W^{FB}(v, \bar{c}, c_{-i})\) is independent of supplier \(i\)’s type and its distribution, and so independent of \(e_j^S\), it follows that each supplier \(j\)’s problem at the investment stage, taking as given that the other agents choose investments \(\bar{\mathcal{e}}_{-j}\), is \(\max_{e_j^S} \mathbb{E}_{v,c|e_j^S,\bar{\mathcal{e}}_{-j}} [W^{FB}(v, c)] - \Psi_j^S(e_j^S). \) An analogous optimization problem applies to the buyer \(i\)’s choice of \(e_i^B\), noting that \(W^{FB}(v, v_{-i}, c)\) is independent of buyer \(i\)’s type and its distribution, and so independent of \(e_i^B\). It then follows that the planner’s solution \(\bar{\mathcal{e}}\) is a Nash equilibrium if incomplete information bargaining permits the first-best. This proves the first part of Proposition 8 below.

Under additional conditions, the converse is also true, that is, if \(\bar{\mathcal{e}}\) being a Nash equilibrium outcome in the game in which agents’ first-stage investments are followed by incomplete information bargaining implies that bargaining is efficient. Given investments, for \(j \in \mathcal{N}^S\), let \(G_j(\cdot; e_j^S)\) and for \(i \in \mathcal{N}^B\), let \(F_i(\cdot; e_i^B)\) denote supplier \(j\)’s and buyer \(i\)’s type distributions, respectively, with virtual type functions assumed to be monotone. Sufficient conditions for that converse to hold are: for all \(j \in \mathcal{N}^S\) and \(i \in \mathcal{N}^B\),

\[ \Psi_j^{S_t}(0) = \Psi_i^{B_t}(0) = 0, \text{ for all } e > 0, \text{ } \Psi_j^{S_t}(e), \Psi_i^{B_t}(e) > 0 \text{ and } \Psi_j^{S_u}(e), \Psi_i^{B_u}(e) > 0, \]  

(9)

and for all \(c \in (\underline{c}, \bar{c})\) and \(v \in (\underline{v}, \bar{v})\),

\[ \frac{\partial G_j(c; e)}{\partial e} > 0 \text{ and } \frac{\partial F_i(v; e)}{\partial e} < 0; \]

(10)

and either (i) the type distributions have overlapping supports, \(\underline{v} < \bar{c}\), (ii) \(n^B = n^S\), (iii)
\[ n^B < n^S \quad \text{and for all } j \in \mathcal{N}^S \quad \text{and } c \in [c, \overline{c}], \]
\[ G_j(c; \overline{c}^S_j) \equiv G(c), \quad (11) \]
or (iv) \[ n^B > n^S \quad \text{and for all } i \in \mathcal{N}^B \quad \text{and } v \in [\underline{v}, \overline{v}], \]
\[ F_i(v; \overline{c}^B_i) \equiv F(v). \quad (12) \]

Conditions (9)–(10) imply that the first-best investments \( \overline{c} \) are positive and determined by first-order conditions. This allows one to show that when first-best investments are a Nash equilibrium, the total number of trades under incomplete information bargaining is the same as under the first-best. Given any one of the remaining conditions (i)–(iv), one can show further that it is the same set of buyers and suppliers that trade in the Nash equilibrium as under the first-best. \[ \text{[43]} \]

**Proposition 8.** First-best investments are a Nash equilibrium outcome of the simultaneous investment game if incomplete information bargaining is efficient. Conversely, assuming that (9)–(10) and at least one of (i)–(iv) above holds, if first-best investments are a Nash equilibrium outcome, then incomplete information bargaining is efficient.

**Proof.** See Appendix B.

As shown in Proposition 8 when incomplete information bargaining is efficient, the agents’ Nash equilibrium investment choices are first-best investments. Because private information protects agents from hold-up, \[ \text{[44]} \] efficient incomplete information bargaining implies efficient investments. \[ \text{[45]} \]

Intuitively, given that the allocation rule is efficient, each agent is the residual claimant to the surplus that its investment generates. Anticipating that this will be the case once types are realized, each agent’s incentives are also aligned with the planner’s at the investment stage because each agent’s and the planner’s reward from in-

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\[ \text{[43]} \] Proposition 8 connects to the equivalence result of Hatfield et al. (2018), which links efficient dominant-strategy mechanisms under incomplete information with efficient investments, and to earlier work by Milgrom (1987) and Rogerson (1992). A difference is that the no-deficit constraint in our setting may preclude the first-best.

\[ \text{[44]} \] Lauermann (2013) finds that private information protects against hold-up in a dynamic search model, finding that it is easier/possible to converge to Walrasian efficiency with private information, but otherwise hold up prevents convergence to efficiency. This is consistent with our results, interpreting search as investment.

\[ \text{[45]} \] In a setup where efficient bargaining is possible because of shared ownership (rather than the absence of any allocation-relevant private information), Schmitz (2002, p. 176) notes that “Intuitively, . . . a party’s ex ante expected utility from an ex post efficient mechanism is (up to a constant) equal to the total expected surplus, so that each party is residual claimant on the margin from his or her point of view.”
vestment are the same. Further, under additional conditions, any inefficiency in bargaining results in inefficient investments.

While Proposition 8 focuses on investments that improve agents’ own types, the first part of Proposition 8 continues to hold if, for example, there is a single buyer and each supplier can invest in the “quality” of its product, thereby increasing the value of its product to the buyer. Our result does not hold if, for example, investment generates externalities, e.g., if there are technology spillovers across suppliers or if investment increases the buyer’s value regardless of its trading partner. Che et al. (2017) consider the latter case and find that the buyer always wants to depart from ex post efficiency in order to boost ex ante investment by suppliers.

6.2 Connecting investment with vertical integration

Using Proposition 8, we can connect investment with vertical integration. We assume that vertical integration does not affect the cost of investment for the integrated firm, so if buyer \( i \) and supplier \( j \) integrate and invest \( e^B_i + e^S_j \), the cost of investment is \( \Psi^B_i(e^B_i) + \Psi^S_j(e^S_j) \). With one buyer and one supplier in the pre-integration market and overlapping supports, incomplete information bargaining is inefficient, which under conditions (9) and (10), implies that equilibrium investments are inefficient. But, by assumption, the allocation is efficient after vertical integration, which by Proposition 8 implies that investments are efficient after vertical integration. Thus, with overlapping supports, vertical integration promotes efficient investment insofar as there is an equilibrium with efficient investments after integration but not before. In contrast, with, say, one buyer and two or more symmetric suppliers and nonoverlapping supports, incomplete information bargaining is efficient for some bargaining weights, including symmetric ones, without vertical integration, which implies that investments are efficient without vertical integration. But following vertical integration, incomplete information bargaining is inefficient, and so, under (9) and (10), and investments are no longer efficient. In this case, vertical integration disrupts efficient investment insofar as there is no equilibrium with efficient investments after integration whereas there was one before integration.

Corollary 3. Assuming that (9) and (10) hold, with \( n^S = n^B = 1 \) and overlapping supports, vertical integration promotes efficient investment; but with \( n^S > n^B = 1 \) or \( n^B > n^S = 1 \) and nonoverlapping supports, if distributions satisfy (11), then vertical integration disrupts
efficient investment if bargaining is efficient prior to vertical integration (which occurs, for example, with symmetric bargaining weights).

6.3 Comparative statics for investment

We now analyze how equilibrium investments are affected by bargaining power and by the extent to which the supports of the value and cost distributions overlap. To analyze investment effects, we parameterize the agents’ type distributions and allow investment to affect the distributional parameter in a way that improves the distribution in a first-order stochastic dominance sense, where investment results in a dominating distribution for buyers and a dominated distribution for suppliers.

We consider a bilateral trade setup with linear virtual types. We hold fixed the support of the supplier’s distribution at $[0, 1]$ and let the support of the buyer’s distribution be $[\nu, \nu + 1]$, where we vary $\nu$ from 0 to 1. Specifically, we fix $X > 0$ and consider a supplier type distribution of $G_{xS}(c) \equiv c^{X-xS}$ with support $[0, 1]$, where $x_S \in [0, X)$ is the supplier’s investment, and a buyer type distribution of $F_{xB}(v) \equiv 1 - (1 + \nu - v)^{X-xB}$ with support $[\nu, \nu + 1]$, where $x_B \in [0, X)$ is the buyer’s investment. We assume that each agent’s investment $x$ has cost $x^2/2$. Relegating the details to Appendix E, we illustrate the effects of bargaining power and the distributional supports on equilibrium investment in Figure 4.

![Figure 4: Nash equilibrium investments with bargaining weights $(w^S, w^B) = (1-\Delta, \Delta)$ for buyer distributions with varying supports. Assumes the linear virtual type setup for bilateral trade with $F(v) = 1 - (1 + \nu - v)^{1.25-xB}$, where $x_B \in [0,1.25)$ is the buyer’s investment, and $G(c) = c^{1.25-xS}$, where $x_S \in [0,1.25)$ is the supplier’s investment. Investment $x$ has cost $x^2/2$. When $\nu = 1$, we obtain $x^{FB} = x^{SB} = 0.25$, implying that first-best (and second-best) investment levels result in uniformly distributed types. For $\nu = 1$, $\rho^{NE} = \max\{w_S, w_B\}$ for all bargaining weights, and for $\nu = 1/4$, $\rho^{NE} > \max\{w_S, w_B\}$ for all bargaining weights.](image-url)
As shown in Figure 4, each agent’s equilibrium investment is maximized away from extreme bargaining weights. This points to an additional benefit of the equalization of bargaining weights; namely, it has the potential to improve the efficiency of investment, in some cases to the first-best.

7 Extensions and discussion

The model presented here can accommodate a range of additional extensions. For example, as shown in Appendix D and discussed briefly below, one can allow the agents to have heterogeneous outside options, in which case some, but not all, of the intuition from complete information bargaining on outside options carries over to incomplete information bargaining. Also in Appendix D we show that one can generalize the setup to allow buyers to have preferences over suppliers, in which case bargaining externalities arise naturally. We also show how one can use the results of Delacrétaz et al. (2019) to further generalize the structure of buyers’ preferences over suppliers.

In what follows, we provide a brief discussion of the effects of mergers on downstream consumers and of the extension to allow variation in agents’ outside options.

Downstream consumers

Thus far, our model does not include a mass of downstream consumers beyond the buyers that participate in incomplete information bargaining. Because competition authorities commonly put weight on the welfare of final consumers, it seems important to extend the model to incorporate final consumers.

A natural and tractable way of doing this is to assume that each buyer in our model is a retailer that has exclusive access to a downstream market. (Whether it is the only supplier in that market does not matter for these purposes; to rule out externalities in the bargaining mechanism, what is important is that none of the other agents participating in the mechanism is active in this market.) The input that the buyers procure can be interpreted as reducing the marginal cost of production in that market or (by and large) equivalently as improving the quality of the product.

A natural model in which the buyer’s value and $\delta CS(\omega)$ move in the same direction is one in which the state $\omega$ merely multiplies demand in a given market. Specifically, let $D(p)$ be the decreasing demand function in the market with a mass of consumers equal to 1 and normalize units so that $D(0) = 1$ and assume $D(\bar{p}) = 0$ for some finite price $\bar{p}$. If we assume that the retailer has constant marginal costs of production, we can normalize these to 0 without loss of generality, and if we assume that $pD(p)$ is concave in $p$, it is optimal for the
retailer to set a uniform price $p^*$, assuming each consumer is privately informed about its value and has single-unit demand. Accordingly, consumer surplus in the market with a mass 1 of consumers and a good of quality 1 is $CS^* = \int_{p^*}^{\overline{p}} D(p)dp - D(p^*)p^*$, and if the mass of consumers in the market is $\omega$, demand at price $p$ is $\omega D(p)$, implying that consumer surplus is $\omega CS^*$ while the retailer’s profit is $\omega p^*D(p^*)$.

If the quality of the retailer’s good improves by the commonly known parameter $\delta > 0$ because it buys the input, consumer surplus if the mass of consumers is $\omega$ increases by $\omega\delta CS^*$ while the retailer’s willingness to pay for the quality increment is $\omega\delta p^*D(p^*)$. Hence, the larger is the buyer’s willingness to pay in this specification, the larger is the consumer surplus effect of this buyer obtaining the input.

In general, the consumers in a given downstream market benefit if and only if the retailer serving that market obtains the quality-improving input. In that sense, the robust, specification-independent implication for consumer surplus effects is the “quantity effect,” that is, whether or not the retailer operating in a given market obtains the input. If, in addition, market specific, privately known shocks $\omega$ are of the multiplicative form just studied, then a consumer surplus standard is the same as a buyer surplus standard because buyers with higher willingness to pay are buyers who increase consumer surplus by more if they obtain the input. In this case, a competition authority with a consumer surplus standard is interested in the efficient allocation among buyers in the incomplete information bargaining process. It welcomes equalization of bargaining powers if this equalization increases the probability of trade and because it reduces or eliminates discrimination among buyers, thereby leading to a more efficient allocation, and hence larger consumer surplus. (This is different both from a buyer-surplus standard and from a social-surplus standard, applied to the incomplete information bargaining process.)

**Variation in agents’ outside options**

Our model is amenable to introducing variations in agents’ outside options, which occupy center stage in complete information bargaining. In the incomplete information setting, outside options can affect an agent’s cost of participating in the mechanism independently of whether the agent trades and can affect its value or cost distribution by shifting its support.\(^{47}\)

The comparative statics with respect to increasing an agent’s participation cost are intuitive and largely the same as in models with complete information because it increases the agent’s share of the surplus that is created; in contrast to complete information models, it may decrease expected social surplus. The effects of changing an agent’s *production-relevant*\(^{47}\) of course, to the extent that outside options affect bargaining weights, the comparative statics are those discussed above.
outside option are more nuanced. For example, as a supplier’s outside option improves, the support of its cost distribution shifts upwards, meaning that higher costs become more likely. Hence, the supplier will tend to be less likely to trade. However, under the assumption of monotone hazard rates, this effect is partly (but not completely) offset by the fact that, for a given cost realization, the supplier’s weighted virtual cost is lower than before the increase in the outside option. This implies that, ex post, given the same cost realization, the supplier is treated more favorably after the outside option increases. This is in line with intuition gleaned from complete information models. But from an ex ante perspective, the increase in the outside option harms the supplier because overall it makes the supplier less likely to trade and thereby decreases the supplier’s ex ante expected payoff. Moreover, as a supplier’s cost distribution worsens, the revenue constraint faced by the mechanism becomes tighter, which further tends to harm the agent.

8 Related literature

The independent-private-values setting with continuous distributions has the virtue that, for a given objective, the mechanism that maximizes this objective, subject to incentive-compatibility, individual-rationality, and no-deficit constraints, is well defined and pinned down (up to a constant in the payments) by the allocation rule, which is unique. Of particular interest to industrial organization and antitrust economics, it also has the feature that, quite generally, there is a tradeoff between allocating efficiently and extracting rents. This tradeoff is at the heart of both industrial organization and Myerson’s optimal auction. This tradeoff is the reason why the Williams frontier is typically not identical to the 45-degree line and, therefore, the basis from which the possibility of social-surplus-increasing equalization of bargaining power emerges. Moreover, the aforementioned assumptions are essentially the only assumptions that permit a tractable approach that maintain the basic tradeoff between profit and social surplus.\[48\]

There has also been a recent upsurge of interest in bargaining (see, for example, Larsen, 2020; Backus et al., 2020; 2019; Zhang et al., 2019), and buyer power (see, for example, Sny-
For example, Decarolis and Rovigatti (2020) find empirical evidence that increased buyer power has reduced Google’s online search revenues. Larsen and Zhang (2018) emphasize the value in abstracting away from the rules or extensive form of a game and instead focusing on outcomes, e.g., allocations and transfers, to estimate bargaining weights and distributions that can then be used for the analysis of counterfactuals. Bargaining has also come to the forefront of the empirical IO literature, in particular in analyses of bundling and vertical integration such as Crawford and Yurukoglu (2012) and Crawford et al. (2018). Collard-Wexler et al. (2019) and Rey and Vergé (2019) provide recent theoretical foundations for the widely used Nash-in-Nash bargaining model. Ho and Lee (2017) apply this framework to the question of countervailing power by insurers when negotiating with hospitals and find evidence that consolidation among insurers improves their bargaining position vis-à-vis hospitals. Our paper contributes to this literature by showing, among other things, that in incomplete information models, bargaining breakdown occurs on the equilibrium path, and that the probability of breakdown can, under suitable assumptions, be used to estimate distributions. Ausubel et al. (2002) explicitly account for inefficiencies in bargaining and focus on the second-best mechanisms introduced by Myerson and Satterthwaite (1983), as do we; however, they focus on the robustness of the Bayesian mechanism design setting in two-person bargaining, which appears not to be a central concern for applied work, given the frequent reliance on models based on Nash bargaining, in which agents literally know each other’s types.

Consistent with our results, the literature on vertical integration and foreclosure also notes that a vertical merger that eliminates internal frictions may create or exacerbate external ones for the case in which buyers are competing downstream intermediaries. Ordover et al. (1990) and Salinger (1988) show that vertical integration leads to an increase in rivals’ (linear) prices and Hart and Tirole (1990) provide a similar insight in the context of secret contracting, without restriction to linear tariffs. Nocke and Rey (2018) and Rey and Vergé (2019) provide conditions under which their estimation procedure works well, including a demonstration based on the $k$-double auction where they estimate both $k$ and the agents’ type distributions, interpreting $k$ as a bargaining weight.

While the empirical literature examining multilateral bargaining focuses on fixed quantities or linear tariffs, Rey and Vergé (2019) allow for non-linear tariffs, take into account the impact of these tariffs on downstream competition (placing it outside the approach of Collard-Wexler et al. (2019)), and provide a micro-foundation for Nash-in-Nash.

As stated by Holmström and Myerson (1983, p. 1809), “Some economists, following Coase have ... argued that we should expect to observe efficient allocations in any economy where there is complete information and bargaining costs are small. However, this positive aspect of efficiency does not extend to economies with incomplete information.”

For an overview of the literature on the competitive effects of vertical integration, see Riordan and Salop (1995). As described there, the literature takes the view that most vertical mergers lead to some efficiencies.
extend the latter insight to multiple strategic suppliers for Cournot and Bertrand downstream competition. Allain et al. (2016) show that, while vertical integration solves hold-up problems for the merging parties, it may also create or exacerbate problems for rivals.

The incomplete information approach also has implications for two-stage models in which investments precede bargaining, which have been at the center of attention in incomplete contracting models in the tradition of Grossman and Hart (1986) and Hart and Moore (1990). As discussed, the predictions could hardly differ more starkly because with incomplete (complete) information efficient bargaining implies efficient (inefficient) investment. There has also been a recent upsurge of interest in industrial organization relating to market structure and the incentives to invest (see, e.g., Federico et al., 2017, 2018; Jullien and Lefouili, 2018; Loertscher and Marx, 2019), onto which our paper—in particular, the results pertaining to mergers and vertical integration—sheds new light as well.

9 Conclusions

We provide an incomplete information bargaining model suitable for analyzing a range of important issues in industrial organization. In a methodological contribution, we show how one can allow multiple buyers and multiple suppliers, with multi-unit demand and supply, while still maintaining the assumption of one-dimensional private information. In our setup, the social surplus increasing effect of an equalization of bargaining power arises naturally because of the inherent tradeoff between social surplus and rent extraction: with independent private values, neither the mechanism that is optimal for buyers nor the one that is optimal for the suppliers is efficient in general, which opens the scope for increasing social surplus by making bargaining powers more equal. We show that socially harmful vertical integration arises naturally in our setting. We also examine the relation between the efficiency of incomplete information bargaining and the incentives to invest, which differs fundamentally from what obtains in complete information models that are based on the assumption that

Nocke and Thanassoulis (2014) provide model within the paradigm of efficient, complete information bargaining in which there is scope for countervailing power because bargaining power can mitigate frictions due to credit constraints.

The tight connection between incentives for efficient investment and efficient allocation in incomplete information models has its roots in the seminal works of Vickrey (1961), Clarke (1971), and Groves (1973) and the subsequent uniqueness results of Green and Laffont (1977) and Holmström (1979). Essentially, dominant strategy incentive compatibility under incomplete information requires each agent to be a price taker, and efficiency then further requires this price to be equal to the agent’s social marginal product (or cost). As demonstrated by Milgrom (1987), Rogerson (1992), Hatfield et al. (2018), and Loertscher and Riordan (2019), this is precisely the set of conditions that have to be satisfied for incentives for investment to be aligned with efficiency.
efficient trade is always possible. In extensions, we show that the effects of outside options can differ relative to complete information setups, and we show that bargaining externalities arise naturally.

Our paper shows that an economic agent’s strength or weakness has two dimensions that are, conceptually, independent. The first one, which may be thought of as the agent’s productive strength or power, refers to the agent’s productivity. Is the agent likely to have a high value if it is a buyer or a low cost if it is a supplier? The second dimension captures the agent’s bargaining power, that is, its ability (or inability) to affect bargaining in its favor. For example, consider a supplier whose bargaining power allows it to make a take-it-or-leave-it offer to a buyer that depends on the realization of the supplier’s cost. The supplier optimally customizes its offer to the productive power of the buyer, with a weaker buyer (in the sense of hazard rate dominance) receiving a lower offer on average. Such differences do not reflect differences in bargaining power as commonly understood. No one would explain that economy airfares are lower than business airfares because of economy customers’ greater bargaining power. What is indicative of the relative bargaining powers is then not so much the level of prices but rather the price-formation process itself. For example, in a bilateral trade setting, if the buyer (supplier) always makes the price offer, then one would conclude that the buyer (supplier) has all the bargaining power, indicating that there is scope for social benefits from an equalization of bargaining power. In contrast, if the buyer and supplier participate in a $k$-double auction with $k = 1/2$, then this may be indicative of equal bargaining powers, suggesting that there is no scope for equalization of bargaining power.

Avenues for future research are many. Among other things, developing a better understanding of what determines bargaining power would add considerable value. The distinction between productive strength and bargaining power brought to light in the present paper may prove useful in that regard.
References


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A Appendix: Mechanism design foundations

In this appendix, we first define and develop the mechanism design concepts relevant for our analysis (Appendix A.1) and then apply these concepts to derive the Myerson-Satterthwaite impossibility result (Appendix A.2).

A.1 Concepts and derivations

For ease of exposition, in this appendix we assume that \( n_B = n_S = 1 \). The extension to multiple buyers and/or suppliers is straightforward.

Take as given a direct mechanism \( \langle Q, M^B, M^S \rangle \), where \( Q : [v, \bar{v}] \times [c, \bar{c}] \rightarrow [0, 1] \) and \( M^B, M^S : [v, \bar{v}] \times [c, \bar{c}] \rightarrow \mathbb{R} \). Given reports \( v \) and \( c \), \( Q(v, c) \in [0, 1] \) is the probability with which the supplier trades with the buyer, \( M^B(v, c) \) is the payment from the buyer to the mechanism, and \( M^S(v, c) \) is the payment from the mechanism to the supplier. By the Revelation Principle, the focus on direct mechanisms is without loss of generality.

Let \( \hat{q}^B(z) \) be the buyer’s expected quantity if it reports \( z \) and the supplier reports truthfully, and let \( \hat{m}^B(z) \) be the buyer’s expected payment if it reports \( z \) and the supplier reports truthfully:

\[
\hat{q}^B(z) = \mathbb{E}_c[Q(z, c)] \quad \text{and} \quad \hat{m}^B(z) = \mathbb{E}_c[M^B(z, c)].
\]

Define \( q^S \) and \( m^S \) analogously, where \( \hat{m}^S \) is the expected payment to the supplier. Because we assume independent draws, for \( i \in \{B, S\} \), \( \hat{q}^i(z) \) and \( \hat{m}^i(z) \) depend only on the report \( z \) and not on the reporting agent’s true type. The expected payoff of a buyer with type \( v \) that reports \( z \) is then \( \hat{q}^B(z)v - \hat{m}^B(z) \), and the expected payoff of a supplier with type \( c \) that reports \( z \) is \( \hat{m}^S(z) - \hat{q}^S(z)c \).

Key constraints

The mechanism is incentive compatible for the buyer if for all \( v, z \in [v, \bar{v}] \),

\[
\hat{u}^B(v) \equiv \hat{q}^B(v)v - \hat{m}^B(v) \geq \hat{q}^B(z)v - \hat{m}^B(z), \tag{13}
\]

and is incentive compatible for the supplier if for all \( c, z \in [c, \bar{c}] \),

\[
\hat{u}^S(c) \equiv \hat{m}^S(c) - \hat{q}^S(c)c \geq \hat{m}^S(z) - \hat{q}^S(z)c. \tag{14}
\]
Individual rationality is satisfied for the buyer if for all $v \in [\underline{v}, \overline{v}]$, $\hat{u}^B(v) \geq 0$, and for the supplier if for all $c \in [\underline{c}, \overline{c}]$, $\hat{u}^S(c) \geq 0$. The mechanism satisfies the no-deficit condition if
\[
\mathbb{E}_{v,c} \left[ M^B(v,c) - M^S(v,c) \right] \geq 0.
\]

**Interim expected payoffs**

Standard arguments (see, e.g., Krishna, 2010, Chapter 5.1) proceed as follows:

Focusing on the buyer, incentive compatibility implies that
\[
\hat{u}^B(v) = \max_{z \in [v, v]} \hat{q}^B(z)v - \hat{m}^B(z),
\]
i.e., $\hat{u}^B$ is a maximum of a family of affine functions, which implies that $\hat{u}^B$ is convex and so absolutely continuous and differentiable almost everywhere in the interior of its domain. In addition, incentive compatibility implies that $\hat{u}^B(z) \geq \hat{q}^B(v)z - \hat{m}^B(v) = \hat{u}^B(v) + \hat{q}^B(v)(z-v)$, which for $\varepsilon > 0$ implies
\[
\frac{\hat{u}^B(v + \varepsilon) - \hat{u}^B(v)}{\varepsilon} \geq \hat{q}^B(v)
\]
and for $\varepsilon < 0$ implies
\[
\frac{\hat{u}^B(v + \varepsilon) - \hat{u}^B(v)}{\varepsilon} \leq \hat{q}^B(v),
\]
so taking the limit as $\varepsilon$ goes to zero, at every point $v$ where $\hat{u}^B$ is differentiable, $\hat{u}^B'(v) = \hat{q}^B(v)$. Because $\hat{u}^B$ is convex, this implies that $\hat{q}^B(v)$ is nondecreasing. Because every absolutely continuous function is the definite integral of its derivative,
\[
\hat{u}^B(v) = \hat{u}^B(v) + \int_v^\overline{v} \hat{q}^B(t)dt,
\]
which implies that, up to an additive constant, a buyer’s expected payoff in an incentive-compatible direct mechanism depends only on the allocation rule. By an analogous argument, $\hat{u}^S(c) = -\hat{q}^S(c)$, $\hat{q}^S(c)$ is nonincreasing, and
\[
\hat{u}^S(c) = \hat{u}^S(\overline{c}) + \int_\underline{c}^{\overline{c}} \hat{q}^S(t)dt.
\]

---

1 A function $h : [\underline{v}, \overline{v}] \rightarrow \mathbb{R}$ is absolutely continuous if for all $\varepsilon > 0$ there exists $\delta > 0$ such that whenever a finite sequence of pairwise disjoint sub-intervals $(v_k, v'_k)$ of $[\underline{v}, \overline{v}]$ satisfies $\sum_k (v'_k - v_k) < \delta$, then $\sum_k |h(v'_k) - h(v_k)| < \varepsilon$. One can show that absolute continuity on compact interval $[a, b]$ implies that $h$ has a derivative $h'$ almost everywhere, the derivative is Lebesgue integrable, and that $h(x) = h(a) + \int_a^x h'(t)dt$ for all $x \in [a, b]$. 

---

2
Mechanism budget surplus

Using the definitions of $\hat{u}^B$ and $\hat{u}^S$ in (13) and (14), we can rewrite these as

$$\hat{m}^B(v) = \hat{q}^B(v)v - \int_v^\infty \hat{q}^B(t)dt - \hat{u}^B(v)$$  \hspace{1cm} (15)$$

and

$$\hat{m}^S(c) = \hat{q}^S(c)c + \int_c^\infty \hat{q}^S(t)dt + \hat{u}^S(c).$$  \hspace{1cm} (16)$$

The expected payment by the buyer is then

$$\mathbb{E}_v \left[ \hat{m}^B(v) \right] = \int_v^\infty \hat{m}^B(v)f(v)dv $$
$$= \int_v^\infty \left( \hat{q}^B(v)v - \int_v^\infty \hat{q}^B(t)dt \right) f(v)dv - \hat{u}^B(v)$$
$$= \int_v^\infty \hat{q}^B(v)vf(v)dv - \int_v^\infty \int_t^\infty \hat{q}^B(t)f(v)dvdt - \hat{u}^B(v)$$
$$= \int_v^\infty \hat{q}^B(v)v\left( v - \frac{1 - F(v)}{f(v)} \right) f(v)dv - \hat{u}^B(v)$$
$$= \int_v^\infty \hat{q}^B(v)\Phi(v)f(v)dv - \hat{u}^B(v)$$
$$= \mathbb{E}_v \left[ \hat{q}^B(v)\Phi(v) \right] - \hat{u}^B(v),$$

where the first equality uses the definition of the expectation, the second uses (15), the third switches the order of integration, the fourth integrates, the fifth collects terms, the sixth uses the definition of the virtual value $\Phi$, and the last equality uses the definition of the expectation. Similarly, using (16), the expected payment to the supplier is

$$\mathbb{E}_c \left[ \hat{m}^S(c) \right] = \int_c^\infty \hat{m}^S(c)g(c)dc = \mathbb{E}_c \left[ \hat{q}^S(c)\Gamma(c) \right] + \hat{u}^S(c).$$

Thus, we have the result that in any incentive-compatible, interim individually-rational direct mechanism $\langle Q, M_B, M_S \rangle$, the mechanism’s expected budget surplus is

$$\mathbb{E}_{v,c} \left[ (\Phi(v) - \Gamma(c)) Q(v,c) \right] - \hat{u}^B(v) - \hat{u}^S(c).$$

As mentioned, it is straightforward to extend these results to the case of multiple buyers
and suppliers.

A.2 Myerson-Satterthwaite impossibility result

For the purpose of making the paper self-contained, we provide a statement and proof of the impossibility theorem of Myerson and Satterthwaite (1983). Under the assumption of independent private values and the assumption that \( v < c \), Myerson and Satterthwaite (1983) show that there is no mechanism satisfying incentive compatibility and individual rationality that allocates ex post efficiently and that does not run a deficit. Their result depends on \( v < c \) because, without this assumption, ex post efficiency subject to incentive compatibility and individual rationality can easily be achieved without running a deficit. For example, the posted price mechanism that has the buyer pay \( p = (v + c)/2 \) to the supplier achieves this.

By now, the proof of this result can be provided in a couple of lines (see, e.g., Krishna, 2010). Consider the dominant strategy implementation in which the buyer pays \( p^B = \max\{c, v\} \) and the supplier receives \( p^S = \min\{v, c\} \) whenever there is trade, and no payments are made otherwise. Notice that \( \hat{u}^B(v) = 0 = \hat{u}^S(c) \). Thus, the individual rationality constraints are satisfied. Further, notice that \( p^B - p^S \leq 0 \), with a strict inequality for almost all type realizations. This implies that the mechanism runs a deficit in expectation. By the payoff equivalence theorem, any other ex post efficient mechanism satisfying incentive compatibility and individual rationality will run a deficit of at least that size (and a larger one if one or both of the individual rationality constraints are slack).

To see how this impossibility result rests on the assumption that \( v < c \), assume to the contrary that \( v \geq c \). Then the mechanism described above continues to satisfy incentive compatibility and individual rationality, but for all type realizations \( p^B = v \geq c = p^S \), which implies that the mechanism does not run a deficit.
B Appendix: Proofs

Proof of Lemma 1 We can write the Lagrangian that corresponds to (5) for the case with multiple buyers and suppliers, each with single-unit demand and supply, as

\[
\mathbb{E}_v c \left[ \sum_{i \in \mathcal{N}^B} \left( w_i^B (v_i - \Phi_i(v_i)) Q_i^B(v, c) + \sum_{j \in \mathcal{N}^S} w_j^S (\Gamma_j(c_j) - c_j) Q_j^S(v, c) \right) \right] + \rho \mathbb{E}_v c \left[ \sum_{j \in \mathcal{N}^B} \Phi_i(v_i) Q_i^B(v, c) - \sum_{j \in \mathcal{N}^S} \Gamma_j(c_j) Q_j^S(v, c) \right]
\]

\[
= \mathbb{E}_v c \left[ \sum_{i \in \mathcal{N}^B} \left[ w_i^B v_i + (\rho - w_i^B) \Phi_i(v_i) \right] Q_i^B(v, c) + \sum_{j \in \mathcal{N}^S} \left[ -w_j^S c_j - (\rho - w_j^S) \Gamma_j(c_j) \right] Q_j^S(v, c) \right]
\]

\[
= \rho \mathbb{E}_v c \left[ \sum_{i \in \mathcal{N}^B} \left[ v_i - \frac{\rho - w_i^B}{\rho} \frac{1 - F_i(v_i)}{f_i(v_i)} \right] Q_i^B(v, c) - \sum_{j \in \mathcal{N}^S} \left[ c_j + \frac{\rho - w_j^S}{\rho} \frac{G_j(c_j)}{g_j(c_j)} \right] Q_j^S(v, c) \right]
\]

\[
= \rho \mathbb{E}_v c \left[ \sum_{i \in \mathcal{N}^B} \Phi_i^{w_i^B/\rho} \left( v_i - \frac{\rho - w_i^B}{\rho} \frac{1 - F_i(v_i)}{f_i(v_i)} \right) Q_i^B(v, c) - \sum_{j \in \mathcal{N}^S} \Gamma_j^{w_j^S/\rho} (c_j) Q_j^S(v, c) \right].
\]

It is then clear that the allocation rule defined in the statement of the lemma maximizes the Lagrangian pointwise subject to the feasibility constraints, which completes the proof. ■

Proof of Proposition 2 Let \( \langle Q^w, M^{w, \eta} \rangle \in \mathcal{M} \) denote the incomplete information bargaining mechanism with weights \( w \) and shares \( \eta \), with associated expected payoff vector \( u(w, \eta) \). Thus, the maximized value of expected weighted welfare over all mechanisms in \( \mathcal{M} \) is \( \sum_{i \in \mathcal{N}^B} w_i^B u_i^B(w, \eta) + \sum_{j \in \mathcal{N}^S} w_j^S u_j^S(w, \eta) \).

We first show that the expected payoffs from \( \langle Q^w, M^{w, \eta} \rangle \) are Pareto undominated among the expected payoffs for any mechanism in \( \mathcal{M} \). Proceeding by contradiction, suppose that \( u(w, \eta) \) is Pareto dominated by expected payoff vector \( \tilde{u} \) associated with a mechanism \( \langle \tilde{Q}, \tilde{M} \rangle \in \mathcal{M} \), i.e., \( \tilde{u}_i^B \geq u_i^B(w, \eta) \) for all \( i \in \mathcal{N}^B \) and \( \tilde{u}_j^S \geq u_j^S(w, \eta) \) for all \( j \in \mathcal{N}^S \), with a strict inequality for at least one agent.

If there exists \( i \in \mathcal{N}^B \cup \mathcal{N}^S \) and \( x \in \{B, S\} \) such that \( \tilde{u}_i^x > u_i^x(w, \eta) \) and \( w_i^x > 0 \), then

\[
\sum_{i \in \mathcal{N}^B} w_i^B \tilde{u}_i^B + \sum_{j \in \mathcal{N}^S} w_j^S \tilde{u}_j^S > \sum_{i \in \mathcal{N}^B} w_i^B u_i^B(w, \eta) + \sum_{j \in \mathcal{N}^S} w_j^S u_j^S(w, \eta), \tag{17}
\]

which contradicts \( \langle Q^w, M^{w, \eta} \rangle \) maximizing expected weighted welfare over mechanisms in \( \mathcal{M} \). So, for all \( i \in \mathcal{N}^B \cup \mathcal{N}^S \) and \( x \in \{B, S\} \) such that \( \tilde{u}_i^x > u_i^x(w, \eta) \), we must have...
\( w_i^x = 0 \). It follows that (17) holds with equality, which says that \( \langle \tilde{Q}, \tilde{M} \rangle \) maximizes expected weighted welfare. By the uniqueness of the allocation rule identified in Lemma 1, we have \( \tilde{Q} = Q^w \). Thus, using the payoff equivalence theorem, for any \( i \in N^B \cup N^S \) and \( x \in \{ B, S \} \) such that \( \tilde{u}_i^x > u_i^x(w, \eta) \), the difference \( \tilde{u}_i^x - u_i^x(w, \eta) \) reflects an increase in the interim expected payment to that agent’s worst-off type. It follows that there exists a mechanism in \( \mathcal{M} \) that has allocation rule \( Q^w \) and payment rule based on \( \tilde{M} \), but that redirects that agent’s fixed payment to an agent with positive bargaining weight, that has greater expected weighted welfare than \( \langle Q^w, M^w, \eta \rangle \), which is a contradiction. Thus, we conclude that there is no mechanism in \( \mathcal{M} \) that Pareto dominates \( \langle Q^w, M^w, \eta \rangle \), completing the first part of the proof.

We now turn to the proof that any Pareto undominated payoff vector can be achieved using \( \langle Q^w, M^w, \eta \rangle \) with appropriately chosen \( w \) and \( \eta \). Let \( \tilde{u} \) be a payoff vector that is Pareto undominated among expected payoff vectors for mechanisms in \( \mathcal{M} \), and let \( \langle \tilde{Q}, \tilde{M} \rangle \in \mathcal{M} \) be a mechanism that generates payoff vector \( \tilde{u} \).

By the assumption of Pareto undominatedness, \( \tilde{u}_i^B \) solves

\[
\max_{\langle Q, M \rangle \in \mathcal{M}} \text{ for } \ell \in N^B \setminus \{i\}, \quad u_i^B \geq \tilde{u}_i^B, \quad \text{and for all } j \in N^S, \quad u_j^S \geq \tilde{u}_j^S
\]

and \( \tilde{u}_j^S \) solves

\[
\max_{\langle Q, M \rangle \in \mathcal{M}} \text{ for } i \in N^B, \quad u_i^B \geq \tilde{u}_i^B, \quad \text{and for all } \ell \in N^S \setminus \{j\}, \quad u_\ell^S \geq \tilde{u}_\ell^S.
\]

To ensure the applicability of the Karush-Kuhn-Tucker Theorem, in what follows, if there exists a buyer \( \ell \) whose payoff \( \tilde{u}_\ell^B \) is equal to that buyer \( \ell \)’s maximum payoff for all mechanisms in \( \mathcal{M} \) then we focus on the problem (18) for buyer \( \ell \), and, if not, then if there exists a supplier \( \ell \) whose payoff \( \tilde{u}_\ell^S \) is equal to that supplier \( \ell \)’s maximum payoff for all mechanisms in \( \mathcal{M} \) then we focus on the problem (19) for supplier \( \ell \), and otherwise we arbitrarily let \( \ell = 1 \) and focus on the problem (18) for buyer \( \ell \). This guarantees that it is feasible for the inequality constraints to hold strictly and so Karush-Kuhn-Tucker conditions are necessary and sufficient for an optimum. (This choice of \( \ell \) ensures that we are not focusing on the problem for an agent \( \ell \) where \( \tilde{u} \) can only be obtained through incomplete information bargaining by giving agent \( \ell \) a bargaining weight of zero. Because we assume that at least one agent has a positive bargaining weight, a choice of \( \ell \) that avoids this issue is always possible.)

In what follows, we assume that agent \( \ell \) is a buyer. Analogous arguments apply if agent \( \ell \) is a supplier.

Using incentive compatibility and individual rationality, the problem (18) for buyer \( \ell \) can
be recast as choosing $Q$, $\hat{u}_i^B(v) \geq 0$ for all $i \in N^B$, and $\hat{u}_j^S(\bar{v}) \geq 0$ for all $j \in N^S$. Noting that buyer $i$’s expected payoff is the expectation of $u_i^B(v, c) \equiv (v_i - \Phi_i(v_i))Q_i^B(v, c) + \hat{u}_i^B(v)$ and supplier $j$’s expected payoff is the expectation of $u_j^S(v, c) \equiv (\Gamma_j(c_j) - c_j)Q_j^S(v, c) + \hat{u}_j^S(\bar{v})$, and letting $\rho \geq 0$ be the multiplier on the no-deficit constraint and $\mu_j^S \geq 0$ be the multiplier on the constraint that $u_j^S \geq \bar{u}_j^S$, the associated Lagrangian is

$$\mathcal{L} \equiv \mathbb{E}_{v, c} \left[ u_i^B(v, c) + \sum_{i \in N^B \setminus \{\ell\}} \mu_i^B(u_i^B(v, c) - \bar{u}_i^B) + \sum_{j \in N^S} \mu_j^S(u_j^S(v, c) - \bar{u}_j^S) \right]$$

$$+ \rho \mathbb{E}_{v, c} \left[ \sum_{i \in N^B} (\Phi_i(v_i)Q_i^B(v, c) - \hat{u}_i^B(v)) - \sum_{j \in N^S} (\Gamma_j(c_j)Q_j^S(v, c) - \hat{u}_j^S(\bar{v})) \right],$$

which we can rewrite, up to terms that do not involve the allocation rule, as

$$\mathbb{E}_{v, c} \left[ (v_\ell - \Phi_\ell(v_\ell) + \rho \Phi_\ell(v_\ell))Q_\ell^B(v, c) + \sum_{i \in N^B \setminus \{\ell\}} \left( \mu_i^B(v_i - \Phi_i(v_i)) + \rho \Phi_i(v_i) \right)Q_i^B(v, c) \right]$$

$$+ \mathbb{E}_{v, c} \left[ \sum_{j \in N^S} \left( \mu_j^S(\Gamma_j(c_j) - c_j) - \rho \Gamma_j(c_j) \right)Q_j^S(v, c) \right].$$

Let $\tilde{Q}$ denote the solution value for the allocation rule. Denote the expected budget surplus under $\tilde{Q}$ not including payments to worst-off types by

$$\tilde{R} \equiv \mathbb{E}_{v, c} \left[ \sum_{i \in N^B} \Phi_i(v_i)\tilde{Q}_i^B(v, c) - \sum_{j \in N^S} \Gamma_j(c_j)\tilde{Q}_j^S(v, c) \right],$$

which is nonnegative because any solution satisfies the no-deficit constraint. Then the solution values for the payments to the worst-off types are given by, for all $i \in N^B \setminus \{\ell\}$,

$$\hat{u}_i^B(v) = \bar{u}_i^B - \mathbb{E}_{v, c} \left[ (v_i - \Phi_i(v_i))\tilde{Q}_i^B(v, c) \right],$$

and for all $j \in N^S$,

$$\hat{u}_j^S(\bar{v}) = \bar{u}_j^S - \mathbb{E}_{v, c} \left[ (\Gamma_j(c_j) - c_j)\tilde{Q}_j^S(v, c) \right],$$

and using the Pareto optimality of $\tilde{Q}$, which implies that the mechanism must pay out all of $\tilde{R}$ to the agents,

$$\hat{u}_\ell^B(v) = \tilde{R} - \sum_{i \in N^B \setminus \{\ell\}} \hat{u}_i^B(v) - \sum_{j \in N^S} \hat{u}_j^S(\bar{v}).$$
Given the solution values for the multipliers \( \mu \), let \( \bar{w} \equiv \max \{ \mu_B, ..., \mu_{l-1}, 1, \mu_{l+1}, ..., \mu_m, \mu_1^S, ..., \mu_n^S \} \) and define \( \tilde{w} \equiv (\frac{\mu_1}{w}, ..., \frac{\mu_{l-1}}{w}, \frac{1}{w}, \frac{\mu_{l+1}}{w}, ..., \frac{\mu_m}{w}, \frac{\mu_1^S}{w}, ..., \frac{\mu_n^S}{w}) \). Recall that \( Q^w \) has associated Lagrangian, up to terms that do not involve the allocation rule, given by

\[
{L}^w \equiv E_{v,c} \left[ \sum_{i \in N^B} (w^B_i (v_i - \Phi_i(v_i)) + \rho \Phi_i(v_i)) Q^B_i(v,c) + \sum_{j \in N^S} (w^S_j (\Gamma_j(c_j) - c_j) - \rho \Gamma_j(c_j)) Q^S_j(v,c) \right].
\]

It follows that \( L \) is equal to \( \bar{w}L^{\tilde{w}} \) plus terms that do not involve \( Q \), and so \( \tilde{Q} \) is the same allocation rule as \( Q^{\tilde{w}} \). Further, the payoffs \( \tilde{u} \) are replicated by \( \langle Q^{\tilde{w}}, M^{\tilde{w},\tilde{\eta}} \rangle \) with any specification of \( \tilde{\eta} \) if \( \tilde{R} = 0 \) and otherwise with for \( j \in N^S \),

\[
\tilde{\eta}^S_j = \begin{cases} \frac{1}{R} \left( \tilde{u}^S_j - E_{v,c} \left[ (\Gamma_j(c_j) - c_j) \tilde{Q}^S_j(v,c) \right] \right) & \text{if } \mu^S_j = \bar{w}, \\ 0 & \text{otherwise}, \end{cases}
\]

for \( i \in N^B \setminus \{ \ell \} \),

\[
\tilde{\eta}^B_i = \begin{cases} \frac{1}{R} \left( \tilde{u}^B_i - E_{v,c} \left[ (v_i - \Phi_i(v_i)) \tilde{Q}^B_i(v,c) \right] \right) & \text{if } \mu^B_i = \bar{w}, \\ 0 & \text{otherwise}, \end{cases}
\]

and \( \tilde{\eta}^B_\ell = 1 - \sum_{i \in N^B \setminus \{ \ell \}} \eta^B_i - \sum_{j \in N^S} \eta^S_j \), which completes the proof. ■

Proof of Proposition 3. The discussion in the text shows that the planner’s and market’s outcomes coincide (up to fixed payments) if (i)–(iv) hold, implying that \( W^w = W^* \), and so there is no benefit from equalization of bargaining power. It remains to show that \( W^w < W^* \) if any one of these conditions fails.

Case 1. Suppose that \( K^B \leq K^S \) and (7) fails to hold. (Analogous arguments apply if \( K^B > K^S \) and (7) fails.) Then for an open set of types, not all of the \( n^B \) buyers trade under \( Q^w \). Thus, in order for \( Q^w \) and \( Q^* \) to coincide, they must agree on not only the ranking within buyers and within suppliers, but also the ranking across buyers and suppliers. Consistent with (ii)–(iv), suppose that all buyers have the same bargaining weight \( w^B \), all suppliers have the same bargaining weight \( w^S \), \( w^S < w^B \), and all suppliers have the same distribution. (Analogous analysis applies if \( w^S > w^B \) and all buyers have the same distribution.) Then the planner and market both rank the buyers the same and rank the suppliers the same, but they evaluate the buyers’ virtual values using weight \( w^B/\rho^w \) and the suppliers’ virtual costs using weight \( w^S/\rho^w \), where \( w^B/\rho^w > w^S/\rho^w \). Because either \( w^B/\rho^w \neq 1/\rho^1 \) or \( w^S/\rho^w \neq 1/\rho^1 \) or both, \( Q^w(v,c) \neq Q^*(v,c) \) for all \( (v,c) \) in an open
subset of \([v, \overline{v}]^n_B \times [c, \overline{c}]^n_S\).

**Case 2.** If either the buyers’ weights are not equal or the suppliers’ weights are not equal, then the planner and market rank the agents differently on that side of the market and so \(Q^w(v, c) \neq Q^*(v, c)\) for all \((v, c)\) in an open subset of \([v, \overline{v}]^n_B \times [c, \overline{c}]^n_S\).

**Case 3.** Suppose that (i) and (ii) hold and that \(w_S < w_B\), but that \(G_1 \neq G_2\), so that (iii) fails. It follows that \(1 \geq w_B/\rho^w > w_S/\rho^w\). Because \(w_S/\rho^w < 1\) and \(G_1 \neq G_2\), the market’s ranking of suppliers 1 and 2 based on their virtual costs differs from the ranking of their costs for \((c_1, c_2)\) in an open subset of \([c, \overline{c}]^2\). Thus, \(Q^w(v, c) \neq Q^*(v, c)\) for all \((v, c)\) in an open subset of \([v, \overline{v}]^n_B \times [c, \overline{c}]^n_S\).

**Case 4.** Suppose that (i) and (ii) hold and that \(w_B < w_S\), but that \(F_1 \neq F_2\), so that (iv) fails. It follows that \(1 \geq w_S/\rho^w > w_B/\rho^w\). Because \(w_B/\rho^w < 1\) and \(F_1 \neq F_2\), the market’s ranking of buyers 1 and 2 based on their virtual values differs from the ranking of their values for \((v_1, v_2)\) in an open subset of \([v, \overline{v}]^2\). Thus, \(Q^w(v, c) \neq Q^*(v, c)\) for all \((v, c)\) in an open subset of \([v, \overline{v}]^n_B \times [c, \overline{c}]^n_S\).

**Proof of Proposition 4.** We begin by showing that the frontier is decreasing (in \((u_S, u_B)\) space). Let \(w\) be given. For any two points in \(F_w\), indexed by \(\Delta\) and \(\Delta'\), it cannot be the case that all agents’ expected surplus is weakly greater at \(\Delta'\) than at \(\Delta\) and strictly greater for at least one agent. If it were, then weighted welfare must not have been maximized at the point indexed by \(\Delta\) because total surplus could be increased while still satisfying all the constraints and some of that additional surplus could be allocated to one or more of the agents with a positive bargaining weight.

Now turn to the question of concavity. As illustrated in the figure below, suppose that the Williams frontier is not concave.

![Williams Frontier Diagram](image)

Then there exist points on the frontier, which we denote by their associated parameters
Δ, Δ', and Δ'', with Δ > Δ' > Δ'', such that

\[ \sum_{j \in N^S} u_j^S(\Delta) + \sum_{j \in N^S} u_j^S(\Delta'') > \sum_{j \in N^S} u_j^S(\Delta') \]

and

\[ \sum_{i \in N^B} u_i^B(\Delta) + \sum_{i \in N^B} u_i^B(\Delta'') > \sum_{i \in N^B} u_i^B(\Delta'). \]

Let \( \mu(\tilde{\Delta}) \) denote the incomplete information bargaining mechanism for parameter \( \tilde{\Delta} \in \{\Delta, \Delta', \Delta''\} \). Expected weighted welfare with weights \( ((1 - \Delta')w^S, \Delta'w^B) \) under mechanism \( \mu(\Delta') \) satisfies

\[ \sum_{i \in N^B} \Delta'w_i^B u_i^B(\Delta') + \sum_{j \in N^S} (1 - \Delta')w_j^S u_j^S(\Delta') < \sum_{i \in N^B} \Delta'w_i^B u_i^B(\Delta) + \sum_{i \in N^B} (1 - \Delta')w_i^B u_i^B(\Delta'') + \frac{1}{2} \sum_{j \in N^S} (1 - \Delta')w_j^S u_j^S(\Delta) + \frac{1}{2} \sum_{j \in N^S} (1 - \Delta')w_j^S u_j^S(\Delta''), \]

where the right side is the expected weighted welfare with weights \( ((1 - \Delta')w^S, \Delta'w^B) \) under the mechanism that is a 50-50 mixture of \( \mu(\Delta) \) and \( \mu(\Delta'') \), which since the no-deficit condition is satisfied for this mixture mechanism, contradicts the assumption that \( \mu(\Delta') \) is the incomplete information bargaining mechanism with weights \( ((1 - \Delta')w^S, \Delta'w^B) \), thereby completing the proof of concavity.

Turning to the issue of strict concavity, under the assumption that the first-best is achieved at most at one point on the frontier defined by \( w \) and \( \Delta \in (0,1) \), it follows that \( \pi((1-\Delta)w^S, \Delta w^B) = 0 \) for all \( \Delta \in [-1,1] \) and that \( \rho((1-\Delta)w^S, \Delta w^B) \) is decreasing in \( \Delta \) for \( \Delta \in (0,1] \) and increasing in \( \Delta \) for \( \Delta \in [-1,0) \). In this case, we can ignore the effects of the tie-breaking shares because there is no budget surplus to divide. We have shown that the frontier is concave to the origin. If it is not strictly concave, then there exists a linear portion of the frontier, which is to say that there exist \( \Delta', \Delta'' \in [0,1] \) with \( \Delta' > \Delta'' \) and \( \lambda \in (0,1) \) such that, letting \( \Delta_\lambda \equiv \lambda \Delta' + (1 - \lambda) \Delta'' \), we have

\[ \sum_{j \in N^S} u_j^S(\Delta_\lambda) = \lambda \sum_{j \in N^S} u_j^S(\Delta') + (1 - \lambda) \sum_{j \in N^S} u_j^S(\Delta''), \]  

(22)

and

\[ \sum_{i \in N^B} u_i^B(\Delta_\lambda) = \lambda \sum_{i \in N^B} u_i^B(\Delta') + (1 - \lambda) \sum_{i \in N^B} u_i^B(\Delta''). \]  

(23)

By Proposition 10, the allocation rule associated with the point on the frontier defined by \( w \)
Let $\Delta'$ and $\Delta''$ be such that $0 < \Delta'' < \Delta' \leq 1$, and let $\Delta_\lambda = \lambda \Delta' + (1 - \lambda) \Delta''$ for $\lambda \in (0, 1)$. Denote the Lagrange multiplier associated with $\Delta'$, $\Delta_\lambda$, and $\Delta''$ by $\rho'$, $\rho_\lambda$, and $\rho''$, respectively. We have $1 \leq \rho' < \rho_\lambda < \rho''$. This implies that

$$\frac{\Delta'}{\rho'} > \frac{\Delta_\lambda}{\rho_\lambda} > \frac{\Delta''}{\rho''},$$

and, for any $v < \overline{v}$ and $i \in N^B$,

$$\Phi_i^{\Delta''/\rho''} - 1(c) > \Phi_i^{\Delta_\lambda/\rho_\lambda} - 1(c) > \Phi_i^{\Delta'/\rho'} - 1(c).$$

Because $\Gamma_i(a)(c) = a$ for all $i$ and all $a \in [0, 1]$, it follows from the continuity of the weighted virtual cost functions that for an open set of types $(v, c)$ with for all $i \in N^B$, $v_i \in (\Phi_i^{\Delta'/\rho'} - 1(c), \Phi_i^{\Delta_\lambda/\rho_\lambda} - 1(c))$ and for all $i \in N^S$, $c_i$ in a neighborhood of $c$,

$$\sum_{i \in N^B} Q_i^B((1 - \Delta') w^S, \Delta' w^B)(v, c) > 0$$

and

$$\sum_{i \in N^B} Q_i^B((1 - \Delta'') w^S, \Delta'' w^B)(v, c) = 0 = \sum_{i \in N^B} Q_i^B((1 - \Delta_\lambda) w^S, \Delta_\lambda w^B)(v, c).$$

Hence, the allocation rule $Q((1 - \Delta') w^S, \Delta' w^B)$ is not a convex combination of the allocation rules $Q((1 - \Delta') w^S, \Delta' w^B)$ and $Q((1 - \Delta'' w^S, \Delta'' w^B)$. Because $Q((1 - \Delta') w^S, \Delta' w^B)$ is uniquely optimal and because a convex combination of $Q((1 - \Delta') w^S, \Delta' w^B)$ and $Q((1 - \Delta'') w^S, \Delta'' w^B)$ implies a convex combination of the payoffs, it follows that $Q((1 - \Delta' w^S, \Delta' w^B)$ does not induce a convex combination of the payoffs. Hence, the Williams frontier, which we have already shown to be weakly concave, must be strictly concave.

If the Williams frontier coincides with the first-best frontier for $\Delta'$ and $\Delta''$ with $\Delta' < \Delta''$, then the mechanism that is a convex combination of the mechanism corresponding to $\Delta'$ and the mechanism corresponding to $\Delta''$ also achieves the first-best. By the definition of the first-best, no mechanism achieves greater social surplus, so for $\Delta \in (\Delta', \Delta'')$, the frontier must be linear, coinciding with the first-best frontier. 

Proof of Lemma 2 Consider a merger of suppliers 1 and 2. Let $(Q, M)$ be the post-merger incomplete information bargaining mechanism. Construct a pre-merger mechanism $(\hat{Q}, \hat{M})$ that mimics the allocation rule of the post-merger mechanism as follows: define the allocation
rule $\tilde{Q}$ such that for supplier $j \in \mathcal{N}^S \setminus \{1, 2\}$ and buyer $i \in \mathcal{N}^B$,

$$Q^S_j (v, c) \equiv \hat{Q}^S_j (v, h(c_1, c_2), c_{-\{1,2\}}) \quad \text{and} \quad Q^B_i (v, c) \equiv \hat{Q}^B_i (v, h(c_1, c_2), c_{-\{1,2\}}).$$

By the assumption that $Pr_{c_i, c_j} (h(c_i, c_j) \leq z) = G_{i,j}(z)$, the interim expected allocations of the nonmerging agents are the same under $\hat{Q}$ and $\tilde{Q}$, and so their expected thresholds payments are the same as well.

For supplier 1, define the allocation rule by

$$Q^S_1 (v, c) \equiv \min \left\{ k^S_1, \hat{Q}^S_{1,2} (v, h(c_1, c_2), c_{-\{1,2\}}) \right\} \cdot 1_{c_1 \leq c_2} + \max \left\{ 0, \hat{Q}^S_{1,2} (v, h(c_1, c_2), c_{-\{1,2\}}) - k^S_2 \right\} \cdot 1_{c_1 > c_2},$$

and for supplier 2, define

$$Q^S_2 (v, c) \equiv \min \left\{ k^S_2, \hat{Q}^S_{1,2} (v, h(c_1, c_2), c_{-\{1,2\}}) \right\} \cdot 1_{c_2 \leq c_1} + \max \left\{ 0, \hat{Q}^S_{1,2} (v, h(c_1, c_2), c_{-\{1,2\}}) - k^S_1 \right\} \cdot 1_{c_2 > c_1},$$

which implies that

$$\hat{Q}^S_1 (v, c) + \hat{Q}^S_2 (v, c) \equiv \hat{Q}^S_{1,2} (v, h(c_1, c_2), c_{-\{1,2\}}).$$

This mechanism is incentive compatible—the assumptions on $h$ and the incentive compatibility of $\hat{Q}$ imply that $\hat{Q}^S_1$ is nonincreasing in $c_1$ and $\hat{Q}^S_2$ is nonincreasing in $c_2$.

We now show that the sum of the threshold types of suppliers 1 and 2 under $\hat{Q}$ are less than or equal to the threshold types of the merged entity under $\hat{Q}$.

Suppose that $(v, c)$ is such that supplier 1 trades under $\hat{Q}$.

Case 1: $c_1 > c_2$. Because 1 trades even though it has the higher cost, it must be that $k^S_{1,2} > k^S_2$. It then follows by condition (iv) of the Lemma that $c_1 \leq h(c_1, c_2)$. Consider increasing supplier 1’s report $x$ above $c_1$. As $x$ increases, $h(x, c_2)$ continuously weakly increases and so $\hat{Q}^S_{1,2} (v, h(x, c_2), c_{-\{1,2\}})$ weakly decreases, as does $\hat{Q}^S_{1} (v, x, c_{-1})$. So supplier 1’s threshold types are costs $x$ such that $\hat{Q}^S_{1,2}$ decreases at $h(x, c_2)$, implying that supplier 1’s threshold types for its $q$ units are greater than or equal to $c_1$ and less than or equal to the threshold types for the merged entity’s $q$ units with the lowest threshold types.

Case 2: $c_1 \leq c_2$. Then $c_1 \leq h(c_1, c_2)$. As in case 1, as supplier 1’s report $x$ increases above $c_1$, $h(x, c_2)$ continuously weakly increases and so $\hat{Q}^S_{1,2} (v, h(x, c_2), c_{-\{1,2\}})$ weakly decreases, as does $\hat{Q}^S_{1} (v, x, c_{-1})$. As supplier 1’s report increases above $c_2$, supplier 1’s quantity decreases
from \( \min \left\{ k_1^S, \hat{Q}^S_{1,2}(v, h(x^*, c_2), c_{-\{1,2\}}) \right\} \) to \( \max \left\{ 0, \hat{Q}^S_{1,2}(v, h(x^*, c_2), c_{-\{1,2\}}) - k_2^S \right\} \), which is weakly smaller. It follows that supplier 1’s threshold types for its \( q \) units are greater than or equal to \( c_1 \) and less than or equal to the threshold types for the merged entity’s \( q \) units with the lowest threshold types.

A similar argument applies to supplier 2. Thus, the sum of the expected threshold payments of suppliers 1 and 2 is weakly less than the expected threshold payment of the merged entity, and individual rationality is satisfied for suppliers 1 and 2 under their threshold payments.

It then follows that \( \hat{Q} \), augmented with a payment rule based on threshold payments and the apportionment of the expected budget surplus through fixed payments, is an IC, IR, no-deficit mechanism and has weakly greater expected weighted surplus than \( \langle \hat{Q}, \hat{M} \rangle \) does in the post-merger market. Optimizing for the pre-merger market reinforces the result. ■

**Proof of Proposition 5** Assume that \( k_1^S = K^B \) and \( w_1^S = w_2^S = w \), and consider a merger of suppliers 1 and 2, where \( w \) is also the bargaining weight of the merged entity. (Analogous analysis applies to a merger of buyers 1 and 2 with \( k_1^B = K^S \) and \( w_1^B = w_2^B = w_1^{B,2} = w \).) Let \( \mathcal{N}^B \) and \( \mathcal{N}^S \) denote the set of pre-merger buyers and suppliers, respectively. The merged entity draws its constant marginal cost \( c_{1,2} \) for up to \( K^B \) units from the distribution of the \( K^B \)-th lowest of \( \{c_1, \ldots, c_1, c_2, \ldots, c_2\} \), where \( c_1 \) and \( c_2 \) are independent draws from \( G_1 \) and \( G_2 \), respectively. If \( k_2^S = K^B \), then \( G_{1,2}(x) = 1 - (1 - G_1(x))(1 - G_2(x)) \). If \( k_2^S < K^B \), then the \( K^B \)-th lowest element is always \( c_1 \), so \( G_{1,2}(x) = G_1 \). Denote the associated density by \( g_{1,2} \) and weighted virtual cost function by \( \Gamma_{1,2}(x) \equiv x + (1 - a) g_{1,2}(x) \).

Let \( \langle \hat{Q}, \hat{M} \rangle \) be the incomplete information bargaining mechanism in the post-merger market following the merger of suppliers 1 and 2, and let \( \hat{\rho} \) be the associated Lagrange multiplier and \( \hat{\eta} \) be the shares. As described in Lemma 1, \( \hat{Q} \) allocates trades to the buyers with the greatest weighted virtual values, \( \Phi_i^{w/\hat{\rho}}(v_i) \) for \( i \in \mathcal{N}^B \), and the suppliers with the smallest weighted virtual costs, \( \Gamma_{1,2}^{w/\hat{\rho}}(c_{1,2}) \) and for \( j \in \mathcal{N}^S \setminus \{1,2\} \), \( \Gamma_j^{w/\hat{\rho}}(c_j) \), and has the greatest number of trades such that the cutoff weighted virtual cost is less than or equal to the cutoff weighted virtual value.

Let \( \hat{\pi} \) denote the expected budget surplus for the post-merger mechanism, not including fixed payments:

\[
\hat{\pi} \equiv \mathbb{E}_{v, c_{1,2}, c_{-\{1,2\}}} \left[ \sum_{i \in \mathcal{N}^B} \Phi_i(v_i) \hat{Q}^B_i - \sum_{j \in \mathcal{N}^S \setminus \{1,2\}} \Gamma_j(c_j) \hat{Q}^S_j - \Gamma_{1,2}(c_{1,2}) \hat{Q}^S_{1,2} \right],
\]
where we drop the argument \((v, c_{1,2})\) on the allocation rule.

By the payment equivalence theorem, we can, without loss, focus on payment rules based on threshold payments, which are the sum of an agent’s threshold types for each unit traded, where the threshold type for a unit is the worst type (lowest value for a buyer and highest cost for a supplier) that the agent could report and still trade that unit. Specifically, for each buyer \(i \in \mathcal{N}^B\), its payment to the mechanism \(\hat{M}^B_i(v, c_{1,2}, c_{\cdot \{1,2\}})\) is the sum of the threshold types for each unit that it trades (and zero if it does not trade) minus its fixed payment \(\hat{\eta}^B_i \hat{\pi}\). For each supplier \(i \in \mathcal{N}^S \backslash \{1, 2\}\), its payment from the mechanism \(\hat{M}^S_i(v, c_{1,2}, c_{\cdot \{1,2\}})\) is the sum of the threshold types for each unit that it trades (and zero if it does not trade) plus its fixed payment \(\hat{\eta}^S_i \hat{\pi}\). For the merged entity, its payment from the mechanism \(\hat{M}^{S,2}(v, c_{1,2}, c_{\cdot \{1,2\}})\) is the sum of the threshold types for each unit that it trades (and zero if it does not trade) plus its fixed payment \(\hat{\eta}^{S,2} \hat{\pi}\).

Next, we apply \((\hat{Q}, \hat{M})\) to the pre-merger market by defining a pre-merger mechanism \((\hat{\bar{Q}}, \hat{\bar{M}})\) that mimics the allocation rule of the post-merger mechanism and has threshold payments. Specifically, given reports for all of the pre-merger agents \((v, c)\), define \(h(c_{1,2}) \equiv \min\{c_1, c_2\}\) if \(k_{2}^S = K^B\) and \(h(c_{1,2}) \equiv c_1\) if \(k_{2}^S < K^B\), and define the allocation rule for supplier \(j \in \mathcal{N}^S \backslash \{1, 2\}\) by

\[
\hat{Q}^S_j(v, c) \equiv \hat{Q}^S_j(v, h(c_{1,2}), c_{\cdot \{1,2\}}),
\]

and define buyer \(i\)’s allocation rule by

\[
\hat{Q}^B_i(v, c) \equiv \hat{Q}^B_i(v, h(c_{1,2}), c_{\cdot \{1,2\}}).
\]

For suppliers 1 and 2, define the allocation rule by

\[
\hat{Q}^S_1(v, c) \equiv \begin{cases} 
\hat{Q}^S_{1,2}(v, h(c_{1,2}), c_{\cdot \{1,2\}}) & \text{if } c_1 \leq c_2 \text{ and } k_{2}^S = K^B, \\
\hat{Q}^S_{1,2}(v, h(c_{1,2}), c_{\cdot \{1,2\}}) & \text{if } k_{2}^S < K^B, \\
0 & \text{otherwise,}
\end{cases}
\]

and

\[
\hat{Q}^S_2(v, c) \equiv \begin{cases} 
\hat{Q}^S_{1,2}(v, h(c_{1,2}), c_{\cdot \{1,2\}}) & \text{if } c_2 < c_1 \text{ and } k_{2}^S = K^B, \\
0 & \text{otherwise,}
\end{cases}
\]

which are nonincreasing in the supplier 1’s type and supplier 2’s type, respectively, and so satisfy incentive compatibility.

We now show that the expected threshold types of the nonmerging agents are the same
Lemma B.1. The expected threshold types of trading buyers and trading nonmerging suppliers are the same under $\tilde{Q}$ and $\hat{Q}$.

Proof. Because the merged entity’s type is drawn from the distribution of $h(c_1, c_2)$, where $c_1$ is drawn from $G_1$ and $c_2$ is drawn from $G_2$, it suffices to compare threshold types between the two mechanisms for a given pre-merger type vector $(v, c)$ and the corresponding post-merger type vector $(v, h(c_1, c_2), c_{-\{1,2\}})$.

The threshold types for a trading buyer depend at most on the weighted virtual cost of the cutoff supplier (the highest weighted virtual cost supplier that trades) and the weighted virtual values of buyers with units that do not trade. Analogously, the threshold types for a trading supplier depend at most on the weighted virtual value of the cutoff buyer (the lowest weighted virtual value buyer that trades) and the weighted virtual costs of suppliers with units that do not trade.

First, consider the threshold types for trading buyers. It is never the case that both supplier 1 and supplier 2 trade under $\tilde{Q}$. If supplier 1 trades, then using $k_1^S = K^B$, the cutoff weighted virtual cost is $\Gamma_{1,2}^{w/\hat{\rho}}(c_1) = \Gamma_{1,2}^{w/\hat{\rho}}(h(c_1, c_2))$. If only supplier 2 trades, then $c_2 < c_1$ and $k_2^S = K^B$ and the cutoff weighted virtual cost is $\Gamma_{1,2}^{w/\hat{\rho}}(c_2) = \Gamma_{1,2}^{w/\hat{\rho}}(h(c_1, c_2))$. Thus, trading buyers’ threshold types depend on the merging suppliers only through $\Gamma_{1,2}^{w/\hat{\rho}}(h(c_1, c_2))$, which is the same as under $\hat{Q}$. If neither supplier 1 nor supplier 2 trades under $\tilde{Q}$, then the merged supplier with type equal to $h(c_1, c_2)$ does not trade under $\hat{Q}$, and again the buyer’s threshold payments are the same under $\hat{Q}$ and $\tilde{Q}$. This completes the demonstration that trading buyers’ expected threshold types are the same under $\tilde{Q}$ and $\hat{Q}$.

Second, consider the threshold types for trading nonmerging suppliers. Suppose that nonmerging supplier $i$ trades under $\tilde{Q}$. Then because $k_1^S = K^B$ and supplier 2 does not trade when $k_2^S < K^B$, it must be that supplier $i$ has a lower weighted virtual cost than $\Gamma_{1,2}^{w/\hat{\rho}}(h(c_1, c_2))$, i.e., ignoring ties between types,

$$\Gamma_{i}^{w/\hat{\rho}}(c_i) < \Gamma_{1,2}^{w/\hat{\rho}}(h(c_1, c_2)).$$

If supplier $i$ were to report a type greater than $\hat{x} \equiv \Gamma_{i}^{w/\hat{\rho}}^{-1}(\Gamma_{1,2}^{w/\hat{\rho}}(h(c_1, c_2)))$, it would trade zero units, so its threshold types are all less than or equal to $\hat{x}$. This implies that its threshold types only depend on $c_1$ and $c_2$ through $h(c_1, c_2)$. Thus, nonmerging suppliers’ expected threshold payments are the same under $\tilde{Q}$ and $\hat{Q}$. □

Using Lemma B.1 and defining the payments $\tilde{M}$ for the nonmerging agents to be their threshold payments associated with $\tilde{Q}$ minus $\tilde{\eta}_i^B \hat{x}$ for buyer $i \in N^B$ and plus $\tilde{\eta}_j^S \hat{x}$ for supplier
\[ j \in \mathcal{N}^S \setminus \{1, 2\}, \] it follows that the buyers’ and nonmerging suppliers’ expected payments are the same under \( \tilde{M} \) as under \( \hat{M} \).

Now consider the payments of the merging suppliers. Suppose supplier 1 trades, which implies that supplier 2 does not trade. Consider supplier 1’s threshold payment for the \( q \)-th unit under \( \hat{Q} \). It is the worst type that supplier 1 could report and still trade its \( q \)-th unit. The only difference in the calculation of supplier 1’s threshold payment under \( \hat{Q} \) versus the merged entity’s threshold payment under \( \hat{Q} \) is that under \( \hat{Q} \), supplier 1’s threshold types are bounded above by \( c_2 \) when \( k_2^S = K^B \) because then any report greater than \( c_2 \) results in supplier 1’s trading zero units. Thus, when supplier 1 trades (and supplier 2 does not), its expected threshold payment under \( \hat{Q} \) is weakly less (strictly if and only if \( k_2^S = K^B \)) than the expected threshold payment of the merged entity under \( \hat{Q} \). Similarly, when supplier 2 trades (and supplier 1 does not), which implies that \( k_2^S = K^B \), its expected threshold payment under \( \tilde{Q} \) is less than the expected threshold payment of the merged entity under \( \hat{Q} \). Thus, letting \( \tilde{\tau}_j^S(v, c) \) be the threshold payment of supplier \( j \) under \( \tilde{Q} \) and \( \hat{\tau}_j^S(v, c_{1, 2}, c_{-\{1, 2\}}) \) be the threshold payment of the merged entity under \( \hat{Q} \), we have

\[
0 \leq \mathbb{E}_{v, c_{1, 2}, c_{-\{1, 2\}}} \left[ \tilde{\tau}_j^S(v, c_{1, 2}, c_{-\{1, 2\}}) \right] - \mathbb{E}_{v, c} \left[ \hat{\tau}_1^S(v, c) + \hat{\tau}_2^S(v, c) \right] \equiv \Delta,
\]

with a strict inequality if and only if \( k_2^S = K^B \).

This implies that under \( \tilde{Q} \), the budget surplus in the pre-merger market not including fixed payments is \( \hat{\tau} + \Delta \), where \( \Delta \) is the amount by which the merging suppliers’ combined threshold payments are smaller in the pre-merger market under \( \tilde{Q} \) than in the post-merger market under \( \hat{Q} \).

Let \( \tilde{\eta} \) be the pre-merger shares (recall that we assume that the merger does not alter shares, so for nonmerging agents, the shares in \( \tilde{\eta} \) are the same as in \( \hat{\eta} \), and \( \tilde{\eta}_1^S + \tilde{\eta}_2^S = \tilde{\eta}_{1, 2}^S \)). Define for each supplier \( j \in \{1, 2\} \),

\[
\tilde{M}_j^S(v, c) \equiv \tilde{\tau}_j^S(v, c) + \tilde{\eta}_j^S \hat{\tau},
\]

and note that

\[
\mathbb{E}_{v, c} \left[ \tilde{M}_1^S(v, c) + \tilde{M}_2^S(v, c) \right] = \mathbb{E}_{v, c} \left[ \tilde{\tau}_1^S(v, c) + \tilde{\tau}_2^S(v, c) + \tilde{\eta}_{1, 2}^S \hat{\tau} \right] = \mathbb{E}_{v, c_{1, 2}, c_{-\{1, 2\}}} \left[ \tilde{\tau}_1^S(v, c_{1, 2}, c_{-\{1, 2\}}) \right] + \tilde{\eta}_{1, 2}^S \hat{\tau} - \Delta = \mathbb{E}_{v, c_{1, 2}, c_{-\{1, 2\}}} \left[ \hat{M}_{1, 2}^S(v, c_{1, 2}, c_{-\{1, 2\}}) \right] - \Delta.
\]

It follows that \( \langle \tilde{Q}, \tilde{M} \rangle \) is an incentive compatible, individually rational pre-merger mech-
anism and satisfies the no-deficit constraint. In addition, there is budget surplus $\Delta$ to be allocated to the agents according to $\hat{\eta}$.

Comparing expected weighted surpluses, we have (dropping the arguments $(v, c_{1,2}, c_{-\{1,2\}})$ on $(\hat{Q}, \hat{M})$ and $(v, c)$ on $(Q, M)$):

$$\mathbb{E}_{v,c_{1,2},c_{-\{1,2\}}} \left[ \sum_{i \in N^B} w_i^B (\hat{Q}_i^B v_i - \hat{M}_i^B) + \sum_{j \in N^S \setminus \{1,2\}} w_j^S (\hat{M}_j^S - \hat{Q}_j^S c_j) + w (\hat{M}_{1,2}^S - \hat{Q}_{1,2}^S c_{1,2}) \right]$$

$$\leq \mathbb{E}_{v,c} \left[ \sum_{i \in N^B} w_i^B (\hat{Q}_i^B v_i - \hat{M}_i^B + \hat{\eta}_i^B \Delta) + \sum_{j \in N^S \setminus \{1,2\}} w_j^S (\hat{M}_j^S - \hat{Q}_j^S c_j + \hat{\eta}_j^S \Delta) \right] + \sum_{j \in \{1,2\}} w (\hat{M}_j^S - \hat{Q}_j^S c_j + \hat{\eta}_j^S \Delta),$$

where the inequality uses the fact that $\hat{\eta}_i^x > 0$ only if $w_i^x = \max w$ and $\sum \hat{\eta} = 1$, which implies that

$$\sum_{i \in N^B} w_i^B \hat{\eta}_i^B + \sum_{j \in N^S \setminus \{1,2\}} w_j^S \hat{\eta}_j^S + \sum_{j \in \{1,2\}} w \hat{\eta}_j^S = \max w \geq w,$$

and where the inequality is strict if $\Delta > 0$ (which holds if and only if $k_2^S = K^B$) and $w < \max w$.

Thus, $(\hat{Q}, \hat{M})$ is a feasible incomplete information bargaining mechanism in the pre-merger market and generates expected weighted surplus under that is weakly greater (strictly if $k_2^S = K^B$ and $w < \max w$) than under $(\hat{Q}, \hat{M})$ in the post-merger market. It follows that the optimized incomplete information bargaining mechanism in the pre-merger market has weakly greater weighted social surplus (strictly if $k_2^S = K^B$ and $w < \max w$) than $(\hat{Q}, \hat{M})$ does in the post-merger market.

Further, if all nonmerging agents have zero bargaining weight, then $\hat{\rho} = \max w = w$ and the pre-merger mechanism has $\hat{\rho} = \max w = w$. It follows that if $k_2^S = K^B$, no further optimization of the mechanism is possible, and so expected weighted welfare, and indeed, expected surplus for all agents, is the same before and after the merger. ■

Proof of Proposition 7. With nonoverlapping supports and symmetric bargaining weights, the pre-integration market achieves the first-best. Suppose that $n^B = 1$ and $n^S \geq 2$. After integration between the buyer and supplier 1, the buyer’s willingness to pay is the cost realization of the integrated supplier, that is, $c_1$, whose support is $[\underline{c}, \bar{c}]$. Thus, we have a
generalized Myerson-Satterthwaite problem (generalized insofar as there is one buyer but \(n^S - 1 \geq 1\) suppliers). For this setting, impossibility of first-best trade obtains (see, e.g., Delacrétaz et al., 2019), regardless of bargaining weights. An analogous argument applies for the case of \(n^S = 1\) and \(n^B \geq 2\). ■

**Proof of Proposition 8** We have proved the first part in the text and are thus left to prove the second part.

We begin with a brief preamble to establish some notation and useful relations. Let \(\hat{u}^B_{i, Q}(v_i; e^B_{-i}, e^S)\) denote the interim expected payoff of buyer \(i\) with type \(v_i\), not including the (constant) interim expected payment to the worst-off type and not including investment costs, when the allocation rule is \(Q\) and other agents investments are \((e^B_{-i}, e^S)\). Define \(\hat{u}^S_{i, Q}(c_i; e^B, e^S_{-i})\) analogously. Let \(u^B_{i, Q}(e)\) and \(u^S_{i, Q}(e)\) denote the expected payoffs of buyer \(i\) and supplier \(i\), respectively, when the allocation rule is \(Q\) and investments are \(e\).

For any allocation rule \(Q\), let \(q^B_i(v_i; e^B_{-i}, e^S) \equiv \mathbb{E}_{v_i, e^B_{-i}, e^S} [Q^B(v, c)]\) and \(q_i(c_i; e^B, e^S_{-i}) \equiv \mathbb{E}_{v, c_{-i} | e^B, e^S_{-i}} [Q^S(v, c)]\). As discussed in Appendix A.1, by the payoff equivalence theorem, we have, up to a constant,

\[
\hat{u}^B_{i, Q}(v_i; e^B_{-i}, e^S) = \int_{v_i}^{-v_i} q^B_i(x; e^B_{-i}, e^S) \, dx, \tag{24}
\]

and, taking expectations with respect to \(v_i\), one obtains

\[
u^B_{i, Q}(e) = \int_{v_i}^{-v_i} q^B_i(x; e^B_{-i}, e^S)(1 - F(x; e^B_{-i})) \, dx \tag{25}
\]

up to a constant, and, analogously,

\[
u^S_{j, Q}(e) = \int_{c_j}^{c_j} q^S_j(x; e^B, e^S_{-j}) G_j(x; e^S_{-j}) \, dx \tag{26}
\]

up to a constant.

By the definition of \(\bar{e}\) as the vector of first-best investments, we have

\[
\bar{e} \in \arg \max_{e} \sum_{i \in N^B} u^B_{i, Q^P_B}(e) + \sum_{j \in N^S} u^S_{j, Q^P_B}(e) - \sum_{i \in N^B} \Psi^B_{i}(e^B_i) - \sum_{j \in N^S} \Psi^S_{j}(e^S_j).
\]

which implies that for all \(i \in N^B\) and \(j \in N^S\),

\[
\bar{e}^B_i \in \arg \max_{e^B_i} u^B_{i, Q^P_B}(e^B_i, e^B_{-i}, \bar{e}^S) - \Psi^B_{i}(e^B_i) \tag{27}
\]
and
\[ e_j^S \in \arg \max_{e_j^S} u_j^S Q_f(e_j^S, e_j^S, e_{-j}^S) - \Psi_j^S(e_j^S). \quad (28) \]

Assume that (9)–(10) hold. Let \( Q^{w, \pi} \) denote the incomplete information bargaining allocation rule given in Lemma 1, but with the virtual types defined in terms of the type distributions associated with investment \( \bar{e} \), and let \( \rho^{w}_{\pi} \) denote the associated multiplier on the no-deficit constraint. Suppose that first-best investments \( \bar{e} \) are Nash equilibrium investments, which implies that for all \( i \in \mathcal{N}^B \) and \( j \in \mathcal{N}^S \),
\[ e_i^B \in \arg \max_{e_i^B} u_i^B Q^{w, \pi}(e_i^B, e_i^B, e_i^B) - \Psi_i^B(e_i^B) \quad (29) \]

and
\[ e_j^S \in \arg \max_{e_j^S} u_j^S Q^{w, \pi}(e_j^S, e_j^S, e_{-j}^S) - \Psi_j^S(e_j^S). \quad (30) \]

Assumptions (9)–(10) ensure that the first-best investments are characterized by their first-order conditions. Thus, using (25) and (27), we have for all \( i \in \mathcal{N}^B \),
\[ -\int_{c}^{v} q_i^{FB,B}(x; e_i^B, e_i^B) \frac{\partial F_i(x; e_i^B)}{\partial e} \, dx - \Psi_i^B(e_i^B) = 0. \quad (31) \]

Similarly, using (25) and (29), we have
\[ -\int_{c}^{v} q_i^{w, \pi,B}(x; e_i^B, e_i^B) \frac{\partial F_i(x; e_i^B)}{\partial e} \, dx - \Psi_i^B(e_i^B) = 0. \quad (32) \]

Combining (31) and (32), we have
\[ \int_{c}^{v} (q_i^{FB,B}(x; e_i^B, e_i^B) - q_i^{w, \pi,B}(x; e_i^B, e_i^B)) \frac{\partial F_i(x; e_i^B)}{\partial e} \, dx = 0. \quad (33) \]

Writing this in terms of the ex post allocation rules, we have for all \( i \in \mathcal{N}^B \),
\[ \mathbb{E}_{v_i, c_j^{g_i}, e} \left[ \int_{c}^{v} (Q_i^{FB,B}(x, v_i, c) - Q_i^{w, \pi,B}(x, v_i, c)) \frac{\partial F_i(x; e_i^B)}{\partial e} \, dx \right] = 0. \quad (34) \]

Steps analogous to those leading to (33) imply that for all \( j \in \mathcal{N}^S \),
\[ \int_{c}^{v} (q_j^{FB,S}(x; e_j^S, e_j^S) - q_j^{w, \pi,S}(x; e_j^S, e_j^S)) \frac{\partial G_j(x; e_j^S)}{\partial e} \, dx = 0. \quad (35) \]

By Lemma 1, we know that the total number of trades induced by \( Q^{w, \pi}(v, c) \) is the
maximum such that the lowest weighted virtual value of any trading buyer is greater than or equal to the highest weighted virtual cost of any trading supplier. Further, the total number of trades induced by $Q^{FB}(v, c)$ is the maximum such that the lowest value of any trading buyer is greater than or equal to the highest cost of any trading supplier. Because virtual costs are greater than or equal to actual costs and virtual values are less than or equal to actual values, it follows that $\sum_{i \in N^B} Q^w_i(v, c) \leq \sum_{i \in N^B} Q^{FB,B}_i(v, c)$ for all $(v, c)$ (and similarly on the supply side). Because we assume that $\frac{\partial E_i(w_i)}{\partial c} < 0$ for all $v \in (\tilde{v}, \bar{v})$, (34) then implies that

$$\sum_{i \in N^B} Q^w_i(v, c) = \sum_{i \in N^B} Q^{FB,B}_i(v, c) \equiv \xi(v, c)$$

(36)

for all but a zero-measure set of types. By feasibility, the corresponding total supplier-side quantities are also equal to $\xi(v, c)$ for all but a zero-measure set of types. It remains to show that $Q^{w,\bar{\pi}}$ always induces the same agents to trade as does $Q^{FB}$.

We begin by considering the case with overlapping supports and then consider the case in which (ii), (iii), or (iv) holds.

**Case 1:** $\bar{c} > c$. Suppose, contrary to what we want to show, that $Q^{w,\bar{\pi}}$ discriminates among agents based on virtual types for an open set of types—we then show that this implies that the number of trades under $Q^{w,\bar{\pi}}$ must sometimes differ from the number under the first-best, contradicting (36). That is, suppose that there exist suppliers (an analogous argument applies for buyers), which we denote by 1 and 2, and types $(\hat{v}, \hat{c})$ with $\hat{c}_1 \neq \hat{c}_2$ such that supplier 1 trades in the first-best but not under $Q^{w,\bar{\pi}}$, while supplier 2 trades under $Q^{w,\bar{\pi}}$ but not under the first-best, i.e., $Q^{FB,S}_1(\hat{v}, \hat{c}) > 0$, $Q^{w,\bar{\pi},S}_1(\hat{v}, \hat{c}) = 0$, $Q^{w,\bar{\pi},S}_2(\hat{v}, \hat{c}) > 0$, and $Q^{FB,S}_2(\hat{v}, \hat{c}) = 0$. This implies that $\hat{c}_1$ is among the $\xi(\hat{v}, \hat{c})$ lowest elements of $\hat{c}$, but $\hat{c}_2$ is not, and that $\Gamma^{w_2}/\rho^{w_2}_{\bar{\pi}}(\hat{c}_2; \bar{\pi}_2)$ is among the $\xi(\hat{v}, \hat{c})$ lowest elements of $\Gamma^{w_2}/\rho^{w_2}_{\bar{\pi}}(\hat{v}, \bar{\pi}_2)$, but $\Gamma^{w_1}/\rho^{w_1}_{\bar{\pi}}(\hat{c}_1; \bar{\pi}_1)$ is not. It follows that

$$\hat{c}_1 < \hat{c}_2 \leq \Gamma^{w_2}/\rho^{w_2}_{\bar{\pi}}(\hat{c}_2; \bar{\pi}_2) \leq \Gamma^{w_1}/\rho^{w_1}_{\bar{\pi}}(\hat{c}_1; \bar{\pi}_1) \text{ and } \Gamma^{w_2}/\rho^{w_2}_{\bar{\pi}}(\hat{c}_2; \bar{\pi}_2) \leq \Gamma^{w_2}/\rho^{w_2}_{\bar{\pi}}(\hat{v}, \bar{\pi}_2)[\xi(\hat{v}, \hat{c})].$$

Because $\hat{c}_1 < \Gamma^{w_1}/\rho^{w_1}_{\bar{\pi}}(\hat{c}_1; \bar{\pi}_1)$, it follows that $w_1^S/\rho^{w_1}_{\bar{\pi}}(\hat{c}_1; \bar{\pi}_1) < 1$ and so for all $c \in (c, \hat{c})$, $c < \Gamma^{w_1}/\rho^{w_1}_{\bar{\pi}}(c; \bar{\pi}_1)$. Thus, letting $\bar{c}_1 \in (\max\{c, \bar{v}\}, \bar{v})$, $\bar{v}_1 \in (\bar{c}_1, \min\{\bar{v}, \Gamma^{w_1}/\rho^{w_1}_{\bar{\pi}}(\hat{c}_1; \bar{\pi}_1)\})$, for all $i \in N^S \setminus\{1\}$, $\bar{c}_i = \bar{c}$, and for all $i \in N^B \setminus\{1\}$, $\bar{v}_i = \bar{v}$, we have

$$\bar{c}_1 < \bar{v}_1 < \Gamma^{w_1}/\rho^{w_1}_{\bar{\pi}}(\hat{c}_1; \bar{\pi}_1) \text{ and } \max_{i \in N^B \setminus\{1\}} \bar{v}_i < \bar{v}_1 < \min_{i \in N^S \setminus\{1\}} \bar{c}_i,$$

which implies that no trades occur under $Q^{w,\bar{\pi}}$ and exactly only supplier 1 and buyer 1 trade under the first-best. By continuity, for all $(v, c)$ in an open set of types around $(\hat{v}, \hat{c})$,
\[
\sum_{i \in \mathcal{N}^B} Q^w_{i}(v, c) \neq \sum_{i \in \mathcal{N}^B} Q^{FB}_{i}(v, c),
\]
which contradicts (36). Thus, we conclude that \(Q^w\) does not discriminate among suppliers based on virtual types and so \(Q^w\) induces the same suppliers to produce as does \(Q^{FB}\). An analogous argument shows that the set of trading buyers is the same under \(Q^w\) as under \(Q^{FB}\).

**Case 2:** \(v \geq \bar{c}\) and either (ii), (iii), or (iv) holds. Note that \(v \geq \bar{c}\) implies that under the first-best, the number of trades is \(\min\{K^B, K^S\}\). If (ii) holds, i.e., \(K^B = K^S\), then all agents trade under the first-best and so (36) implies that all agents also trade under \(Q^w\), which completes the proof. Suppose that (iii) holds, so that \(K^B < K^S\) and (11) holds. (Analogous arguments apply to the case with \(K^B > K^S\) and (12).) Then all buyers consume their full demands under the first-best. If \(w_1^S = \cdots = w_n^S\), then (11) implies that the ranking of suppliers according to \(\Gamma_{i}^w(c_1; e)\) is the same as the ranking according to \(c_i\). Thus, using (36), \(Q^w\) induces the same suppliers to produce as does \(Q^{FB}\), and again we are done.

So, suppose that \(K^B < K^S\), (11) holds, and the suppliers do not all have the same bargaining weight. Let the suppliers be numbered such that \(w_1^S = \min_{i \in \mathcal{N}^S} w_i^S < w_2^S\). Using (11), we drop the agent subscript on the virtual types and the investment argument in the virtual types. We have, for all \(c \in (\underline{c}, \bar{c})\),

\[
\Gamma^{w_2^S}_i / \rho^w_i (c) < \max_{i \in \mathcal{N}^S} \Gamma^{w_i^S}_i / \rho^w_i (c) = \frac{\Gamma^{w_2^S}_i}{\rho^w_i} (c),
\]

and for all \(c \in (\underline{c}, \bar{c})\),

\[
q^w_1(c_1; e^B, e^S) = \mathbb{E}_{v, c_1 | e^B, e^S} \left[ \text{repetitions of } \frac{\Gamma^{w_i^S}_i}{\rho^w_i} (c_1) \text{ in the } \xi(v, c)-\text{smallest elements of } \Gamma^{w_i^S}_i / \rho^w_i (c, e^S) \right]
\]

\[
= \mathbb{E}_{v, c_1 | e^B, e^S} \left[ \text{repetitions of } c_1 \text{ in the } \xi(v, c)-\text{smallest elements of } \Gamma^{w_i^S}_i / \rho^w_i (c, e^S) \right]
\]

\[
< \mathbb{E}_{v, c_1 | e^B, e^S} \left[ \text{repetitions of } c_1 \text{ in the } \xi(v, c)-\text{smallest elements of } c \right]
\]

\[
= q^{FB}_1(c_1; e^B, e^S),
\]

where the first equality uses the definition of \(Q^w\) and (36), the second equality uses the assumption that \(\Gamma^{w_i^S}_i / \rho^w_i\) is increasing, the inequality follows from (37), which implies that for all \(i \in \mathcal{N}^S\),

\[
\Gamma^{w_i^S}_i / \rho^w_i (c_1) \leq c_1,
\]

and the final equality uses the definition of \(Q^{FB}\) and (36). This result that \(q^w_1(c_1; e^B, e^S) < q^{FB}_1(c_1; e^B, e^S)\) for all \(c \in (\underline{c}, \bar{c})\) contradicts (35), and so we conclude that all suppliers must have the same bargaining weight, and so \(Q^w = Q^{FB}\). Analogously, if \(K^B > K^S\) and (12) holds, then we can use (33) to show that all buyers must have the same bargaining weight.
and so again $Q^{w,v} = Q^{FB}$, completing the proof.
Appendix: $k$-double auction as a special case

In the $k$-double auction of [Chatterjee and Samuelson (1983)], given $k \in [0, 1]$, the buyer and supplier in a $k$-double auction simultaneously submit bids $p_B$ and $p_S$, and trade occurs at the price $kp_B + (1 - k)p_S$ if and only if $p_B \geq p_S$. By construction, the $k$-double auction never incurs a deficit. If the agents’ types are uniformly distributed on $[0, 1]$, then the linear Bayes Nash equilibrium of the $k$-double auction results in trade if and only if $v \geq c + \frac{1}{2k^2} - \frac{1}{2}$. As first noted by [Myerson and Satterthwaite (1983)], for $k = 1/2$ and uniformly distributed types, the $k$-double auction yields the second-best outcome. [Williams (1987)] then generalized this insight by showing that, for uniformly distributed types and any $k \in [0, 1]$, the $k$-double auction implements the outcomes of incomplete information bargaining for some bargaining weights. These outcomes are illustrated in Figure C.1.

![Figure C.1: Payoffs in the $k$-double auction for all $k \in [0, 1]$. Assumes that there is one single-unit supplier and one single-unit buyer that the supplier’s cost and the buyer’s value are uniformly distributed on $[0, 1]$.](image)

To see that incomplete information bargaining encompasses the $k$-double auction as a special case, note that for the case of one single-unit supplier, one single-unit buyer, and uniformly distributed types, for all $w$, $\rho^w$ is such that

$$0 = \mathbb{E}_{v,c} [(\Phi(v) - \Gamma(c)) \cdot Q^w(v, c)] = \int_{1 - \rho^w}^{1} \int_{0}^{v/(2w)} \frac{v - (1 - w)B}{2 - wB + \rho^w} (2v - 1 - 2c) dc dv,$$

where the second equality uses the expression for $Q^w(v, c)$ from Lemma 1 (we write $Q^w$}

\footnote{In the linear Bayes Nash equilibrium, a buyer of type $v$ bids $p_B(v) = (1 - k)k/(2(1 + k)) + v/(1 + k)$ and a supplier with cost $c$ bids $p_S(c) = (1 - k)/2 + c/(2 - k)$. For $k = 1$, $p_B(v) = v/2$ and $p_S(c) = c$, and for $k = 0$, $p_B(v) = v$ and $p_S(c) = (c + 1)/2$. Thus, for $k \in \{0,1\}$, the $k$-double auction reduces to take-it-or-leave-it offers.}
instead of $Q_{1}^{w,s}$ because for the case that we consider here, there is only one relevant quantity, and to reduce notation, we drop the agent indices on $w^{B}$ and $w^{S}$). Solving this for $\rho^{w}$, we get

$$\rho^{w} = \frac{1}{2} \left( w^{B} + w^{S} + \sqrt{w^{B}w^{S} + w^{B}w^{S} + w^{S^{2}}} \right).$$

Making the substitutions $w^{S} = 1 - \Delta$ and $w^{B} = \Delta$ and writing $\rho^{w}$ as a function of $\Delta$, we have

$$\rho^{\Delta} = \frac{1}{2} \left( 1 + \sqrt{1 - 3\Delta + 3\Delta^{2}} \right). \quad (38)$$

It is then straightforward to derive, for a given $\Delta$, the conditions on $(v, c)$ such that there is trade. Equating this condition with the condition for trade in the $k$-double auction allows one to identify the relation between $\Delta$ and $k$ as

$$\Delta_{k} \equiv \frac{(2 - k)k}{1 + 2k - 2k^{2}}, \quad (39)$$

where $\Delta_{k}$ is increasing in $k$ and varies from 0 to 1 as $k$ varies from 0 to 1.

To see that the price-formation mechanism with bargaining differential $\Delta_{k}$ is equivalent to the $k$-double auction, substitute the expression for $\rho^{\Delta}$ in place of $\rho^{w}$ into the expression derived from Lemma 1 for $Q^{(1-\Delta, \Delta)}(v, c)$ to get

$$Q^{(1-\Delta, \Delta)}(v, c) \equiv \begin{cases} 1 & \text{if } v \geq \frac{1 - 2\Delta(1 - c) + (1 + 2c)\sqrt{1 - 3\Delta + 3\Delta^{2}}}{2(1 - \Delta) + 2\sqrt{1 - 3\Delta + 3\Delta^{2}}}, \\ 0 & \text{otherwise.} \end{cases}$$

Using (39), it then follows that

$$Q^{(1-\Delta_{k}, \Delta_{k})}(v, c) = \begin{cases} 1 & \text{if } v \geq c\frac{k + k}{2 - k} + \frac{1 - k}{2}, \\ 0 & \text{otherwise,} \end{cases}$$

which is the same allocation rule as for the $k$-double auction.

To conclude, note that we can replicate the incomplete information bargaining outcome with bargaining weights $w$ by using bargaining weights $(1 - \Delta, \Delta)$ with $\Delta = \frac{w^{B}}{w^{B} + w^{S}}$. Thus, for any bargaining weights $w$, there exists $k \in [0,1]$, namely $k$ such that $\Delta_{k} = \frac{w^{B}}{w^{B} + w^{S}}$, such that the outcome of the $k$-double auction is the same as the outcome of incomplete information bargaining with weights $w$. Conversely, for any $k \in [0,1]$, there exist bargaining weights $w$, namely $w = (1 - \Delta_{k}, \Delta_{k})$, such that incomplete information bargaining with weights $w$ yields the same outcome as the $k$-double auction.
D Appendix: Extensions

In Section D.1 we extend the model to allow heterogeneous outside options, and in Section D.2, we extend the model to allow buyers to have heterogeneous preferences over suppliers. Section D.3 provides a generalization of the one-to-many setup that encompasses additional models.

D.1 Heterogeneous outside options

The values of agents’ outside options are central for determining the division of social surplus in complete information bargaining models. We now briefly discuss how our model can be augmented or reinterpreted to account for similar features. As we show, there are two types of outside options that can vary across agents: the opportunity cost of participating in the mechanism and the opportunity cost of producing (or buying), which we address in turn. Some of the comparative statics with respect to these costs are the same as with complete information bargaining, while other aspects are novel relative to complete information models.

Fixed costs of participating in the mechanism

For the purposes of this extension, we assume that \( n^B = K^B = 1 \) and drop the buyer subscripts. In this case, we can also assume, without further loss, that \( k^S_j = 1 \) for all \( j \in \mathcal{N}^S \).

We first extend the model to allow the buyer and each supplier to have a positive outside option, denoted by \( x_B \geq 0 \) for the buyer and \( x_j \geq 0 \) for supplier \( j \). These outside options are best thought of as fixed costs of participating in the mechanism because they have to be borne regardless of whether an agent trades. In this case, the price-formation mechanism with weights \( w \) is the solution to

\[
\max_{(Q,M) \in \mathcal{M}} E_{v,c} [W_{Q,M}^w(v,c)] \quad \text{s.t.} \quad \eta^B w \geq x_B \quad \text{and for all} \quad j \in \mathcal{N}^S, \eta^S_j w \geq x_j.
\]

Similar to the case in which the value of the outside options was zero for all agents, the allocation rule is as defined in Lemma 1, but where \( \rho^w \) is the smallest \( \rho \geq \max \mathcal{w} \) such that

\[
E_{v,c} \left[ \sum_{j \in \mathcal{N}^S} \left( \Phi(v) - \Gamma_j(c_j) \right) \cdot 1_{\Phi(v) \geq \Gamma_j(c_j)} \right] \geq x_B + \sum_{j \in \mathcal{N}^S} x_j,
\]

if such a \( \rho \) exists (if no such \( \rho \) exists, then the constraints cannot be met).
Consider the case of symmetric suppliers in this setup. As the number of suppliers increases, the range of outside options that can be accommodated increases. As the suppliers’ outside option increases, the expected social surplus decreases—the need to generate revenue for the suppliers distorts the overall market outcome—and eventually the suppliers’ payoffs exceed that of the buyer, even if the buyer has all the bargaining power. Further, if the suppliers’ outside option is sufficiently large, then the buyer and society are better off when the number of suppliers is reduced below the maximum number sustainable in the market.

**Production-relevant outside options**

Alternatively, one can think of outside options as affecting a supplier’s cost of producing or as the buyer’s best alternative to procuring the good. Typically, one would expect these to be more sizeable than the costs of participating in the mechanism. To allow for heterogeneity in these production-relevant outside options, we now relax the assumption that all suppliers’ cost distributions have the identical support $[c, \bar{c}]$ and assume instead that, with a commonly known outside option of value $y_j \geq 0$, the support of supplier $j$’s cost distribution is $[\underline{c}_j, \overline{c}_j]$ with $\underline{c}_j = c + y_j$ and $\overline{c}_j = \bar{c} + y_j$. If $G_j(c)$ is $j$’s cost distribution without the outside option, then given outside option $y_j$, its cost distribution is $G^o_j(c) = G_j(c - y_j)$, with density $g^o_j(c) = g_j(c - y_j)$ and support $[\underline{c}_j, \overline{c}_j]$. In other words, increasing a supplier’s outside option shifts its distribution to the right without changing its shape. Likewise, given outside option $y_B \geq 0$, the distribution of the buyer’s value $v$ is $F^o(v) = F(v + y_B)$ with density $f^o(v) = f(v + y_B)$ and support $[\underline{v} - y_B, \overline{v} - y_B]$.

Increasing the value of an agent’s outside option has two effects. First, it worsens its distribution in the sense that for $y_j > 0$ and $y_B > 0$, we have $G^o_j(c) \leq G_j(c)$ for all $c$ and $F^o(v) \geq F(v)$ for all $v$. Hence, under the first-best, an agent is less likely to trade the larger is the value of its outside option. While this effect differs from what one would usually obtain in complete information models, it is an immediate implication of the “worsening” of the agent’s distribution.

The second effect is less immediate and partly, but not completely, offsets the first under the assumption that hazard rates are monotone, that is, assuming that $G_j(c)/g_j(c)$ is increasing in $c$ and $(1 - F(v))/f(v)$ is decreasing in $v$. To see this, let us focus on supplier $j$. The arguments for the buyer (and of course all other suppliers) are analogous. We denote the weighted virtual cost of supplier $j$ when it has outside option $y_j$ by

$$
\Gamma^o_{j,a}(c) \equiv c + (1 - a) \frac{G_j(c - y_j)}{g_j(c - y_j)} = \Gamma_{j,a}(c - y) + y < \Gamma_{j,a}(c),
$$

where the inequality holds for all $a < 1$ because the monotone hazard rate assumption
implies that $\Gamma'_{j,a}(c) > 1$ for all $a < 1$. This in turn has two, somewhat subtle implications. Let $z$ be the threshold for supplier $j$ to trade when its outside option is zero, i.e., keeping $z$ fixed, supplier $j$ trades if and only if $\Gamma_{j,a}(c) \leq z$. (Note that $z$ will be the minimum of the buyer’s weighted virtual value and the smallest weighted virtual cost of supplier $j$’s competitors, but this does not matter for the argument that follows.) Assuming that $a < 1$ and $y_j < \bar{c} - \underline{c}$, which implies that $c_j < \bar{c}$, it follows that there are costs $c \in [c_j, \bar{c}]$ and thresholds $z$ such that supplier $j$ trades when it has the outside option and not without it, that is, $\Gamma^o_{j,a}(c) < z < \Gamma_{j,a}(c)$. This reflects the reasonably well-known result that optimal mechanisms tend to discriminate in favor of weaker agents (McAfee and McMillan, 1987), which in this case is the agent with the positive outside option. It also resonates with intuition from complete information models: keeping costs fixed, the agent with the better outside option is treated more favorably, indeed, it is evaluated according to a smaller weighted virtual cost. However, from an ex ante perspective, the larger is the value of the outside option, the less likely is the agent to trade. To see this, consider a fixed realization of $z$. (The distribution of these thresholds is not be affected by supplier $j$’s outside option and hence our argument extends directly once one integrates over $z$ and its density.) Given $y_j$, supplier $j$ trades if and only if its cost $c$ is below $\tau(y)$ satisfying $\Gamma^o_{j,a}(\tau(y)) = z$. Using (41), this is equivalent to $\Gamma_{j,a}(\tau(y) - y) + y = z$, which in turn is equivalent to $\tau(y) = \Gamma^{-1}_{j,a}(z - y) + y$, whose derivative for $a < 1$ satisfies

$$0 < \tau'(y) = -\frac{1}{\Gamma'_{j,a}(\Gamma^{-1}_{j,a}(z - y))} + 1 < 1,$$

where the inequalities follow because $\Gamma'_{j,a}(c) > 1$. This implies that, for a fixed $z$, the probability that supplier $j$ trades decreases in $y$. To see this, notice that this probability is $G^o_j(\tau(y)) = G_j(\tau(y) - y)$, whose derivative with respect to $y$ is $g_j(\tau(y) - y)(\tau'(y) - 1) < 0$. In words, although the threshold $\tau(y)$ increases in $y$, it does so with a slope that is less than 1, which implies that the probability that supplier $j$ trades decreases in $y$. This effect is not present in complete information models, which in a sense take an ex post perspective by looking at outcomes realization by realization. While improving the outside option $y_j$ improves supplier $j$’s payoff after its value or cost has been realized, supplier $j$’s ex ante expected payoff decreases in $y_j$. Moreover, because an increase in $y_j$ worsens supplier $j$’s distribution, the revenue constraint becomes (weakly) tighter, implying an increase in $\rho^w$, which further reduces supplier $j$’s expected payoff.
D.2 Preferences over suppliers and bargaining externalities

To allow for and investigate bargaining externalities, we restrict attention to the case of one buyer, \( n^B = 1 \), with demand for \( K^B \geq 1 \) units, and \( n^S \geq 2 \) suppliers, but we generalize the setup to allow the buyer to have heterogeneous preferences over the suppliers. To this end, we let \( \theta = (\theta_1, \ldots, \theta_n) \) be a commonly known vector of taste parameters of the buyer, with the meaning that the value to the buyer of trade with supplier \( j \) when the buyer’s type is \( v \) is \( \theta_j v \). Thus, under (ex post) efficiency, trade should occur between the buyer and supplier \( j \) if and only if \( \theta_j v - c_j \) is positive and among the \( K^B \) highest values of \( (\theta_j v - c_\ell)_{\ell \in N^S} \). The problem is trivial if \( \max_{j \in N^S} \theta_j \pi \leq \zeta \) because then it is never ex post efficient to have trade with any supplier, so assume that \( \max_{j \in N} \theta_j \pi > \zeta \).

This setup encompasses (i) differentiated products by letting the supplier-specific taste parameters differ; (ii) a one-buyer version of the Shapley and Shubik (1972) model by setting \( K^B = 1 \); and (iii) a version of the Shapley-Shubik model in which the buyer has demand for multiple products of the suppliers by setting \( K^B > 1 \). For a generalization of the one-to-many setup that encompasses additional models, see Section D.3.

We define the virtual surplus \( \Lambda^w_\theta \) associated with trade between the buyer and supplier \( j \), accounting for the agents’ bargaining weights \( w \) and the buyer’s preferences \( \theta \), with \( \rho^w_\theta \) defined analogously to before as \( \Lambda^w_\theta(v, c_j) \equiv \theta_j \Phi(w, \theta(v) - \Gamma^w_\theta(c_j)) \). Let \( \Lambda^w_\theta(v, c) \equiv (\Lambda^w_\theta(v, c_j))_{j \in N^S} \) and denote by \( \Lambda^w_\theta(v, c)_{(K^B)} \) the \( K^B \)-highest element of \( \Lambda^w_\theta(v, c) \). As before, in order to save notation, we ignore ties.

**Lemma D.2.** Assuming that \( n^B = 1 \) and \( n^S \geq 2 \), in the generalized setup with buyer preferences \( \theta \), incomplete information bargaining with weights \( w \) has the allocation rule for \( j \in N^S \), \( Q^w_\theta(v, c) \equiv 1 \) if \( \Lambda^w_\theta(v, c_j) \geq \max \{0, \Lambda^w_\theta(v, c)_{(K^B)} \} \), and otherwise \( Q^w_\theta(v, c) \equiv 0 \).

**Proof.** The extension to allow supplier specific quality parameters follows by analogous arguments to Lemma 1 noting that the buyer’s value for supplier \( j \)’s good is \( \theta_j v \), which has distribution \( \hat{F}(x) \equiv F(x/\theta_j) \) on \( [\theta_j v, \theta_j \pi] \) with density \( \hat{f}(x) = \frac{1}{\theta_j} f(v/\theta_j) \). Thus, the virtual type when the buyer’s value is \( v \) is

\[
\theta_j v - \frac{1 - \hat{F}(\theta_j v)}{\hat{f}(\theta_j v)} = \theta_j v - \theta_j \frac{1 - F(v)}{f(v)} = \theta_j \Phi(v).
\]

Thus, the parameter \( \theta_j \) “factors out” of the virtual type function. The extension to multi-object demand follows by standard mechanism design arguments. ■

We can now use this generalized setup to analyze bargaining externalities between sup-
pliers. If \( K^B < n \), then one effect of an increase in \( \theta_i \) is that agents other than \( i \) are less likely to be among the at-most \( K^B \) agents that trade. In contrast, if \( K^B \geq n \) and \( \rho^{w,\theta} > \max w \), then the probability that supplier \( j \) trades, \( \Pr(\theta_j \Phi^{n^B/\rho^{w,\theta}}(v) \geq \Gamma^{w_S/\rho^{w,\theta}}(c_j)) \), does not depend on the preference parameters of the other suppliers except through their effect on \( \rho^{w,\theta} \). If \( \rho^{w,\theta} > \max w \), then an increase in a rival supplier’s preference parameter causes an increase in \( \rho^{w,\theta} \), which increases the probability of trade and so benefits the supplier. Thus, we have the following result:

**Proposition 9.** Assuming that \( n^B = 1 \) and \( n^S \geq 2 \), in the generalized setup with bargaining weights \( w \) and buyer preferences \( \theta \), if \( K^B \geq n \) and \( \rho^{w,\theta} > \max w \), then an increase in the preference parameter for one supplier increases the payoffs for all suppliers.

The result of Proposition 9 does not necessarily extend to the case with \( K^B < n \), as shown in the following example.

**Example with bargaining externalities**

In Table 1, we consider the case of one buyer and two suppliers with symmetric bargaining weights. Assuming that \( F, G_1, \) and \( G_2 \) are the uniform distribution on \([0, 1]\), and assuming that \( \theta_2 = 1 \), we allow the buyer’s preference for supplier 1, \( \theta_1 \), and the buyer’s total demand, \( D \), to vary.

Table 1: Outcomes for one-to-many price formation for the case of one buyer and two suppliers with \( w = 1 \), symmetric \( \eta_i \) types that are uniformly distributed on \([0, 1]\), and \( \theta_2 = 1 \). The values of \( D \) and \( \theta_1 \) vary as indicated in the table.

<table>
<thead>
<tr>
<th>( \theta_1 )</th>
<th>( D = 1 )</th>
<th>( D = 2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 1/\rho^{w,\theta} )</td>
<td>0.73</td>
<td>0.76</td>
</tr>
<tr>
<td>( u_B )</td>
<td>0.13</td>
<td>0.34</td>
</tr>
<tr>
<td>( u_1 )</td>
<td>0.05</td>
<td>0.21</td>
</tr>
<tr>
<td>( u_2 )</td>
<td>0.05</td>
<td>0.01</td>
</tr>
</tbody>
</table>

As shown in Table 1, focusing on the case with \( D = 1 \), an increase in the buyer’s preference for supplier 1 from \( \theta_1 = 1 \) to \( \theta_1 = 2 \) benefits supplier 1 (\( u_1 \) increases) but harms supplier 2 (\( u_2 \) decreases). The increase in the buyer’s preference for supplier 1 means that supplier 2 is less likely to trade. As a result, supplier 2 is harmed by the increase in the buyer’s preference for supplier 1. But when \( D = 2 \), the results differ. Supplier 1 again benefits from being preferred by the buyer, but in this case supplier 2 also benefits, albeit less than supplier 1.
The increase in the buyer’s value from trade with supplier 1 means that the value of $\rho^{w, \theta}$ decreases, so supplier 2 trades more often. As a result of the change from $\theta_1 = 1$ to $\theta_1 = 2$, both $u_1$ and $u_2$ increase.

## D.3 Generalization

Here we provide a further generalization of the setup with one buyer and multiple suppliers to allow a more general structure for the buyer’s preferences over suppliers.

Let $P$ be the set of subsets of $N^S$ with no more than $K^B$ elements (including the empty set) and let $\theta = \{\theta_X\}_{X \in P}$ be a commonly known vector of taste parameters of the buyer satisfying the “size-dependent discounts” condition of Delacrétaz et al. (2019). Specifically, let there be supplier-specific preferences $\{\hat{\theta}_j\}_{j \in N^S}$ and size-dependent discounts $\{\delta_j\}_{j \in N^S}$ with $0 = \delta_0 = \delta_1 \leq \delta_2 \leq \cdots \leq \delta_n$ such that for all $X \in P$, $\theta_X = \sum_{i \in X} \hat{\theta}_i - \delta_{|X|}$. Thus, the buyer’s value for purchasing from suppliers in $X \in P$ when its type is $v$ is $\theta_X v$, which depends on the buyer’s value, the buyer’s preferences for standalone purchases from the suppliers in $X$, and a discount that depends on the total number of units purchased. Note that $\theta_\emptyset = 0$, so that the value to the buyer of no trade is zero.

This setup encompasses (i) the homogeneous good model with constant marginal value or decreasing marginal value by setting $\hat{\theta}_j = \theta$ for some common $\theta$ and for $j \in N^S$, $\delta_j$ either all zero for constant marginal value or increasing in $j$ for decreasing marginal value; (ii) differentiated products by letting $\hat{\theta}_j$ differ by $j$ and setting all $\delta_j$ to zero; (iii) a one-buyer version of the Shapley-Shubik model by setting $K^B = 1$; and (iv) a version of the Shapley-Shubik model in which the buyer has demand for multiple products of the suppliers by setting $K^B > 1$.

Define

$$X^*_\rho(v, c) \in \arg \max_{X \in P} \theta_X \Phi^{1/\rho}(v) - \sum_{i \in X} \Gamma_i^{1/\rho}(c_i),$$

i.e., $X^*_\rho(v, c)$ is the set of trading partners for the buyer that maximizes the difference between the ironed weighted virtual value, scaled by $\theta_{X^*_\rho(v, c)}$, and the ironed weighted virtual costs of the trading partners. We then define $\rho^*$ to be the smallest $\rho \geq 1$ such that

$$\mathbb{E}_{v, c} \left[ \theta_{X^*_\rho(v, c)} \Phi(v) - \sum_{i \in X^*_\rho(v, c)} \Gamma_i(c_i) \right] = 0.$$

Given the type realization $(v, c)$, the one-to-many $\rho^*$-mechanism induces trade between the
buyer and suppliers in $X^*_\rho(v, c)$. The expected payoff of the buyer is

$$\mathbb{E}_v \left[ \hat{u}_B(v) + \int_v^\infty \sum_{X \in \mathcal{P}} \theta_X \Pr(X \in X^*_\rho(x, c)) \, dx \right],$$

and the expected payoff of supplier $j$ is

$$\mathbb{E}_{c_j} \left[ \hat{u}_j(c_j) + \int_{c_j}^{\infty} \Pr(i \in X^*_\rho(v, x, c_{-j})) \, dx \right].$$
E Details for investment comparative statics

Here we provide details underlying Section 6.3, which examines how equilibrium investments are affected by bargaining power and by the extent to which the supports of the value and cost distributions overlap.

As described in the body of the paper, we consider a bilateral trade setup with linear virtual types. We hold fixed the support of the supplier’s distribution at \([0, 1]\) and let the support of the buyer’s distribution be \([v, v + 1]\), where we vary \(v\) from 0 to 1. Specifically, we fix \(X > 0\) and consider a supplier type distribution of \(G_{x_S}(c) \equiv c^{X-x_S}\) with support \([0, 1]\), where \(x_S \in [0, X]\) is the supplier’s investment, and a buyer type distribution of \(F_{x_B}(v) \equiv 1 - (1 + v - v)^{X-x_B}\) with support \([v, v + 1]\), where \(x_B \in [0, X]\) is the buyer’s investment. We assume that each agent’s investment \(x\) has cost \(x^2/2\).

In this setup, the first-best investment \(x_{FB}\) is the same for the buyer and supplier and satisfies

\[
(x_{FB}, x_{FB}) \in \arg \max_{x_S, x_B} \int_0^{v + 1} \int_0^1 (v - c) \cdot 1_{c \leq v} \cdot dG_{x_S}(c) dF_{x_B}(v) - x_B^2/2 - x_S^2/2.
\]

For example, if \(X = 1.25\) and \(v = 1\), then the first-best investment is \(x_{SB}^F = x_{FB}^F = 0.25\), implying that under the first-best investments, types are uniformly distributed for both the supplier and the buyer.

Second-best investment is also the same for the buyer and supplier and satisfies\(^3\)

\[
(x_{SB}, x_{SB}) \in \arg \max_{x_S, x_B} \int_0^{v + 1} \int_0^1 (v - c) \cdot 1_{\Gamma_{\rho}^{SB}(v; x_B) \leq \Phi_{\rho}^{SB}(v; x_B)} \cdot dG_{x_S}(c) dF_{x_B}(v) - x_B^2/2 - x_S^2/2,
\]

where \(\rho_{SB}\) is the smallest \(\rho \geq 1\) such that \(\pi^{(1, 1)}(x_B, x_S; \rho) \geq 0\), where

\[
\pi^w(x_B, x_S; \rho) \equiv \int_0^{v + 1} \int_0^1 (\Phi(v; x_B) - \Gamma(c; x_S)) \cdot 1_{\Gamma_{\rho}^{NE}(c; x_S) \leq \Phi_{\rho}(v; x_B)} \cdot dG_{x_S}(c) dF_{x_B}(v).
\]

Now consider the Nash equilibrium investments. We assume that investments are not observed, which implies that given Nash equilibrium investments \((x_{SB}^{NE}, x_{FB}^{NE})\), trade occurs if and only if \(\Gamma_{\rho_{NE}}^{NE}(c; x_S^{NE}) \leq \Phi_{\rho_{NE}}^{NE}(v; x_B^{NE})\). Further, fixed payments are determined by the agents’ shares \((\eta_S, \eta_B)\) and the Nash equilibrium budget surplus \(\pi^{NE} \equiv \pi(x_B, x_S; \rho^{NE})\).

\(^3\)The linear virtual type functions are given by

\[
\Phi_{\beta}(v; x_B) \equiv v \frac{1 - \beta + X - x_B}{X - x_B} - (1 + v)(1 - \beta) \quad \text{and} \quad \Gamma_{\beta}(c; x_S) \equiv c \frac{1 - \beta + X - x_S}{X - x_S}.
\]
The buyer’s Nash equilibrium investment solves
\[
x^\text{NE}_B \in \arg \max_x \int_0^{v+1} \int_0^1 (v - \Phi(v; x)) \cdot 1_{\Gamma(x^\text{NE}_S/c; x^\text{NE}_B) \leq \Phi(x^\text{NE}_B)} \cdot dG_{x^\text{NE}_S}(c) dF_{x^\text{NE}_B}(v) - x^2/2 + \eta_B \pi^\text{NE},
\]
which has first-order condition
\[
x_{x^\text{NE}_B}^\text{NE} = -\int_0^{v+1} \int_0^1 \frac{\partial F_{x^\text{NE}_B}(v)}{\partial x} \bigg|_{x=x^\text{NE}_B} \cdot 1_{\Gamma(x^\text{NE}_S/c; x^\text{NE}_B) \leq \Phi(x^\text{NE}_B)} \cdot g_{x^\text{NE}_B}(c) dc dv.
\]
(42)

Analogously, the supplier’s Nash equilibrium investment solves
\[
x^\text{NE}_S \in \arg \max_x \int_0^{v+1} \int_0^1 (\Gamma(c; x) - c) \cdot 1_{\Gamma(x^\text{NE}_S/c; x^\text{NE}_B) \leq \Phi(x^\text{NE}_B)} \cdot dG_{x^\text{NE}_S}(c) dF_{x^\text{NE}_B}(v) - x^2/2 + \eta_S \pi^\text{NE},
\]
which has first-order condition
\[
x_{x^\text{NE}_B}^\text{NE} = \int_0^{v+1} \int_0^1 \frac{\partial G_{x^\text{NE}_B}(c)}{\partial x} \bigg|_{x=x^\text{NE}_B} \cdot 1_{\Gamma(x^\text{NE}_S/c; x^\text{NE}_B) \leq \Phi(x^\text{NE}_B)} \cdot f_{x^\text{NE}_B}(v) dc dv.
\]
(43)

Solving for \((x^\text{NE}_S, x^\text{NE}_B) \in [0, X] \) and \(\rho^\text{NE} \geq \max\{w_S, w_B\}\) that satisfy (42), (43),
\[
\pi^w(x^\text{NE}_B, x^\text{NE}_S; \rho^\text{NE}) \geq 0, \quad \text{and} \quad (\rho^\text{NE} - \max\{w_S, w_B\}) \pi^w(x^\text{NE}_B, x^\text{NE}_S; \rho^\text{NE}) = 0,
\]
we obtain the Nash equilibrium investments and Lagrange multiplier on the no-deficit constraint.

We illustrate the effects of bargaining power and the distributional supports on equilibrium investment in Figure E.2.
Figure E.2: Nash equilibrium investments with bargaining weights \((w^S, w^B) = (1 - \Delta, \Delta)\) for buyer distributions with varying supports. Assumes the linear virtual type setup for bilateral trade with \(F(v) = 1 - (1 + \frac{1}{2} - v)^{0.25-x_B}\), where \(x_B \in [0, 1.25]\) is the buyer’s investment, and \(G(c) = e^{1.25-x_S}\), where \(x_S \in [0, 1.25]\) is the supplier’s investment. Investment \(x\) has cost \(x^2/2\). When \(v = 1\), we obtain \(x^{FB} = x^{SB} = 0.25\), implying that first-best (and second-best) investment levels result in uniformly distributed types. For \(v = 1\), \(\rho^{NE} = \max\{w_S, w_B\}\) for all bargaining weights. For \(v \in \{1/4, 1/8, 0\}\), \(\rho^{NE} \geq \max\{w_S, w_B\}\) for all bargaining weights. For \(v \in \{1/2, 3/4\}\), \(\rho^{NE} = \max\{w_S, w_B\}\) for sufficiently asymmetric bargaining weights and \(\rho^{NE} > \max\{w_S, w_B\}\) otherwise.
References for the online appendix


