Welfare Effects of Buyer and Seller Power

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Abstract

We examine the welfare effects of buyer and seller power in vertically related markets and introduce an empirical approach for quantifying the contribution of each to market power distortions. Our model nests both monopsony distortions from buyer power and double-marginalization distortions from seller power. Rather than imposing either distortion by assumption, we analyze welfare effects when the source of the distortion is unknown. We characterize when buyer and seller power are countervailing or distortionary, offer a test to separate them empirically, and discuss implications for collective bargaining and merger policy. We demonstrate the application of our model in three empirical settings to examine whether (i) labor unions countervail employer monopsony power, (ii) agricultural cooperatives induce double marginalization, and (iii) vertical distortions in coal procurement stem from monopoly or monopsony power.

Keywords: Monopsony, Bargaining, Vertical Relations
JEL codes: J42, L10, J51, L41

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1 Introduction

There is growing interest in the buyer power of firms, both in labor markets (Card, Cardoso, Heining, and Kline, 2018; Berger, Herkenhoff, and Mongey, 2022; Lamadon, Mogstad, and Setzler, 2022) and in vertically-related industries (Grennan, 2013; Gowrisankaran, Nevo, and Town, 2015; Rubens, 2023). This attention is mirrored in policy circles; for instance, the Department of Justice has challenged mergers on the grounds of monopsony concerns (DOJ, 2022), and tackling labor market power has come to the forefront of economic policy-making (DOJ and FTC, 2023; The White House, 2023).

However, the welfare implications of buyer power vary drastically across different vertical models used in the empirical bargaining literature, much of which has relied on the "Nash-in-Nash" bargaining protocol (Horn and Wolinsky, 1988; Collard-Wexler, Gowrisankaran, and Lee, 2019). A first class of models assumes that input prices are negotiated but the downstream party controls how much input to buy, so equilibrium lies on its input demand curve as in Spengler (1950)'s successive monopoly framework (Abowd and Lemieux, 1993; Crawford and Yurukoglu, 2012; Ho and Lee, 2019). In these models, *seller power* creates vertical distortions by generating upstream *markups*, and buyer power can countervail these distortions. In contrast, a second class of models features bargaining while equilibrium lies on an input supply curve as in Robinson (1933)'s monopsony framework (Azkarate-Askasua and Zerecero, 2025; Angerhofer, Collard-Wexler, and Weinberg, 2026).[1] In these models, *buyer power* creates vertical distortions by generating input price *markdowns*. Thus, the same increase in buyer power can be pro-competitive in one class of models and anti-competitive in the other. This raises the question of how to determine whether buyer power countervails seller power or creates vertical distortions of its own.

We answer this question by characterizing the welfare effects of buyer and seller power in a unified framework and providing an empirical approach to quantify them. The key novelty is that we do not assume a specific type of vertical model; rather, we characterize the conditions under which buyer power is countervailing or distortionary, as a function of model primitives such as supply and demand curves. This framework yields an empirical approach that identifies whether vertical distortions arise from buyer or seller power, with minimal data requirements and without estimating a bargaining model.

Our model is a Nash-in-Nash bargaining game between buyers ("downstream") and sellers ("upstream") that bilaterally bargain over a linear input price, and equilibrium lies either on the input demand curve ("monopolistic vertical conduct") or on the input supply curve ("monopsonistic vertical conduct"). We consider two measures of "buyer power":

[1] Although Angerhofer et al. (2026) develop an oligopsony model, rationing can bring equilibrium onto the labor demand curve.

the relative bargaining weight of buyers and sellers, which we treat as a policy-invariant primitive, and their relative disagreement payoffs. We avoid functional-form assumptions on the demand and cost curves and allow for both simultaneous and sequential timing. Using this model, we analyze vertical distortions, defined as the output reduction relative to joint-profit maximization in the vertical chain.

The main motivation for our paper is the observation that, under increasing upstream marginal costs and decreasing downstream marginal revenue, an equilibrium exists under both monopsonistic and monopolistic vertical conduct. This contrasts with two standard settings: (i) the constant-marginal-cost setting assumed in most empirical IO models, where only monopolistic conduct is possible, and (ii) the perfectly-elastic-demand setting of most labor monopsony models, where only monopsonistic conduct is possible.[2] However, in settings with both increasing marginal costs and decreasing marginal revenue, we show that both types of vertical conduct can occur, and vertical distortions can be induced either by the monopsony power of buyers or by the monopoly power of sellers.

We argue that such settings are common and illustrate the application of our model in three contexts: (i) a labor union bargaining with an employers' association, (ii) a sellers' cooperative bargaining with a buyer, and (iii) a manufacturer with increasing marginal costs bargaining with a downstream firm. For each setting, we provide an empirical application that demonstrates how to determine whether the vertical distortions stem from the buyer's monopsony power or the seller's monopoly power.

We begin our analysis by examining monopolistic and monopsonistic bargaining separately. We first show that buyer power has opposite effects on output under the two types of vertical conduct. Under monopolistic bargaining, greater buyer power raises output by reducing the double marginalization problem of Spengler (1950). In contrast, under monopsonistic bargaining, buyer power lowers output due to a different form of double marginalization, in which the buyer marks down input prices in addition to marking up consumer prices (Robinson, 1933).

To understand the distortions arising from these vertical conduct types, we compare them with joint-profit maximization, in which there are no vertical distortions. We show that for a unique interior value of the buyer's bargaining weight $\beta^* \in (0, 1)$, both the monopsonistic and monopolistic equilibria coincide with the joint-profit maximization outcome. This result is intuitive: at β^*, which we call the "bilaterally-efficient bargaining weight," the buyer's monopsony power and the seller's monopoly power exactly offset each other, leading to an outcome without vertical distortions.

[2]Recently, monopsony models have been developed in which downstream residual demand is not perfectly elastic, such as Kroft, Luo, Mogstad, and Setzler (2025), Rubens (2023), and Lobel (2026).

We characterize β^* as a function of the relative disagreement payoffs of buyers and sellers and the relative elasticities of upstream cost and downstream demand, as these govern the extent of downstream monopsony power (cost curve) and upstream monopoly power (demand curve). More inelastic input supply (a steeper marginal cost curve) increases the potential for monopsony power, requiring more seller power (lower β^*) to countervail it. Similarly, less-elastic demand amplifies the scope for double marginalization, necessitating greater buyer power (higher β^*) to countervail seller power.

These results show that vertical distortions can arise under both conduct types with distinct welfare effects, making their source ambiguous. To resolve this, we augment our model by imposing a constraint on the Nash bargaining problem: the seller must earn a nonnegative markup and the buyer a nonnegative markdown. This constraint is reasonable when frictions prevent internal transfers that would allow parties to operate marginal units at a loss (Holmstrom and Tirole, 1991; Scharfstein and Stein, 2000). For example, if the seller is a labor union, a negative markup would require transfers among members to subsidize some workers to accept wages below their reservation levels, a scenario that is implausible. However, in other settings, a party may accept an offer with an unprofitable marginal unit because inframarginal units keep its overall profits positive. For such cases, we introduce an alternative constraint that leads to the same results.

We find that under this assumption, the nature of vertical distortions depends on how the bargaining weight (β) compares to the bilaterally-efficient bargaining weight (β^*). If $\beta < \beta^*$, vertical distortions arise solely from the seller's monopoly power, which can be countervailed by increasing buyer power (i.e., the buyer's disagreement payoff). Conversely, if $\beta > \beta^*$, vertical distortions arise solely from the buyer's monopsony power, which can be countervailed by increasing seller power (i.e., the seller's disagreement payoff). Thus, at any bargaining weight, the vertical distortion arises from a single source. A benefit of this approach is that it compares a policy-invariant primitive, β, to a policy-variant object, β^*, which enables prospective analysis of changes in cost/demand curves and disagreement payoffs, for instance in response to horizontal mergers.

Beyond such prospective analysis, this result also delivers an empirical criterion for identifying vertical conduct ex post. We show that estimates of the cost and demand curves, combined with transacted input prices—but no data on quantities—suffice to determine whether vertical distortions stem from monopsony or monopoly power. The criterion compares the transacted input price to the input price that would lead to the bilaterally-efficient quantity under linear contracting. Input prices below the threshold imply a monopsony distortion, whereas input prices above the threshold imply a monopoly distortion. Because the threshold depends only on the estimated cost and demand curves, the criterion requires neither estimating bargaining weights nor specifying disagreement payoffs. If transacted quantities are observed in addition to input prices, the nonnegative markup/markdown constraint can be tested.

Turning to the applications of our model, we first use it to analyze how prospective changes in market structure and the contracting environment affect market outcomes. One example is the competitive effect of mergers. We show that increased buyer power from horizontal mergers between buyers can either counteract or reinforce losses in consumer surplus from increased market power in the downstream market, depending on the nature of vertical conduct. Thus, our model reconciles prior analyses of buyer power in merger control, where it is argued to be pro-competitive in Nevo (2014), Craig, Grennan, and Swanson (2021), and Sheu and Taragin (2021) but anti-competitive in Hemphill and Rose (2018) and Berger, Hasenzagl, Herkenhoff, Mongey, and Posner (2025). Similarly, the model can be used to bound the welfare effects of vertical integration.

Another type of prospective analysis involves understanding the effects of moving from posted to negotiated prices, for instance due to unionization. On the one hand, negotiation can countervail buyer power (Dodini, Salvanes, and Willén, 2022); on the other hand, it can induce double marginalization due to increased seller power. We show that the bilaterally-efficient bargaining weight β^* serves as a sufficient statistic to understand these potential benefits and costs of switching from posted to negotiated prices. We illustrate this point by using prior elasticity estimates to compute β^* in three markets—U.S. construction, Brazilian labor markets, and Chinese tobacco—and argue that the welfare tradeoff between price-posting and negotiation differs substantially across these settings.

Second, we apply our empirical criterion to identify the source of vertical distortions in coal procurement by power plants in the Texas ERCOT market from 2005 to 2014. Detailed cost data from coal mines and power plants, alongside transacted coal and electricity prices, make this an ideal setting to estimate both cost *and* demand curves. Following Asker, Collard-Wexler, and De Loecker (2019), we estimate coal mining cost curves from unit-level production and cost data. Following Puller (2007), we estimate residual electricity demand and power plant marginal costs. Using these estimates, we identify the conduct of each mining firm–power firm pair as monopsonistic or monopolistic, and find that 58.7% of the vertical distortion in the market comes from the monopoly power of mining firms, and the remaining 41.3% is due to the monopsony power of power firms.

Before turning to the related literature, we note two caveats. First, this paper focuses on the static effects of buyer and seller power while remaining agnostic about potential dynamic effects, such as those relating to innovation or investment incentives, which may be critical for welfare (Inderst and Shaffer, 2007; Inderst and Wey, 2007; Parra and Marshall, 2024). Second, we do not take a stand on how to weigh the surpluses of buyers and sellers; rather, we examine how buyer and seller power affect total and consumer surplus.

Contribution to the Literature First, this paper contributes to the literature on Nash-in-Nash bargaining models under bilateral monopoly/oligopoly (Horn and Wolinsky, 1988; Collard-Wexler et al., 2019). These models have been applied in labor to analyze wage bargaining (Manning, 1987; Abowd and Lemieux, 1993; Hosken, Larson-Koester, and Taragin, 2025; Angerhofer et al., 2026), in IO to study firm-to-firm bargaining (Crawford and Yurukoglu, 2012; Grennan, 2013; Gowrisankaran et al., 2015; Crawford, Lee, Whinston, and Yurukoglu, 2018; Ho and Lee, 2019; Cuesta, Noton, and Vatter, 2025), and in international trade to study importer-exporter bargaining (Atkin, Blaum, Fajgelbaum, and Ospital, 2024; Alviarez, Fioretti, Kikkawa, and Morlacco, 2026). In these models, equilibrium lies on the input demand curve, implying that vertical distortions are due to seller power.[3,4]

Second, a distinct literature studies monopsony power in vertical relations in which equilibrium lies on the input supply curve, rather than the input demand curve. In these models, the downstream party sets input prices while facing an upward-sloping input supply (Card et al., 2018; Azar, Berry, and Marinescu, 2022; Berger et al., 2022; Lamadon et al., 2022; Rubens, 2023; Decarolis and Rovigatti, 2021).[5] A recent literature has introduced monopsony power into Nash-in-Nash bargaining models, including Angerhofer et al. (2026), which is the closest empirical paper to ours, Azkarate-Askasua and Zerecero (2025), and Rubens (2025).

We contribute to these two literatures by introducing a unified framework in which we are agnostic about the source of vertical distortions (whether equilibrium lies on the input demand or supply curve), and by developing an empirical method to identify whether the vertical distortions are due to upstream monopoly or downstream monopsony power. In doing so, we also relate our results to Atkin et al. (2024), which tests monopsonistic versus monopolistic conduct when buyers or sellers make take-it-or-leave-it offers, which are corner cases of our model.

Third, we contribute to the literature on countervailing power (e.g., Galbraith, 1954; Horn and Wolinsky, 1988; Snyder, 1996; Iozzi and Valletti, 2014; Loertscher and Marx, 2022; Toxvaerd, 2024), for which empirical evidence was documented by Gowrisankaran

[3] In the labor literature, equilibrium on the labor demand curve is usually obtained through employers' "right to manage", which is typically assumed in wage bargaining settings except under efficient bargaining between unions and employers, as in McDonald and Solow (1981).

[4] A distinct class of incomplete-information bargaining models (Loertscher and Marx, 2022; Larsen and Zhang, 2026) yields similar countervailing-power results, as shown by Loertscher and Marx (2026). A key benefit of that approach is that it naturally rationalizes linear price contracts.

[5] These are the "neoclassical" monopsony models, as opposed to the "dynamic" monopsony models in the search-and-matching tradition (Manning, 2003).

et al. (2015), Barrette, Gowrisankaran, and Town (2022) and Dodini et al. (2022). We advance this literature by identifying the conditions under which buyer power is countervailing or distortionary.[6] In contemporaneous and complementary research, Avignon, Chambolle, Guigue, and Molina (2026) derive similar results in a bargaining model where the supplier also has monopsony power, giving rise to a novel "double markdownization" phenomenon. Our model differs in allowing nonzero disagreement payoffs and accommodating both simultaneous and sequential timing. Moreover, we take vertical conduct as exogenous rather than an equilibrium outcome and implement our model empirically.

Fourth, our paper relates to the literature that analyzes bilateral bargaining when suppliers face non-constant marginal costs. Previous work in this literature has examined the effects of buyer size (Chipty and Snyder, 1999), supplier incentives (Inderst and Wey, 2007), and supplier uncertainty (Smith and Thanassoulis, 2012) under different cost function assumptions. More recently, Mukherjee and Sinha (2024) analyze the effects of vertical mergers on output when the supplier's cost function is convex. We contribute to this literature by analyzing the different vertical distortions within a unified framework.

Finally, our paper contributes to the literature on imperfect competition in energy markets (Cicala, 2015; Asker et al., 2019; Hortaçsu, Luco, Puller, and Zhu, 2019; Jha, 2022; Preonas, 2023; Gowrisankaran, Langer, and Zhang, 2024) by studying the sources of market power in this industry.

The paper proceeds as follows. In Section 2, we set up our model. Section 3 analyzes the welfare effects of buyer power while taking vertical conduct as given. Section 4 develops tools to determine the source of vertical distortions empirically. In Section 5, we use our model for prospective analysis of vertical distortions in antitrust and collective bargaining. Section 6 presents an empirical application in which we identify the sources of vertical distortions from data. Section 7 concludes. All proofs are given in the Online Appendix.

2 Model Setup

2.1 Costs, Demand, and Payoffs

We consider a vertical market in which a set of upstream parties $\mathcal{U}$ ("suppliers") supplies a homogeneous input to a set of downstream parties $\mathcal{D}$ ("buyers"). For a given supplier–buyer trade (U, D), the supplier sells a quantity q_{ud} at an input price w_{ud} using a linear pricing contract. We assume for simplicity that the buyer resells this good directly to consumers without incurring additional costs. Online Appendix E relaxes this assumption by providing an extension that allows downstream production to use multiple inputs.

[6]See Toxvaerd (2024) for a review of results in this literature.

Each buyer D faces a residual inverse demand curve $P_d(Q_d)$, with weakly decreasing marginal revenue, and each supplier U has an average cost curve $C_u(Q_u)$, with weakly increasing marginal cost. The parties' profits are

$$\Pi^d\left(w_{ud}, q_{ud}; \boldsymbol{w}_d^{-u}, \boldsymbol{q}_d^{-u}\right) = P_d\left(Q_d^{-u} + q_{ud}\right)\left(Q_d^{-u} + q_{ud}\right) - \sum_j w_{jd}\, q_{jd},$$
$$\Pi^u\left(w_{ud}, q_{ud}; \boldsymbol{w}_u^{-d}, \boldsymbol{q}_u^{-d}\right) = \sum_k w_{uk}\, q_{uk} - C_u\left(Q_u^{-d} + q_{ud}\right)\left(Q_u^{-d} + q_{ud}\right),$$

where Q_d^{-u} and Q_u^{-d} denote D's purchases from suppliers other than U and U's sales to buyers other than D. The vectors $(\boldsymbol{w}_d^{-u}, \boldsymbol{q}_d^{-u})$ and $(\boldsymbol{w}_u^{-d}, \boldsymbol{q}_u^{-d})$ collect the prices and quantities of the parties' trades with their other partners.

U and D bargain over the input price w_{ud} to maximize a Nash product with respective bargaining weights $(1 - \beta_{ud})$ and β_{ud}, and the quantity q_{ud} is determined by either the input demand or supply curve as described later:

$$\max_{w_{ud}} \left(\Pi^d\left(w_{ud}, q_{ud}; \boldsymbol{w}_d^{-u}, \boldsymbol{q}_d^{-u}\right) - \Pi_{0,ud}^d\right)^{\beta_{ud}} \left(\Pi^u\left(w_{ud}, q_{ud}; \boldsymbol{w}_u^{-d}, \boldsymbol{q}_u^{-d}\right) - \Pi_{0,ud}^u\right)^{1-\beta_{ud}},$$

where $\Pi_{0,ud}^d$ and $\Pi_{0,ud}^u$ denote the disagreement profits of D and U if bargaining breaks down. In line with the Nash-in-Nash bargaining solution concept (Horn and Wolinsky, 1988), we impose a passive-beliefs assumption, meaning that when negotiating, both U and D treat the agreements reached with all other partners, $(\boldsymbol{w}_d^{-u}, \boldsymbol{q}_d^{-u})$ and $(\boldsymbol{w}_u^{-d}, \boldsymbol{q}_u^{-d})$, as fixed. Using this assumption, D's profit can be written as a function of the pair's own trade (w_{ud}, q_{ud}), conditional on the other outcomes:

$$\Pi^d\left(w_{ud}, q_{ud}; \boldsymbol{w}_d^{-u}, \boldsymbol{q}_d^{-u}\right) = \left(p_{ud}(q_{ud}) - w_{ud}\right)q_{ud} + K_{ud}^d, \tag{1}$$

where $p_{ud}(q)$ is D's average incremental revenue from the q units after conditioning on its trades with all other suppliers, and K_{ud}^d is a pair-specific constant.[7] Analogously, U's profit equals

$$\Pi^u\left(w_{ud}, q_{ud}; \boldsymbol{w}_u^{-d}, \boldsymbol{q}_u^{-d}\right) = \left(w_{ud} - c_{ud}(q_{ud})\right)q_{ud} + K_{ud}^u, \tag{2}$$

where $c_{ud}(q)$ is U's average cost of producing the q units after conditioning on its trades with all other buyers. Because the constants appear in both the agreement and the

[7] To see this, define $p_{ud}(q) \equiv \left[P_d(Q_d^{-u} + q)(Q_d^{-u} + q) - P_d(Q_d^{-u})\, Q_d^{-u}\right]/q$, the average incremental revenue of the q units given D's other deals. Substituting $Q_d = Q_d^{-u} + q_{ud}$ into Π^d gives $\Pi^d = \left(p_{ud}(q_{ud}) - w_{ud}\right)q_{ud} + K_{ud}^d$ with $K_{ud}^d \equiv P_d(Q_d^{-u})\, Q_d^{-u} - \sum_{j \neq u} w_{jd}\, q_{jd}$. Decreasing marginal revenue in the primitive demand curve carries over to the residual curve: $p_{ud}(q) = \frac{1}{q}\int_0^q MR_d(Q_d^{-u} + s)\, ds$ is a running average of marginal revenue, so decreasing marginal revenue implies $p'_{ud}(q) \le 0$. The cost side is symmetric.

disagreement payoffs, they cancel out, and in the remainder of the paper we work with the pair-specific profit functions $\pi^d_{ud}(w,q) \equiv \big(p_{ud}(q) - w\big)q$ and $\pi^u_{ud}(w,q) \equiv \big(w - c_{ud}(q)\big)q$ and the corresponding disagreement payoffs $\pi^d_{0,ud}$ and $\pi^u_{0,ud}$.[8] Moreover, since each bilateral negotiation is analyzed independently, we drop the ud subscripts and write w, q, β, $p(q)$, $c(q)$, π^d, π^u, π^d_0, and π^u_0 for the pair under consideration. See Online Appendix D.1 for the formal derivations of these results.

2.2 Monopsonistic vs. Monopolistic Bargaining

Our main analysis contrasts two alternative behavioral models of vertical conduct. In the first model, the parties bargain over the input price, and the transacted quantity lies on the input supply curve ($mc(q) = w$), meaning that the input price is equal to U's marginal cost $mc(q) \equiv d(c(q)q)/dq$:

$$(w^{ms}, q^{ms}) = \begin{cases} \arg\max\limits_{w} \, [(\pi^d(w,q) - \pi^d_0)^{\beta}(\pi^u(w,q) - \pi^u_0)^{1-\beta}] & (3) \\ w = mc(q) & (4) \end{cases}$$

We call this first bargaining model "monopsonistic bargaining" because the input quantity is pinned down by the input supply curve, implying that the buyer needs to pay a higher price to raise the input quantity, which is the standard definition of monopsony power (Manning, 2003). Monopsonistic bargaining nests the classical monopsony model of Robinson (1933) as a special case when the buyer has the entire bargaining weight ($\beta = 1$). It does not, however, nest the successive monopoly model of Spengler (1950) at $\beta = 0$, which further motivates the "monopsonistic" label.

In the second type, the parties again bargain over the input price, but this time the transacted quantity lies on the input demand curve ($mr(q) = w$), meaning that the input price is equal to D's marginal revenue product, $mr(q) \equiv d(p(q)q)/dq$:

$$(w^{mp}, q^{mp}) = \begin{cases} \arg\max\limits_{w} \, [(\pi^d(w,q) - \pi^d_0)^{\beta}(\pi^u(w,q) - \pi^u_0)^{1-\beta}] \\ w = mr(q) \end{cases} \tag{5}$$

We call this second bargaining model "monopolistic bargaining" because the input quantity is pinned down by the buyer's input demand curve, implying that the supplier raises the price it obtains by lowering the quantity it sells, which is the standard notion of upstream market power in vertical chains. This model nests Spengler (1950)'s successive monopoly model as a special case when the seller has the entire bargaining weight ($\beta = 0$).

[8] The pair-specific constant K^d_{ud} in D's profit, $\Pi^d = \pi^d_{ud}(w_{ud}, q_{ud}) + K^d_{ud}$, also appears in D's disagreement profit: upon disagreement, the other agreements are unchanged under passive beliefs, so $\Pi^d_{0,ud} = K^d_{ud} + \pi^d_{0,ud}$, where $\pi^d_{0,ud}$ is any additional payoff D obtains upon disagreement. Hence K^d_{ud} cancels from the Nash product.

We assume that there are gains from trade under both types of conduct, ensuring that a solution exists in each case (see Assumption OA-1).[9]

Whether the input demand or input supply curve binds depends on the underlying model of firm behavior and on the contracting environment. For instance, in a firm-to-firm application, quantity determination by the buyer implies monopolistic conduct, whereas quantity determination by the supplier implies monopsonistic conduct.[10] We discuss examples of these conduct types, and the other environments in which either the input supply or the input demand curve binds, in Section 2.3.

Timing Assumptions

We consider two versions of our model that differ in timing. In both versions, U and D first observe the primitives: $c(\cdot)$, $p(\cdot)$, β, disagreement payoffs, and vertical conduct. Then, the parties negotiate and quantities are determined. The two timing assumptions differ in whether bargaining and the quantity outcome occur simultaneously or sequentially.

Definition 1 (Simultaneous Bargaining)**.** *The quantity is determined simultaneously with bargaining over the input price.*

Definition 2 (Sequential Bargaining)**.** *The parties first bargain over an input price, after which the quantity is determined.*

Both timing assumptions are widely used in the literature. The simultaneous model appears in Ho and Lee (2017) and Crawford et al. (2018), while the sequential model is used in Crawford and Yurukoglu (2012) and in several right-to-manage union bargaining models (Oswald, 1982; Nickell and Andrews, 1983; Abowd and Lemieux, 1993).

Assuming that the second-order conditions hold, the solution to the bargaining problem in Equation (3) is characterized by the following first-order condition (FOC):

$$\beta \frac{d\pi^d(w,q)}{dw}(\pi^u - \pi^u_0) + (1-\beta)\frac{d\pi^u(w,q)}{dw}(\pi^d - \pi^d_0) = 0 \tag{6}$$

for $\beta \in (0,1)$.[11,12] The solution to monopolistic bargaining is given by Equations (5–6), while the solution to monopsonistic bargaining is given by Equations (4) and (6). Under

[9] We further assume that the profit functions π^d and π^u are strictly log-concave in q under each conduct model. This guarantees that the second-order conditions of the bargaining problem hold and that the bargaining solution is unique (Online Appendix B.2).

[10] A quantity choice $\max_q \pi^d$ leads to $w = mr(q)$, whereas $\max_q \pi^u$ leads to $w = mc(q)$.

[11] Online Appendix B.1 and Supplemental Material S.2 present the closed-form expressions of these FOCs for the sequential and simultaneous versions of the model, respectively. The FOCs characterize the solution only for $\beta \in (0,1)$. At the corner cases $\beta \in \{0,1\}$, these models are instead solved as constrained optimization problems, as the participation constraints become binding. Online Appendix D.2 analyzes these cases.

[12] The second-order condition for the bargaining first-order condition is presented in Online Appendix B.2 for

simultaneous timing, Equation (6) simplifies to $\beta(\pi^u - \pi_0^u) = (1-\beta)(\pi^d - \pi_0^d)$, whereas under sequential timing, the parties additionally internalize how the input price w affects the output quantity ($dq/dw \neq 0$). We present the results under sequential timing in the main text and report the corresponding results under simultaneous timing in the Supplemental Material.[13]

2.3 Discussion and Empirical Examples

Our paper differs from the recent empirical IO literature by allowing for an upward-sloping supply curve. An upward-sloping supply curve is necessary for vertical distortions from monopsony power to be well-defined, since otherwise the supplier would supply an arbitrarily large quantity whenever the input price exceeds constant marginal cost. We argue that allowing for an upward-sloping supply curve is important because this feature characterizes many vertical environments. We highlight three such environments below.

Example 1. ***Unions:*** *Labor unions with heterogeneous reservation wages.*

A long tradition of research studies wage bargaining and labor unions (Ashenfelter and Johnson, 1969; Card, 1986; Abowd and Lemieux, 1993; Azkarate-Askasua and Zerecero, 2025; Angerhofer et al., 2026). In this literature, the supplier U is a labor union bargaining over wages w with an employers' association (or individual employer) D, and residual labor supply is upward sloping due to heterogeneity in workers' reservation wages. Monopsonistic conduct in this setting corresponds to a market in which workers whose reservation wages lie below the negotiated wage supply their labor, whereas those with higher reservation wages do not. Therefore, employment is pinned down by the labor supply curve. On the other hand, monopolistic conduct occurs if employers have the right to manage and can ration labor, meaning that some workers would want to work at the negotiated wage but are turned down by employers. In this case, employment is pinned down by the labor demand curve instead. Both conduct types appear in the literature; for example, Angerhofer et al. (2026) study union wage bargaining and allow for both conduct types. We discuss the union application in more detail in the context of U.S. construction workers in Section 5.

Example 2. ***Cooperatives:*** *Cooperatives of suppliers with heterogeneous marginal costs.*

sequential timing and in the Supplemental Material for simultaneous timing. This second-order condition is always satisfied under simultaneous timing, while under sequential timing it holds whenever the profit functions are strictly log-concave in q (Online Appendix B.2).

[13] We present results under a single timing assumption because each timing assumption requires a separate derivation, and presenting both would substantially lengthen the exposition. We adopt sequential timing as the baseline because it nests the classical models of Spengler (1950) and Robinson (1933), it is more commonly used in the empirical literature, and it is more tractable.

When the supplier U is a cooperative bargaining with a buyer on behalf of its member producers, the supply curve slopes upward due to heterogeneity in producers' costs. Agricultural cooperatives, which are prevalent in both the U.S. and developing countries, are an example of this structure (Cook, 1995; Ito, Bao, and Su, 2012). Monopsonistic conduct in this setting occurs when a cooperative and a buyer negotiate an input price, and farmers whose costs are below that price produce and sell to the buyer.[14] If, on the other hand, buyers determine the quantity purchased, monopolistic conduct would apply. We illustrate this setting in Section 5 in the context of Chinese tobacco markets.

Example 3. ***Firm-Level Decreasing Returns to Scale:*** *Individual suppliers with increasing marginal costs at the firm level.*

In Examples 1–2, the aggregation of atomistic production units generates an upward-sloping supply curve for the supplier. Individual firms can also face an upward-sloping supply curve due to decreasing returns to scale, or because they operate multiple plants with heterogeneous costs. Monopsonistic conduct in this setting corresponds to "output contracts" (Weistart, 1973), which are common in energy markets. It also arises under resale price maintenance, where the supplier constrains the downstream price and thereby (indirectly) controls the quantity sold to consumers.[15] Monopolistic conduct, on the other hand, occurs if input quantities are chosen by the buyer to maximize its profits given the input price w. In our application to coal markets in Section 6, we discuss how some contracts reflect monopsonistic conduct, whereas others reflect monopolistic conduct.

2.4 Conceptualizing "Buyer Power"

In our model, two key parameters govern how surplus is divided between the buyer and the supplier. The first is the bargaining weight β, which directly shapes the split of the surplus and is micro-founded in Collard-Wexler et al. (2019). The second is the relative disagreement payoffs, π_0^d and π_0^u, which determine each party's bargaining leverage: a higher π_0^d strengthens the buyer's position, while a higher π_0^u strengthens the supplier's.

Therefore, the term "buyer power" can be conceptualized both as the relative bargaining strength of the buyer (Grennan, 2013; Craig et al., 2021; Avignon et al., 2026) and as the relative disagreement payoff of the buyer (Ho and Lee, 2017; Hemphill and Rose, 2018).[16] In the remainder of our theoretical analysis, we present results for both measures

[14] For an example of this type of contract, see Peace River Seed Co-operative and Proseeds Marketing Inc., where Proseeds agreed to buy Peace River's entire two-year grass-seed output at a fixed price.

[15] Examples of output contracts are certain types of power purchase agreements in which the buyer purchases all the output of a power plant; see, for example, GreenLife Solar and Shine Partners Agreement and County of Santa Clara PPA.

[16] Similarly, "seller power" is either the bargaining strength of the seller or its relative disagreement payoff.

of buyer power unless specified otherwise. However, when we discuss applications of our model, we mostly treat the bargaining weight β as a policy-invariant primitive and the disagreement payoffs as policy-variant.

2.5 Sources of Market Power in Vertical Relations

To quantify the distortions due to market power in the vertical chain, we consider joint profit maximization as a benchmark, which can be achieved through a two-part tariff or vertical integration. The quantity q^* that solves this problem is simply the quantity at which upstream marginal cost equals downstream marginal revenue: $mc(q^*) = mr(q^*)$.[17]

We define "vertical distortion" as the extent to which the quantity realized through the linear contract is below the joint-profit maximizing quantity q^*. This distortion arises if there is a wedge between $mc(q)$ and $mr(q)$. Since we do not take a stance on whether conduct is monopsonistic or monopolistic, this wedge can arise from two sources in our model: a seller markup and a buyer markdown. As usual, we define the markup as the wedge between the input price w and the seller's marginal cost, and the markdown as the wedge between the buyer's marginal revenue and the input price (Syverson, 2025):

$$\text{Seller Markup: } \mu^u(w, q) \equiv \frac{w - mc(q)}{mc(q)}, \qquad \text{Buyer Markdown: } \Delta^d(w, q) \equiv \frac{mr(q) - w}{mr(q)}.$$

Under monopolistic bargaining, the distortion arises from the upstream markup (since the markdown is zero, $mr(q) = w$), whereas under monopsonistic bargaining, it arises from the downstream markdown (since the markup is zero, $mc(q) = w$). Throughout the paper, we distinguish these vertical distortions by referring to the seller markup as "upstream monopoly power" and the buyer markdown as "downstream monopsony power." Note that a downstream markup set by the buyer over its marginal costs also reflects market power. This markup is distinct from the vertical distortion, given that it exists independently of vertical conduct, and is also present under joint-profit maximization.

Linear Price Contracts vs. Two-Part Tariffs

One might question why firms use a linear price contract instead of a two-part tariff, which would yield a higher joint profit. We remain agnostic about firms' motivations for using linear pricing and instead focus on analyzing vertical distortions that arise from linear contracts. Linear contracts are well documented across industries and are commonly used to model vertical relationships in the literature; see Cussen (2025) for a review. That

[17]We assume that such a quantity exists; that is, marginal revenue and marginal cost cross at a finite and unique output level.

said, in one of our results, we provide conditions under which at least one firm unilaterally finds a linear price contract more profitable than a two-part tariff (with fixed β), offering a rationale for linear pricing within the context of our model (Section 4.3).

3 Effects of Buyer Power: Monopsonistic vs. Monopolistic Conduct

We begin our analysis by examining the existence of the monopsonistic and monopolistic equilibria. We then characterize the effects of buyer power on output, consumer surplus, and total surplus separately under monopsonistic and monopolistic bargaining. In the next section, we unify both forms of conduct and jointly analyze them.

3.1 Existence of Monopsonistic and Monopolistic Conduct

We establish the existence of equilibrium in monopsonistic and monopolistic bargaining by highlighting two special cases: constant marginal cost and constant marginal revenue.

Proposition 1.

(i) *If the upstream marginal cost is constant, $mc'(q) = 0$, the monopsonistic bargaining problem does not have an interior solution for any β.*

(ii) *If the downstream marginal revenue is constant, $mr'(q) = 0$, the monopolistic bargaining problem does not have an interior solution for any β.*

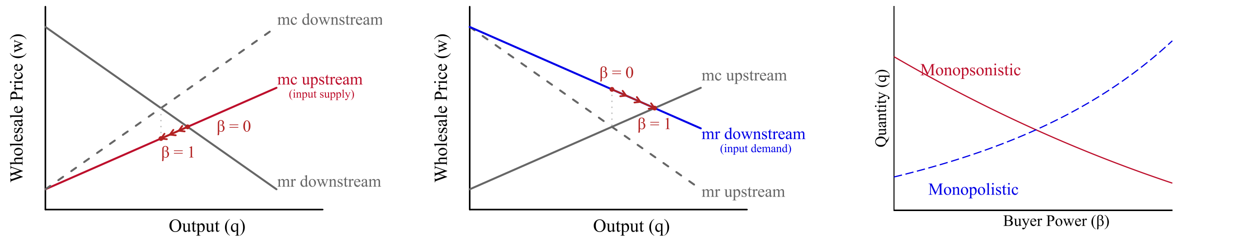
(iii) *If $mc'(q) > 0$ and $mr'(q) < 0$, both the monopsonistic and monopolistic bargaining problems have an interior solution for $\beta \in (0, 1)$.*

The intuition behind Proposition 1(i)–(ii) is straightforward. Under constant upstream marginal costs, input supply is perfectly elastic, implying infinite or no input supply, so only monopolistic bargaining is well-defined (as in much of the IO literature).[18] Similarly, if marginal revenue is constant, input demand is perfectly elastic, implying infinite or no input demand, so only monopsonistic bargaining is well-defined (as in the classical monopsony literature). Yet, as shown in Proposition 1(iii), either conduct admits an interior equilibrium when upstream marginal costs are increasing and downstream marginal revenue is decreasing. Such settings, illustrated in Examples 1–3, have received growing attention as monopsony power has been integrated into IO models (see reviews by Card, 2022; Azar and Marinescu, 2024). This motivates our unified approach.[19]

[18] When the input price equals marginal cost, the supplied quantity is indeterminate, and the supplier earns zero profit at any of these quantities.

[19] In light of Proposition 1, we assume for the remainder of this section that $mc'(q) > 0$ when analyzing monopsonistic bargaining and $mr'(q) < 0$ when analyzing monopolistic bargaining to ensure that the solutions are well-defined.

Figure 1: Illustration of the Effects of Buyer Power on Output



(a) Monopsonistic Conduct **(b)** Monopolistic Conduct **(c)** Buyer Power vs. Output

Notes: Panels (a) and (b) show the equilibrium in the input market as the buyer's bargaining weight β increases, moving along the input supply curve under monopsonistic conduct (Panel a) and along the input demand curve under monopolistic conduct (Panel b). Panel (c) presents numerical simulation results using cost curve $c(q) = q^{\psi}/(1+\psi)$ and demand curve $p(q) = q^{1/\eta}$ with parameter values $\psi = 1/4$ and $\eta = -6$. For equilibrium derivations, see Online Appendix D.5.

3.2 Output and Buyer Power

We now characterize the relationship between equilibrium output q and buyer power under both monopsonistic and monopolistic bargaining.

Theorem 1.

(i) *Under monopsonistic bargaining, the output quantity q decreases with the buyer's bargaining weight (β) and the buyer's disagreement payoff (π_0^d), and increases with the supplier's disagreement payoff (π_0^u).*

(ii) *Under monopolistic bargaining, the output quantity q increases with the buyer's bargaining weight (β) and the buyer's disagreement payoff (π_0^d), and decreases with the supplier's disagreement payoff (π_0^u).*[20]

Theorem 1 reveals a key distinction between the two types of vertical conduct. An increase in buyer power reduces output under monopsonistic bargaining, but increases it under monopolistic bargaining. Figure 1 illustrates the intuition behind this result. In monopsonistic bargaining, the equilibrium is on the input supply curve. An increase in buyer power, be it through the buyer's bargaining weight or through its disagreement payoff, leads to a movement along this input supply curve by lowering the input price. This, in turn, reduces output. In monopolistic bargaining, by contrast, equilibrium lies on the input *demand* curve. Consequently, an increase in either β or π_0^d induces a movement along this input demand curve, increasing output.

[20]The comparative statics with respect to the disagreement payoffs hold for $\beta \in (0,1)$; at the corner values $\beta \in \{0,1\}$, the equilibrium quantity does not vary with one or both disagreement payoffs (Online Appendix D.2). The monotonicity in β extends to the corner values.

While similar theoretical insights have appeared in the literature under parametric assumptions or for a single conduct type (e.g., Chen, 2003; Aghadadashli, Dertwinkel-Kalt, and Wey, 2016; Mukherjee and Sinha, 2024; Toxvaerd, 2024), our results provide, to the best of our knowledge, the first nonparametric treatment of this problem in a unified framework with nonzero disagreement payoffs, and under both simultaneous and sequential timing.

3.3 Distinguishing between "Buyer Power" and "Monopsony Power"

In the literature, the terms *buyer power* and *monopsony power* are often used interchangeably. Our results clarify the distinction between these two concepts.

Corollary 1.

(i) Under monopolistic bargaining, the downstream markdown Δ^d is always zero, so even if the buyer has buyer power, it does not induce a monopsony distortion. In this case, buyer power is countervailing because it reduces the upstream markup μ^u.

(ii) Under monopsonistic bargaining, the upstream markup μ^u is always zero, so even if the seller has seller power, it does not induce a monopoly distortion. In this case, seller power is countervailing because it reduces the downstream markdown Δ^d.

Even when the buyer's bargaining weight is nonzero ($\beta > 0$) under monopolistic bargaining, the buyer markdown is always zero, because the marginal revenue equals the input price. Hence, although there is "buyer power" that can affect input prices, there is no monopsony distortion. Similarly, under monopsonistic bargaining, even when the seller has positive bargaining weight ($\beta < 1$), the seller markup is always zero, because the upstream marginal cost equals the input price. Hence, there is no distortion from monopoly power of the seller. As a result, downstream monopsony power arises only when increased *buyer* power reduces output, whereas upstream monopoly power arises only when increased *seller* power reduces output. In all other cases, buyer and seller power are countervailing.[21,22]

3.4 Characterization of the Bilaterally-Efficient Bargaining Weight

Having established how output depends on buyer power under each vertical conduct type, we turn to the implications of buyer power for bilateral joint surplus, consumer

[21]See Chen (2008) for a review of the various definitions of buyer power in the literature.

[22]While buyer power under monopolistic conduct and seller power under monopsonistic conduct raise output, they do so at the expense of the other party's profit. This redistribution could have adverse dynamic consequences, such as on investment and entry incentives. Such effects are outside the scope of our analysis.

surplus, and total surplus. We begin by characterizing when the equilibrium under each conduct reaches the joint-profit maximizing output.

Proposition 2. *Under the assumption that disagreement payoffs are sufficiently low, there exists a unique bargaining weight, which we term the "bilaterally-efficient bargaining weight",*

$$\beta^* = \frac{-p'(q^*)(q^*)^2 - \pi_0^d}{\big(c'(q^*) - p'(q^*)\big)(q^*)^2 - (\pi_0^u + \pi_0^d)} \in (0,1)$$

such that the equilibrium output from both the monopsonistic and monopolistic bargaining models corresponds to the joint-profit maximizing output. With zero disagreement payoffs, this expression simplifies to $\beta^* = \dfrac{-p'(q^*)}{c'(q^*) - p'(q^*)}$.

β^* is the level of buyer power at which the buyer's monopsony power and the seller's monopoly power exactly offset one another.[23] The intuition for why the *same* β^* applies to both conduct models is that at q^* the change in quantity induced by the input price has no first-order effect on the surplus split. Under either conduct model, the envelope theorem makes the quantity-setter's *own* profit insensitive to the induced change in quantity, while joint-surplus maximization ($mr(q^*) = mc(q^*)$) does the same for the other party's profit. Both bargaining FOCs therefore reduce to the same surplus-sharing condition, $\beta\,(\pi^u - \pi_0^u) = (1-\beta)\,(\pi^d - \pi_0^d)$, and since profits at q^* are identical under both models, β^* is the same.

The bilaterally-efficient bargaining weight β^* relates to the slopes of the cost and demand curves and to the disagreement payoffs in an intuitive way, as shown in the following corollary.

Corollary 2.

(i) *β^* weakly decreases as the upstream cost curve becomes steeper ($c'(q^*)$ increases) and weakly increases as the downstream inverse demand curve becomes steeper ($-p'(q^*)$ increases).*

(ii) *β^* decreases with the downstream disagreement payoff ($\partial\beta^*/\partial\pi_0^d < 0$) and increases with the upstream disagreement payoff ($\partial\beta^*/\partial\pi_0^u > 0$).*

A steeper upstream cost curve or a larger downstream disagreement payoff raises the potential monopsony distortion. Counterbalancing this effect requires greater seller bargaining power, that is, a lower β^*. Similarly, steeper downstream demand or a larger

[23] Proposition 2 has some similarity to the condition in Hosios (1990), which states that the worker's bargaining share must align with the ease of finding a job relative to the difficulty of filling a vacancy. Rather than balancing congestion and market thickness externalities as in Hosios (1990), the bilaterally-efficient bargaining weight balances markup and markdown distortions in our model.

upstream disagreement payoff amplifies the potential distortion from upstream market power, and counterbalancing it requires greater buyer bargaining power. As a result, if input supply becomes perfectly inelastic ($c'(q) \to \infty$), the joint-profit maximizing quantity is reached with full seller power ($\beta^* = 0$), whereas if demand becomes perfectly inelastic ($-p'(q) \to \infty$), it is reached with full buyer power ($\beta^* = 1$).

Two remarks about Proposition 2 are worth noting. First, if disagreement payoffs are sufficiently high—that is, if $\pi^d(w^*, q^*) < \pi_0^d$ or $\pi^u(w^*, q^*) < \pi_0^u$, where $w^* \equiv mc(q^*) = mr(q^*)$ is the input price at q^*—the linear price contract cannot achieve q^*, because at q^* either the buyer's or seller's profit is below its disagreement payoff. In such cases, one of the corners, $\beta = 0$ or $\beta = 1$, yields the equilibrium output closest to q^*, and the same corner applies under both conduct types ($\beta = 0$ when $\pi^d(w^*, q^*) < \pi_0^d$, and $\beta = 1$ when $\pi^u(w^*, q^*) < \pi_0^u$). For the remainder of the paper, if the linear contract cannot attain q^*, we define β^* as the corresponding corner value.

Second, β^* is a function of the cost and demand curves and the disagreement payoffs, all of which are policy-variant objects that change with the economic environment. This makes β^* useful for analyzing policy questions such as mergers and unionization, as we will see in Section 5. Alternatively, one could characterize the disagreement payoffs that achieve bilateral efficiency as a function of β, but this formulation does not enjoy the same advantages, as β is often considered a policy-invariant primitive.[24]

3.5 Consumer and Total Surplus

In this section, we ask which level of buyer power maximizes consumer and total surplus. Let $q(\beta)$ denote the equilibrium output at bargaining weight β under the conduct model in question. Since consumer surplus is increasing in output,[25] it is maximized at the output-maximizing bargaining weight:

Proposition 3. *Consumer surplus is maximized at full buyer power ($\beta = 1$) under monopolistic bargaining and at full seller power ($\beta = 0$) under monopsonistic bargaining.*

A notable implication of our results is that equilibrium output under linear contracting can exceed the joint-profit maximizing output (q^*), meaning that consumer surplus could be higher under linear contracting than under a two-part tariff or vertical integration. As shown in Figure 1(c), this happens when $\beta < \beta^*$ in the monopsonistic model and when $\beta > \beta^*$ in the monopolistic model. This outcome arises because, in these regions, either

[24] Moreover, since there are two disagreement payoff parameters, this alternative does not reduce to a single sufficient statistic.

[25] Holding the buyer's other trades and any downstream rivals' quantities fixed, consumer surplus in D's market is strictly increasing in $q(\beta)$; see Online Appendix Lemma OA-7.

the upstream markup or the downstream markdown becomes negative, resulting in lower downstream prices than those implied by joint-profit maximization.

We next turn to total surplus, the area between downstream demand and upstream marginal cost up to the equilibrium quantity, conditional on the parties' other trades:

Proposition 4. *Under monopolistic bargaining, total surplus is maximized at some $\beta^\dagger$ in the range $\beta^* \leq \beta^\dagger \leq 1$, whereas under monopsonistic bargaining it is maximized at $\beta = 0$.*

Proposition 4 shows that, unlike in the constant marginal cost case, total surplus is not necessarily maximized at full buyer power under monopolistic bargaining. The reason is that with increasing marginal costs, full buyer power can lead to socially inefficient overproduction. Strong buyer power pushes the input price far below the supplier's marginal cost and expands output along the input demand curve. Output can rise so far that the downstream price falls below the supplier's marginal cost, even though the supplier still earns nonnegative profits on its inframarginal units. In contrast, under monopsonistic bargaining, total surplus is maximized with full seller power. In that scenario, the seller makes a take-it-or-leave-it offer to the buyer, driving the buyer down to its disagreement payoff. This yields the highest output under monopsonistic conduct, while input prices equal marginal cost, so there is no socially inefficient overproduction.

4 Determining Vertical Distortions

In Section 3 we showed that under general conditions, vertical distortions can arise from either monopsonistic or monopolistic bargaining, and that buyer power has opposite welfare effects across these two models of vertical conduct. These results are useful for understanding the impact of buyer power when conduct is known, for example, from the institutional setting or by estimating conduct using historical data. However, in many cases, vertical conduct is either not known ex ante or not easily estimable. In this section, we augment our model to analyze vertical distortions in those cases and develop ways to identify the sources of vertical distortions.

In the augmented model, parties bargain subject to the constraint that the markup and markdown be nonnegative. With this constraint, we show that, at any given bargaining weight, vertical distortions can arise from either monopoly *or* monopsony, but not both. This result has two main uses. First, it enables prospective analysis of the effects of changes in buyer or seller power when conduct is ex ante unknown, as we illustrate in Section 5. Second, it allows us to identify the sources of vertical distortions from data using observed input prices, without observing quantities or estimating a full bargaining model. We illustrate this case in Section 6.

4.1 Augmented Bargaining Model

We impose nonnegative markup/markdown constraints directly in the bargaining problem.

Constraint 1 (Nonnegative Markup/Markdown Constraint)**.** *The parties bargain over w subject to the constraint that the equilibrium markup and markdown are nonnegative. Under each conduct model, the constrained bargaining problem is:*

$$\textit{Monopolistic:} \quad \begin{cases} \max_{w} \ \left(\pi^d - \pi_0^d\right)^{\beta} \left(\pi^u - \pi_0^u\right)^{1-\beta} \quad s.t. \quad w \geq mc(q) \\ w = mr(q) \end{cases}$$

$$\textit{Monopsonistic:} \quad \begin{cases} \max_{w} \ \left(\pi^d - \pi_0^d\right)^{\beta} \left(\pi^u - \pi_0^u\right)^{1-\beta} \quad s.t. \quad w \leq mr(q) \\ w = mc(q) \end{cases}$$

These constraints require that the marginal production unit be profitable for each party: the supplier's marginal cost must not exceed the input price ($w \geq mc(q)$), and the buyer's marginal revenue must not fall below the input price ($w \leq mr(q)$). They are motivated by the fact that a violation would require internal transfers: the loss on the marginal unit needs to be covered by shifting surplus from the inframarginal units, which is not always possible, as we discuss below. By imposing the constraints directly in the bargaining problem, we allow both parties to internalize the constraint when negotiating rather than imposing it ex post.

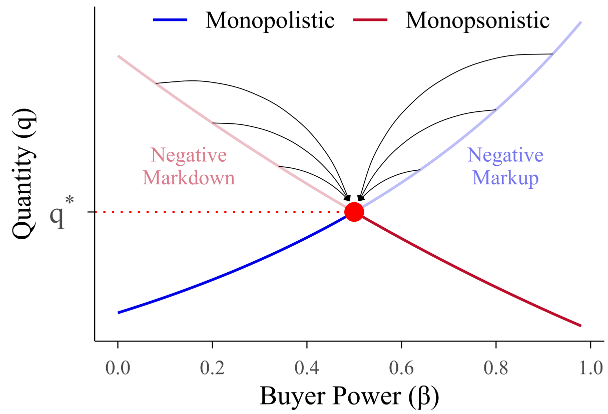
The following theorem shows that under Constraint 1, a vertical distortion exists at any given $\beta \neq \beta^*$ under exactly one of the two conduct models:

Theorem 2. *Under the nonnegative markup/markdown constraint, at any $\beta \in [0,1]$, the vertical distortion exists only under monopolistic conduct if $\beta < \beta^*$ and under monopsonistic conduct if $\beta > \beta^*$.*

The intuition, depicted in Figure 2, is as follows.[26] Under monopolistic bargaining, the upstream markup μ^u decreases in β. For $\beta \leq \beta^*$, the unconstrained solution gives $\mu^u \geq 0$, as shown in Section 3, so the constraint is slack and the standard outcome prevails. For $\beta > \beta^*$, the unconstrained solution implies $\mu^u < 0$, so the constraint $w \geq mc(q)$ binds. Because the quantity lies on the input demand curve ($mr(q) = w$), this forces $q = q^*$ and $w = w^*$, where $w^* \equiv mc(q^*) = mr(q^*)$ is the input price at the joint-profit maximizing quantity. The argument for monopsonistic bargaining is symmetric: the downstream

[26]We formally characterize the constrained equilibria in Online Appendix C.8.

Figure 2: Determining Vertical Distortions



Notes: This figure illustrates the relationship between buyer power (β) and output (q) in bargaining models under the nonnegative markup/markdown constraint, using numerical simulation under the design in Figure 1(c). Solid lines show the constrained equilibrium under each conduct model. The faint lines show the corresponding unconstrained equilibrium over the range where the markup would be negative (monopolistic, $\beta > \beta^*$) or the markdown would be negative (monopsonistic, $\beta < \beta^*$); the arrows indicate the constraint pulling these branches down to the joint-profit maximizing quantity q^*, marked by the red dot and the dotted horizontal line.

markdown Δ^d increases in β, so the constraint $w \leq mr(q)$ binds only for $\beta < \beta^*$, yielding $q = q^*$ and $w = w^*$.[27] Thus, for every $\beta \neq \beta^*$, the two conduct models generate distinct equilibrium outcomes: one model yields an unconstrained equilibrium, with a distortion, while the other, when it exists, coincides with the joint-profit maximizing outcome.

Discussion of the Nonnegative Markup/Markdown Constraint

Even with negative markups or markdowns, both parties can still earn positive profits from trade through their inframarginal units; a negative markup or markdown means the marginal unit operates at a loss. The constraint is therefore most plausible in settings where such internal transfers are not feasible. One example is when the trading party represents a collection of agents who cannot efficiently transfer surplus among themselves. For instance, in the labor union context (Example 1), it is unrealistic for a union to tax some members' wages in order to compensate others for accepting wages below their reservation wage. Moreover, even within a single organization, fairness considerations, organizational constraints, or agency problems can prevent internal transfers (Kahneman, Knetsch, and Thaler, 1986; Holmstrom and Tirole, 1991; Scharfstein and Stein, 2000).

The equilibrium under the nonnegative markup/markdown constraint also has some

[27] As noted before, if $\pi^d(w^*, q^*) < \pi_0^d$ or $\pi^u(w^*, q^*) < \pi_0^u$, the linear contract cannot reach the joint-profit maximizing solution. In this case, the monopolistic equilibrium does not exist for $\beta > \beta^*$ whereas the monopsonistic equilibrium does not exist for $\beta < \beta^*$ (see Online Appendix C.8). This is consistent with Theorem 2: in these ranges the conduct model is not constrained to q^* but instead fails to exist, so the vertical distortion still has a unique source at every β.

desirable properties. First, when supply or demand comes from atomistic agents, the constraint implies an equilibrium with excess supply (rationing) instead of excess demand (involuntary supply). For example, in a teachers' union negotiation with a school district, this corresponds to the equilibrium being pushed onto the labor supply curve rather than forcing teachers to work below their reservation wages, as assumed in Angerhofer et al. (2026). Second, it generates output at or below the joint-profit maximizing level, implying, for example, that vertical integration never increases vertical distortions (absent foreclosure concerns). Third, the constraint has a testable implication (Corollary 3), which we test in our empirical application in Section 6.

Of course, the nonnegative markup/markdown constraint is not always reasonable. For example, a multi-establishment firm (Example 3) could operate its marginal units at a loss, especially if there are sunk investments or dynamic incentives. To address these cases, we develop an alternative assumption that pins down the source of vertical distortions without the markup/markdown constraint, which we describe in Section 4.3.

4.2 Empirical Analysis of Vertical Distortions

We now turn to how the preceding result can be implemented empirically to examine the nature of vertical distortions.

We start by considering settings in which transacted input prices (w) are observed, but transacted quantities (q) are not. This is relevant in settings such as collective bargaining by labor unions or cooperatives, in which wages and input prices are observable in the centrally negotiated contracts, whereas employment and quantity flows are much harder to measure (Angerhofer et al., 2026). Later in this section, we turn to settings in which both input prices and quantities are observed.

We find that imposing the nonnegative markup/markdown constraint allows us to identify the sources of vertical distortions by comparing the observed input price w to the input price that yields the joint-profit maximizing solution under linear contracting, $w^* = mc(q^*) = mr(q^*)$:

Proposition 5. *Under the nonnegative markup/markdown constraint:*

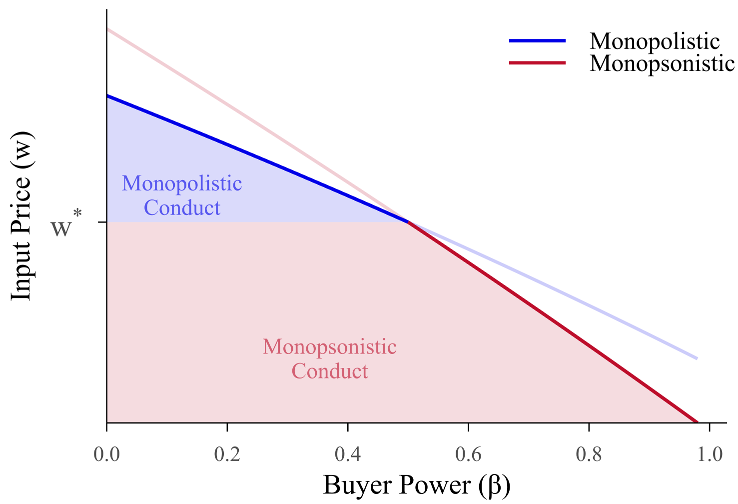
(i) *Under monopolistic bargaining, the equilibrium input price satisfies $w \geq w^*$.*

(ii) *Under monopsonistic bargaining, the equilibrium input price satisfies $w \leq w^*$.*

Therefore, vertical conduct is identified by the sign of $w - w^*$.

Figure 3 illustrates Proposition 5: w^* separates the two conduct regions. Input prices above w^* are consistent only with monopolistic conduct, while input prices below w^*

Figure 3: Conduct Identification via the Input Price



Notes: This figure illustrates Proposition 5. The boundary between the shaded regions marks w^*. Under monopolistic bargaining, $w \geq w^*$, while under monopsonistic bargaining, $w \leq w^*$. The shaded regions indicate the range of input prices consistent with each conduct model.

are consistent only with monopsonistic conduct. The reason input prices are useful for conduct identification, whereas quantities are not, follows from Theorem 2, which shows that the vertical distortion exists only under monopolistic conduct when $\beta < \beta^*$ and only under monopsonistic conduct when $\beta > \beta^*$. Since the input price is monotone in β under both types of conduct, w^* separates the price space into two regions, each corresponding to one type of vertical distortion. This is not true for q: because q moves in opposite directions with buyer power across the two conduct models (Theorem 1), a given equilibrium output is generally consistent with both conduct types, at different bargaining weights.

A key practical advantage is that w^* depends only on cost and demand primitives: $w^* = mc(q^*) = mr(q^*)$, where q^* is the unique solution to $mc(q) = mr(q)$. Neither object depends on the bargaining weight β or on the disagreement payoffs π_0^d and π_0^u. Thus, identifying vertical conduct using input prices does not require estimating a bargaining model. This matters in practice, because estimating bargaining weights requires rich data, and disagreement payoffs require assumptions on what firms do off the equilibrium path.

While w is sufficient to identify conduct, q is still useful for testing the nonnegative markup/markdown constraint.

Corollary 3. *Under the nonnegative markup/markdown constraint, equilibrium output is bounded above by the joint-profit maximizing quantity: $q \leq q^*$.*

This follows directly from Theorem 2, which implies that the equilibrium quantity is always at or below the joint-profit maximizing quantity. The nonnegative markup/markdown constraint can thus be tested empirically by checking whether observed quantities lie at or below the joint-profit maximizing quantity. We implement this test in our main empirical application in Section 6 and provide further details there.

4.3 Discussion and Extensions

Alternative Assumption to Determine Vertical Distortions

For settings in which the nonnegative markup/markdown constraint is not reasonable, we provide another extension of our model that allows us to determine the source of vertical distortions. In Online Appendix E.2, we augment our bargaining model by introducing the possibility that firms negotiate over a two-part tariff instead of over a linear input price contract, if doing so is incentive-compatible. We show that, holding the primitives (β, $c(q)$, $p(q)$) fixed, when a party is granted the right to choose between a linear price contract and a two-part tariff, it prefers a linear price contract for some values of β and a two-part tariff for others. In both cases, the resulting equilibrium quantity (and hence the vertical distortion) coincides with the solution implied by the nonnegative markup/markdown constraint, which gives an alternative assumption under which our results hold.

Other Ways to Empirically Identify Vertical Distortions

While we developed our results under the assumption that conduct is not known ex ante, if one has historical data on prices and quantities, conduct can also be identified directly by testing whether the observed prices and quantities lie on the input supply or the input demand curve. This test, however, requires an instrument that moves the equilibrium but is excluded from both the input supply and the input demand curve, so that the observed price–quantity pairs reveal which of the two curves the equilibrium lies on.[28] Imposing the nonnegative markup/markdown constraint is therefore useful when such an instrument is unavailable or when conducting prospective analysis.

5 Prospective Analysis: Antitrust and Collective Bargaining

In this section, we use our model for prospective analysis of changes in market structure and in the contracting environment. In Section 5.1, we examine the competitive effects of horizontal and vertical mergers in negotiated vertical markets. In Section 5.2, we ask whether labor unions and supplier cooperatives countervail monopsony power or induce double marginalization. Finally, in Section 5.3, we examine the effects of policies that limit strikes.

[28]Such instruments are often difficult to find; Atkin et al. (2024) provide an example, exploiting discretionary import restrictions as quantity shifters excluded from both curves.

5.1 Antitrust Policy

Horizontal Mergers

Our results are relevant for understanding the effects of horizontal mergers between buyers on consumer and total surplus. Such mergers decrease the relative disagreement payoffs of the sellers, as each seller loses one outside option ($\pi_0^u \downarrow$). One could also let the merger alter β, as in Grennan (2013), which has similar effects to changing disagreement payoffs, as shown in our model.

First, we discuss the case in which vertical conduct is known. Under monopolistic conduct, the decrease in the seller's disagreement payoff decreases the vertical distortion, as it reduces the supplier's markup. This can potentially counteract losses in consumer surplus from the merger's effect on downstream market power, echoing the "countervailing" merger defense in Grennan (2013), Nevo (2014), and Sheu and Taragin (2021). In contrast, under monopsonistic conduct, the decrease in the seller's disagreement payoff *increases* the vertical distortion, thereby lowering output. According to our analysis, it is also possible that an increase in buyer power harms total surplus while increasing consumer surplus. This can occur because, under monopolistic conduct, the increase in buyer power can induce the downstream price to fall below the supplier's marginal cost, leading to socially inefficient overproduction (Proposition 4).

Second, if vertical conduct is unknown, the effects of the merger on vertical distortions are ambiguous, as is clear from the discussion above. In this case, determining the welfare effects of horizontal mergers requires identifying vertical conduct from the data. Our empirical analysis in Section 6 shows that this can be accomplished by an antitrust authority with limited data and without knowledge of disagreement payoffs or bargaining weights.

Vertical Mergers

Our model can also help quantify the potential competitive gains from the elimination of double marginalization in vertical mergers (Chipty, 2001; Crawford et al., 2018; Luco and Marshall, 2020; Cuesta et al., 2025). The conventional view is that vertical integration eliminates double marginalization (if any), thereby potentially increasing consumer surplus. Our model shows that this is not necessarily true when marginal costs are increasing and marginal revenue is decreasing. As shown in Section 3, if the markup or the markdown is negative before the merger, the equilibrium output is larger than the joint-profit-maximizing output q^*, whereas vertical integration leads to the lower output q^*. This implies that vertical integration could reduce output in the vertical chain even in the absence of foreclosure incentives.[29]

5.2 Collective Bargaining

A second natural application of our model is to study collective wage bargaining institutions, as described in Example 1. With growing empirical evidence of monopsony power in labor markets (Card et al., 2018; Berger et al., 2022; Lamadon et al., 2022; Yeh, Macaluso, and Hershbein, 2022), a key question is whether labor unions can effectively countervail this power (Azkarate-Askasua and Zerecero, 2025; Angerhofer et al., 2026) or induce double marginalization instead.

We consider the effects of introducing collective wage bargaining, as opposed to wage-posting by employers. When employers unilaterally post wages that atomistic, price-taking workers take as given, this corresponds to $\beta = 1$ under monopsonistic conduct. If employees were instead allowed to unionize, thereby bargaining over wages collectively rather than individually, then the employer would presumably have less than full buyer power ($\beta < 1$), and conduct could be either monopsonistic or monopolistic. What effect would this have on vertical distortions if we remain agnostic about counterfactual vertical conduct?

Our analysis in Section 3 shows that, without further assumptions, the answer is ambiguous. Under our nonnegative markdown and markup constraint, however, one can use β^* to assess the likely welfare effect.[30] If counterfactual conduct is monopsonistic, output increases as β decreases from 1 to β^*, and is flat from β^* to 0. In contrast, if counterfactual conduct is monopolistic, output is flat from 1 to β^* and decreases from β^* to 0. Therefore, the higher β^*, the smaller the potential welfare gains from introducing collective bargaining by a union, and the larger the potential welfare costs.

To illustrate this point, we have collected residual input supply and demand elasticities for three settings that prior work has studied as cases of "pure" monopsony, that is, in which employers or buyers unilaterally set input prices. First, we collect labor supply and goods demand elasticities for U.S. construction workers from Kroft et al. (2025). Second, we collect labor supply and goods demand elasticities for Brazilian labor markets from Lobel (2026). Third, we consider the possible introduction of seller cooperatives, as discussed in Example 2, in the context of Chinese tobacco farmers selling to cigarette manufacturers, using supply elasticities from Rubens (2023). All parameters used are reported in Table 1, and Online Appendix F provides detailed documentation of these empirical applications.

[29] Of course, other effects of vertical integration besides the elimination of double marginalization need to be taken into account as well, such as potential foreclosure, which we abstract from in our analysis.

[30] We derive this in Online Appendix D.5.

Table 1: Parameters for Empirical Illustrations

Industry	Sources	ψ	η	β^*
U.S. construction workers	Kroft et al. (2025)	0.29	-7.30	0.42
Brazilian labor markets	Lobel (2026)	0.24	-1.43	0.92
Chinese tobacco farmers	Rubens (2023) Ciliberto and Kuminoff (2010)	1.90	-1.14	0.92

Notes: This table reports parameters for the inverse price elasticity of supply, ψ, and the own-price elasticity of residual downstream demand, η, as estimated in the referenced studies, for each empirical application. The final column shows the implied bilaterally-efficient bargaining weight, β^*, computed from the parameters using the loglinear approximation derived in Online Appendix D.5.

Using these cost and demand elasticities, we calculate the bilaterally-efficient bargaining weight β^* in these three settings by setting disagreement payoffs to zero, which in the labor settings implies that, in the event of a strike, employees earn nothing and the firm shuts down. For U.S. construction workers, we find $\beta^* = 0.42$. This estimate suggests that collective wage bargaining requires careful consideration as a means to counteract monopsony power. If the resulting labor union has a bargaining weight above $1 - \beta^* = 0.58$ and the equilibrium is on the labor demand curve, there would be a monopoly distortion as the union would create double marginalization. Our compilation of bargaining weights from the union literature in Table OA-3 and Figure OA-3 suggests that this scenario is plausible: union bargaining power exceeds the $1 - \beta^*$ threshold (0.58) in roughly half of the reviewed studies.

In the Brazilian setting, $\beta^* = 0.92$ is much higher, indicating that relative to the U.S., unions there are more likely to induce monopoly distortions and less likely to countervail monopsony distortions. Similarly, in the tobacco farmers' case, we find a high $\beta^* = 0.92$ despite a very inelastic farmer supply, again indicating that double marginalization from a cooperative is more likely to induce distortions than monopsony.[31] Therefore, unless the cooperative's bargaining power is extremely low—which prior estimates reported in Table OA-3 do not support—any vertical distortions under negotiated leaf prices would be due to double marginalization by a farmers' cooperative rather than to monopsony power of the manufacturers.

5.3 Effects of Strike Prohibitions

Having discussed changes in the wage-formation process, we now turn to changes in the disagreement payoffs of unions and employers. In some industries, although wages are collectively bargained by a union, the union is prohibited from going on strike. Such

[31]However, there are other inefficiencies from monopsony power, such as misallocation (Rubens, 2023).

clauses exist, for instance, for U.S.-based airline pilots, flight attendants, and air-traffic controllers. Our model speaks to the effects of lifting such clauses on both consumer and total surplus. Given that strikes hurt employers disproportionately more than employees (a pilot strike costs pilots their daily wage throughout the strike, but can cause millions of dollars in losses to the carrier), lifting strike prohibitions decreases the relative disagreement payoff of employers, $\pi_0^d \downarrow$. Under the nonnegative markup/markdown constraint, the potential effect of such a decrease in buyer power depends, again, on the labor supply elasticity of pilots relative to the demand elasticity for airline tickets. The more inelastic airline demand is, the more likely it is that lifting strike prohibitions would lead to double marginalization. On the other hand, the more inelastic the labor supply is, the more likely it is that lifting strike prohibitions would countervail monopsony distortions.

6 Quantifying Vertical Distortions: Coal Procurement

The previous section applied the model prospectively to changes in the contracting environment and in market structure. This section turns to an ex post analysis of a single vertical market, coal procurement by Texas power plants from mining firms, in which we decompose the vertical distortions into monopsony and monopoly components.

To this end, we implement the empirical strategy outlined in Section 4.2. A key advantage of this approach is that conduct identification requires only the observed input price w and the price w^* that yields the joint-profit maximizing quantity q^* under linear contracting. The latter object depends solely on cost and demand primitives and not on the bargaining weights or disagreement payoffs. We therefore do not need to estimate a full bargaining model, which would require modeling the outside options of both coal mines and power plants. The cost of this parsimony is that we cannot simulate counterfactual policies, which would require both the disagreement payoffs and the bargaining weights.

Our empirical setting is coal procurement by power plants in the ERCOT (Electric Reliability Council of Texas) market. Electricity markets, and ERCOT in particular, provide several advantages for studying vertical distortions (Hortaçsu and Puller, 2008; Hortaçsu et al., 2019): (i) detailed transaction-level data are available, including prices, quantities, and coal characteristics, along with detailed production and cost data for both power plants and coal mines; (ii) the majority of power plants are deregulated, which makes an oligopoly model of the downstream market appropriate; and (iii) ERCOT operates independently, without inter-regional trade.

In our analysis, we model mining costs by estimating individual mine marginal costs and then aggregating them to the firm level. For estimating residual electricity demand, we closely follow the seminal works in the literature (Borenstein and Bushnell, 1999;

Borenstein, Bushnell, and Wolak, 2002; Puller, 2007). We model coal transactions between all power plants operating in ERCOT and their coal suppliers, which may be located within or outside the ERCOT region. We analyze the 10-year period between 2005 and 2014.

6.1 Institutional Details

Coal mining firms extract coal through underground and surface operations, with marginal costs varying across geographic regions and mine types due to differences in geological conditions and local labor markets. Generally, surface mines have lower extraction costs than underground mines. Many mining companies operate multiple mines with different characteristics, leading to increasing marginal costs at the firm level. During our sample period, electricity generation was the primary use of coal in the U.S., accounting for 93.1% of coal consumption in 2010 (Watson, Paduano, Raghuveer, and Thapa, 2010).

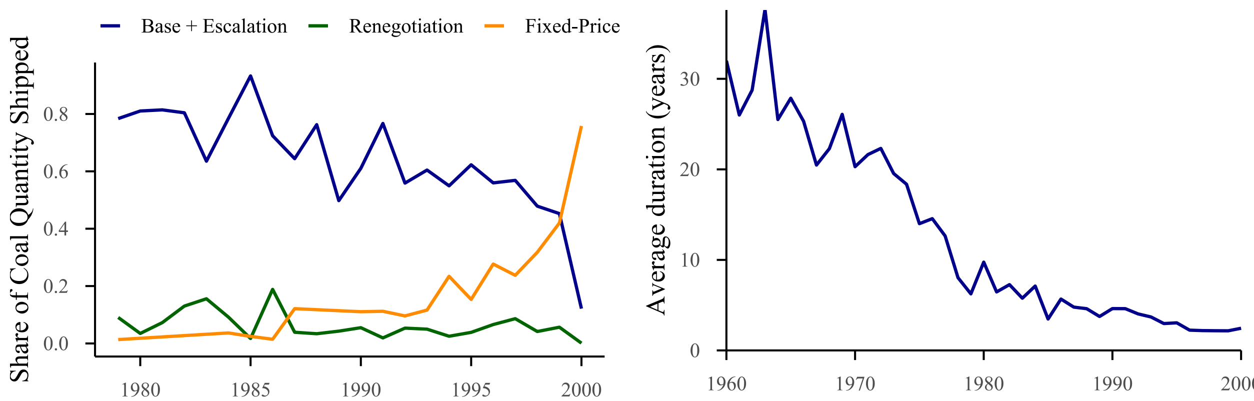
Coal-fired power plants generate electricity by burning coal to produce steam, which drives turbines. The generated electricity is injected into the transmission grid and distributed across the ERCOT region through an organized bidding market. Power plants source most of their coal through contracts, meeting residual needs on the spot market. The bulk of coal is transported from mines to power plants by rail. Additionally, coal quality varies considerably, depending on attributes such as heat content (measured in Btu/lb), sulfur content, and ash levels. Higher heat content directly increases electricity output per ton of coal, whereas sulfur and ash content primarily affect compliance with environmental regulations.

In recent years, coal-fired power plants and coal mines have undergone significant structural changes, with many facilities closing due to stricter emissions regulations and falling natural gas prices driven by the shale gas boom (Davis, Holladay, and Sims, 2022). To isolate our analysis from these confounding factors, we restrict our study to the period 2005–2014, during which coal's share of electricity generation in ERCOT remained relatively stable at 35%–41% (Figure OA-4). This timeframe also largely precedes the substantial wave of mine closures initiated in the early 2010s.[32]

Contract Types and Vertical Conduct The characteristics of the coal procurement market make it an ideal empirical setting to apply our framework. First, empirical evidence supports the widespread use of linear price contracts. While our data do not include contract

[32] We specifically conclude our sample in 2014, when the average capacity factor for coal power plants dropped notably from 89% to 72%. As noted by Gowrisankaran et al. (2024), this decline was largely due to the rise of fracking, resulting in increased cycling and ramping costs and consequently accelerating coal plant retirements. Modeling ramping costs and exit decisions requires a dynamic framework (Borrero, Gowrisankaran, and Langer, 2024), which is beyond the scope of our static model. Thus, we select a period when ramping considerations were less critical and abstract away from these dynamics.

Figure 4: Coal Contract Characteristics by Signing Year



(a) Contract Type by Signing Year

(b) Avg. Contract Duration by Signing Year

Notes: Data come from the EIA's Coal Transportation Rate Database for 1979–2000, as described in Online Appendix G.1. Panel (a) shows the share of coal quantity shipped by year for each of the three main contract types in the dataset. "Fixed-Price Contracts" are linear price contracts whose price remains constant throughout the contract's duration. Panel (b) presents average contract duration (in years) by signing year. Contracts signed prior to 1979 appear due to their overlap with the data period.

types during the sample period we study, historical data from 1979–2000 suggest that contracts take several forms, including base-price-plus-escalation contracts, market-indexed contracts, cost-plus contracts, and linear price contracts (Kozhevnikova and Lange, 2009). The data indicate that the share of linear price contracts increased from about 1% in 1979 to over 75% by 2000, as shown in Figure 4(a). Assuming this trend was not reversed after 2000, linear price contracts likely represent the majority of contracts in our sample period.

Second, the literature and antitrust enforcers have expressed concerns about both monopsony and monopoly power in this industry, and existing contracts do not necessarily specify whether the equilibrium lies on the input demand or supply curve. For example, the FTC flagged the market power of coal mines when challenging the proposed joint venture between Peabody Energy and Arch Coal (Federal Trade Commission, 2020), whereas several empirical studies document monopsony power exercised by utility firms (Atkinson and Kerkvliet, 1986, 1989; Wilson, O'Boyle, and Lehr, 2020; Kellogg and Reguant, 2021).[33] Consistent with this, publicly available contracts suggest that both conduct types are possible in this industry: "requirements" contracts allow downstream firms to determine quantities at a given linear price, whereas "take-or-pay" contracts set quantities at signing and require the buyer to accept the specified volume (Baruya, 2015).[34]

It is also worth discussing the hold-up problem and coal specificity in this industry,

[33]For other examples of concerns about monopsony power, see Pacific Power (2023) and Neuburger (2024).

[34]For an example of a requirements contract, see Coal Supply Agreement Mill Creek, and for an example of a take-or-pay contract, see Armstrong Energy Inc. Contract #598018. In these take-or-pay contracts, the available information typically does not specify which party makes the quantity decision.

studied by Joskow (1985, 1987, 1988) in a series of seminal papers. Since the 1980s, coal markets have undergone significant changes that reduced asset specificity due to technological and regulatory reforms. For example, the adoption of scrubbers has made coal more homogeneous for power plants, mitigating hold-up concerns (Kacker, 2014). Environmental regulations and railroad transportation reforms have further diminished supplier specificity by incentivizing boiler upgrades and expanding access to diverse coal markets (Ellerman, Joskow, Schmalensee, Montero, and Bailey, 2000).[35] Together, these developments reduced reliance on long-term contracts: the average contract duration fell from over 30 years in the 1960s to around 2 years by 2000, as shown in Figure 4(b).

6.2 Data Sources and Summary Statistics

Our analysis combines data from five sources: Velocity Suite, CostMine, the Bureau of Labor Statistics (BLS), the Mine Safety and Health Administration (MSHA), and the Coal Transportation Rate Database of the Energy Information Administration (EIA). We describe these data sources in Online Appendix G.1 and provide an overview below.

Our coal mine data come from multiple sources. We use datasets from MSHA, which include quarterly data on production and employment as well as technical characteristics of mines, such as openings and vein thickness. Mine ownership details are sourced from Velocity Suite. Mine-level cost data, including detailed operating and capital expenses, come from the 2019 Coal Cost Guide published by CostMine Intelligence, which has been used in the mining engineering literature (Shafiee and Topal, 2012) and other academic studies (World Bank, 2017). This guide classifies costs by mine characteristics, such as mining technology, daily capacity, and vein thickness. For wage information, we use the BLS Quarterly Census of Employment and Wages, which we average annually at the state level and convert to hourly wages.

Power plant characteristics, costs, and generation data are compiled from Velocity Suite, which integrates information from various public sources such as EIA, EPA, NERC, and proprietary research. The datasets include detailed monthly generator characteristics, hourly generation and emissions data from the EPA's Continuous Emissions Monitoring System (CEMS), EIA-923, ERCOT hourly load data, and ERCOT's 60-Day SCED Disclosure Reports. Lastly, coal transaction data are sourced from Velocity Suite, which combines information on transaction details, prices, transportation costs, and contractual arrange-

[35] The 1990 Clean Air Act Amendment led power plants to adopt technologies accommodating lower-sulfur coal, increasing their fuel flexibility (Ellerman et al., 2000). Supporting this observation, Kacker (2014) finds that during Phase I of the Amendment, plants required to switch technology were more likely to adopt shorter-term and fixed-price contracts than unaffected plants. Moreover, the 1980 Railroad Reform expanded the coal market for power plants by reducing transportation costs.

Table 2: Summary Statistics

	Upstream	Downstream
	Panel A. Firm Characteristics	
Number of units (mine or generator)	25	19
Number of firms	9	2
Avg. number of units per firm	2.49	8.80
Avg. number of trade partners	22.15	2.55
Avg. share of largest partner	0.42	0.53
	Panel B. Transaction Characteristics	
Avg. FOB price (USD per MMBtu)	-	0.84
Avg. Contract duration (years)	-	1.33
Share of spot-market transactions	-	0.02

Notes: This table presents summary statistics for the sample used in our analysis. Panel A reports the characteristics of mining firms (upstream) and power firms (downstream), whereas Panel B provides information on transaction details. The average number of units per firm is the number of distinct mines (upstream) or generators (downstream) active in a year, averaged over firm-years. The sample includes all mining firms supplying coal to ERCOT power plants and all power firms operating coal-fired plants in ERCOT between 2005 and 2014.

ments, primarily based on EIA-923 forms supplemented with railroad waybills.

Table 2 presents summary statistics for our empirical sample, which includes all mining firms supplying coal to ERCOT power plants and all electricity-generation firms (power firms) operating coal-fired plants in ERCOT. The sample consists of nine upstream mining firms operating 25 mines and two downstream power firms operating 19 coal-fired generators. Mining firms deal with 22.2 partners on average, including those outside of ERCOT, while power firms engage with an average of 2.55 partners, suggesting that sourcing from multiple trade partners is common. The largest trading partner accounts for about half of a firm's transaction volume, on both sides of the market. We provide the list of upstream and downstream firms in Table OA-2.

Panel B of Table 2 provides summary statistics on transactions. The transactions typically take the form of medium-term contracts, with an average duration of 1.33 years and an average price of $0.84 per MMBtu. Most transactions occur through contracts, with spot market transactions accounting for 2% of total transactions.[36]

6.3 Model Primitives

We begin by estimating the model's primitives: the cost curve of mining firms, the cost curve of power firms, and the residual electricity demand faced by power firms. Although we estimate these objects separately for each year, we omit year subscripts for notational

[36] Although these transactions are labeled as "spot", there is no centralized spot market for coal. Instead, these transactions are still bilateral contracts, but with very short durations.

simplicity. Online Appendix G provides the details of the estimation procedures, and Table OA-1 summarizes the model's notation.

Cost Curve of Mining Firms

Each upstream mining firm u operates a portfolio of n_u mines indexed by i. Each mine has capacity $\bar{q}^c_{iu}$ and a constant marginal cost c_{iu} that is determined by mine characteristics and labor costs.[37] To estimate marginal cost, we first specify the mine production function. Mine i produces q^c_{iu} short tons of coal using l_{iu} labor hours and m_{iu} units of intermediate inputs according to a Leontief production function:

$$q^c_{iu} = \min\{l_{iu}\gamma_{\theta(iu)}, m_{iu}\}\omega_{iu}$$

The Leontief specification imposes perfect complementarity between labor and intermediate inputs, reflecting the limited substitution possibilities in short-run coal production (Byrnes, Färe, Grosskopf, and Knox Lovell, 1988). It has also been applied to other extractive industries, such as oil drilling (Asker et al., 2019). Two key parameters capture technological heterogeneity in the production function: (i) $\gamma_{\theta(iu)}$, which determines the materials-to-labor ratio based on mine type θ (characterized by the combination of capacity bin, vein thickness, and mining technology), and (ii) ω_{iu}, which accounts for mine-specific productivity differences.[38]

Given hourly wages w^l_{iu} and material costs p^m_{iu}, the Leontief production function implies the following marginal cost function:

$$c_{iu} = w^l_{iu}\frac{l_{iu}}{q^c_{iu}}\left(1 + \gamma_{\theta(iu)}\frac{p^m_{iu}}{w^l_{iu}}\right) \quad \text{if} \quad q^c_{iu} \leq \bar{q}^c_{iu}. \tag{7}$$

While we can estimate unit labor costs by multiplying wages (w^l_{iu}) and the mine-level unit labor requirement (l_{iu}/q^c_{iu}), unit material costs are not directly estimable because our data do not include materials expenditures at the mine level. To address this, we use the Coal Cost Guide described above, which provides engineering estimates of both labor and material unit costs for different mine types θ. From these data, we calculate the materials-to-labor cost ratio, equal to $\gamma_{\theta(iu)}(p^m_{iu}/w^l_{iu})$ for mines of type θ, which allows us to recover marginal costs in Equation (7).

Coal's value in electricity generation depends primarily on its heat content (measured

[37]Because the EIA no longer makes its coal mine capacity data available to researchers, we infer capacity from production, defining a mine's capacity in each year as its maximum production up to that year. This approach makes mine capacity time-varying, as it reflects changes in production over time.
[38]The Coal Cost Guide provides 69 different mine types θ, of which 16 occur in our dataset.

in millions of British thermal units, or MMBtu) rather than its weight. To convert between these measures, we define a mine-specific conversion factor λ_{iu}, which equals heat content per short ton for mine i. This factor transforms weight-based quantities into heat-based quantities through $q_{iu} = \lambda_{iu} q^c_{iu}$. The conversion factor λ_{iu} varies by coal type and mining area, representing an important source of heterogeneity across mines. Following this conversion, we express all coal quantities and mine capacities in MMBtu and coal costs per MMBtu for the remainder of the paper.

Using mine marginal costs, we construct firm-level cost curves by ordering each firm's mines from lowest to highest marginal cost and calculating cumulative production cost. Dividing the cumulative cost by output yields the following firm-level average cost curve:

$$C_u(Q, \boldsymbol{c}_u, \bar{\boldsymbol{q}}_u) = \begin{cases} \frac{1}{Q} \sum_{i=1}^{n_u} c_{iu} \max\left\{0, \min\left[\bar{q}_{iu}, Q - \sum_{s=1}^{i-1} \bar{q}_{su}\right]\right\}, & \text{if } 0 < Q \leq \sum_{i=1}^{n_u} \bar{q}_{iu}, \\ \infty, & \text{if } Q > \sum_{i=1}^{n_u} \bar{q}_{iu} \end{cases}$$

where the vector $\boldsymbol{c}_u := \{c_{iu}\}_{i=1}^{n_u}$ is such that $c_{1u} \leq c_{2u} \leq \cdots \leq c_{n_u u}$ and $\bar{\boldsymbol{q}}_u$ is the vector of mine capacities.

Cost Curve of Power Firms

Each downstream power firm d operates a portfolio of n_d generators. Generator j is characterized by a constant marginal cost c_{jd} and a capacity k_{jdt}. The capacity can vary over time due to intermittency in renewable resources across seasons and hours of the day. We therefore define hourly capacity for each hour type t, representing specific combinations of month, hour, and weekend/weekday status.[39]

The marginal cost of a fossil-fuel generator depends on fuel prices and its efficiency, which is measured by the heat rate. We define marginal costs as follows:

$$c_{jd} = \begin{cases} (w_d + \kappa_{jd}) h_{jd} + c^{om}_{jd} & \text{if coal} \\ w^{gas} h_{jd} + c^{om}_{jd} & \text{if gas} \\ 0 & \text{if nuclear or renewable} \end{cases}$$

where h_{jd} represents generator j's heat rate, w^{gas} is the natural gas price common to all gas generators, w_d is firm d's weighted average FOB coal price, and c^{om}_{jd} represents the variable operations and maintenance (O&M) cost. For coal generators, we also add generator j's average transportation cost per MMBtu, κ_{jd}.[40] We assume constant heat rates within a year

[39] For example, 8 a.m. on a weekday in January represents one hour type t in our model. Even though capacity does not vary meaningfully across weekdays and weekends, we include this distinction to capture variation in demand.

[40] We treat transportation costs κ_{jd} as exogenous and do not model railroad firms as separate agents. Railroad

for each generator, calculated as total heat input divided by total electricity generation.[41]

Because of maintenance downtime in fossil-fuel units and intermittency in renewables, nameplate capacity overstates availability. We therefore calculate an "effective" capacity k_{jdt} by multiplying nameplate capacity by a capacity factor. For fossil-fuel units, we use annual, fuel-type-specific factors from the Generating Availability Data System (GADS) maintained by the North American Electric Reliability Corporation (NERC). For nuclear and renewable units, we compute a time-varying factor for each unit as the ratio of average hourly generation in hour type t to nameplate capacity.[42]

Using unit-level capacity and cost data, we construct firm d's cost function in hour type t by ordering all units in ascending order of marginal cost and calculating their cumulative cost. Dividing the cumulative cost by output yields the average cost curve in hour type t:

$$C_{dt}(Q, \boldsymbol{c}_d, \boldsymbol{k}_{dt}) = \begin{cases} \frac{1}{Q}\sum_{j=1}^{n_d} c_{jd} \max\left\{0, \min\left[k_{jdt}, Q - \sum_{s=1}^{j-1} k_{sdt}\right]\right\}, & \text{if } 0 < Q \leq \sum_{j=1}^{n_d} k_{jdt}, \\ \infty, & \text{if } Q > \sum_{j=1}^{n_d} k_{jdt} \end{cases}$$

where $\boldsymbol{c}_d := \{c_{jd}\}_{j=1}^{n_d}$ is the vector of marginal costs ordered such that $c_{1d} \leq c_{2d} \leq \cdots \leq c_{n_d d}$, and $\boldsymbol{k}_{dt}$ is the vector of generator capacities.

Downstream Electricity Demand and Profit

We model competition in the electricity market using a Cournot framework, following the prior literature (Borenstein et al., 2002; Puller, 2007). In this model, regulated firms and small firms (< 5% of total market capacity) act as price takers, while larger firms behave strategically. Although only two power firms operate coal-fired generators, our demand model includes all power firms with generation capacity in ERCOT.[43] Since both demand and capacity fluctuate hourly, we estimate a separate Cournot model for each hour type t. The expected demand curve faced by strategic firms is given by

$$Q_t(P) = \bar{Q}_t^D - Q_t^{\text{fr}}(P),$$

companies could have significant market power in coal procurement (Preonas, 2023). In our model, upstream agents can be interpreted as jointly representing coal firms and railroad operators: if the two bargain efficiently, the upstream entity maximizes their joint profits. Thus, double marginalization attributed to coal firms can alternatively be interpreted as arising from railroad companies' market power.

[41] We calculate the marginal cost using coal prices from the transaction data, transportation costs, and the heat rate. This assumes that coal from different suppliers is blended, so that the generator's fuel cost is the quantity-weighted average price rather than the cost of a specific shipment.

[42] The capacity factors are, on average, 92, 90, 29, and 21% for coal, gas, wind, and solar, respectively. For coal and gas, these are availability-based factors from GADS and thus differ from the realized utilization rates reported earlier (89% to 72% for coal), which also reflect dispatch decisions.

[43] Five strategic and 247 fringe firms are present in our data. In Online Appendix G.6, we present the details of how we implement the Cournot model.

where $\bar{Q}_t^D$ denotes the expected inelastic demand during hour type t, and $Q_t^{\text{fr}}(P)$ denotes the quantity supplied by the competitive fringe firms at a price P. We assume that firms have rational expectations, so $\bar{Q}_t^D$ equals the mean inelastic demand in hour type t.[44] Let $P_t(Q)$ denote the inverse demand curve faced by strategic firms. The profit function of firm d in hour type t is given by

$$\Pi_t^d(Q_{dt}, C_{dt}) = P_t(Q_{-dt} + Q_{dt})Q_{dt} - C_{dt}(Q_{dt})\, Q_{dt},$$

where Q_{-dt} denotes the total production of all strategic firms except firm d, which we hold at its observed level. The annual profit function is obtained by summing hourly profits:

$$\Pi^d(\boldsymbol{Q}_d, C_d) = \sum_t f_t \Pi_t^d(Q_{dt}, C_{dt}). \tag{8}$$

Here, f_t is the number of occurrences of hour type t in a year, $\boldsymbol{Q}_d = \{Q_{dt}\}_{t=1}^T$ is the vector of quantities, and $C_d = \{C_{dt}\}_{t=1}^T$ denotes the set of average cost curves of firm d. Coal enters this profit function through the cost curves C_{dt}: producing Q_{dt} runs the firm's units in ascending order of marginal cost, and the generation of its coal units, converted at their heat rates, gives the coal used.

Upstream Profit

Each mining firm u faces a set of coal buyers $\mathcal{D}_u$, where quantity q_{ud} is traded with each buyer d at price w_{ud}. The mining firm's profit function is the total revenue from these transactions minus the total production cost:

$$\Pi^u(\boldsymbol{w}_u, \boldsymbol{q}_u) = \sum_{d \in \mathcal{D}_u} w_{ud} q_{ud} - C_u\left(\sum_{d \in \mathcal{D}_u} q_{ud}\right)\left(\sum_{d \in \mathcal{D}_u} q_{ud}\right). \tag{9}$$

Here, $\boldsymbol{w}_u$ and $\boldsymbol{q}_u$ represent the vectors of all prices and quantities for firm u. The set $\mathcal{D}_u$ includes buyers outside ERCOT, whose purchases we hold fixed at their observed levels, so that a mining firm's marginal cost is evaluated at its total output.

6.4 Identifying Vertical Conduct

After constructing the cost and demand primitives and firms' profit functions, we next construct the objects required for conduct identification. For this, we use Proposition 5, which requires the joint-profit maximizing quantity q_{ud}^* and the associated input price w_{ud}^*

[44] The realized demand is given by $Q_{\tau t} = \bar{Q}_t^D + \nu_{\tau t}$, where τ is an hour within an hour type t and $\nu_{\tau t}$ is a mean-zero error term. Hence $\bar{Q}_t^D = \mathbb{E}_t[Q_{\tau t}]$, which we estimate by the sample average of realized demand within hour type t.

for each trading pair. To find q^*_{ud}, we first write the gains from trade. If bargaining between u and d breaks down, upstream obtains a disagreement payoff $\Pi^u_{0,ud}$ and downstream obtains $\Pi^d_{0,ud}$. Using the profit functions in Equations (8)–(9), the gains from trade are:

$$\mathrm{GFT}^u_{ud} = \Pi^u(\boldsymbol{w}_u, \boldsymbol{q}_u) - \Pi^u_{0,ud}, \qquad \mathrm{GFT}^d_{ud} = \Pi^d(\boldsymbol{Q}_d, C_d) - \Pi^d_{0,ud}.$$

Since the disagreement payoffs do not depend on q_{ud} by the passive-beliefs assumption, the quantity that maximizes the joint gains from trade also maximizes the sum of profits:

$$q^*_{ud} = \underset{q_{ud}}{\operatorname{argmax}} \left\{\mathrm{GFT}^u_{ud} + \mathrm{GFT}^d_{ud}\right\} = \underset{q_{ud}}{\operatorname{argmax}} \left\{\Pi^u + \Pi^d\right\}. \tag{10}$$

The joint-profit maximizing quantity q^*_{ud} and the associated input price $w^*_{ud} = mc_{ud}(q^*_{ud}) = mr_{ud}(q^*_{ud})$ are the same under both monopsonistic and monopolistic conduct, and depend only on cost and demand primitives, not on the bargaining weights or the disagreement payoffs. By Proposition 5, vertical conduct for each pair-year is identified by comparing the observed coal price to w^*_{ud}: $w_{ud} > w^*_{ud}$ indicates monopolistic conduct and $w_{ud} < w^*_{ud}$ indicates monopsonistic conduct. Although it is not obvious that the non-negative markup/markdown constraint holds in the case of firm-to-firm negotiations, the availability of quantity data allows us to test this constraint, as we discuss further below.

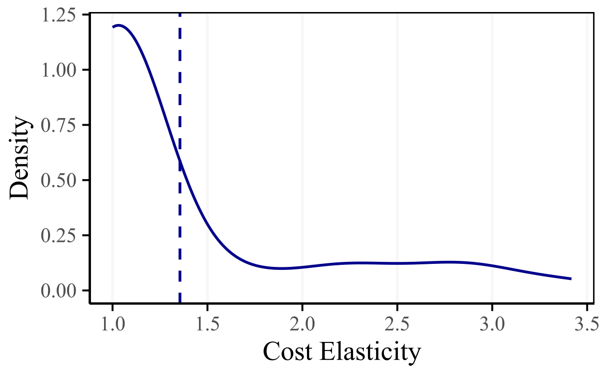
6.5 Estimation

We estimate the model separately for each contracting pair (mining and power firms) by year. The estimation proceeds in two steps: we first estimate the cost and demand primitives, and then use them to compute w^*_{ud} and q^*_{ud} for each pair-year.

To estimate the primitives, we first construct the residual demand curve. We assume total electricity demand is fully inelastic in the short run and compute this demand by averaging observed demand within each hour type. To estimate fringe supply, we derive the marginal cost curve for each fringe firm and aggregate these curves to the industry level. We then assume fringe firms supply quantities in each hour such that the market price equals their marginal cost. Subtracting this fringe supply curve from the inelastic total demand yields the residual industry demand curve faced by strategic firms, which we use in the estimation of the Cournot model.

Using the estimated demand and cost functions, we compute q^*_{ud} for each contracting pair using Equation (10). We then compute w^*_{ud}, the price at which the marginal cost of upstream production (from Equation (9)) equals the marginal revenue of downstream sales (from Equation (8)). We then classify vertical conduct for each pair-year by comparing w^*_{ud} to the actual input price w_{ud}.

Figure 5: Distribution of Cost and Demand Elasticities



(a) Upstream Cost Estimates

(b) Downstream Demand Estimates

Notes: Panel (a) presents a kernel density estimate of the distribution of one plus the elasticity of the marginal cost curve of mining firms. A cost elasticity of one implies constant marginal costs. Panel (b) presents a kernel density estimate of the distribution of the absolute value of the residual elasticity of demand of power firms (the elasticity of $P_t^{-1}(\cdot)$ in our notation). Each observation corresponds to a mining firm-year in Panel (a) and an hour-firm pair in Panel (b). Since cost and demand functions are estimated nonparametrically, we report the elasticities at the observed quantity levels in Panel (a) and Panel (b). The dashed vertical line indicates the average in each panel.

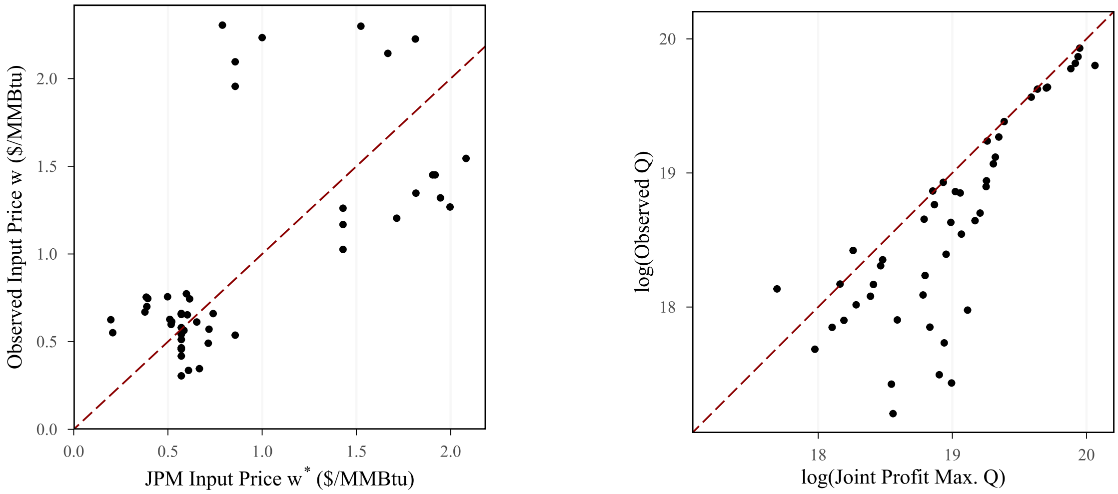
The only source of uncertainty in our model is the inelastic demand curve in the market in a given hour type. To account for this uncertainty, we implement a bootstrap procedure, resampling the demand in each hour within each hour type with replacement. Online Appendix G provides details on the estimation procedure.

6.6 Results: Cost and Demand Elasticity Estimates

Figure 5(a) presents the distribution of estimated cost elasticities by mining-firm-year. The estimates cluster around one, indicating that many firms have approximately constant firm-level marginal costs; however, several firms exhibit elasticities ranging from 1.0 to 2.5. This variation primarily arises from geographic differences. For instance, mines in the Powder River Basin (Wyoming and Montana) are characterized by large-capacity surface operations with relatively flat marginal cost curves, while mines in the Gulf region tend to be smaller underground facilities with more heterogeneous marginal cost structures. We find an average materials-to-labor cost ratio $\gamma_{\theta(iu)}(p^m_{iu}/w^l_{iu})$ of 2.50, which indicates that material costs are on average more than twice as high as labor costs. However, there is large heterogeneity across mines, with this ratio being merely 0.39 at the 10th percentile of mines, but 5.79 at the 90th percentile.

Figure 5(b) presents the distribution of estimated residual demand elasticities, with each observation corresponding to an hour-firm pair. The estimates exhibit considerable variation, though most are concentrated between 2 and 6. This variability primarily arises from changes in the shape of the fringe firms' supply curve across different times of day

Figure 6: Conduct Identification and Model Testing



(a) Observed vs. Bilaterally-Efficient Coal Price **(b)** Observed vs. Bilaterally-Efficient Quantity

Notes: Panel (a) plots w_{ud} against w^*_{ud} for each buyer-seller-year combination. Points above the 45-degree line (dashed red) indicate monopolistic conduct ($w > w^*$), and points below indicate monopsonistic conduct ($w < w^*$). Panel (b) compares the logarithm of observed coal-transaction quantities $\log(q)$ to the logarithm of the joint-profit maximizing quantity $\log(q^*)$. Under the nonnegative markup/markdown constraint, all observations should lie at or below the 45-degree line.

and seasons. Additionally, we estimate the average market-level demand elasticity faced by strategic firms to be -0.85, which is broadly consistent with Puller (2007), who reports an average demand elasticity of -1.24 in the California electricity market.

6.7 Sources of Vertical Distortions

Figure 6(a) plots w_{ud} against w^*_{ud} for each buyer-seller-year combination, classifying vertical conduct following Proposition 5. About half of the observations lie above the 45-degree line ($w_{ud} > w^*_{ud}$), indicating monopolistic conduct in which the mining firm charges a markup, while the remainder lie below it ($w_{ud} < w^*_{ud}$), indicating monopsonistic conduct in which the power firm earns a markdown. That both conduct types appear in roughly equal measure suggests that neither seller nor buyer power alone characterizes coal procurement, motivating our agnostic treatment of the sources of vertical distortions. Moreover, many observations lie far from the 45-degree line, indicating that the vertical distortion is economically meaningful for a large share of transactions.

We also test the nonnegative markup/markdown constraint using Corollary 3, which states that observed output quantities should not exceed the joint-profit maximizing quantity q^*. Figure 6(b) illustrates this comparison, showing observed quantities relative to joint-profit maximizing quantities for each trading relationship. With only a few exceptions, the observed output is lower than the joint-profit maximizing output, lending

Table 3: Decomposing Vertical Distortions

	Estimates
	Panel A. Total Quantity Distortion (%)
Percent Misallocated Quantity	27.36 (0.21)
	Panel B. Distortion Decomposition (%)
Due to Monopsony Power	41.3 (1.64)
Due to Monopoly Power	58.7 (1.64)

Notes: This table reports the reduction in coal quantity relative to the joint-profit maximizing benchmark, expressed as a share of observed purchases, $\sum_{ud}(q^*_{ud} - q_{ud})/\sum_{ud} q_{ud}$, which under inelastic demand is made up by higher-cost fringe generation, and decomposes it into its monopsony and monopoly power components. Numbers in parentheses are bootstrapped standard errors for the percentages, computed as the standard deviation across 250 bootstrap draws.

empirical support to the nonnegative markup/markdown constraint. We test this formally using the moment inequality implied by Corollary 3, $\mathbb{E}[\log(q)] \leq \mathbb{E}[\log(q^*)]$. The sample mean of $\log(q^*) - \log(q)$ is 0.355 (s.e. 0.063), so the inequality holds in the data and a one-sided test does not reject it at any conventional level.

As a model validation exercise, we exploit the fact that our dataset includes transactions between a vertically integrated buyer and seller. We find substantially lower output distortion for the vertically integrated pair than for other pairs (8.30% versus 44.7%), consistent with the prediction that vertical integration reduces vertical distortions.

We now turn to the main quantitative exercise: we use the estimated model to quantify the total vertical distortion and decompose it into components attributable to monopsony power and monopoly power. Since short-run electricity demand is inelastic, market power distortions in electricity markets arise primarily from allocative inefficiency rather than lost output (Borenstein et al., 2002). Specifically, monopoly and monopsony distortions induce strategic firms to produce less than they would in the absence of vertical distortions, shifting production to higher-cost fringe firms. Accordingly, we measure the vertical distortion as the reduction in coal purchased by strategic firms relative to the joint-profit maximizing benchmark, expressed as a share of observed coal purchases.

To decompose the total vertical distortion into monopsony and monopoly components, we first calculate the difference between the observed output and joint-profit maximizing output for each trading pair, separately for trades classified as monopsonistic and monopolistic. This gives us both the total underproduction of strategic firms compared to the joint-profit maximizing benchmark and a decomposition of this amount into monopsonistic and monopolistic components.

The results are presented in Table 3. We estimate that the total misallocation in the

ERCOT market corresponds to 27.36% of the total observed output from coal transactions. In other words, output under joint-profit maximization would be 27.36% higher than the observed quantities. This suggests that total efficiency losses are non-negligible, consistent with the observation in Figure 6(a) that many observed coal prices differ substantially from the bilaterally-efficient coal price.

In terms of sources, 58.7% of the vertical distortion is attributed to the monopoly power of coal mining firms, while the remaining portion is due to the monopsony power of power firms. Therefore, an increase in buyer power would reduce the distortion for the monopolistic pairs while increasing it for the monopsonistic pairs. An increase in seller power would do the reverse. Because the two shares are of comparable magnitude, neither a uniform increase in buyer power nor one in seller power is unambiguously countervailing in this market, which underscores the importance of identifying the sources of vertical distortions.

7 Concluding Remarks

Vertical relationships between buyers and sellers are studied across a variety of settings, ranging from unionized labor markets to healthcare markets, in order to quantify market distortions under monopsony/oligopsony and double marginalization. In this paper, we introduce a unified framework that nests both monopsonistic and monopolistic vertical conduct. We first show that with increasing upstream marginal costs and decreasing downstream marginal revenue, an equilibrium exists under both conduct types with distinct welfare implications. We then provide a method to determine the source of vertical distortions using transacted input prices together with the cost and demand curves.

We apply our model to derive insights for antitrust policy. For horizontal mergers, we characterize the conditions under which changes in the bargaining power of upstream and downstream firms are distortionary or countervailing, and examine the ensuing consequences for consumer and total surplus. Our model also sheds light on the welfare effects of collective bargaining compared to input price-posting, and on the effects of strike regulations. In each of these cases, we show that the relative elasticities of input supply and input demand are informative about the welfare costs and benefits of these changes in the contracting environment.

In our main empirical application, we use the model to quantify the sources of vertical distortions in coal procurement by power plants in Texas. We find substantial inefficiencies due to market power in the vertical chain, with 58.7% of the vertical distortion arising from the monopoly power of mining firms and the remaining 41.3% from the monopsony power of power firms.

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Welfare Effects of Buyer and Seller Power

Mert Demirer and Michael Rubens

Online Appendix

Contents

A Existence of Equilibrium and the Bilaterally-Efficient Bargaining Weight

This section establishes the conditions under which (i) an equilibrium with positive trade exists and (ii) the joint-profit maximizing quantity q^* is achievable. We also characterize what happens when the joint-profit maximizing quantity cannot be reached.

A.1 Gains-from-Trade Assumption

Under each conduct model, the input price is pinned down by q (via $w = mc(q)$ under monopsonistic conduct or $w = mr(q)$ under monopolistic conduct), so the profit of each party becomes a function of q alone:

Monopsonistic conduct ($w = mc(q)$):

$$\pi^u(q) = c'(q)\, q^2, \tag{OA.1}$$
$$\pi^d(q) = \big(p(q) - c(q) - c'(q)\, q\big)\, q. \tag{OA.2}$$

Monopolistic conduct ($w = mr(q)$):

$$\pi^d(q) = -p'(q)\, q^2, \tag{OA.3}$$
$$\pi^u(q) = \big(p(q) + p'(q)\, q - c(q)\big)\, q. \tag{OA.4}$$

We impose the following assumption:

Assumption OA-1 (Gains from Trade under Monopolistic and Monopsonistic Conduct)**.** *Under each conduct model, the set of quantities at which both participation constraints are satisfied strictly is nonempty. Specifically, define the feasible set under each conduct model as:*
Under monopsonistic conduct ($w = mc(q)$):

$$\mathcal{Q}^{ms} \equiv \left\{q > 0 : (p(q) - c(q) - c'(q)q)q > \pi_0^d \ \textit{and}\ \ c'(q)q^2 > \pi_0^u\right\} \neq \emptyset.$$

Under monopolistic conduct ($w = mr(q)$):

$$\mathcal{Q}^{mp} \equiv \left\{q > 0 : -p'(q)q^2 > \pi_0^d \ \textit{and}\ \ (p(q) + p'(q)q - c(q))q > \pi_0^u\right\} \neq \emptyset.$$

This assumption ensures that under each conduct model, there is a nonempty set of output levels at which both parties strictly prefer trade to their disagreement payoffs.

A.2 When Is the Joint-Profit Maximizing Quantity Achievable?

Proposition OA-1 (Conditions for $\beta^* \in (0,1)$)**.** *There exists an interior bargaining weight $\beta^* \in (0,1)$ at which the equilibrium output equals q^* under both conduct models if and only if each* *party's profit at q^* (Lemma OA-10) strictly exceeds its disagreement payoff:*

$$\pi_0^d < \pi^{d*} \equiv -p'(q^*)(q^*)^2, \tag{OA.5}$$

$$\pi_0^u < \pi^{u*} \equiv c'(q^*)(q^*)^2. \tag{OA.6}$$

These conditions require that each party's profit at the joint-profit maximizing quantity q^* (under the input price $w^* = mc(q^*) = mr(q^*)$) exceeds its disagreement payoff. When both conditions hold, this interior β^* is unique.

Proof. Necessity: At q^* under monopsonistic conduct, $\pi^u(q^*) = c'(q^*)(q^*)^2 = \pi^{u*}$ and $\pi^d(q^*) = -p'(q^*)(q^*)^2 = \pi^{d*}$. At any interior bargaining weight $\beta \in (0,1)$, both parties earn strictly above their disagreement payoffs at the bargaining solution (Proposition 1(iii)). Hence, for the equilibrium at an interior β^* to achieve q^*, we need $\pi^u(q^*) > \pi_0^u$ and $\pi^d(q^*) > \pi_0^d$, which gives conditions (OA.5)–(OA.6).

Under monopolistic conduct, the same profit values obtain at q^* (since $mc(q^*) = mr(q^*)$ implies the same w^* and hence same profits), so the same conditions are necessary.

Sufficiency: When both conditions hold, the proof of Proposition 2 (Section C.4) derives the formula for β^* and verifies $\beta^* \in (0,1)$. $\square$

A.3 When the Joint-Profit Maximizing Quantity Is Not Achievable

When conditions (OA.5)–(OA.6) fail (that is, $\pi_0^d \geq \pi^{d*}$ or $\pi_0^u \geq \pi^{u*}$; under Assumption OA-1 at most one of the two can fail, since otherwise $\pi_0^d + \pi_0^u \geq \pi^{d*} + \pi^{u*}$ and no quantity would give both parties strict gains) but Assumption OA-1 holds, trade still occurs but the joint-profit maximizing quantity q^* cannot be reached at any interior β. We show that in these cases, the equilibrium output nearest to q^* is achieved at a corner value of β.

The proof relies on four facts: (i) by Assumption OA-1 and Proposition 1(iii), an equilibrium exists for every $\beta \in (0,1)$, and at the corner values $\beta \in \{0,1\}$ it is given by the constrained problems of Section D.2, to which the interior solution converges (Lemmas OA-3–OA-6), so $q(\beta)$ is defined on the full interval; (ii) $q(\beta)$ is continuously differentiable on $(0,1)$ (Lemma OA-11) and continuous on $[0,1]$ by (i); (iii) by Theorem 1, $q(\beta)$ is strictly monotone ($dq^{ms}/d\beta < 0$ and $dq^{mp}/d\beta > 0$); (iv) when $\beta^* \notin (0,1)$, q^* is not attained at any interior β, so the range of $q(\beta)$ lies weakly on one side of q^*, attaining q^* at most at a corner (the knife-edge equality cases below).

Proposition OA-2. *If $\pi_0^d \geq \pi^{d*}$ (downstream disagreement payoff too high) and Assumption OA-1 holds, then for every $\beta \in [0,1]$, the equilibrium output satisfies $q(\beta) \leq q^*$ under monopsonistic conduct and $q(\beta) \geq q^*$ under monopolistic conduct, with strict inequalities for all $\beta \in (0,1]$ and,* *whenever $\pi_0^d > \pi^{d*}$, also at $\beta = 0$. The output nearest to q^* is achieved at $\beta = 0$ under both conduct models, and equals q^* exactly in the knife-edge case $\pi_0^d = \pi^{d*}$.*

Proof. Since $\pi^d(q^*) = \pi^{d*} \leq \pi_0^d$, the equilibrium at any interior $\beta \in (0,1)$ cannot achieve exactly q^*: both parties earn strictly above their disagreement payoffs at an interior solution (Proposition 1(iii)), but downstream would earn $\pi^{d*} \leq \pi_0^d$ at q^*. Therefore $q(\beta) \neq q^*$ for any $\beta \in (0,1)$; the corner values are handled directly below.

Monopsonistic conduct: At $\beta = 0$ (Section D.2.2), upstream makes a TIOLI offer and the equilibrium quantity $q^{ms}(0)$ is the largest solution of $(p(q) - mc(q))q = \pi_0^d$. The function $(p(q)-mc(q))q$ is single-peaked (by the maintained log-concavity) with derivative $mr(q^*)-mc(q^*)-mc'(q^*)q^* = -mc'(q^*)q^* < 0$ at q^*, so its value π^{d*} at q^* is attained on the decreasing branch. Hence the largest solution satisfies $q^{ms}(0) \leq q^*$, with equality if and only if $\pi_0^d = \pi^{d*}$. Since $q^{ms}(\beta)$ is strictly decreasing in β, $q^{ms}(\beta) < q^{ms}(0) \leq q^*$ for all $\beta \in (0,1]$. The maximum output (nearest to q^*) is at $\beta = 0$.

Monopolistic conduct: At $\beta = 0$ (Section D.2.4), the upstream firm has full bargaining power and the downstream participation constraint $\pi^d(q) = -p'(q)q^2 \geq \pi_0^d$ requires $q \geq \underline{q}^d$, where $\underline{q}^d \geq q^*$ (since $\pi^d(q^*) = \pi^{d*} \leq \pi_0^d$ and $-p'(q)q^2$ is strictly increasing), with $\underline{q}^d = q^*$ if and only if $\pi_0^d = \pi^{d*}$. The upstream objective $(mr(q) - c(q))q$ has derivative $mr'(q^*)q^* < 0$ at q^* and is single-peaked, so on the feasible set it is maximized at the boundary: $q^{mp}(0) = \underline{q}^d \geq q^*$, with equality exactly in the knife-edge case. Since $q^{mp}(\beta)$ is strictly increasing in β, $q^{mp}(\beta) > q^{mp}(0) \geq q^*$ for all $\beta \in (0,1]$. The minimum output (nearest to q^*) is at $\beta = 0$. □

Proposition OA-3. *If $\pi_0^u \geq \pi^{u*}$ (upstream disagreement payoff too high) and Assumption OA-1 holds, then for every $\beta \in [0,1]$, the equilibrium output satisfies $q(\beta) \geq q^*$ under monopsonistic conduct and $q(\beta) \leq q^*$ under monopolistic conduct, with strict inequalities for all $\beta \in [0,1)$ and, whenever $\pi_0^u > \pi^{u*}$, also at $\beta = 1$. The output nearest to q^* is achieved at $\beta = 1$ under both conduct models, and equals q^* exactly in the knife-edge case $\pi_0^u = \pi^{u*}$.*

Proof. The argument is symmetric to Proposition OA-2 with the roles of upstream and downstream interchanged.

Monopsonistic conduct: The upstream participation constraint $\pi^u(q) = c'(q)q^2 \geq \pi_0^u$ requires $q \geq \underline{q}^u$, where $\underline{q}^u \geq q^*$ (since $\pi^u(q^*) = \pi^{u*} \leq \pi_0^u$ and $c'(q)q^2$ is strictly increasing), with $\underline{q}^u = q^*$ if and only if $\pi_0^u = \pi^{u*}$. At $\beta = 1$ (Section D.2.1), the classical-monopsony quantity lies below q^* and is therefore infeasible, so the constraint binds and $q^{ms}(1) = \underline{q}^u \geq q^*$, with equality exactly in the knife-edge case. Since $q^{ms}(\beta)$ is strictly decreasing in β, $q^{ms}(\beta) > q^{ms}(1) \geq q^*$ for all $\beta \in [0,1)$. The minimum output (nearest to q^*) is at $\beta = 1$.

Monopolistic conduct: At $\beta = 1$ (buyer's TIOLI, Section D.2.3), the equilibrium quantity $q^{mp}(1)$ is the largest solution of $(mr(q) - c(q))q = \pi_0^u$. The function $(mr(q) - c(q))q$ is single-peaked (by the maintained log-concavity) with derivative $mr(q^*) + mr'(q^*)q^* - mc(q^*) = mr'(q^*)q^* < 0$ at q^*, so its value π^{u*} at q^* is attained on the decreasing branch. Hence $q^{mp}(1) \leq q^*$, with equality if and only if $\pi_0^u = \pi^{u*}$. Since $q^{mp}(\beta)$ is strictly increasing in β, $q^{mp}(\beta) < q^{mp}(1) \leq q^*$ for all $\beta \in [0, 1)$. The maximum output (nearest to q^*) is at $\beta = 1$. □

Summary. In both cases, the corner value of β that achieves the output nearest to q^* is the same under both conduct models: $\beta^* = 0$ when $\pi_0^d > \pi^{d*}$ (Case 2) and $\beta^* = 1$ when $\pi_0^u > \pi^{u*}$ (Case 3), matching the convention in Section 3. The knife-edge equalities ($\pi_0^d = \pi^{d*}$ or $\pi_0^u = \pi^{u*}$) fall under Case 1: there the corner value of β^* (0 or 1, respectively) attains q^* exactly, consistent with the interior formula for β^*, which reaches that corner value precisely at equality. We adopt this as the definition of β^* whenever the joint-profit maximizing quantity is not achievable at an interior β.

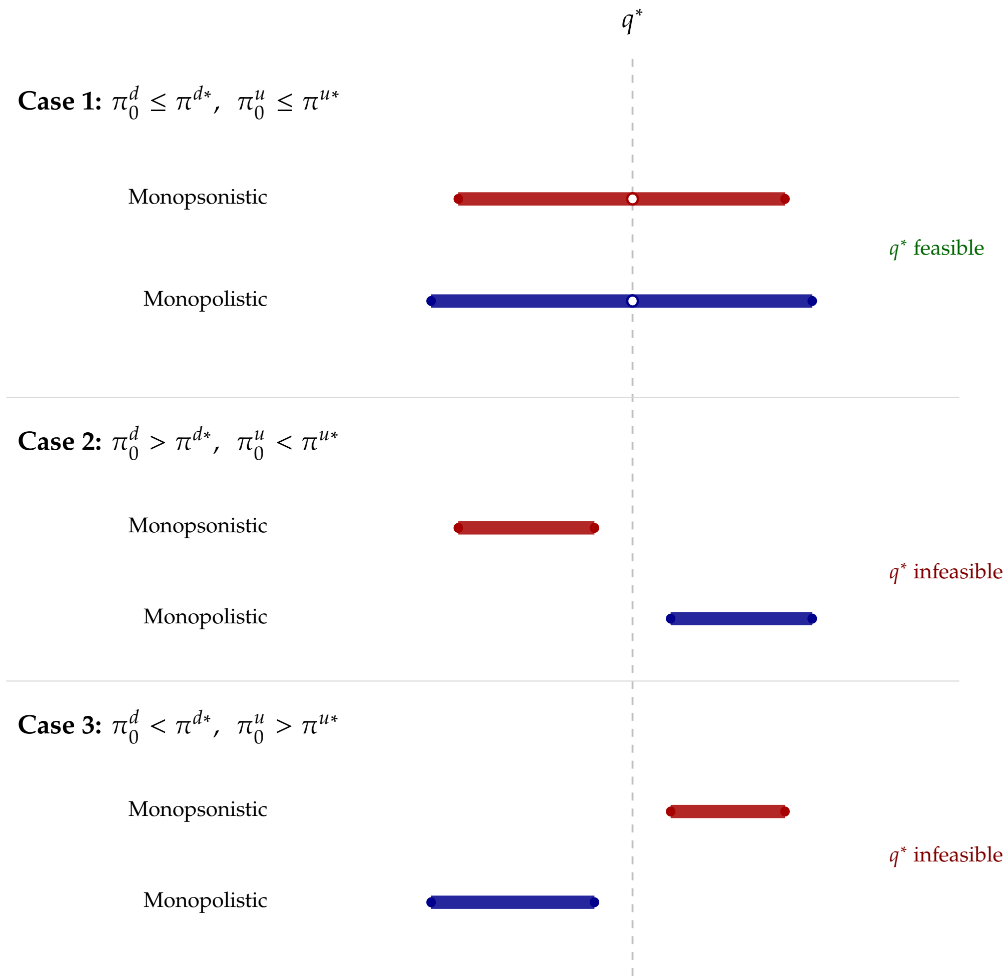
A.4 Illustration

Figure OA-1 illustrates the existence results of this section. Each horizontal bar traces the feasible quantity set—the range of outputs at which both parties earn strictly more than their disagreement payoffs—under a given conduct model (red for monopsonistic, blue for monopolistic) and disagreement-payoff regime. The dashed vertical line marks the joint-profit maximizing quantity q^*, and an open circle indicates that q^* itself is feasible. In Case 1 ($\pi_0^d \leq \pi^{d*}$ and $\pi_0^u \leq \pi^{u*}$), q^* is feasible under both conduct models and is implemented by some $\beta^* \in [0, 1]$; when both inequalities are strict, q^* lies strictly inside the feasible set and β^* is interior. In Cases 2 and 3, one disagreement payoff is too high: q^* falls outside the feasible set, the feasible quantities lie entirely on one side of q^*, and no β^* implements q^*. The output closest to q^* is then reached at a corner value of β—$\beta = 0$ in Case 2 and $\beta = 1$ in Case 3—as established above.

B First- and Second-Order Conditions

This section provides the first- and second-order conditions of monopolistic and monopsonistic bargaining, their derivations, and sufficient conditions for the second-order conditions to hold.

Figure OA-1: Summary of feasible quantity sets across all cases and conduct models.



Notes: Each bar represents the feasible quantity set under the indicated conduct model and disagreement-payoff regime. The dashed vertical line marks q^*; open circles indicate that q^* belongs to the corresponding feasible set, $\mathcal{Q}^{ms}$ or $\mathcal{Q}^{mp}$. In Case 1, β^* exists. In Cases 2 and 3, q^* is infeasible (or a boundary point, in the knife-edge equality cases) and the feasible set lies on one side of q^*. Red bars: monopsonistic; blue bars: monopolistic.

B.1 First-Order Conditions

Under the sequential bargaining models with disagreement payoffs $\pi_0^d \geq 0$ and $\pi_0^u \geq 0$, the maximization problems are given by:

$$\begin{cases} w = mr(q) & \text{(Input demand)} \\ w = mc(q) & \text{(Input supply)} \\ \max\limits_{w} \left[\left(p\left(q^d(w)\right) q^d(w) - w\, q^d(w) - \pi_0^d \right)^{\beta} \left(w\, q^d(w) - c\left(q^d(w)\right) q^d(w) - \pi_0^u \right)^{1-\beta} \right] & \text{(MP bargaining)} \\ \max\limits_{w} \left[\left(p\left(q^u(w)\right) q^u(w) - w\, q^u(w) - \pi_0^d \right)^{\beta} \left(w\, q^u(w) - c\left(q^u(w)\right) q^u(w) - \pi_0^u \right)^{1-\beta} \right] & \text{(MS bargaining)} \end{cases}$$

For $\beta \in (0,1)$ and under Assumption OA-1, the equilibrium satisfies $\pi^d > \pi_0^d$ and $\pi^u > \pi_0^u$ (both parties earn strictly above their disagreement payoffs) and is characterized by the following first-order conditions, derived in Section B.3[45]:

$$\begin{cases} \beta \left(\dfrac{-q + (p'(q)q + [p(q) - w])\,(dq^d/dw)}{[p(q) - w] \cdot q - \pi_0^d} \right) + (1-\beta) \left(\dfrac{q + ([w - c(q)] - c'(q)q)\,(dq^d/dw)}{[w - c(q)] \cdot q - \pi_0^u} \right) = 0 & \text{(D-B-FOC)} \\ \beta \left(\dfrac{-q + (p'(q)q + [p(q) - w])\,(dq^u/dw)}{[p(q) - w] \cdot q - \pi_0^d} \right) + (1-\beta) \left(\dfrac{q + ([w - c(q)] - c'(q)q)\,(dq^u/dw)}{[w - c(q)] \cdot q - \pi_0^u} \right) = 0 & \text{(U-B-FOC)} \end{cases}$$

where $dq^d/dw = 1/(2p'(q) + p''(q)q)$ and $dq^u/dw = 1/(2c'(q) + c''(q)q)$. The numerators represent the total derivatives of each party's profit with respect to w (accounting for the indirect effect through $q(w)$), while the denominators represent the net gains from trade for each party.

Substituting the input supply and demand equations and simplifying, the equilibrium-quantity conditions are:

$$\begin{cases} \beta \left(\dfrac{-q}{-p'(q)q^2 - \pi_0^d} \right) + (1-\beta) \left(\dfrac{q + (p(q) - c(q) + p'(q)q - c'(q)q) \cdot \dfrac{1}{2p'(q) + p''(q)q}}{[p(q) - c(q) + p'(q)q]\, q - \pi_0^u} \right) = 0 & \text{(MP-Q-FOC)} \\ \beta \left(\dfrac{-q + ([p(q) - c(q)] + [p'(q)q - c'(q)q])\, \dfrac{1}{2c'(q) + c''(q)q}}{[p(q) - c(q) - c'(q)q]q - \pi_0^d} \right) + (1-\beta) \left(\dfrac{q}{c'(q)q^2 - \pi_0^u} \right) = 0 & \text{(MS-Q-FOC)} \end{cases}$$

B.2 Second-Order Conditions

Bargaining SOCs. The second-order condition of monopsonistic bargaining under sequential timing is given by:

$$\beta \left\{ \frac{1}{\mathrm{GFT}^d} \left[\frac{N'(q)T(q) - N(q)T'(q)}{T(q)^3} - \frac{1}{T(q)} \right] - \left[\frac{N(q) - qT(q)}{\mathrm{GFT}^d T(q)} \right]^2 \right\} + (1-\beta) \left\{ \frac{1}{T(q)\,\mathrm{GFT}^u} - \frac{q^2}{(\mathrm{GFT}^u)^2} \right\} < 0$$

where

$$\begin{aligned} M(q) &\equiv p(q) - c(q) - qc'(q), \qquad & N(q) &\equiv p(q) - c(q) + q[p'(q) - c'(q)], \\ T(q) &\equiv 2c'(q) + qc''(q), \qquad & \mathrm{GFT}^d &\equiv M(q) \cdot q - \pi_0^d, \quad \mathrm{GFT}^u \equiv c'(q)q^2 - \pi_0^u. \end{aligned}$$

[45] To simplify the notation, we use q instead of q^u and q^d whenever there is no ambiguity.

Here $\mathrm{GFT}^d = \pi^d - \pi_0^d$ and $\mathrm{GFT}^u = \pi^u - \pi_0^u$ represent the net gains from trade for the downstream and upstream firms, respectively.

The second-order condition of monopolistic bargaining under sequential timing is given by:

$$(1-\beta)\left\{\frac{1}{\widetilde{\mathrm{GFT}}^u}\left[\frac{\tilde{N}'(q)\tilde{T}(q)-\tilde{N}(q)\tilde{T}'(q)}{\tilde{T}(q)^3}+\frac{1}{\tilde{T}(q)}\right]-\left[\frac{\tilde{N}(q)+q\tilde{T}(q)}{\widetilde{\mathrm{GFT}}^u\tilde{T}(q)}\right]^2\right\}+\beta\left\{-\frac{1}{\tilde{T}(q)\widetilde{\mathrm{GFT}}^d}-\frac{q^2}{(\widetilde{\mathrm{GFT}}^d)^2}\right\}<0$$

where

$$\begin{aligned}
&\tilde{M}(q) \equiv p(q) + qp'(q) - c(q), && \tilde{N}(q) \equiv p(q) - c(q) + q[p'(q) - c'(q)],\\
&\tilde{T}(q) \equiv 2p'(q) + qp''(q), && \widetilde{\mathrm{GFT}}^d \equiv -p'(q)q^2 - \pi_0^d, \quad \widetilde{\mathrm{GFT}}^u \equiv \tilde{M}(q)\cdot q - \pi_0^u.
\end{aligned}$$

Under each conduct model, these second-order conditions hold whenever the profit functions are strictly log-concave in q. Substituting the conduct FOC ($w = mc(q)$ under monopsonistic and $w = mr(q)$ under monopolistic bargaining), the log Nash objective is a function of q alone,

$$f(q) = \beta \ln\left(\pi^d - \pi_0^d\right) + (1-\beta)\ln\left(\pi^u - \pi_0^u\right).$$

If π^d and π^u are strictly log-concave in q, then so are the gains from trade $\pi^d - \pi_0^d$ and $\pi^u - \pi_0^u$ on the bargaining set, because subtracting the disagreement payoff—constant in q—preserves strict log-concavity where the gains remain positive. Hence $\ln(\pi^d - \pi_0^d)$ and $\ln(\pi^u - \pi_0^u)$ are strictly concave, so f is a nonnegative weighted sum of strictly concave functions and thus strictly concave for every $\beta \in [0,1]$. Since w and q are related one-to-one by the conduct FOC, $dq/dw \neq 0$; writing $\mathcal{L}(w) \equiv f(q(w))$ for the log Nash objective as a function of w, the bargaining first-order condition $\mathcal{L}'(w) = f'(q)\,(dq/dw) = 0$ implies $f'(q) = 0$ at the optimum. Evaluated there, $\mathcal{L}''(w) = f''(q)\,(dq/dw)^2 + f'(q)\,(d^2q/dw^2) = f''(q)\,(dq/dw)^2 < 0$, so the second-order condition holds and, for $\beta \in (0,1)$, the first-order condition characterizes the unique global maximum. At the corner values $\beta \in \{0,1\}$, a participation constraint can bind and the maximum can lie on the boundary of the bargaining set; these cases are analyzed in Section D.2.

B.3 Derivation of FOCs Under Sequential Bargaining

B.3.1 U-B-FOC

Proof. We differentiate the logarithm of the objective with respect to w:

$$\beta\left(\frac{1}{[p(q)-w]\,q-\pi_0^d}\cdot\frac{d}{dw}\left([p(q)-w]\,q\right)\right)+(1-\beta)\left(\frac{1}{[w-c(q)]\,q-\pi_0^u}\cdot\frac{d}{dw}\left([w-c(q)]\,q\right)\right)=0.$$

Note the following intermediate derivatives:

$$\frac{d}{dw}\left([p(q)-w]\,q\right) \;=\; \left(\frac{d}{dw}[p(q)-w]\right)q+[p(q)-w]\frac{dq}{dw} \;=\; -q+\left(p'(q)q+[p(q)-w]\right)\frac{dq}{dw}$$

$$\frac{d}{dw}\left([w-c(q)]\,q\right) \;=\; \left(\frac{d}{dw}[w-c(q)]\right)q+[w-c(q)]\frac{dq}{dw} \;=\; q+\left([w-c(q)]-c'(q)q\right)\frac{dq}{dw}$$

Differentiating both sides of the input supply condition, $w=c(q)+c'(q)\,q$, with respect to w, we find

$$\frac{dq}{dw}=\frac{1}{2\,c'(q)+c''(q)\,q}.$$

Substituting the expressions above into the FOC yields:

$$\beta\left(\frac{-q+\left(p'(q)q+[p(q)-w]\right)\dfrac{dq}{dw}}{[p(q)-w]\,q-\pi_0^d}\right)+(1-\beta)\left(\frac{q+\left([w-c(q)]-c'(q)q\right)\dfrac{dq}{dw}}{[w-c(q)]\,q-\pi_0^u}\right)=0,$$

and plugging in dq/dw:

$$\beta\left(\frac{-q+\left(p'(q)q+[p(q)-w]\right)\dfrac{1}{2c'(q)+c''(q)q}}{[p(q)-w]\,q-\pi_0^d}\right)+(1-\beta)\left(\frac{q+\left([w-c(q)]-c'(q)q\right)\dfrac{1}{2c'(q)+c''(q)q}}{[w-c(q)]\,q-\pi_0^u}\right)=0.$$

From the input supply condition, substitute $w=c(q)+c'(q)q$ and simplify to obtain:

$$\beta\left(\frac{-q+\left([p(q)-c(q)]+[p'(q)q-c'(q)q]\right)\dfrac{1}{2c'(q)+c''(q)q}}{[p(q)-c(q)-c'(q)q]\,q-\pi_0^d}\right)+(1-\beta)\left(\frac{q}{c'(q)q^2-\pi_0^u}\right)=0.$$

□

B.3.2 D-B-FOC

Proof. Calculate dq/dw using $w = p(q) + p'(q)q$:

$$\frac{dq}{dw} = \frac{1}{2p'(q) + p''(q)q}.$$

Substitute dq/dw into the FOC:

$$\beta \left(\frac{-q + (p'(q)q + [p(q) - w]) \cdot \frac{1}{2p'(q)+p''(q)q}}{[p(q) - w] \cdot q - \pi_0^d} \right) + (1 - \beta) \left(\frac{q + ([w - c(q)] - c'(q)q) \cdot \frac{1}{2p'(q)+p''(q)q}}{[w - c(q)] \cdot q - \pi_0^u} \right) = 0.$$

From the input demand condition, substitute $w = p(q) + p'(q)q$ and simplify to obtain:

$$\beta \left(\frac{-q}{-p'(q)q^2 - \pi_0^d} \right) + (1 - \beta) \left(\frac{q + (p(q) - c(q) + p'(q)q - c'(q)q) \cdot \dfrac{1}{2p'(q) + p''(q)q}}{[p(q) - c(q) + p'(q)q]\, q - \pi_0^u} \right) = 0.$$

□

C Proofs of Main Results

This section provides the proofs of all results stated in the main text, in the order they appear.

C.1 Proof of Proposition 1

Proof. Throughout the proof, we maintain the mild boundary regularity that output generates no revenue and no cost in the limit of zero quantity,

$$\lim_{q \to 0} p(q)\, q = 0 \qquad \text{and} \qquad \lim_{q \to 0} c(q)\, q = 0,$$

which holds, in particular, when the choke price is finite and there is no fixed cost.

Part (i): Monopsonistic bargaining with constant marginal cost.

Under monopsonistic bargaining, every candidate solution (w, q) lies on the input supply curve, $w = mc(q)$ (Equation (4)). If marginal cost is constant, $mc(q) = \bar{c}$, the supply condition pins down the input price at $w = \bar{c}$ for *every* quantity. Integrating $mc(q) = \partial(c(q)q)/\partial q = \bar{c}$ and using the boundary regularity $\lim_{q \to 0} c(q)q = 0$ gives total cost $c(q)q = \bar{c}q$, so average cost is constant, $c(q) = \bar{c}$. Hence, at every candidate solution,

$$\pi^u = \big(w - c(q)\big)q = \big(\bar{c} - c(q)\big)q = 0 \qquad \text{for all } q > 0.$$

An interior solution requires $\pi^u > \pi_0^u \geq 0$, which is therefore impossible. Hence the monopsonistic bargaining problem has no interior solution for any $\beta \in [0, 1]$ and any disagreement payoffs.

Part (ii): Monopolistic bargaining with constant marginal revenue.

Symmetrically, under monopolistic bargaining every candidate solution lies on the input demand curve, $w = mr(q)$ (Equation (5)). If marginal revenue is constant, $mr(q) = \bar{m}$, the demand condition pins down $w = \bar{m}$ for every quantity, and integrating $mr(q) = d(p(q)q)/dq = \bar{m}$ and using the boundary regularity $\lim_{q\to 0} p(q)q = 0$ gives revenue $p(q)q = \bar{m}q$, so average revenue is constant, $p(q) = \bar{m}$. Hence, at every candidate solution,

$$\pi^d = \big(p(q) - w\big)q = \big(p(q) - \bar{m}\big)q = 0 \qquad \text{for all } q > 0.$$

An interior solution requires $\pi^d > \pi_0^d \geq 0$, which is impossible, so the monopolistic bargaining problem has no interior solution for any $\beta \in [0, 1]$ and any disagreement payoffs.

Part (iii): Existence of an interior solution when $mc'(q) > 0$ and $mr'(q) < 0$.

We present the argument for monopsonistic bargaining; the argument for monopolistic bargaining is symmetric along the input demand curve $w = mr(q)$, with profits given by Equations (OA.3)–(OA.4), and is omitted.

Step 1 (Profits along the supply curve). Substituting the supply condition $w = mc(q)$, the parties' profits become functions of q alone (Equations (OA.1)–(OA.2)):

$$\pi^u(q) = c'(q)\,q^2, \qquad \pi^d(q) = \big(p(q) - mc(q)\big)\,q.$$

Define the gains from trade $\mathrm{GFT}^d(q) \equiv \pi^d(q) - \pi_0^d$ and $\mathrm{GFT}^u(q) \equiv \pi^u(q) - \pi_0^u$, and the strict-feasibility set

$$\mathcal{Q}^{ms} \equiv \big\{q > 0 : \mathrm{GFT}^d(q) > 0 \ \text{ and } \ \mathrm{GFT}^u(q) > 0\big\},$$

which is nonempty by Assumption OA-1 and open by continuity of the profit functions.

Step 2 (The feasible set is bounded). Let q^* denote the joint-profit maximizing quantity (Section 2.5). Since average revenue is the running mean of marginal revenue, $p(q) = \frac{1}{q}\int_0^q mr(s)\,ds$, and $mr(s) < mc(q^*)$ for $s > q^*$, average revenue falls below $mc(q^*)$ plus a term that vanishes as q grows, while $mc(q)$ rises strictly above $mc(q^*)$. Hence $\pi^d(q) = (p(q) - mc(q))q$ turns negative for all q exceeding some finite $\bar{q}^{\,ms}$, so $\mathrm{GFT}^d(q) < 0$ there and $\mathcal{Q}^{ms} \subseteq (0, \bar{q}^{\,ms}]$ is bounded.

Step 3 (Existence and characterization). Fix $\beta \in (0, 1)$ and consider the log-Nash objective

$$f(q) \equiv \beta \ln \mathrm{GFT}^d(q) + (1 - \beta) \ln \mathrm{GFT}^u(q),$$

whose maximization over $\mathcal{Q}^{ms}$ is equivalent to maximizing the Nash product over the quantities satisfying both participation constraints. By the maintained assumption that π^d and π^u are strictly log-concave in q (Section 2), the gains GFT^d and GFT^u are strictly log-concave where positive, $\mathcal{Q}^{ms}$ is an open interval (q_l, q_h) with $q_h \leq \bar{q}^{ms}$ finite (Step 2), and f is strictly concave. As q approaches either endpoint, at least one gain vanishes — by continuity at a positive endpoint, and at $q_l = 0$ because both profits vanish in the limit of zero output by the boundary regularity — so $f(q) \to -\infty$ at both endpoints. A continuous function on an open interval that diverges to $-\infty$ at both endpoints attains an interior maximum; hence there exists $\hat{q} \in \mathcal{Q}^{ms}$ with $f'(\hat{q}) = 0$. Since w and q are related one-to-one along the supply curve ($dq/dw = 1/(2c'(q) + c''(q)q) > 0$), the pair $(\hat{w}, \hat{q})$ with $\hat{w} = mc(\hat{q})$ satisfies the bargaining first-order condition (6) — equivalently, the MS-Q-FOC of Section B.1. By construction, $\pi^d(\hat{q}) > \pi_0^d$ and $\pi^u(\hat{q}) > \pi_0^u$, so $(\hat{w}, \hat{q})$ is an interior solution of the monopsonistic bargaining problem; by strict concavity of f, it is unique and the first-order condition characterizes it.

□

C.2 Proof of Theorem 1

Proof. In both parts, we write the B-FOC as $\Phi(\beta, \pi_0^d, \pi_0^u, w) = \beta \cdot A(w) + (1-\beta) \cdot B(w) = 0$ and apply the Implicit Function Theorem. The second-order condition ensures $\partial\Phi/\partial w < 0$ throughout. Since the first-order conditions characterize the equilibrium for $\beta \in (0, 1)$, the comparative statics are established on the interior in the proof. The monotonicity in β extends to the corner values $\beta \in \{0, 1\}$: by Lemmas OA-3–OA-6, the interior solution converges to the corner solutions of Section D.2 as $\beta \to 0$ and $\beta \to 1$, so $q(\beta)$ is continuous on $[0, 1]$ and the strict monotonicity in β is preserved. The comparative statics with respect to the disagreement payoffs, in contrast, apply only for $\beta \in (0, 1)$: at the corner values, the equilibrium quantity does not vary with one or both disagreement payoffs (Section D.2).

Part (i): Monopsonistic bargaining. We prove $dq^{ms}/d\beta < 0$, $dq^{ms}/d\pi_0^d < 0$, and $dq^{ms}/d\pi_0^u > 0$.

Under monopsonistic conduct, the U-B-FOC gives:

$$A(w) = \frac{d\pi^d/dw}{\pi^d - \pi_0^d} = \frac{-q + (p'(q)q + [p(q) - w])\,(dq^u/dw)}{[p(q) - w] \cdot q - \pi_0^d},$$

$$B(w) = \frac{d\pi^u/dw}{\pi^u - \pi_0^u} = \frac{q}{c'(q)q^2 - \pi_0^u}.$$

We note that $B > 0$: on the input supply curve $\pi^u = c'(q)q^2$, so the denominator of B equals the gains from trade $\pi^u - \pi_0^u$, which is strictly positive at an interior equilibrium (Proposition 1(iii)). Since $\beta A + (1-\beta)B = 0$ with $B > 0$ and $\beta \in (0,1)$, it follows that $A < 0$. Note also that $dq/dw = 1/(2c'(q) + c''(q)q) > 0$ under monopsonistic bargaining.

$\underline{dq^{ms}/d\beta < 0}$: We have $\partial\Phi/\partial\beta = A - B < 0$ (since $A < 0$ and $B > 0$). By the IFT:

$$\frac{dw}{d\beta} = -\frac{\partial\Phi/\partial\beta}{\partial\Phi/\partial w} = -\frac{\overbrace{(A-B)}^{<0}}{\underbrace{\partial\Phi/\partial w}_{<0}} < 0.$$

Since $dq/dw > 0$ under monopsonistic bargaining: $dq^{ms}/d\beta = \underbrace{(dq/dw)}_{>0} \cdot \underbrace{(dw/d\beta)}_{<0} < 0$.

$\underline{dq^{ms}/d\pi_0^d < 0}$: Only A depends on π_0^d, through its denominator $\mathrm{GFT}^d \equiv [p(q) - w]q - \pi_0^d$. Write $A = N_A/\mathrm{GFT}^d$ where $N_A \equiv d\pi^d/dw < 0$. Differentiating: $\partial A/\partial\pi_0^d = N_A/(\mathrm{GFT}^d)^2 < 0$. Therefore $\partial\Phi/\partial\pi_0^d = \beta \cdot (\partial A/\partial\pi_0^d) < 0$. By the IFT:

$$\frac{dw}{d\pi_0^d} = -\frac{\overbrace{\partial\Phi/\partial\pi_0^d}^{<0}}{\underbrace{\partial\Phi/\partial w}_{<0}} < 0.$$

Hence $dq^{ms}/d\pi_0^d = \underbrace{(dq/dw)}_{>0} \cdot \underbrace{(dw/d\pi_0^d)}_{<0} < 0$.

$\underline{dq^{ms}/d\pi_0^u > 0}$: Only B depends on π_0^u, through its denominator $\mathrm{GFT}^u \equiv c'(q)q^2 - \pi_0^u$. Differentiating: $\partial B/\partial\pi_0^u = q/(\mathrm{GFT}^u)^2 > 0$. Therefore $\partial\Phi/\partial\pi_0^u = (1-\beta) \cdot (\partial B/\partial\pi_0^u) > 0$. By the IFT:

$$\frac{dw}{d\pi_0^u} = -\frac{\overbrace{\partial\Phi/\partial\pi_0^u}^{>0}}{\underbrace{\partial\Phi/\partial w}_{<0}} > 0.$$

Hence $dq^{ms}/d\pi_0^u = \underbrace{(dq/dw)}_{>0} \cdot \underbrace{(dw/d\pi_0^u)}_{>0} > 0.$

Part (ii): Monopolistic bargaining. We prove $dq^{mp}/d\beta > 0$, $dq^{mp}/d\pi_0^d > 0$, and $dq^{mp}/d\pi_0^u < 0$.

Under monopolistic conduct, the D-B-FOC gives:

$$A(w) = \frac{d\pi^d/dw}{\pi^d - \pi_0^d} = \frac{-q}{-p'(q)q^2 - \pi_0^d},$$

$$B(w) = \frac{d\pi^u/dw}{\pi^u - \pi_0^u} = \frac{q + ([w - c(q)] - c'(q)q)\,(dq^d/dw)}{[w - c(q)] \cdot q - \pi_0^u}.$$

We note that $A < 0$: on the input demand curve $\pi^d = -p'(q)q^2$, so the denominator of A equals the gains from trade $\pi^d - \pi_0^d$, which is strictly positive at an interior equilibrium (Proposition 1(iii)). Since $\beta A + (1-\beta)B = 0$ with $A < 0$ and $\beta \in (0,1)$, it follows that $B > 0$. Note also that $dq/dw = 1/(2p'(q) + p''(q)q) < 0$ under monopolistic bargaining (since $mr'(q) < 0$).

<u>$dq^{mp}/d\beta > 0$</u>: $\partial\Phi/\partial\beta = A - B < 0$. By the IFT:

$$\frac{dw}{d\beta} = -\frac{\overbrace{(A-B)}^{<0}}{\underbrace{\partial\Phi/\partial w}_{<0}} < 0.$$

Since $dq/dw < 0$ under monopolistic bargaining: $dq^{mp}/d\beta = \underbrace{(dq/dw)}_{<0} \cdot \underbrace{(dw/d\beta)}_{<0} > 0.$

<u>$dq^{mp}/d\pi_0^d > 0$</u>: Only A depends on π_0^d, through $\widetilde{\text{GFT}}^d \equiv -p'(q)q^2 - \pi_0^d$. Differentiating:

$\partial A/\partial \pi_0^d = -q/(\widetilde{\text{GFT}}^d)^2 < 0$. Therefore $\partial \Phi/\partial \pi_0^d = \beta \cdot (\partial A/\partial \pi_0^d) < 0$. By the IFT:

$$\frac{dw}{d\pi_0^d} = -\frac{\overbrace{\partial \Phi/\partial \pi_0^d}^{<0}}{\underbrace{\partial \Phi/\partial w}_{<0}} < 0.$$

Hence $dq^{mp}/d\pi_0^d = \underbrace{(dq/dw)}_{<0} \cdot \underbrace{(dw/d\pi_0^d)}_{<0} > 0$.

<u>$dq^{mp}/d\pi_0^u < 0$</u>: Only B depends on π_0^u, through $\widetilde{\text{GFT}}^u \equiv [w - c(q)]q - \pi_0^u$. Write $B = N_B/\widetilde{\text{GFT}}^u$ where $N_B > 0$. Differentiating: $\partial B/\partial \pi_0^u = N_B/(\widetilde{\text{GFT}}^u)^2 > 0$. Therefore $\partial \Phi/\partial \pi_0^u = (1-\beta) \cdot (\partial B/\partial \pi_0^u) > 0$. By the IFT:

$$\frac{dw}{d\pi_0^u} = -\frac{\overbrace{\partial \Phi/\partial \pi_0^u}^{>0}}{\underbrace{\partial \Phi/\partial w}_{<0}} > 0.$$

Hence $dq^{mp}/d\pi_0^u = \underbrace{(dq/dw)}_{<0} \cdot \underbrace{(dw/d\pi_0^u)}_{>0} < 0$.

□

C.3 Proof of Corollary 1

Proof. Part (i): Under monopolistic bargaining, the equilibrium lies on the input demand curve, $w = mr(q)$, so the downstream markdown $\Delta^d = (mr(q) - w)/mr(q) = 0$. The upstream markup is $\mu^u = (w - mc(q))/mc(q) = (mr(q) - mc(q))/mc(q)$. Since $w = mr(q)$ and q increases with buyer power (Theorem 1), while $mr(q)$ is decreasing and $mc(q)$ is increasing, the markup μ^u decreases with buyer power.

Part (ii): Under monopsonistic bargaining, the equilibrium lies on the input supply curve, $w = mc(q)$, so the upstream markup $\mu^u = (w - mc(q))/mc(q) = 0$. The downstream markdown is $\Delta^d = (mr(q) - w)/mr(q) = (mr(q) - mc(q))/mr(q)$. Since $w = mc(q)$ and q decreases with buyer power (Theorem 1), while $mc(q)$ is increasing and $mr(q)$ is decreasing, a decrease in q raises $mr(q)$ and lowers $mc(q)$, increasing the markdown Δ^d with buyer power. □

C.4 Proof of Proposition 2

We prove that there exists a unique $\beta^* \in (0, 1)$ at which both the monopsonistic and monopolistic bargaining models yield the joint-profit maximizing quantity q^*, with the formula:

$$\beta^* = \frac{-p'(q^*)(q^*)^2 - \pi_0^d}{\big(c'(q^*) - p'(q^*)\big)(q^*)^2 - (\pi_0^u + \pi_0^d)}.$$

Proof. By Lemma OA-10, define $w^* \equiv mc(q^*) = mr(q^*)$ and the profit levels $\pi^{d*} \equiv -p'(q^*)(q^*)^2$ and $\pi^{u*} \equiv c'(q^*)(q^*)^2$, which are the same under both conduct models.

Vanishing indirect effects at q^*. Under sequential timing, the total derivative of each party's profit with respect to w has a direct and an indirect component:

$$\frac{d\pi^i}{dw} = \underbrace{\frac{\partial \pi^i}{\partial w}}_{\text{direct}} + \underbrace{\frac{\partial \pi^i}{\partial q} \cdot \frac{dq}{dw}}_{\text{indirect (through } q(w))}.$$

We show that at $q = q^*$, the indirect effects vanish for both parties under both conduct models. The argument relies on two observations:

(i) Vanishing own indirect effect: Under monopsonistic conduct, the quantity lies on the input supply curve, $w = mc(q)$. Since $\partial \pi^u / \partial q = w - c(q) - c'(q)q = w - mc(q)$, this derivative is zero at every point on the supply curve, so the indirect effect on the upstream profit is zero:

$$\frac{d\pi^u}{dw} = \frac{\partial \pi^u}{\partial w} + \underbrace{\frac{\partial \pi^u}{\partial q}}_{=0} \cdot \frac{dq}{dw} = \frac{\partial \pi^u}{\partial w} = q.$$

Similarly, under monopolistic conduct the quantity lies on the input demand curve, $w = mr(q)$, and $\partial \pi^d / \partial q = mr(q) - w = 0$ along the curve, so $d\pi^d/dw = \partial \pi^d / \partial w = -q$. This holds at any q on the binding curve, not just at q^*.

(ii) Joint surplus is stationary at q^*: Define joint surplus $S(q) \equiv \pi^d + \pi^u = (p(q) - c(q))q$. Since the input price w cancels between buyer and seller, $\partial S / \partial w = 0$. Moreover, $\partial S / \partial q = mr(q) - mc(q) = 0$ at q^*. Therefore, the total derivative of joint surplus with respect to w

vanishes at q^*:

$$\left.\frac{dS}{dw}\right|_{q^*} = \underbrace{\frac{\partial S}{\partial w}}_{=0} + \underbrace{\left.\frac{\partial S}{\partial q}\right|_{q^*}}_{=0} \cdot \frac{dq}{dw} = 0.$$

Combining (i) and (ii): Since $dS/dw = d\pi^d/dw + d\pi^u/dw = 0$ at q^*, it follows from (i) that under monopsonistic conduct $d\pi^d/dw\big|_{q^*} = -\,d\pi^u/dw = -q^*$, and under monopolistic conduct $d\pi^u/dw\big|_{q^*} = -\,d\pi^d/dw = q^*$.

Verification by direct calculation:

- Under monopsonistic bargaining (input supply: $w = mc(q)$), we have $d\pi^u/dw = q + ([w - c(q)] - c'(q)q) \cdot dq/dw = q$ at any q (since $w - c(q) = c'(q)q$). For the downstream term: $d\pi^d/dw = -q + (p'(q)q + [p(q) - w]) \cdot dq/dw$. At q^*, $p(q^*) - w^* = -p'(q^*)q^*$, so $p'(q^*)q^* + [p(q^*) - w^*] = p'(q^*)q^* - p'(q^*)q^* = 0$. Hence $d\pi^d/dw\big|_{q^*} = -q^*$.
- Under monopolistic bargaining (input demand: $w = mr(q)$), we have $d\pi^d/dw = -q$ at any q (since $p(q) - w = -p'(q)q$). For the upstream term: $d\pi^u/dw = q + ([w - c(q)] - c'(q)q) \cdot dq/dw$. At q^*, $w^* - c(q^*) = c'(q^*)q^*$, so $[w^* - c(q^*)] - c'(q^*)q^* = 0$. Hence $d\pi^u/dw\big|_{q^*} = q^*$.

Therefore, at q^*, the B-FOC under *both* conduct models reduces to:

$$\frac{\beta \cdot (-q^*)}{\pi^{d*} - \pi_0^d} + \frac{(1-\beta) \cdot q^*}{\pi^{u*} - \pi_0^u} = 0.$$

Dividing by $q^* > 0$ and rearranging:

$$\frac{\beta}{\pi^{d*} - \pi_0^d} = \frac{1-\beta}{\pi^{u*} - \pi_0^u}$$

$$\beta(\pi^{u*} - \pi_0^u) = (1-\beta)(\pi^{d*} - \pi_0^d).$$

Solving for β:

$$\beta^* = \frac{\pi^{d*} - \pi_0^d}{\pi^{d*} + \pi^{u*} - \pi_0^d - \pi_0^u} = \frac{-p'(q^*)(q^*)^2 - \pi_0^d}{\big(c'(q^*) - p'(q^*)\big)(q^*)^2 - (\pi_0^u + \pi_0^d)}.$$

Conditions for $\beta^* \in (0,1)$. We now verify that the conditions $\pi_0^d < \pi^{d*}$ and $\pi_0^u < \pi^{u*}$ (Proposition OA-1) imply $\beta^* \in (0,1)$. For $\beta^* > 0$: $\pi_0^d < \pi^{d*}$ ensures the numerator is positive, and $\pi_0^d + \pi_0^u < \pi^{d*} + \pi^{u*}$ ensures the denominator is positive. For $\beta^* < 1$: we need numerator < denominator, which requires $\pi_0^u < \pi^{u*}$. When either condition fails, q^* is not achievable and the analysis of Section A (Propositions OA-2–OA-3) applies.

Uniqueness. Since q^* is the unique solution to $mc(q^*) = mr(q^*)$ (by Lemma OA-12), and the formula maps uniquely to β^*, the bilaterally-efficient bargaining weight is unique.

□

C.5 Proof of Corollary 2

Proof. Part (i): We examine how β^* changes with $c'(q^*)$ and $|p'(q^*)|$, holding all else equal. Note, however, that changes in $|p'(q)|$ and $c'(q)$ also affect q^*, which enters the formula for β^*. Therefore, we condition on q^* and analyze changes in $|p'(q)|$ and $c'(q)$ at q^*. Using the formula $\beta^* = \dfrac{-p'(q^*)(q^*)^2 - \pi_0^d}{\big(c'(q^*) - p'(q^*)\big)(q^*)^2 - (\pi_0^u + \pi_0^d)}$:

An increase in $c'(q^*)$ increases the denominator while leaving the numerator unchanged (since $p'(q^*)$ is fixed), so β^* weakly decreases.

For the effect of $|p'(q^*)|$: write $1/\beta^* = 1 + (c'(q^*)(q^*)^2 - \pi_0^u)/(-p'(q^*)(q^*)^2 - \pi_0^d)$. An increase in $|p'(q^*)| = -p'(q^*)$ increases the denominator of the second term, decreasing $1/\beta^*$, hence increasing β^*.

Part (ii): We differentiate β^* with respect to π_0^d and π_0^u.

Write $\beta^* = N/D$ where $N = \pi^{d*} - \pi_0^d$ and $D = \pi^{d*} + \pi^{u*} - \pi_0^d - \pi_0^u$.

Effect of π_0^d:

$$\frac{\partial \beta^*}{\partial \pi_0^d} = \frac{(-1)\cdot D - N\cdot(-1)}{D^2} = \frac{N-D}{D^2} = \frac{-(\pi^{u*} - \pi_0^u)}{D^2} < 0,$$

since $\pi^{u*} > \pi_0^u$ by Proposition OA-1.

Effect of π_0^u:

$$\frac{\partial \beta^*}{\partial \pi_0^u} = \frac{0\cdot D - N\cdot(-1)}{D^2} = \frac{N}{D^2} = \frac{\pi^{d*} - \pi_0^d}{D^2} > 0,$$

since $\pi^{d*} > \pi_0^d$ by Proposition OA-1. □

C.6 Proof of Proposition 3

Proof. By Lemma OA-7, consumer surplus is strictly increasing in output q. Therefore, it is maximized at the β that maximizes output.

Under monopolistic bargaining, $dq^{mp}/d\beta > 0$ by Theorem 1. Hence consumer surplus is increasing in β and is maximized at $\beta = 1$.

Under monopsonistic bargaining, $dq^{ms}/d\beta < 0$ by Theorem 1. Hence consumer surplus is decreasing in β and is maximized at $\beta = 0$. $\square$

C.7 Proof of Proposition 4

Proof. By Lemma OA-8, total welfare is maximized at $q^\dagger$ defined by $\tilde{p}(q^\dagger) = mc(q^\dagger)$, with $q^\dagger > q^*$.

First, consider monopsonistic bargaining. As shown in Section D.2.2, at $\beta = 0$ the equilibrium quantity satisfies the binding participation constraint $(p(q) - mc(q))q = \pi_0^d$. Since $\pi_0^d \geq 0$, this implies $p(q^{ms}(0)) \geq mc(q^{ms}(0))$, hence $\tilde{p}(q^{ms}(0)) \geq p(q^{ms}(0)) \geq mc(q^{ms}(0))$ and $q^{ms}(0) \leq q^\dagger$, with equality when $\pi_0^d = 0$ and U is D's only supplier. Since output strictly decreases in β (Theorem 1) and total surplus is strictly increasing for $q \leq q^\dagger$ (Lemma OA-8), total surplus is maximized at $\beta = 0$.

Second, consider monopolistic bargaining, and suppose first that β^* is interior, i.e., $\pi_0^d < \pi^{d*}$ and $\pi_0^u < \pi^{u*}$ (Proposition OA-1). At $\beta = \beta^*$, the equilibrium quantity is q^*, which lies below the welfare-maximizing quantity, $q^* < q^\dagger$ (Lemma OA-8). Since output increases with β under monopolistic bargaining (Theorem 1), total surplus is not maximized at any $\beta < \beta^*$.

Consider next the equilibrium quantity $q^{mp}(1)$ at $\beta = 1$ (Section D.2.3). Define the price–cost margin $m(q) \equiv p(q) - c(q)$ and the marginal-cost wedge $b(q) \equiv mc(q) - c(q)$, so that at any quantity

$$p(q) - mc(q) = m(q) - b(q).$$

It follows that there are three possibilities:

$$\begin{cases} b(q^{mp}(1)) = m(q^{mp}(1)) & \Rightarrow \beta^\dagger = 1 \\ b(q^{mp}(1)) < m(q^{mp}(1)) & \Rightarrow \beta^\dagger = 1 \\ b(q^{mp}(1)) > m(q^{mp}(1)) & \Rightarrow \beta^\dagger \in (\beta^*, 1) \end{cases}$$

First, if $b(q^{mp}(1)) = m(q^{mp}(1))$, $\beta = 1$ maximizes total welfare and leads to the first-best solution $p(q^{mp}(1)) = mc(q^{mp}(1))$. Second, if $b(q^{mp}(1)) < m(q^{mp}(1))$, prices are still too high at $\beta = 1$, as $p(q^{mp}(1)) > mc(q^{mp}(1))$. However, given that $\beta = 1$ is the highest possible value of β, welfare is maximized at this value. Third, if $b(q^{mp}(1)) > m(q^{mp}(1))$, the price at $\beta = 1$ is below marginal costs, meaning that there is overproduction. Given that $\frac{\partial q}{\partial \beta} > 0$ under monopolistic conduct and β^* leads to a total quantity lower than first-best, this implies that total welfare is maximized at $\beta^* < \beta < 1$.

Finally, suppose β^* is a corner value (Section A, Propositions OA-2–OA-3). If $\beta^* = 0$, the stated range $[\beta^*, 1] = [0, 1]$ contains $\beta^\dagger$ trivially. If $\beta^* = 1$, then $q^{mp}(\beta) \leq q^* < q^\dagger$ for all β (Proposition OA-3), so total surplus is strictly increasing in β (Theorem 1 and Lemma OA-8) and $\beta^\dagger = 1 = \beta^*$. □

C.8 Proof of Theorem 2

Proof. We show that under Constraint 1, at any $\beta \in [0, 1]$, the vertical distortion exists only under monopolistic conduct if $\beta < \beta^*$ and under monopsonistic conduct if $\beta > \beta^*$. We consider three cases depending on the disagreement payoffs.

Case 1: $\pi_0^d \leq \pi^{d*}$ and $\pi_0^u \leq \pi^{u*}$ ($\beta^* \in [0, 1]$)

Monopolistic conduct:

Under monopolistic bargaining, the input demand condition gives $w = mr(q)$, so the markdown $\Delta^d = 0$ automatically. The constraint that must be satisfied is the nonnegative markup: $w \geq mc(q)$, i.e., $mr(q) \geq mc(q)$, i.e., $q \leq q^*$.

- If $\beta \leq \beta^*$: From Theorem 1, q^{mp} is increasing in β, and by Proposition 2, $q^{mp}(\beta^*) = q^*$. Therefore $q^{mp}(\beta) \leq q^*$ for $\beta \leq \beta^*$, so $w = mr(q^{mp}) \geq mr(q^*) = mc(q^*) \geq mc(q^{mp})$. The constraint $w \geq mc(q)$ is satisfied (slack). The standard unconstrained equilibrium prevails with a vertical distortion ($\mu^u > 0$ when $\beta < \beta^*$).

- If $\beta > \beta^*$: The unconstrained solution would give $q^{mp} > q^*$, implying $w = mr(q^{mp}) < mr(q^*) = mc(q^*) < mc(q^{mp})$, which violates $w \geq mc(q)$. Since the log Nash product is strictly concave along the input demand curve (by log-concavity of the profit functions), it is strictly increasing below its unconstrained peak $q^{mp} > q^*$; on the feasible set $q \leq q^*$ the maximum is therefore attained at the boundary, and the constraint binds: $w = mc(q)$ together with $w = mr(q)$ forces $mc(q) = mr(q)$, hence $q = q^*$ and $w = w^*$.

Monopsonistic conduct:

Under monopsonistic bargaining, the input supply condition gives $w = mc(q)$, so the markup $\mu^u = 0$ automatically. The constraint that must be satisfied is the nonnegative markdown: $w \leq mr(q)$, i.e., $mc(q) \leq mr(q)$, i.e., $q \leq q^*$.

- If $\beta \geq \beta^*$: From Theorem 1, q^{ms} is decreasing in β, and by Proposition 2, $q^{ms}(\beta^*) = q^*$. Therefore $q^{ms}(\beta) \leq q^*$ for $\beta \geq \beta^*$, so $w = mc(q^{ms}) \leq mc(q^*) = mr(q^*) \leq mr(q^{ms})$. The constraint $w \leq mr(q)$ is satisfied (slack). The standard unconstrained equilibrium prevails with a vertical distortion ($\Delta^d > 0$ when $\beta > \beta^*$).

- If $\beta < \beta^*$: The unconstrained solution would give $q^{ms} > q^*$, implying $w = mc(q^{ms}) > mc(q^*) = mr(q^*) > mr(q^{ms})$, which violates $w \leq mr(q)$. By the same single-peakedness argument along the input supply curve, the maximum on the feasible set $q \leq q^*$ is attained at the boundary, and the constraint binds: $w = mr(q)$ together with $w = mc(q)$ forces $mc(q) = mr(q)$, hence $q = q^*$ and $w = w^*$.

Case 2: $\pi_0^d > \pi^{d*}$ ($\beta^* = 0$)

By Proposition OA-2, $q^{ms}(\beta) < q^*$ for all β under monopsonistic conduct, and $q^{mp}(\beta) > q^*$ for all β under monopolistic conduct.

- *Monopsonistic conduct:* Since $q^{ms}(\beta) < q^*$ for all β, we have $w = mc(q^{ms}) < mc(q^*) = mr(q^*) < mr(q^{ms})$, so $w \leq mr(q)$ is satisfied. The constraint is slack and the monopsonistic equilibrium has a distortion ($\Delta^d > 0$) for all $\beta > 0$.

- *Monopolistic conduct:* Since $q^{mp}(\beta) > q^*$ for all β, we have $w = mr(q^{mp}) < mr(q^*) = mc(q^*) < mc(q^{mp})$, so $w \geq mc(q)$ is violated. The constraint requires $q \leq q^*$, and by the same single-peakedness argument the constrained optimum would be at $q = q^*$ with $w = w^*$. However, at q^* downstream earns $\pi^d(q^*) = \pi^{d*} < \pi_0^d$, violating downstream's participation constraint. Therefore, the monopolistic equilibrium does not exist under Constraint 1.

Since $\beta^* = 0$, the condition "monopolistic if $\beta < \beta^*$" is never satisfied, and "monopsonistic if $\beta > \beta^*$" holds for all $\beta \in (0, 1]$, consistent with the theorem.

Case 3: $\pi_0^u > \pi^{u*}$ ($\beta^* = 1$)

By Proposition OA-3, $q^{ms}(\beta) > q^*$ for all β under monopsonistic conduct, and $q^{mp}(\beta) < q^*$ for all β under monopolistic conduct.

- *Monopolistic conduct:* Since $q^{mp}(\beta) < q^*$ for all β, we have $w = mr(q^{mp}) > mr(q^*) = mc(q^*) > mc(q^{mp})$, so $w \geq mc(q)$ is satisfied. The constraint is slack and the monopolistic equilibrium has a distortion ($\mu^u > 0$) for all $\beta < 1$.

- *Monopsonistic conduct:* Since $q^{ms}(\beta) > q^*$ for all β, we have $w = mc(q^{ms}) > mc(q^*) = mr(q^*) > mr(q^{ms})$, so $w \leq mr(q)$ is violated. The constraint requires $q \leq q^*$, and by the same single-peakedness argument the constrained optimum would be at $q = q^*$ with $w = w^*$. However, at q^* upstream earns $\pi^u(q^*) = \pi^{u*} < \pi_0^u$, violating upstream's participation constraint. Therefore, the monopsonistic equilibrium does not exist under Constraint 1.

Since $\beta^* = 1$, the condition "monopolistic if $\beta < \beta^*$" holds for all $\beta \in [0, 1)$, and "monopsonistic if $\beta > \beta^*$" is never satisfied, consistent with the theorem.

In Case 1, for any $\beta < \beta^*$, monopolistic conduct operates unconstrained (with distortion $\mu^u > 0$) while monopsonistic conduct is constrained to q^* (no distortion); for $\beta > \beta^*$, monopsonistic conduct operates unconstrained (with distortion $\Delta^d > 0$) while monopolistic conduct is constrained to q^* (no distortion); and at $\beta = \beta^*$, both models yield q^* with no distortion. In Cases 2 and 3, the conduct model that would be constrained to q^* instead fails to exist, because the corresponding participation constraint is violated at q^*: in Case 2 ($\beta^* = 0$), the monopolistic equilibrium does not exist and monopsonistic conduct operates unconstrained with a distortion for all $\beta > 0$; in Case 3 ($\beta^* = 1$), the monopsonistic equilibrium does not exist and monopolistic conduct operates unconstrained with a distortion for all $\beta < 1$. In all three cases, therefore, a vertical distortion exists only under monopolistic conduct when $\beta < \beta^*$ and only under monopsonistic conduct when $\beta > \beta^*$, as stated in the theorem. $\square$

C.9 Proof of Proposition 5

Proof. Under Constraint 1, output satisfies $q \leq q^*$ under both conduct models (as shown in the proof of Theorem 2).

Part (i): Monopolistic bargaining $\Rightarrow w \geq w^*$.

Under monopolistic bargaining, $w = mr(q^{mp})$. Since $q^{mp} \leq q^*$ and $mr'(q) < 0$:

$$w = mr(q^{mp}) \geq mr(q^*) = w^*.$$

Part (ii): Monopsonistic bargaining $\Rightarrow w \leq w^*$.

Under monopsonistic bargaining, $w = mc(q^{ms})$. Since $q^{ms} \leq q^*$ and $mc'(q) > 0$:

$$w = mc(q^{ms}) \leq mc(q^*) = w^*.$$

Therefore, $w > w^*$ identifies monopolistic conduct and $w < w^*$ identifies monopsonistic conduct. $\square$

C.10 Proof of Corollary 3

Proof. Consider the three disagreement-payoff cases in the proof of Theorem 2 (Section C.8). In Case 1, under monopolistic conduct the constraint is slack for $\beta \leq \beta^*$ with $q^{mp}(\beta) \leq q^*$ (Theorem 1 and Proposition 2), and binds for $\beta > \beta^*$ with $q = q^*$; the monopsonistic case is symmetric. In Cases 2 and 3, whenever the constrained equilibrium exists, it coincides with the unconstrained equilibrium, whose output lies strictly below q^* (Propositions OA-2 and OA-3). In every case, $q \le q^*$. □

D Auxiliary Lemmas and Results

D.1 Bilateral Representation of the Bargaining Problem

This subsection formalizes the bilateral representation introduced in Section 2: each pair's bargaining problem over the multi-partner profit functions Π^d and Π^u is identical to the bargaining problem over the pair-specific profit functions π^d_{ud} and π^u_{ud}, and the properties assumed on the primitives carry over to the residual curves p_{ud} and c_{ud}.

Fix a pair (U, D) and recall the notation of Section 2: D purchases quantities q_{jd} at prices w_{jd} from suppliers j, U sells quantities q_{uk} at prices w_{uk} to buyers k, and $Q_d^{-u} \equiv \sum_{j\neq u} q_{jd}$ and $Q_u^{-d} \equiv \sum_{k\neq d} q_{uk}$ denote D's purchases from suppliers other than U and U's sales to buyers other than D. The total profits are

$$\Pi^d\big(w_{ud}, q_{ud};\, \boldsymbol{w}_d^{-u}, \boldsymbol{q}_d^{-u}\big) \;=\; P_d\big(Q_d^{-u} + q_{ud}\big)\big(Q_d^{-u} + q_{ud}\big) \;-\; \sum_j w_{jd}\, q_{jd},$$

$$\Pi^u\big(w_{ud}, q_{ud};\, \boldsymbol{w}_u^{-d}, \boldsymbol{q}_u^{-d}\big) \;=\; \sum_k w_{uk}\, q_{uk} \;-\; C_u\big(Q_u^{-d} + q_{ud}\big)\big(Q_u^{-d} + q_{ud}\big).$$

Define the marginal revenue and marginal cost of the primitives as

$$MR_d(Q) \equiv \frac{\mathrm{d}}{\mathrm{d}Q}\big[P_d(Q)\,Q\big], \qquad MC_u(Q) \equiv \frac{\mathrm{d}}{\mathrm{d}Q}\big[C_u(Q)\,Q\big].$$

As in Section 2, $MR_d(\cdot)$ is nonincreasing (weakly decreasing marginal revenue) and $MC_u(\cdot)$ is nondecreasing (weakly increasing marginal cost) on the relevant range.

Lemma OA-1 (Bilateral representation)**.** *Fix the other trades $(\boldsymbol{w}_d^{-u}, \boldsymbol{q}_d^{-u})$ and $(\boldsymbol{w}_u^{-d}, \boldsymbol{q}_u^{-d})$, and define the pair's residual curves, as functions of a generic quantity $q > 0$ traded between the pair,*

$$p_{ud}(q) \;\equiv\; \frac{P_d\big(Q_d^{-u} + q\big)\big(Q_d^{-u} + q\big) - P_d\big(Q_d^{-u}\big)\,Q_d^{-u}}{q},$$

$$c_{ud}(q) \;\equiv\; \frac{C_u\big(Q_u^{-d} + q\big)\big(Q_u^{-d} + q\big) - C_u\big(Q_u^{-d}\big)\,Q_u^{-d}}{q}.$$

Then:

(i) (Representation) *The total profits decompose as*

$$\Pi^d = \pi^d_{ud}(w_{ud}, q_{ud}) + K^d_{ud}, \qquad \Pi^u = \pi^u_{ud}(w_{ud}, q_{ud}) + K^u_{ud},$$

where $\pi^d_{ud}(w,q) \equiv \big(p_{ud}(q) - w\big)q$ *and* $\pi^u_{ud}(w,q) \equiv \big(w - c_{ud}(q)\big)q$*, and*

$$K^d_{ud} \equiv P_d\big(Q^{-u}_d\big)\, Q^{-u}_d - \sum_{j\neq u} w_{jd}\, q_{jd}, \qquad K^u_{ud} \equiv \sum_{k\neq d} w_{uk}\, q_{uk} - C_u\big(Q^{-d}_u\big)\, Q^{-d}_u$$

do not depend on (w_{ud}, q_{ud})*.*

(ii) (Disagreement) *Suppose that upon disagreement the parties' other agreements remain unchanged, and that each party may in addition undertake an arbitrary fallback trade with an outside party — D buying* $\bar{q}_d \geq 0$ *at price* $\bar{w}_d$*, and U selling* $\bar{q}_u \geq 0$ *at price* $\bar{w}_u$*, with* $\bar{q}_d = \bar{q}_u = 0$ *nesting no replacement. Then the disagreement profits satisfy*

$$\Pi^d_0 = K^d_{ud} + \pi^d_0, \qquad \Pi^u_0 = K^u_{ud} + \pi^u_0,$$

where $\pi^d_0 \equiv \big(p_{ud}(\bar{q}_d) - \bar{w}_d\big)\bar{q}_d$ *and* $\pi^u_0 \equiv \big(\bar{w}_u - c_{ud}(\bar{q}_u)\big)\bar{q}_u$ *are the pair-specific disagreement payoffs; they are nonnegative whenever the fallback trades are voluntary, and equal zero with no replacement.*

(iii) (Equivalence) *For any* (w_{ud}, q_{ud}) *and any* $\beta_{ud} \in [0,1]$*,*

$$\big(\Pi^d - \Pi^d_0\big)^{\beta_{ud}}\big(\Pi^u - \Pi^u_0\big)^{1-\beta_{ud}} = \big(\pi^d_{ud}(w_{ud}, q_{ud}) - \pi^d_0\big)^{\beta_{ud}}\big(\pi^u_{ud}(w_{ud}, q_{ud}) - \pi^u_0\big)^{1-\beta_{ud}}.$$

The two objectives are equal identically, so the bargaining problem, its first-order conditions, the participation constraints, and the conduct conditions coincide under the two formulations.

Proof. Step 1 (Representation, buyer). Adding and subtracting $P_d\big(Q^{-u}_d\big)Q^{-u}_d$ in Π^d and using the definition of p_{ud}:

$$\begin{aligned}
\Pi^d &= P_d\big(Q^{-u}_d + q_{ud}\big)\big(Q^{-u}_d + q_{ud}\big) - w_{ud}\, q_{ud} - \sum_{j\neq u} w_{jd}\, q_{jd} \\
&= \underbrace{\Big[P_d\big(Q^{-u}_d + q_{ud}\big)\big(Q^{-u}_d + q_{ud}\big) - P_d\big(Q^{-u}_d\big)\, Q^{-u}_d\Big] - w_{ud}\, q_{ud}}_{=\big(p_{ud}(q_{ud}) - w_{ud}\big)q_{ud} \,=\, \pi^d_{ud}(w_{ud}, q_{ud})} \;+\; \underbrace{P_d\big(Q^{-u}_d\big)\, Q^{-u}_d - \sum_{j\neq u} w_{jd}\, q_{jd}}_{=K^d_{ud}}.
\end{aligned}$$

Step 2 (Representation, supplier). Symmetrically, adding and subtracting $C_u\big(Q^{-d}_u\big)Q^{-d}_u$ in Π^u yields $\Pi^u = \pi^u_{ud}(w_{ud}, q_{ud}) + K^u_{ud}$.

Step 3 (Disagreement). Upon disagreement, D's trades with its other suppliers are unchanged and it purchases $\bar{q}_d$ at $\bar{w}_d$ from an outside party. Since the fallback units are perfect substitutes entering the same total quantity, D's disagreement profit is

$$\Pi_0^d = P_d\big(Q_d^{-u} + \bar{q}_d\big)\big(Q_d^{-u} + \bar{q}_d\big) - \bar{w}_d\,\bar{q}_d - \sum_{j\neq u} w_{jd}\,q_{jd} = K_{ud}^d + \big(p_{ud}(\bar{q}_d) - \bar{w}_d\big)\bar{q}_d,$$

where the second equality applies Step 1 with $(\bar{w}_d, \bar{q}_d)$ in place of (w_{ud}, q_{ud}). Setting $\pi_0^d \equiv (p_{ud}(\bar{q}_d) - \bar{w}_d)\bar{q}_d$ gives $\Pi_0^d = K_{ud}^d + \pi_0^d$; with no replacement ($\bar{q}_d = 0$), $\pi_0^d = 0$, and if the fallback is chosen voluntarily, $\pi_0^d \geq 0$ since $\bar{q}_d = 0$ is always available. The supplier's side is symmetric.

Step 4 (Equivalence). Subtracting the expressions in Steps 1–3, the constants cancel:

$$\Pi^d - \Pi_0^d = \pi_{ud}^d(w_{ud}, q_{ud}) - \pi_0^d, \qquad \Pi^u - \Pi_0^u = \pi_{ud}^u(w_{ud}, q_{ud}) - \pi_0^u.$$

Raising to the powers β_{ud} and $1-\beta_{ud}$ and multiplying yields the claimed identity. Since the objectives are equal for every (w_{ud}, q_{ud}), all first-order conditions, participation constraints, and conduct conditions coincide. □

Lemma OA-2 (Properties of the residual curves)**.** *Fix any conditioning quantities $Q_d^{-u}, Q_u^{-d} \geq 0$, and let $mr(q) \equiv \frac{\mathrm{d}}{\mathrm{d}q}\big[p_{ud}(q)q\big]$ and $mc(q) \equiv \frac{\mathrm{d}}{\mathrm{d}q}\big[c_{ud}(q)q\big]$ denote the pair-level marginal revenue and marginal cost. Then:*

(i) If P_d has weakly decreasing marginal revenue, then so does p_{ud}: $mr(q) = MR_d\big(Q_d^{-u} + q\big)$ is nonincreasing, and $p'_{ud}(q) \leq 0$.

(ii) If C_u has weakly increasing marginal cost, then so does c_{ud}: $mc(q) = MC_u\big(Q_u^{-d} + q\big)$ is nondecreasing, and $c'_{ud}(q) \geq 0$.

Proof. Step 1 (Integral form). By the fundamental theorem of calculus,

$$P_d\big(Q_d^{-u} + q\big)\big(Q_d^{-u} + q\big) - P_d\big(Q_d^{-u}\big)\,Q_d^{-u} = \int_{Q_d^{-u}}^{Q_d^{-u}+q} MR_d(x)\,\mathrm{d}x = \int_0^q MR_d\big(Q_d^{-u} + s\big)\,\mathrm{d}s.$$

Dividing by q, the residual curve $p_{ud}(q) = \frac{1}{q}\int_0^q MR_d\big(Q_d^{-u} + s\big)\,\mathrm{d}s$ is the average of the primitive marginal revenue over the increment. The cost side is identical with MC_u in place of MR_d. Since the running average of a nonincreasing (nondecreasing) function is nonincreasing (nondecreasing), $p'_{ud}(q) \leq 0$ and $c'_{ud}(q) \geq 0$.

Step 2 (Marginal curves inherit monotonicity). Since $p_{ud}(q)\,q = \int_0^q MR_d\big(Q_d^{-u} + s\big)\,\mathrm{d}s$, differentiating gives $mr(q) = MR_d\big(Q_d^{-u} + q\big)$: the pair-level marginal revenue is the primitive marginal revenue evaluated at D's total quantity. Hence $mr(\cdot)$ is nonincreasing whenever $MR_d(\cdot)$ is. Symmetrically, $mc(q) = MC_u\big(Q_u^{-d} + q\big)$ is nondecreasing whenever $MC_u(\cdot)$ is. □

D.2 Equilibrium Under Limit Cases for β

We solve the bargaining model (monopolistic and monopsonistic) as a constrained profit-maximization model in the limiting cases of $\beta = 1$ and $\beta = 0$ and compare these corner solutions to the solutions obtained from the first-order conditions derived in Section B.1.

D.2.1 Monopsonistic Bargaining, $\beta = 1$

At $\beta = 1$, downstream has full bargaining power. The stage-2 quantity is determined by upstream's FOC ($w = mc(q)$). The stage-1 problem is:

$$\max_{q} \, (p(q) - mc(q))q \quad \text{s.t.} \quad c'(q)q^2 \geq \pi_0^u.$$

The unconstrained FOC gives the classical monopsony condition:

$$mr(q) = mc'(q)q + mc(q), \quad w = mc(q).$$

If the participation constraint is slack at this solution (i.e., $c'(q)q^2 \geq \pi_0^u$), this is the equilibrium. If the constraint binds, the equilibrium quantity is instead determined by $c'(q)q^2 = \pi_0^u$. To see this, note that the gain $(p(q) - mc(q))q - \pi_0^d$ is strictly log-concave in q under the maintained strict log-concavity of the profit functions (Section B.2), hence single-peaked, and therefore so is the objective $(p(q) - mc(q))q$. Since the unconstrained maximizer lies below the feasible set $\{q : c'(q)q^2 \geq \pi_0^u\}$, single-peakedness implies the objective is decreasing on the feasible set, so the constrained maximum is at the boundary.

D.2.2 Monopsonistic Bargaining, $\beta = 0$

At $\beta = 0$, upstream has full bargaining power. The stage-2 quantity is determined by upstream's FOC ($w = mc(q)$). The stage-1 problem is:

$$\max_{q} \, c'(q)q^2 \quad \text{s.t.} \quad (p(q) - mc(q))q \geq \pi_0^d.$$

Upstream maximizes its own profit $\pi^u = c'(q)q^2$, which is strictly increasing in q. Therefore, upstream wants q as large as possible. The binding constraint is downstream's participation: $(p(q) - mc(q))q = \pi_0^d$, whose largest solution is the equilibrium quantity (upstream's objective is increasing in q). When $\pi_0^d = 0$, this gives $p(q) = mc(q)$, i.e., price equals marginal cost (the first-best outcome). When $\pi_0^d > 0$, the equilibrium quantity is the largest solution of $(p(q) - mc(q))q = \pi_0^d$.

D.2.3 Monopolistic Bargaining, $\beta = 1$

At $\beta = 1$, downstream has full bargaining power. The stage-2 quantity is determined by downstream's FOC ($w = mr(q)$). The stage-1 problem is:

$$\max_q \; -p'(q)q^2 \quad \text{s.t.} \quad (mr(q) - c(q))q \geq \pi_0^u.$$

Downstream maximizes its own profit $\pi^d = -p'(q)q^2$, which is strictly increasing in q. Therefore, downstream wants q as large as possible. The binding constraint is upstream's participation: $(mr(q) - c(q))q = \pi_0^u$, whose largest solution is the equilibrium quantity (downstream's objective is increasing in q). When $\pi_0^u = 0$, this gives $mr(q) = c(q)$, i.e., $w = c(q)$. When $\pi_0^u > 0$, the equilibrium quantity is the largest solution of $(mr(q)-c(q))q = \pi_0^u$.

D.2.4 Monopolistic Bargaining, $\beta = 0$

At $\beta = 0$, upstream has full bargaining power. The stage-2 quantity is determined by downstream's FOC ($w = mr(q)$). The stage-1 problem is:

$$\max_q \; (mr(q) - c(q))q \quad \text{s.t.} \quad -p'(q)q^2 \geq \pi_0^d.$$

The unconstrained FOC gives the full double marginalization condition:

$$mr(q) = w, \quad mc(q) = mr'(q)q + mr(q).$$

If the participation constraint is slack at this solution (i.e., $-p'(q)q^2 \geq \pi_0^d$), this is the equilibrium. If the constraint binds, the equilibrium quantity is instead determined by $-p'(q)q^2 = \pi_0^d$. To see this, note that the gain $(mr(q) - c(q))q - \pi_0^u$ is strictly log-concave in q under the maintained strict log-concavity of the profit functions (Section B.2), hence single-peaked, and therefore so is the objective $(mr(q) - c(q))q$. Since the unconstrained maximizer lies below the feasible set $\{q : -p'(q)q^2 \geq \pi_0^d\}$, single-peakedness implies the objective is decreasing on the feasible set, so the constrained maximum is at the boundary.

D.3 Auxiliary Lemmas on Equilibrium Existence

In this appendix, we discuss the existence and uniqueness of the monopolistic and monopsonistic equilibria in the bargaining model.

For each conduct model, we show that the FOC solution for interior β converges to the direct constrained-optimization solution at the corner values $\beta = 0$ and $\beta = 1$. We then rely on continuity to establish existence for all $\beta \in [0, 1]$.

Lemma OA-3. *The solution to the monopsonistic bargaining problem with disagreement payoffs π_0^d and π_0^u, characterized by its FOCs given in Appendix B.1, converges, as $\beta \longrightarrow 1$, to the solution of the constrained-optimization problem at $\beta = 1$ provided in Appendix D.2.1.*

Proof. The B-FOC under monopsonistic conduct is $\beta\, A(q) + (1-\beta)\, B(q) = 0$ where:

$$A(q) = \frac{d\pi^d/dw}{\pi^d - \pi_0^d},$$

$$B(q) = \frac{q}{c'(q)q^2 - \pi_0^u}.$$

Write $\beta = 1 - \varepsilon$. The equation becomes $(1-\varepsilon)A + \varepsilon B = 0$, i.e., $A = -\frac{\varepsilon}{1-\varepsilon}B$.

As $\varepsilon \longrightarrow 0$, the right side tends to zero. Two cases arise:

Case (a): If B remains bounded (i.e., $c'(q)q^2 - \pi_0^u$ stays bounded away from zero), then $A \longrightarrow 0$, which gives $d\pi^d/dw = 0$. This is the classical monopsony condition $mr(q) = mc'(q)q + mc(q)$ from Appendix D.2.1, with the participation constraint $c'(q)q^2 \geq \pi_0^u$ slack.

Case (b): If $B \longrightarrow \pm\infty$ (i.e., $c'(q)q^2 - \pi_0^u \longrightarrow 0$), then the limit gives $c'(q)q^2 = \pi_0^u$, which is the binding participation constraint from Appendix D.2.1. This case arises when the classical monopsony quantity q_{cm} (defined by $mr(q_{cm}) = mc'(q_{cm})q_{cm} + mc(q_{cm})$) satisfies $c'(q_{cm})q_{cm}^2 < \pi_0^u$, so that upstream would not participate at q_{cm}. For any $\beta < 1$, the interior FOC solution satisfies $\pi^u(q(\beta)) > \pi_0^u$ (both participation constraints hold with strict inequality). Since $dq^{ms}/d\beta < 0$ (Theorem 1), output $q(\beta)$ decreases as β increases, and upstream profit $\pi^u(q) = c'(q)q^2$ increases with q (since $\frac{d}{dq}[c'(q)q^2] = c''(q)q^2 + 2c'(q)q > 0$). Being decreasing in β and bounded below, $q(\beta)$ converges to some limit q_L with $\pi^u(q_L) \geq \pi_0^u$. If $\pi^u(q_L) > \pi_0^u$, then $B(q(\beta))$ would remain bounded, so the FOC would force $A(q(\beta)) \longrightarrow 0$, i.e., the classical monopsony condition of Case (a) in the limit, $q_L = q_{cm}$; but every interior solution satisfies $q(\beta) > \underline{q}^u > q_{cm}$, where $c'(\underline{q}^u)(\underline{q}^u)^2 = \pi_0^u > c'(q_{cm})q_{cm}^2$ — a contradiction. Hence $\pi^u(q(\beta))$ is squeezed toward π_0^u from above, and the equilibrium converges to $\underline{q}^u$ where $c'(\underline{q}^u)(\underline{q}^u)^2 = \pi_0^u$. In the B-FOC, since $(1-\varepsilon)A + \varepsilon B = 0$ holds at each $\varepsilon > 0$, we have $\varepsilon B = -(1-\varepsilon)A$. As $\varepsilon \to 0$, $(1-\varepsilon) \to 1$ and $A(q(\varepsilon)) \to A(\underline{q}^u)$, which is finite (since $\pi^d(\underline{q}^u) > \pi_0^d$ at the limit). Therefore $\varepsilon B \to -A(\underline{q}^u)$, confirming that εB remains finite.

In both cases, the FOC solution converges to the direct constrained-optimization solution at $\beta = 1$. □

Lemma OA-4. *The solution to the monopolistic bargaining problem with disagreement payoffs π_0^d*

and π_0^u, characterized by its FOCs given in Appendix B.1, converges, as $\beta \to 1$, to the solution of the constrained-optimization problem at $\beta = 1$ provided in Appendix D.2.3.

Proof. Define

$$A(q) \equiv \frac{d\pi^d/dw}{\pi^d - \pi_0^d} = \frac{-q}{-p'(q)q^2 - \pi_0^d},$$

$$B(q) \equiv \frac{d\pi^u/dw}{\pi^u - \pi_0^u} = \frac{q + [p(q) - c(q) + p'(q)q - c'(q)q]\frac{1}{2p'(q)+p''(q)q}}{[p(q) - c(q) + p'(q)q]q - \pi_0^u}$$

The FOC that characterizes equilibrium q is $\beta\, A(q) \;+\; (1-\beta)\, B(q) \;=\; 0$. Rewrite β as $1-\varepsilon$. Then, the equation becomes

$$(1-\varepsilon)\, A(q) \;+\; \varepsilon\, B(q) \;=\; 0 \quad \Longrightarrow \quad \frac{1-\varepsilon}{\varepsilon}\, A(q) \;=\; -B(q).$$

As $\varepsilon \to 0$, the left side tends to $\pm\infty$ (since $A(q) = -q/(-p'(q)q^2 - \pi_0^d) \neq 0$). Thus, $B(q)$ must also become unbounded in magnitude. The numerator of $B(q)$ is bounded, so the denominator must vanish:

$$[p(q) - c(q) + p'(q)q]q - \pi_0^u \;\to\; 0.$$

When $\pi_0^u = 0$, this gives $p(q) - c(q) + qp'(q) = 0$, i.e., $mr(q) = c(q)$. When $\pi_0^u > 0$, the condition becomes $[p(q) + p'(q)q - c(q)]q = \pi_0^u$, which pins down the equilibrium quantity at $\beta = 1$. Because the left-hand side equals the upstream profit $\pi^u(q) = [mr(q) - c(q)]q$ along the input demand curve, every interior solution satisfies $\pi^u(q(\beta)) > \pi_0^u$ and hence lies strictly between the two roots of $[mr(q) - c(q)]q = \pi_0^u$; since $q^{mp}(\beta)$ is increasing in β (Theorem 1), the limit as $\beta \to 1$ is the larger root, which lies on the decreasing branch of $[mr(q) - c(q)]q$. In both cases, this corresponds to the solution of the constrained-optimization problem at $\beta = 1$ given in Appendix D.2.3. □

Lemma OA-5. *The solution to the monopsonistic bargaining problem with disagreement payoffs π_0^d and π_0^u, characterized by its FOC given in Appendix B.1, converges, as $\beta \to 0$, to the solution of the constrained-optimization problem at $\beta = 0$ given in Appendix D.2.2.*

Proof. Define

$$A(q) \equiv \frac{d\pi^d/dw}{\pi^d - \pi_0^d} = \frac{-q + \left([p(q) - c(q)] + [p'(q)q - c'(q)q]\right)\frac{1}{2c'(q)+c''(q)q}}{[p(q) - c(q) - c'(q)q]q - \pi_0^d},$$

$$B(q) \equiv \frac{d\pi^u/dw}{\pi^u - \pi_0^u} = \frac{q}{c'(q)q^2 - \pi_0^u}$$

The FOC that characterizes equilibrium q is $\beta\, A(q) \;+\; (1-\beta)\, B(q) \;=\; 0$. Rewrite β as ε. Then, the equation becomes

$$\varepsilon A(q) + (1-\varepsilon)B(q) = 0 \quad \Longrightarrow \quad \frac{\varepsilon}{1-\varepsilon} = -\frac{B(q)}{A(q)}$$

As $\varepsilon \to 0$ (i.e., $\beta \to 0$), the multiplier $\frac{\varepsilon}{1-\varepsilon}$ tends to 0. If $B(q) \neq 0$ is finite, we must have $A(q)$ become unbounded (go to $\pm\infty$). The numerator of $A(q)$ is bounded, so the denominator must vanish:

$$[p(q) - c(q) - c'(q)q]q - \pi_0^d \;\to\; 0.$$

When $\pi_0^d = 0$, this gives $p(q) - c(q) - c'(q)q = 0$, i.e., $p(q) = mc(q)$. When $\pi_0^d > 0$, the condition becomes $[p(q) - c(q) - c'(q)q]q = \pi_0^d$, which pins down the equilibrium quantity at $\beta = 0$. Because the left-hand side equals the downstream profit $\pi^d(q) = [p(q) - mc(q)]q$ along the input supply curve, every interior solution satisfies $\pi^d(q(\beta)) > \pi_0^d$ and hence lies strictly between the two roots of $[p(q) - mc(q)]q = \pi_0^d$; since $q^{ms}(\beta)$ is decreasing in β (Theorem 1), the limit as $\beta \to 0$ is the larger root, which lies on the decreasing branch of $[p(q) - mc(q)]q$. In both cases, this corresponds to the solution of the constrained-optimization problem in Appendix D.2.2. □

Lemma OA-6. *The solution to the monopolistic bargaining problem with disagreement payoffs π_0^d and π_0^u, characterized by its FOCs given in Appendix B.1, converges, as $\beta \to 0$, to the solution of the constrained-optimization problem at $\beta = 0$ provided in Appendix D.2.4.*

Proof. The B-FOC under monopolistic conduct is $\beta\, A(q) + (1-\beta)\, B(q) = 0$ where:

$$A(q) = \frac{-q}{-p'(q)q^2 - \pi_0^d},$$

$$B(q) = \frac{d\pi^u/dw}{\pi^u - \pi_0^u}.$$

Write $\beta = \varepsilon$. The equation becomes $\varepsilon A + (1-\varepsilon)B = 0$, i.e., $B = -\frac{\varepsilon}{1-\varepsilon}A$.

As $\varepsilon \to 0$, the right side tends to zero. Two cases arise:

Case (a): If A remains bounded (i.e., $-p'(q)q^2 - \pi_0^d$ stays bounded away from zero), then $B \to 0$, which gives $d\pi^u/dw = 0$. This is the full double marginalization condition $mc(q) = mr'(q)q + mr(q)$ from Appendix D.2.4, with the participation constraint $-p'(q)q^2 \geq \pi_0^d$ slack.

Case (b): If $A \to \pm\infty$ (i.e., $-p'(q)q^2 - \pi_0^d \to 0$), then the limit gives $-p'(q)q^2 = \pi_0^d$, which is the binding participation constraint from Appendix D.2.4. This case arises when the double marginalization quantity would violate $\pi^d \geq \pi_0^d$. The squeeze argument of Lemma OA-3 applies with the roles interchanged: as $\beta \to 0$, $q(\beta)$ decreases toward a limit q_L with $\pi^d(q_L) \geq \pi_0^d$; if the inequality were strict, A would remain bounded and the FOC would force $B \to 0$, i.e., q_L would satisfy the double marginalization condition of Case (a), which is infeasible here — a contradiction. Hence the downstream constraint binds in the limit.

In both cases, the FOC solution converges to the direct constrained-optimization solution at $\beta = 0$. □

Lemma OA-7 (Consumer surplus and output)**.** *Let $P(\cdot)$, with $P'(\cdot) < 0$, denote the inverse demand curve in D's downstream market, and let $Q \equiv Q_{-d} + Q_d^{-u} + q$ denote the total quantity sold in that market, where Q_{-d} collects the sales of other downstream firms (with $Q_{-d} = 0$ if D is the only one) and Q_d^{-u} the quantity D obtains from its other suppliers, so that $P_d(Q_d) = P(Q_{-d} + Q_d)$. Consumer surplus is $CS \equiv \int_0^Q \big(P(x) - P(Q)\big)\,dx$. Holding Q_{-d} and Q_d^{-u} fixed, $dCS/dq = -P'(Q)\,Q > 0$.*

Proof. Differentiating $CS = \int_0^Q P(x)\,dx - P(Q)Q$ with respect to Q gives $P(Q) - P'(Q)Q - P(Q) = -P'(Q)Q$, which is strictly positive for $Q > 0$ since $P'(Q) < 0$. Under passive beliefs, D's trades with its other suppliers are held fixed, as are the quantities of any other downstream firms, so $dQ/dq = 1$ and hence $dCS/dq = -P'(Q)Q > 0$. □

Lemma OA-8. *Let $\tilde{p}(h) \equiv P_d(Q_d^{-u} + h)$, with $\tilde{p}'(h) = P_d'(Q_d^{-u} + h) < 0$, denote the downstream price when the pair trades h units, holding D's other trades fixed. Conditional on the parties' other trades, the total surplus generated by the pair's trade is $TS(q) \equiv \int_0^q [\tilde{p}(h) - mc(h)]\,dh$. It is maximized at $q^\dagger$ defined by $\tilde{p}(q^\dagger) = mc(q^\dagger)$, and $q^\dagger > q^*$.*

Proof. The derivative of total surplus is $\partial TS/\partial q = \tilde{p}(q) - mc(q)$. Since $\tilde{p}'(q) < 0$ and $mc'(q) > 0$, $\tilde{p}(q) - mc(q)$ is strictly decreasing, so TS is strictly concave. The unique maximum is at $q^\dagger$ where $\tilde{p}(q^\dagger) = mc(q^\dagger)$.

To show $q^\dagger > q^*$: rearranging the definition of $p(\cdot)$ gives $p(q) = \tilde{p}(q) - \frac{Q_d^{-u}}{q}\big[P_d(Q_d^{-u}) - P_d(Q_d^{-u} + q)\big] \leq \tilde{p}(q)$, since P_d is decreasing. Moreover, $mr(q) = p(q) + p'(q)q < p(q)$ for all $q > 0$ (because $p'(q) < 0$). Hence at q^* we have $\tilde{p}(q^*) \geq p(q^*) > mr(q^*) = mc(q^*)$. Since $\tilde{p}(q) - mc(q)$ is strictly decreasing and equals zero at $q^\dagger$, it follows that $q^\dagger > q^*$. □

For $i \in \{d, u\}$ and a given bargaining weight β, denote by $\pi^{i,ms}(\beta)$ and $\pi^{i,mp}(\beta)$ the equilibrium profit of party i under monopsonistic and monopolistic linear-price bargaining, respectively. Denote by $\pi^{i,jpm}(\beta)$ the profit of party i under joint-profit maximization with a two-part tariff (Section E.2), in which the parties trade q^* and divide the joint surplus $S(q^*) \equiv \big(p(q^*) - c(q^*)\big)q^*$ according to the Nash bargaining weights:

$$\pi^{d,jpm}(\beta) = \pi_0^d + \beta\big(S(q^*) - \pi_0^d - \pi_0^u\big), \qquad \pi^{u,jpm}(\beta) = \pi_0^u + (1-\beta)\big(S(q^*) - \pi_0^d - \pi_0^u\big).$$

Note that $\pi^{i,jpm}(\beta)$ is a function of β and differs from the constant π^{i*}, the linear-price profit at q^* (Lemma OA-10); substituting the formula for β^* from Proposition 2 shows that the two coincide exactly at $\beta = \beta^*$. We suppress the argument β when there is no ambiguity.

Lemma OA-9. *In the bargaining model, the following inequalities about profits apply for $\beta \in (0, 1)$:*

$$\begin{cases} \pi^{d,ms} > \pi^{d,jpm} \\ \pi^{u,ms} < \pi^{u,jpm} \end{cases} (\beta < \beta^*) \quad \begin{cases} \pi^{d,mp} > \pi^{d,jpm} \\ \pi^{u,mp} < \pi^{u,jpm} \end{cases} (\beta < \beta^*) \quad \begin{cases} \pi^{d,ms} < \pi^{d,jpm} \\ \pi^{u,ms} > \pi^{u,jpm} \end{cases} (\beta > \beta^*) \quad \begin{cases} \pi^{d,mp} < \pi^{d,jpm} \\ \pi^{u,mp} > \pi^{u,jpm} \end{cases} (\beta > \beta^*)$$

Proof. We prove the result for monopsonistic bargaining; the monopolistic case follows the same structure with the roles of upstream and downstream interchanged. Define $S(q) \equiv (p(q) - c(q))q$ as the joint surplus of the two firms. Since $dS/dq = mr(q) - mc(q)$ and mr is strictly decreasing while mc is strictly increasing, q^* is the unique maximizer of S.

Step 1: Profits agree at β^*. By Proposition 2, at $\beta = \beta^*$ both monopsonistic bargaining and joint-profit maximization yield q^*. By Lemma OA-10, the profits at q^* are the same under both conduct models, so $\pi^{u,ms}(\beta^*) = \pi^{u,jpm}(\beta^*)$ and $\pi^{d,ms}(\beta^*) = \pi^{d,jpm}(\beta^*)$.

Step 2: Corner verification at $\beta = 1$. Under joint-profit maximization at $\beta = 1$, downstream has full power and drives upstream to its disagreement payoff: $\pi^{u,jpm}(\beta = 1) = \pi_0^u$. Under monopsonistic bargaining at $\beta = 1$ (Section D.2.1), the equilibrium quantity $q^{ms}(1)$ satisfies either $mr(q^{ms}(1)) = mc'(q^{ms}(1))q^{ms}(1) + mc(q^{ms}(1))$ (classical monopsony, if the participation constraint $c'(q)q^2 \geq \pi_0^u$ is slack) or $c'(q^{ms}(1))q^{ms}(1)^2 = \pi_0^u$ (if the constraint binds). In either case, $\pi^{u,ms} = c'(q^{ms}(1))q^{ms}(1)^2 \geq \pi_0^u = \pi^{u,jpm}$.

Step 3: Corner verification at $\beta = 0$. Under monopsonistic bargaining at $\beta = 0$ (Section D.2.2), upstream makes a TIOLI offer, driving downstream to its participation constraint: $\pi^{d,ms} = \pi_0^d$. Upstream earns $\pi^{u,ms} = S(q^{ms}(0)) - \pi_0^d$ where $q^{ms}(0)$ satisfies $(p(q^{ms}(0)) - mc(q^{ms}(0)))q^{ms}(0) = \pi_0^d$. Under joint-profit maximization at $\beta = 0$, upstream captures the entire surplus above disagreement payoffs: $\pi^{u,jpm}(\beta = 0) = S(q^*) - \pi_0^d$. Since $S(q^{ms}(0)) <$

$S(q^*)$ (because $q^{ms}(0) \neq q^*$ and S is maximized at q^*), we have $\pi^{u,ms} = S(q^{ms}(0)) - \pi_0^d < S(q^*) - \pi_0^d = \pi^{u,jpm}$.

Step 4: Continuity. From Steps 1–3: $\pi^{u,ms} = \pi^{u,jpm}$ at β^*, $\pi^{u,ms} \geq \pi^{u,jpm}$ at $\beta = 1$, and $\pi^{u,ms} < \pi^{u,jpm}$ at $\beta = 0$. By Proposition 2, β^* is the unique value at which the profits agree. For any $\beta \in (\beta^*, 1)$, both participation constraints are strictly slack, so $\pi^{u,ms} > \pi_0^u = \pi^{u,jpm}(\beta = 1)$ and the profit functions are continuous. Since $\pi^{u,ms}$ and $\pi^{u,jpm}$ agree only at β^* in the interior, continuity implies $\pi^{u,ms} > \pi^{u,jpm}$ for all $\beta \in (\beta^*, 1)$ and $\pi^{u,ms} < \pi^{u,jpm}$ for all $\beta \in [0, \beta^*)$. At $\beta = 1$ the inequality is weak, $\pi^{u,ms} \geq \pi^{u,jpm}$, with equality when the upstream participation constraint binds (Step 2). The downstream inequalities follow from the total surplus comparison: $\pi^{d,ms} = S(q^{ms}) - \pi^{u,ms}$ and $\pi^{d,jpm} = S(q^*) - \pi^{u,jpm}$. Since $S(q^{ms}) \leq S(q^*)$ and $\pi^{u,ms} > \pi^{u,jpm}$ (for $\beta > \beta^*$), we have $\pi^{d,ms} < \pi^{d,jpm}$. The case $\beta < \beta^*$ follows analogously. □

D.4 Other Auxiliary Lemmas

Lemma OA-10. *At the joint-profit maximizing quantity q^* (where $mc(q^*) = mr(q^*)$), the input price $w^* \equiv mc(q^*) = mr(q^*)$ is the same under both monopsonistic and monopolistic conduct, and the upstream and downstream profits are:*

$$\pi^{u*} \equiv (w^* - c(q^*))q^* = c'(q^*)(q^*)^2,$$
$$\pi^{d*} \equiv (p(q^*) - w^*)q^* = -p'(q^*)(q^*)^2.$$

These expressions are independent of the conduct model.

Proof. Under monopsonistic conduct, $w = mc(q)$. At q^*: $w^* = mc(q^*) = mr(q^*)$. The upstream profit is $\pi^u = (w^* - c(q^*))q^* = (mc(q^*) - c(q^*))q^* = c'(q^*)(q^*)^2$. The downstream profit is $\pi^d = (p(q^*) - w^*)q^* = (p(q^*) - mr(q^*))q^* = -p'(q^*)(q^*)^2$.

Under monopolistic conduct, $w = mr(q)$. At q^*: $w^* = mr(q^*) = mc(q^*)$, which is the same w^*. The profit expressions are therefore identical. □

Lemma OA-11. *Under Assumption OA-1 and the second-order condition (Section B.2), the equilibrium quantity $q(\beta)$ is continuously differentiable in β for $\beta \in (0, 1)$ under both monopsonistic and monopolistic conduct.*

Proof. The equilibrium is characterized by the B-FOC $\Phi(\beta, \pi_0^d, \pi_0^u, w) = 0$, as in the proof of Theorem 1. The second-order condition ensures $\partial\Phi/\partial w < 0$ at the equilibrium. By the Implicit Function Theorem, $w(\beta)$ is continuously differentiable in β in a neighborhood of any $\beta \in (0, 1)$. Under monopsonistic conduct, $q = q^u(w)$ where $dq^u/dw = 1/(2c'(q) + c''(q)q)$ is continuous (since $mc'(q) > 0$). Under monopolistic conduct, $q = q^d(w)$ where

$dq^d/dw = 1/(2p'(q) + p''(q)q)$ is continuous (since $mr'(q) < 0$). Therefore $q(\beta) = q(w(\beta))$ is continuously differentiable as the composition of continuously differentiable functions. □

Lemma OA-12. *The joint profit-maximizing quantity q^* is unique.*

Proof. q^* is characterized by $mr(q^*) - mc(q^*) = 0$. Since $mr'(q) < 0$ and $mc'(q) > 0$, there is a unique solution to this equation. □

D.5 Loglinear Version of the Model

We solve the bargaining model with zero disagreement payoffs ($\pi_0^d = \pi_0^u = 0$) and loglinear costs and demand:

$$c(q) = \frac{1}{1+\psi} q^{\psi} \quad \text{and} \quad p(q) = q^{\frac{1}{\eta}}.$$

The input supply condition in the monopsonistic conduct case results in the factor supply curve $w = q^{\psi}$. The input demand condition in the monopolistic conduct case results in the factor demand curve $w = q^{\frac{1}{\eta}}(\frac{\eta+1}{\eta})$. The joint-profit-maximizing output level is found by equating marginal costs to marginal revenue, which results in $q^* = (\frac{1+\eta}{\eta})^{\frac{1}{\psi - \frac{1}{\eta}}}$.

Solving the bargaining first-order condition (B-FOC) under each conduct model and finding the intersection of the two output–buyer-power curves results in the bilaterally-efficient bargaining weight

$$\beta^* = \left(\frac{1+\eta}{1+\psi} - \eta\right)^{-1}.$$

D.5.1 Corollary 2 in terms of elasticities

In the loglinear version of the model, we can write Corollary 2 as a function of supply and demand elasticities rather than the first derivatives of costs and demand.

Corollary OA-1. *The bilaterally-efficient level of buyer power β^* weakly decreases with the elasticity of downstream demand and weakly increases with the elasticity of upstream supply.*

Proof. The β^* expression derived above for the loglinear model is:

$$\beta^* = \left(\frac{1+\eta}{1+\psi} - \eta\right)^{-1}.$$

The elasticity of downstream demand, η, is negative; we therefore conduct comparative statics in terms of $(-\eta)$, so that a higher value of this parameter indicates more elastic demand. Taking the first derivative of β^* with respect to $(-\eta)$ results in:

$$\frac{\partial \beta^*}{\partial(-\eta)} = -\frac{\psi(1+\psi)}{(1-\eta\psi)^2} \leq 0$$

Hence, more elastic downstream demand implies a lower bilaterally-efficient level of buyer power β^*.

The elasticity of upstream supply is $\frac{1}{\psi}$. Taking the first derivative of β^* with respect to ψ results in:

$$\frac{\partial \beta^*}{\partial \psi} = \frac{1+\eta}{(1-\eta\psi)^2} \leq 0$$

This expression is weakly negative because $\eta \leq -1$ is required for profit maximization, and because $\frac{1+\eta}{1+\psi} - \eta = \frac{1}{\beta^*} \geq 0$. It follows that the more inelastic the upstream supply is, the lower β^*. Hence, the more elastic the upstream supply, the higher β^*. □

E Extensions

In this Appendix, we extend our model by incorporating (i) multi-input downstream production and (ii) an alternative distortion classification criterion based on incentive compatibility of linear pricing. We show that our main results are robust to these extensions.

E.1 Multi-Input Downstream Production

Our baseline model assumes a single-input production function where the downstream firm simply resells the input in the downstream market. In this Appendix, we extend this model to incorporate multi-input downstream production. We show that while the bargaining problem remains largely unchanged, it requires some modifications. Specifically, under monopsonistic bargaining, the upstream firm's output choice influences downstream output through a monotone function rather than by determining it directly, as the downstream firm can substitute to other inputs in its production process. Similarly, under monopolistic bargaining, the downstream firm's output choice no longer directly dictates the upstream quantity; rather, it influences it via a monotone input demand function.

The multi-input production introduces a key parameter affecting the model's comparative statics: the elasticity of substitution between inputs. When this elasticity approaches zero, the production function converges to a Leontief form, creating a one-to-one mapping between upstream and downstream output, mirroring our baseline model. Conversely, as the elasticity of substitution grows, the relationship between upstream and downstream outputs weakens, reducing the scope of buyer and seller power in the vertical chain.

E.1.1 Monopolistic Bargaining

Assume that the downstream firm produces according to the following CES production function with two inputs:

$$q = (\alpha_1 x_1^\rho + \alpha_2 x_2^\rho)^{1/\rho}.$$

For simplicity, we assume that there is no productivity term. Under monopolistic bargaining, the downstream firm takes the market price w_1 of input x_1 as given and negotiates over the price w_2 of input x_2. Given the negotiation outcome of w_2 and market price w_1, it then determines its profit-maximizing quantity. From this, we can express the firm's demand for x_2 as a function of its target output quantity q:

$$x_2(q) = \left(\frac{\alpha_2}{w_2}\right)^{\frac{1}{1-\rho}} q \left(\left(\alpha_1/w_1^\rho\right)^{1/(1-\rho)} + \left(\alpha_2/w_2^\rho\right)^{1/(1-\rho)}\right)^{-1/\rho}.$$

The CES function leads to the following average cost function:

$$c_d(w_2) = \left(\left(\alpha_1/w_1^\rho\right)^{1/(1-\rho)} + \left(\alpha_2/w_2^\rho\right)^{1/(1-\rho)}\right)^{1-1/\rho},$$

which equals the marginal cost $mc_d(w_2)$ due to constant returns to scale. With these objects, we can write the firms' maximization problems as

$$\begin{aligned}
\pi^d(w_2, q) &= \big(p(q) - mc_d(w_2)\big)q \\
\pi^u(w_2, q) &= \big(w_2 - c_u(x_2(q))\big)x_2(q),
\end{aligned}$$

where $c_u(\cdot)$ is the average cost function of the upstream firm. These problems resemble the problem in the paper with the following exceptions: w_2 in the downstream firm's maximization problem shows up in $mc_d(w_2)$ instead of as a simple linear function in w_2. Similarly, q in the upstream firm's problem enters through the input demand $x_2(q) = K(w_1, w_2)\, q$, which is proportional to q but with a price-dependent factor $K(w_1, w_2)$, rather than entering one-for-one as in the baseline. Since $mc_d(w_2)$ is increasing in w_2 and $x_2(q)$ is increasing in q, having a multi-input downstream firm does not change the main economics of the problem.

We evaluate this model for two extreme cases for the substitution parameter ρ. First, consider $\rho \to -\infty$ where the production function takes the Leontief form:

$$q = \min\{x_1, x_2\}.$$

In this case, we are back to the model in the main text, but with an additional marginal cost term w_1, which is non-negotiated.

Second, consider the case $\rho = 1$, which corresponds to perfect substitutes:

$$q = \alpha_1 x_1 + \alpha_2 x_2.$$

Under this production function, the firm will only use x_2 if $\frac{\alpha_2}{w_2} \geq \frac{\alpha_1}{w_1}$. Hence, the bargaining problem over w_2 is only relevant to the extent that this condition holds.

Finally, for any $-\infty < \rho < 1$, firms bargain over w_2 while internalizing that x_1 and x_2 are either gross complements (if $\rho < 0$) or gross substitutes (if $\rho > 0$). We refer to Rubens (2025) for an empirical implementation of the monopsonistic bargaining model with a CES production function under gross complements.

E.1.2 Monopsonistic Bargaining

Now we will consider monopsonistic bargaining. In monopsonistic bargaining, the production function remains the same, but since the upstream firm determines the input x_2, the downstream firm will take x_2 as given. Therefore, the firm will solve the constrained cost minimization problem conditional on x_2

$$\min_{x_1} \; w_1 x_1 \quad \text{s.t.} \quad q \leq (\alpha_1 x_1^\rho + \alpha_2 x_2^\rho)^{1/\rho}.$$

This leads to a factor demand conditional on x_2:

$$x_1(q, x_2) = \left(\frac{\alpha_1}{w_1}\right)^{\frac{1}{1-\rho}} \left(\frac{q^\rho - \alpha_2 x_2^\rho}{(\alpha_1/w_1^\rho)^{1/(1-\rho)}}\right)^{1/\rho}.$$

Similarly, we obtain a conditional average cost function:

$$c_d(q, x_2) = \frac{1}{q}\left[(q^\rho - \alpha_2 x_2^\rho)^{1/\rho}\left((\alpha_1/w_1^\rho)^{1/(1-\rho)}\right)^{(\rho-1)/\rho} + w_2 x_2\right].$$

Taking the derivative of the total cost $c_d(q, x_2)\, q$ with respect to q to find the marginal cost,

$$mc_d(q, x_2) = \left(\frac{w_1^\rho}{\alpha_1}\right)^{1/\rho} q^{\rho-1}(q^\rho - \alpha_2 x_2^\rho)^{\frac{1}{\rho}-1}.$$

Given x_2, the firm will set marginal cost to marginal revenue: $mc_d(q, x_2) = p'(q)q + p(q)$. Let the solution to this problem be $q_d(x_2)$. Now, we can write the firms' maximization problems as

$$\pi^d(w_2, x_2) = \big(p(q_d(x_2)) - c_d(q_d(x_2), x_2)\big)q_d(x_2)$$
$$\pi^u(w_2, x_2) = \big(w_2 - c_u(x_2)\big)x_2.$$

These problems resemble the problem in the paper: w_2 still enters the downstream firm's profit linearly, as $-w_2x_2$ (with coefficient x_2 rather than q); the modification is the monotone output map $q_d(x_2)$ on the revenue side. In this case, we do not see any change in the upstream firm's cost function. Since $q_d(x_2)$ is a monotone function, it does not change the basic mechanisms of the model.

E.2 Selecting Conduct: Incentive Compatibility of Linear Pricing

The sequential bargaining model provides another criterion to distinguish the source of the vertical distortions without directly imposing nonnegative markups and markdowns. We augment our bargaining model by introducing the possibility that firms bargain over a two-part tariff instead of over a linear contract if it is incentive-compatible.

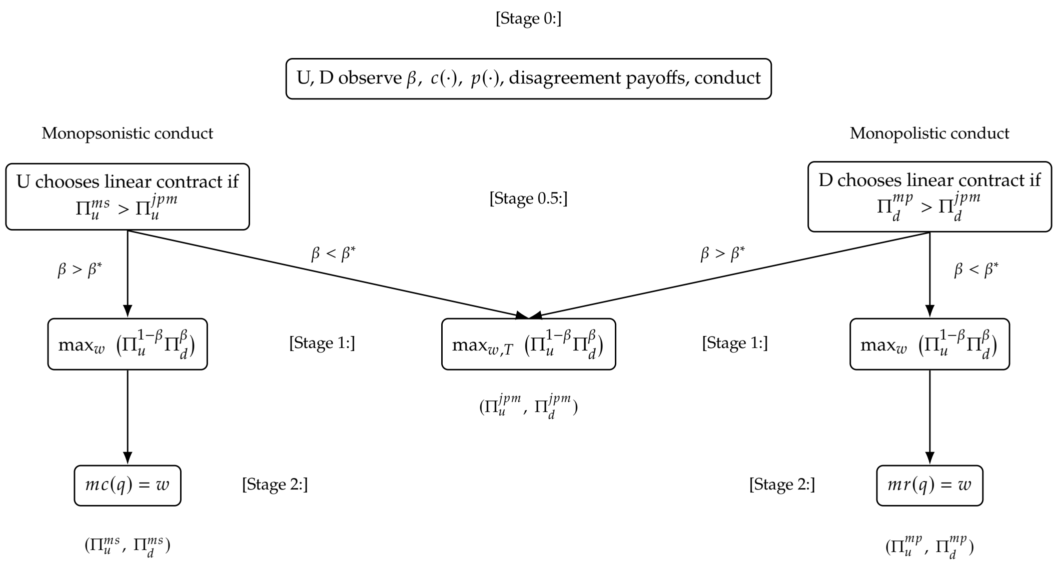
Constraint OA-1 (Incentive Compatibility of Linear Pricing)**.** *Under monopsonistic conduct, the upstream firm chooses a linear price contract only if it earns a higher profit under a linear contract than under a two-part tariff (w, T), with T denoting a lump-sum transfer. Under monopolistic conduct, the downstream firm chooses a linear price contract only if it earns higher profits under a linear contract than under a two-part tariff (w, T).*

Constraint OA-1 states that U or D is willing to choose a linear price contract over a two-part tariff only if the resulting profit surpasses the profit it would earn under joint-profit maximization (i.e., the profit it would earn when bargaining over a two-part tariff). Figure OA-2 illustrates the resulting decision tree by adding a stage before bargaining where either the upstream or the downstream firm chooses the terms of the contract.

Theorem OA-1. *Under Constraint OA-1, for any $\beta \in (0, 1)$ with $\beta \neq \beta^*$, either (w^{ms}, q^{ms}) or (w^{mp}, q^{mp}) is an equilibrium with a linear price contract, but not both. Specifically, this equilibrium occurs under monopsonistic conduct if $\beta > \beta^*$, and under monopolistic conduct if $\beta < \beta^*$.*

Theorem OA-1 implies, by revealed preference, that if we observe a linear price contract, the equilibrium is monopsonistic when $\beta > \beta^*$ or monopolistic when $\beta < \beta^*$. If $\beta = \beta^*$, neither party has the incentive to choose a linear price contract, and firms simply maximize joint profits.

Figure OA-2: Decision Tree: Incentive Compatibility of Linear Pricing



Notes: This decision tree illustrates the augmented bargaining game under the distortion selection rule defined in Online Appendix E.2. The addition is Stage 0.5, where the upstream or downstream firm decides the contract terms based on Constraint OA-1. Π_i^{ms}, Π_i^{mp}, and Π_i^{jpm} denote the profit of party i under monopsonistic bargaining, monopolistic bargaining, and joint-profit maximization, respectively. The game is formally defined in Online Appendix E.2.1.

This theorem rests on the insight that parties may earn greater profits under monopsonistic or monopolistic vertical conduct than under joint-profit maximization.[46] Under monopsony, the upstream firm's profit from linear pricing exceeds the two-part tariff profit if $\beta > \beta^*$, whereas under monopolistic bargaining, the downstream firm's profit from linear pricing exceeds the two-part tariff profit if $\beta < \beta^*$. Thus, this distortion selection rule ensures that the party choosing the contract is never worse off than it would be under joint-profit maximization.

The finding that firms do not always choose two-part tariffs has broader implications for full-information vertical bargaining models with linear contracts. A potential criticism of this class of models is that firms could achieve Pareto improvements by switching to nonlinear pricing (Lee, Whinston, and Yurukoglu, 2021). In our model, the possibility of linear contracting arises from a holdup problem due to a lack of commitment. Under commitment, a two-part tariff would always be reached because either party can convince the other not to choose a linear contract in Stage 0.5 by committing to bargaining less

[46] To see this, assume $\beta = 1$. Under monopsonistic bargaining, which corresponds to classical monopsony, the upstream profit is $c'(q)q^2 > \pi_0^u$ provided the upstream participation constraint is slack, whereas under a two-part tariff, the upstream profit equals its disagreement payoff π_0^u. The possibility of higher profit from linear prices than from a two-part tariff holds only under sequential timing, because the two-part tariff profit weakly dominates the linear price profit for any β under simultaneous timing.

aggressively in Stage 1. However, since the bargaining weights are predetermined and fixed, such a commitment would not be credible. This holdup rationalization of linear price contracts has similarities to prior work on vertical contracts, such as Iyer and Villas-Boas (2003), where shocks between contract signing and delivery induce firms not to negotiate over two-part tariffs.

E.2.1 Proof of Theorem OA-1

Proof. We formally define the bargaining game as follows:

- **Players:** $i \in \{U, D\}$
- **Actions:** $a_i \in \{L, NL\}$ (Linear pricing (q on supply or demand curve), Nonlinear pricing (q negotiated))
- **States:** $\sigma \in \{MS, MP\}$ (Monopsonistic Conduct, Monopolistic Conduct)
- **Payoffs:**

$$\begin{aligned}
&\pi^i(a_j = NL, \sigma) = \pi^{i,jpm} && \forall i, j\\
&\pi^u(a_u = L, \sigma = MS) = \pi^{u,ms}\\
&\pi^d(a_u = L, \sigma = MS) = \pi^{d,ms}\\
&\pi^u(a_d = L, \sigma = MP) = \pi^{u,mp}\\
&\pi^d(a_d = L, \sigma = MP) = \pi^{d,mp}
\end{aligned}$$

We assume that the side whose supply or demand curve pins down q (upstream/input supply curve under monopsony, downstream/input demand curve under monopoly) sets the action a_i: it decides whether to negotiate a linear price contract (in which case $a_i = L$) or to bargain over T (which is equivalent to bargaining over q), in which case $a_i = NL$. Hence, there are four possible subgame equilibria that we need to examine, two for each conduct state: (i) $\sigma = MS, a_u = L$, (ii) $\sigma = MS, a_u = NL$, (iii) $\sigma = MP, a_d = L$, (iv) $\sigma = MP, a_d = NL$.

In each conduct state, the acting player decides whether to negotiate a linear or non-linear contract in Stage 0.5 of the game by comparing its expected profits under the two actions. First, consider monopsonistic conduct, in which upstream sets a_u. Suppose $\beta < \beta^*$. From Lemma OA-9, it follows that $\pi^{u,ms} < \pi^{u,jpm}$. Hence, $a_u = L$ is not a subgame perfect equilibrium in this case, whereas $a_u = NL$ is: the game ends at Stage 1 when upstream chooses nonlinear pricing, by bargaining over both w and T.

In contrast, if $\beta > \beta^*$, Lemma OA-9 implies that $\pi^{u,ms} > \pi^{u,jpm}$. Hence, $a_u = NL$ is not a subgame perfect equilibrium in this case, whereas $a_u = L$ is: the game proceeds to Stage

1 in which U and D bargain over input prices, which is followed by Stage 2, in which the quantity is pinned down by the input supply curve.

Second, consider monopolistic conduct. Suppose $\beta < \beta^*$. From Lemma OA-9, it follows that $\pi^{d,mp} > \pi^{d,jpm}$: downstream expects that if it chooses a linear price contract in Stage 0.5, this will result in higher profits than under nonlinear pricing. Hence, $a_d = NL$ is not a subgame perfect equilibrium in this case, whereas $a_d = L$ is: firms bargain over input prices in Stage 1, which is followed by quantity being pinned down by the input demand curve.

In contrast, if $\beta > \beta^*$, Lemma OA-9 implies that $\pi^{d,mp} < \pi^{d,jpm}$. Hence, $a_d = L$ is not a subgame perfect equilibrium in this case, whereas $a_d = NL$ is: the game ends at Stage 1 when downstream chooses to bargain over a two-part tariff.

In summary, if a linear price contract is observed (either $a_d = L$ or $a_u = L$), this only happens under monopsonistic bargaining if $\beta > \beta^*$ and under monopolistic bargaining if $\beta < \beta^*$. □

F Empirical Application Appendix: Unions and Cooperatives

F.1 U.S. Construction Workers

In our labor unions application, we rely on the estimates for labor supply and demand for U.S. construction workers from Kroft et al. (2025). Given that their labor supply model is loglinear, it has the same functional form as the numerical example used in the calibrations in the main text. Using their notation of firms being indexed as j and years as t, wages W_{jt} and number of workers L_{jt}, their inverse labor supply curve at the firm level is

$$W_{jt} = L_{jt}^{\psi} U_{jt},$$

where U_{jt} is a firm-specific labor supply shifter. Denoting output as Q_{jt}, the goods price as P_{jt}, and an aggregate price index as $\bar{P}_t$, their downstream residual demand curve is

$$Q_{jt} = \left(\frac{P_{jt}}{\bar{P}_t}\right)^{\frac{-1}{\epsilon}}.$$

Hence, their inverse elasticity of labor supply is ψ and their inverse elasticity of goods demand is ϵ.

The production function is Leontief in materials and a composite term of labor and capital. Given that we study wage bargaining in the short term, we treat capital as fixed. In addition, we assume that short-run output is proportional to the labor input, as would obtain if the labor–capital composite were Leontief and labor were the binding factor at the fixed capital level. Under this proportionality, the residual product demand elasticity coincides with the residual labor demand elasticity, and translating their notation into ours gives $\eta = -\frac{1}{\epsilon}$.

We use the β^* formula applied to the loglinear example, as worked out in Online Appendix D.5. In this notation, this gives

$$\beta^* = \left(\frac{1 - \frac{1}{\epsilon}}{1 + \psi} + \frac{1}{\epsilon} \right)^{-1}.$$

We use the estimated inverse demand elasticity $\epsilon = 0.137$ from Table 2, Panel B, and the RDD estimate for the inverse labor supply elasticity $\psi = 0.286$ from Table 2, Panel A. Plugging these into the β^* formula above results in $\beta^* = 0.417$.

F.2 Brazilian Labor Markets

Similarly to above, we use the estimated labor supply and product demand elasticities from Lobel (2026). We transform the reported residual labor supply elasticity for small firms to the inverse labor supply elasticity as

$$\psi^{\text{small}} = \frac{1}{4.15} = 0.24.$$

We also use their estimated demand elasticity of $\eta = -1.43$. We treat capital as a fixed input and, as in the construction application, assume that short-run output is proportional to the labor input, so that the residual product demand elasticity equals the residual labor demand elasticity. Also, we set disagreement payoffs to zero. Using the elasticity-based formula for β^* above results in the estimates reported in Table 1.

F.3 Chinese Tobacco Farmers

In our farmer cooperatives application, we focus on the setting of tobacco farmers in China, as analyzed in Rubens (2023). Although Rubens (2023) presents a discrete-choice oligopsony model in Appendix A1, we take a first-order approximation of this model by modeling loglinear leaf supply and assuming monopsonistic competition instead. Denoting total leaf production at manufacturer f as M_f, the leaf price at firm f as P_f^m, an aggregate leaf price as $\bar{P}^m$, and a supply residual (shifter) as A_f, leaf supply is given by

$$M_f = \left(\frac{P_f^m}{\bar{P}^m} \right)^{\frac{1}{\psi}} A_f.$$

In equilibrium, the ratio of the marginal revenue product of tobacco leaf MRPM over the leaf price is equal to one plus the inverse leaf-supply elasticity:

$$\frac{\text{MRPM}}{P_f^m} = 1 + \psi.$$

Using the preferred GMM specification in Rubens (2023), the MRPM/leaf price ratio is estimated at 2.904, which implies an inverse leaf-supply elasticity of $\psi = 1.904$.

Given that the production function is Leontief in tobacco leaf, cigarette production is proportional to tobacco-leaf usage. We approximate cigarette demand by the same loglinear demand function used above, denoting cigarette production at firm f as Q_f, the cigarette price as P_f, a price aggregator as $\bar{P}$, and the inverse demand elasticity as ϵ:

$$Q_f = \left(\frac{P_f}{\bar{P}}\right)^{\frac{-1}{\epsilon}}.$$

As an estimate of the cigarette demand elasticity $-1/\epsilon$, we rely on the estimates of Ciliberto and Kuminoff (2010). Given that only median own-price elasticities (rather than average elasticities) are reported, we rely on these median elasticities. We use the estimate of $\frac{1}{\epsilon} = 1.14$ from Table 4, column 6, since this is one of the two preferred GMM-based specifications. Using the formula above results in $\beta^* = 0.916$. The key driver of the large bilaterally-efficient level of buyer power is the inelastic demand for cigarettes due to their addictive nature. Alternatively, using the other GMM specification (in column 7) of $\frac{1}{\epsilon} = 1.11$ results in a similar $\beta^* = 0.93$.

G Empirical Application Appendix: Coal Procurement

G.1 Data Sources

Coal-Mine Characteristics and Production Data. For coal mines, we use two datasets: one from the Mine Safety and Health Administration (MSHA) (Mine Safety and Health Administration, 2024) and one from Velocity Suite. The MSHA data provides information on production, employment, and technical mine characteristics. Quarterly production and employment (in hours worked and total employment) come from MSHA Form 8. Mine characteristics, such as the number and type of openings and the vein thickness, are obtained from MSHA Form 10. We merge these MSHA datasets with each other by matching on the MSHA mine identifier. We use the Velocity data to obtain ownership information. While ownership details are also available in the MSHA data, we found them unreliable due to the lack of unique owner IDs, inconsistent spellings, and unaccounted-for ownership changes.

Coal-Mine Cost Data. We purchased cost information for coal mines from the 2019 Coal

Cost Guide published by CostMine Intelligence. This data source provides detailed data on operating costs, capital costs, labor requirements, and equipment expenses for different mining technologies used in the United States and Canada. The Coal Cost Guide provides data on five types of operating expenses (in USD per short ton) and capital expenses (in USD), reported in nine categories for surface mines and six for underground mines. The data is provided at the level of mine characteristics, which consist of a combination of: (i) the mine type (Surface, Continuous Underground with Ramp Access, Continuous Underground with Shaft Access, Longwall Underground with Ramp Access, Longwall Underground with Shaft Access, Room & Pillar Underground with Ramp Access, Room & Pillar Underground with Shaft Access), (ii) the mine's daily capacity (in short kilotons: 1, 2, 4, 8, 24, 72, 216), (iii) the average vein thickness (in meters: 1.5, 2.5, and 3.5 for underground mines; 1, 3, 12, 18, 24, and 27 for surface mines). We obtain this data from pages 5–74 in Chapter 3 of the 2019 Coal Cost Guide (InfoMine USA, 2019).

Power-Plant Characteristics, Cost and Generation Data. For data on power plants, we rely on data from Velocity Suite, which compiled data from EIA 860, EIA 906, EIA 923, NERC 411 forms, EPA, as well as from their own proprietary research. We use five different datasets from Velocity. The first dataset is at the month-generator level and includes the universe of all generators in the U.S., capturing characteristics such as age, fuel type, boiler type, capacity, location, ISO region, installation date, operating status, ownership and regulation status of the owner. Velocity collects this data from various public sources and their proprietary research. The second dataset provides hourly generation data for fossil fuel generation units, sourced from the EPA's CEMS database, which includes details on generation, fuel usage, heat rate, and emissions. The third dataset contains monthly plant-level data, offering information on plant characteristics and monthly generation by fuel type, compiled from the EIA-923 form. The fourth dataset is hourly load data for ERCOT, sourced directly from ERCOT's website. Finally, the fifth dataset consists of hourly generation data for generation units in ERCOT, obtained from ERCOT's 60-Day SCED Disclosure Report.

BLS Wage Data. We obtain weekly earnings of coal miners from the Quarterly Census of Employment and Wages of the U.S. Bureau of Labor Statistics (U.S. Bureau of Labor Statistics, 2024). We download the data at the 4-digit industry level for industry '2121 Coal Mining'.[47] We keep weekly earnings at the state-quarter level and average across quarters to obtain annual averages of weekly earnings per state. For some states in some years,

[47]The data is available at more disaggregated industry levels (e.g., surface vs. underground mining) and geographical levels (e.g., county), but both of these more detailed data sources have the disadvantage of being much sparser, both along the time and geographical dimensions.

earnings are not reported. In these cases, we impute wages by averaging over broader regions that correspond to the coal basins: Northwest, Southwest, Midwest, Appalachia, and Southeast. We convert weekly earnings into hourly wages by assuming a 45-hour work week, following average data reported by the CDC.[48]

Coal Transaction Data [2005–2014]. Velocity Suite provides two datasets related to coal transactions between power plants and coal mines. The first dataset is transaction-level, where each record includes coal mine and plant IDs, quantity shipped, FOB price, transportation price, contract information (ID and duration), and coal characteristics (ash, sulfur, and type). Most of the information in this dataset comes from the EIA-923 form, and Velocity augments this data with FOB prices obtained from railroad waybills and their own internal model. The second dataset focuses on coal routes and includes leg-level transportation information, such as the mode of transport (railroad, truck, vessel), carrier details for railroads, costs, and routing points. This data is sourced from waybills and Velocity's proprietary research.

Coal Transaction Data [1979–2000]. This dataset provides historical information on coal transactions and contracts from 1979 to 2000, sourced from the EIA's Coal Transportation Rate Database. It includes details on transportation rates, contract terms, and other relevant information about coal shipments during this period. We use this dataset to obtain historical information on contract types and duration.

G.2 Hourly Electricity Generation Construction for Power Plants

Since we estimate Cournot competition for every hour, we must observe hourly generation data of all generators operating in ERCOT. This data is sourced from three main datasets: (i) the CEMS database of hourly generation from the EPA, (ii) the ERCOT 60-day hourly generation report, and (iii) EIA monthly generation data at the plant-fuel level. The CEMS data cover all fossil-fuel generation units subject to environmental regulations but exclude renewables and other plants not regulated under these standards. For renewables, we rely on unit-level data from the ERCOT 60-day generation report. For a small subset of units without hourly generation data from either source, we use EIA Form 923 to obtain monthly generation information and assume that monthly generation is uniformly distributed across hours within the given month.

[48] https://www.cdc.gov/niosh/mining/content/economics/safetypayscostesttechguide.html

G.3 Capacity Estimation of Coal Mines and Power Plants

Power Plants

We calculate capacities separately for fossil-fuel power plants and other generation sources. For fossil-fuel power plants, we obtain capacity factor information by fuel type from the GADS database, calculated based on the maintenance frequency of power plants using different fuel types. In our analysis, these capacity factors are applied uniformly across all hours; we do not account for strategic maintenance timing, as this involves a complex, dynamic problem that is beyond the scope of this study. The effective capacity of each unit is thus determined by multiplying its capacity factor by its nameplate capacity.

For solar, wind, hydroelectric, geothermal, other renewables, and nuclear power plants, we calculate capacity factors based on their generation, as these are zero-marginal-cost generators, and their actual generation should reflect their availability to produce electricity. For these generators, we compute a unit-level capacity factor by averaging their generation within a given month-hour-weekend/weekday bin and dividing it by their nameplate capacity. Multiplying this capacity factor by the nameplate capacity provides the effective capacity of the generator by hour type.

Coal Mines

Because the EIA no longer makes its coal mine capacity data available to researchers (which were used by Johnsen, LaRiviere, and Wolff, 2019), we infer capacity from production, defining a mine's capacity in each year as its maximum production up to that year. This approach makes mine capacity time-varying, as it reflects changes in production over time.

G.4 Heat Rate Calculations and Coal Weight to Heat Content Conversion

To determine the cost of fossil-fuel generators, we calculate their heat rate annually by dividing their total MMBtu fuel consumption by their total electricity generation. This heat rate is assumed to remain constant throughout the year. To estimate the generation cost per MWh, we multiply the heat rate by the per-MMBtu cost of coal.

To convert coal quantities from short tons to MMBtu, we calculate, for each mine, an annual conversion factor by dividing the total heat content of the coal it shipped during the year (in MMBtu) by the corresponding tonnage (in short tons). This conversion factor is then assumed to remain constant throughout the year.

G.5 Marginal Cost Estimation Details for Coal Mines

Matching the Coal Cost Guide with the MSHA data

We match the Coal Cost Guide dataset to the MSHA data as follows. First, we rely on the 'technology' variable in the MSHA data to match the mine types. We group 'surface', 'strip/open pit', and 'mountain top' mines in the MSHA data into the 'surface mine' category of the Coal Cost Guide, and the 'continuous', 'longwall', and 'room-pillar' technologies from the MSHA into the corresponding technologies in the Coal Cost Guide. If the technology variable is unobserved in the MSHA dataset, we categorize the mine type as 'other'. We keep only mines of the types 'Auger', 'Bank', 'Surface', 'Underground', and 'Surface at Underground' from the MSHA data, in order to exclude non-production units such as administrative offices.

We categorize mines for which there are one or more shafts reported in the MSHA dataset as 'shaft access' in the Coal Cost Guide, and the remaining mines as 'ramp access'. We use the 'maximum vein thickness' variable in the MSHA data to classify the mines into the corresponding vein thickness category in the Coal Cost Guide. If the vein thickness is unobserved in the MSHA data, we assign the smallest vein thickness type (which corresponds to the highest marginal cost). We assign each mine to the Coal Cost Guide daily-capacity categories based on its maximum historical daily production, calculated by dividing production by the number of days the mine operated.

Computation of Materials-to-Labor Cost Ratios

We use the 'hourly labor cost' subdivision of the operating costs variable in the Coal Cost Guide as our definition of variable labor costs, and the remaining operating costs reported as intermediate input costs. We also add the 'equipment costs' reported under capital expenditure into intermediate input costs because extracting more coal requires more equipment. Given that equipment costs are unlikely to fully depreciate within a year, unlike the other operating costs listed, we let them depreciate linearly over a period of 5 years. We consider the remaining capital expenses listed in the Coal Cost Guide ('Working Capital', 'Engineering & Construction Management', 'Contingency', 'Preproduction Development' and 'Surface Facilities' for underground mines, and 'Haul Roads/Site Work', 'Pre-production Stripping', 'Buildings', 'Electrical System' and 'Sustaining Capital' for surface mines) to be fixed costs, so we do not include these in our marginal cost measures.

Taking the ratio of these two cost categories, intermediate input expenditure over variable labor costs, yields the type-level cost ratio $\gamma_{\theta(iu)} \frac{p^m_{iu}}{w^l_{iu}}$ that enters Equation (7) directly. We assume this cost ratio is the same across all mines of a given type θ.

Computation of Mining Marginal Costs

The unit labor and intermediate input costs in the Coal Cost Guide are based on the average input requirements within a mine type. However, the mines in our dataset can diverge from the average daily labor requirements in the Coal Cost Guide because mines are heterogeneous in terms of their productivity. This prevents us from directly using the cost information in the Coal Cost Guide. To address this, we compute the observed unit labor requirement for mine i as hours worked per ton of coal extracted l_{iu}/q^c_{iu} from the MSHA data. This unit labor requirement (inverse labor productivity) is proportional to the inverse of total factor productivity under the Leontief production function assumption, as implied by the production function in Section 6.3.

One complication is that the MSHA data reports the total hours worked per year for all labor, including production and non-production workers. Since non-production workers should be considered as fixed costs, we isolate the production worker hours using the 'hourly labor' information in the Coal Cost Guide. In particular, we convert the total hours reported in the MSHA data to the total hours worked by hourly workers by taking the ratio of the hourly worker requirement to the total worker requirement reported in the Coal Cost Guide. We compute this ratio as an average at the level of the mine type θ, as surface and underground mines and mines with different capacities differ in their production-to-total (hourly-to-total) worker ratios. We multiply this ratio by the total hours reported in the MSHA data to obtain the total hours worked by hourly workers in mine i in a given year.

We compute hourly wages w^l_{iu} from the BLS data as explained above. We multiply hourly wages by the unit labor requirement to compute the labor cost per ton in each mine, and combine this with the ratio of intermediate to labor costs to compute marginal costs for each mine, as shown in Equation (7).

We then aggregate these marginal costs to the firm level as described in Section 6.3. For firms with a small number of mines, this leads to a discrete cost function, which makes it difficult to compute the joint-profit-maximizing quantity q^*_{ud} and price w^*_{ud}. Therefore, we smooth the cost function at the firm level using a polynomial approximation.

G.6 Cournot Demand Estimation Details

As described in the main text, we assume a Cournot competition model with strategic and fringe firms. We estimate a separate and independent Cournot competition model in each hour type, which is a month-hour-weekday/weekend combination. We assume that all regulated firms and firms whose total capacity is below 5% of the total market capacity are fringe firms in a given year. With these assumptions, modeling downstream competition requires the consumer demand and supply of fringe firms in every hour type.

We assume that total demand is fully inelastic in the short run and calculate the short-run demand by averaging the observed demand for each hour type. We assume that this average is the expected demand during the bargaining between upstream and downstream firms. For fringe supply, we first calculate the cost curve of each fringe firm and aggregate them to the industry level. We assume that fringe firms supply a quantity in a given hour such that the price equals the marginal cost.

Subtracting this fringe supply curve from the inelastic demand yields the industry demand curve faced by strategic firms. The analysis then follows standard Cournot competition modeling, in which each strategic firm faces a residual demand curve given by industry demand minus the observed generation from other strategic firms.

G.7 Standard Error Calculations

The only source of uncertainty in our model is the inelastic market demand for a given hour type. We calculate the inelastic demand in a given hour type t as the average demand value across a finite sample of hours of that type in our estimation. To account for this uncertainty in the estimates, we implement a bootstrap procedure with 250 iterations, in which we calculate the average demand for hour type t by resampling hours within that hour type with replacement. We then repeat the entire estimation procedure to obtain a bootstrap distribution of our estimates.

H Additional Tables

Table OA-1: Key Notation Used in the Model

Mining (Upstream)		**Power (Downstream)**	
q^c_{iu}	Coal output of mine i (short tons)	$\bar{Q}^D_t$	Expected electricity demand in hour type t
l_{iu}	Labor hours used at mine i	Q^{fr}_t	Fringe supply in hour type t
m_{iu}	Intermediate inputs at mine i	P_t	Electricity price in hour type t
$\theta(iu)$	Mine type for mine i	c_{jd}	Marginal cost of generator j in firm d
$\gamma_{\theta(iu)}$	Material–labor ratio by mine type	c^{om}_{jd}	Variable O&M cost of generator j in firm d
ω_{iu}	Productivity shifter at mine i	k_{jdt}	Capacity of generator j in hour type t
w^l_{iu}	Hourly wage at mine i	$C_{dt}(Q_{dt})$	Downstream average cost curve in hour type t
p^m_{iu}	Material unit cost at mine i	Q_{-dt}	Output of other downstream firms in hour type t
λ_{iu}	Conversion factor (short ton to MMBtu)		**Bargaining**
c_{iu}	Marginal cost at mine i	$\mathcal{D}_u$	Set of downstream partners for firm u
$\boldsymbol{c}_u$	Vector of mine marginal costs for firm u	q_{ud}	Quantity traded between u and d
$\bar{\boldsymbol{q}}_u$	Vector of mine capacities for firm u	w_{ud}	Transacted coal price between u and d
$C_u(Q_u)$	Upstream average cost curve for firm u	Π^u	Profit function of firm u
Q_u	Total coal output of firm u	Π^d_t	Period-t profit of downstream firm d
n_u	Number of mines owned by u	β_{ud}	Bargaining power of buyer in pair (u, d)
$\bar{q}_{iu}$	Capacity of mine i		

Notes: Subscripts i, j, u, d, and t denote mine index, generator index, upstream firm, downstream firm, and hour type, respectively.

Table OA-2: List of Firms

Upstream Firms	**Downstream Firms**	
	A. With Coal Plants	*B. Without Coal Plants*
Peabody Energy Corp	NRG Energy Inc	Energy Capital Partners
Rio Tinto Energy America	Vistra Energy	Energy Future Holdings Corp
Westmoreland Coal Co		NextEra Energy Inc
Cloud Peak Energy		
Arch Resources Inc		
Foundation Coal Corp		
Peter Kiewit Sons Inc		
Alpha Natural Resources LLC		
Vistra Energy		

Notes: This table lists the upstream and downstream firms in Section 6. The upstream firms and the downstream firms with coal power plants enter the bargaining model; the remaining downstream firms with more than 5% of total market capacity are strategic firms in the demand model.

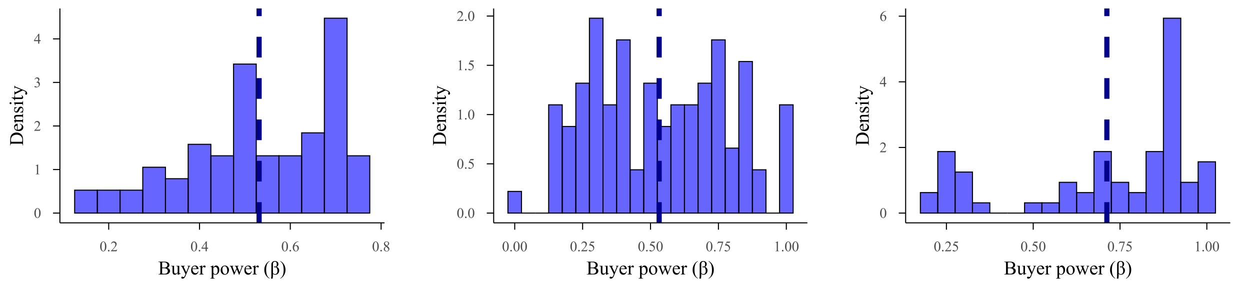
Table OA-3: Buyer Power from the Empirical Bargaining Literature

Sources	Industry	Range	Mean	Median	Std. Dev.
		Panel A. Firm-to-Firm			
Crawford and Yurukoglu (2012)	Television	[0.170, 0.770]	0.559	0.595	0.159
Gowrisankaran et al. (2015)	Healthcare	{0.500}	0.500	0.500	0
Crawford et al. (2018)	Television	[0.280, 0.370]	0.325	0.325	0.064
Ho and Lee (2017, 2019)	Healthcare	[0.310, 0.470]	0.387	0.380	0.080
Hosken et al. (2025)	Healthcare	[0.370, 0.990]	-	0.930	-
Alviarez et al. (2026)	Intl. Trade	-	0.812	-	0.101
Cuesta et al. (2025)	Healthcare	[0.167, 0.680]	0.476	0.518	0.187
		Panel B. Union-to-Firm			
Svejnar (1986)	Multiple	[0.140, 0.890]	0.513	0.555	0.281
Doiron (1992)	Woodworking	[0.499, 0.791]	0.648	0.678	0.116
Abowd and Lemieux (1993)	Multiple	[0.608, 0.850]	0.727	0.738	0.078
Mumford and Dowrick (1994)	Coal	{0.141}	0.141	0.141	0
Cahuc et al. (2006)	Multiple	[0.020, 1.000]	0.804	0.855	0.247
Coles and Hildreth (2000)	Manufacturing	-	0.144	-	0.088
Breda (2014)	Multiple	[0.636, 0.805]	0.713	0.709	0.061
Fuess (2001)	Multiple	[0.176, 0.592]	0.357	0.250	0.099
		Panel C. Cooperative-to-Firm			
Prasertsri and Kilmer (2008)	Dairy	[0.217, 0.334]	0.267	0.267	0.034
Ahn and Sumner (2012)	Dairy	[0.861, 0.912]	0.889	0.896	0.020
Ge et al. (2015)	Dairy	[0.880, 0.881]	0.880	0.880	0.000
Hayashida (2018)	Dairy	[0.209, 1.179]	0.874	0.977	0.247
Shokoohi et al. (2019)	Dairy	{0.690}	0.690	0.690	0
Sano et al. (2022)	Vegetables	[0.481, 0.844]	0.707	0.707	0.089

Notes: This table summarizes bargaining parameters from empirical papers implementing models with a *Nash-in-Nash* bargaining protocol. All weights denote buyer power. We summarize the estimates from the authors' preferred specifications when available. Some papers (e.g., Crawford and Yurukoglu, 2012) provide weights from bargaining pairs (some only report the distribution, e.g., Coles and Hildreth, 2000), and others (e.g., Abowd and Lemieux, 1993) provide weights under different model specifications. Cahuc et al. (2006) do not specifically study union-based wage negotiation, but we include them in this panel for their focus on wage bargaining.

I Additional Figures

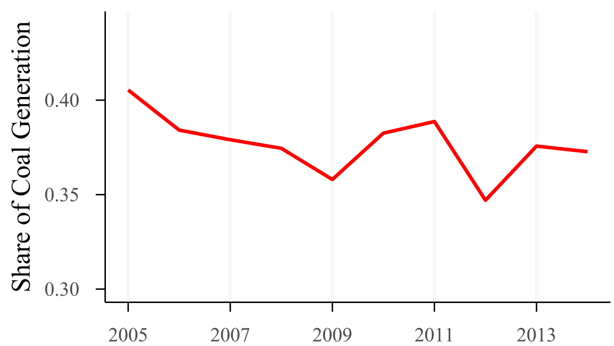
Figure OA-3: Buyer Power from the Empirical Bargaining Literature



(a) Firm-to-Firm **(b)** Union-to-Firm **(c)** Cooperative-to-Firm

Notes: This figure presents the distribution of bargaining weights from Table OA-3. The dashed line denotes the average value of the weights.

Figure OA-4: ERCOT Share of Coal Generation



Notes: This figure reports the share of electricity generation by coal-fired generators in the ERCOT market during the sample period between 2005 and 2014.

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Welfare Effects of Buyer and Seller Power

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Supplemental Material

(Not for Publication)

S Supplemental Material: The Model Under Simultaneous Timing

The main text presents the theoretical results of the paper under the sequential timing assumption. This section presents the corresponding analysis under the *simultaneous* timing assumption, allowing for nonzero disagreement payoffs. The section is self-contained: all definitions, assumptions, and intermediate results used below are stated within the section, and results are numbered S.1, S.2, . . . independently of the main text and of the rest of the Online Appendix.

S.1 Setup

A supplier U sells a quantity q to a buyer D at an input price w under a linear pricing contract. The buyer faces a residual inverse demand curve $p(q)$ with $p'(q) \leq 0$, and the supplier produces at a residual average cost curve $c(q)$ with $c'(q) \geq 0$; both functions are three times continuously differentiable. There are gains from trade on an interval $(0, \bar{q})$: $p(q) > c(q)$ for all $q \in (0, \bar{q})$, with $p(\bar{q}) = c(\bar{q})$. The parties' profits are

$$\pi^d(w, q) \equiv \big(p(q) - w\big)q, \qquad \pi^u(w, q) \equiv \big(w - c(q)\big)q,$$

and $\pi_0^d \geq 0$ and $\pi_0^u \geq 0$ denote the (lump-sum) disagreement payoffs of D and U if bargaining breaks down. Marginal revenue and marginal cost are

$$mr(q) \equiv \frac{d\big(p(q)q\big)}{dq} = p(q) + p'(q)q, \qquad mc(q) \equiv \frac{d\big(c(q)q\big)}{dq} = c(q) + c'(q)q,$$

and the seller markup and buyer markdown are defined as

$$\mu^u(w, q) \equiv \frac{w - mc(q)}{mc(q)}, \qquad \Delta^d(w, q) \equiv \frac{mr(q) - w}{mr(q)}.$$

The joint-profit maximizing quantity q^* solves $mr(q^*) = mc(q^*)$; it is unique whenever $mr(q)$ is strictly decreasing and $mc(q)$ is strictly increasing, which we maintain whenever

q^* is used. We write $w^* \equiv mc(q^*) = mr(q^*)$ for the associated input price and

$$\pi^{d*} \equiv \big(p(q^*) - w^*\big)q^* = -p'(q^*)(q^*)^2, \qquad \pi^{u*} \equiv \big(w^* - c(q^*)\big)q^* = c'(q^*)(q^*)^2, \tag{S.1}$$

for the parties' profits at (w^*, q^*), with $S(q^*) \equiv \pi^{d*} + \pi^{u*} = \big(p(q^*) - c(q^*)\big)q^*$ denoting the joint surplus at q^*.

Definition S.1 (Simultaneous Bargaining)**.** *The quantity is determined simultaneously with bargaining over the input price: the parties bargain over w taking the quantity as given, and the quantity is determined by the conduct condition—the input supply or the input demand curve introduced below—at the negotiated input price. In particular, the bargaining problem does not internalize the dependence of the quantity on the input price (dq/dw does not enter the bargaining problem).*

As in the main text, we consider two models of vertical conduct. Under *monopsonistic* bargaining, the transacted quantity lies on the input supply curve, and under *monopolistic* bargaining it lies on the input demand curve:

$$(w^{ms}, q^{ms}) : \begin{cases} \max\limits_{w} \ \left[(\pi^d(w,q) - \pi_0^d)^\beta \, (\pi^u(w,q) - \pi_0^u)^{1-\beta}\right] \\ w = mc(q) \end{cases}$$

$$(w^{mp}, q^{mp}) : \begin{cases} \max\limits_{w} \ \left[(\pi^d(w,q) - \pi_0^d)^\beta \, (\pi^u(w,q) - \pi_0^u)^{1-\beta}\right] \\ w = mr(q) \end{cases}$$

where $\beta \in [0,1]$ is the buyer's bargaining weight. Under each conduct model, the input price is pinned down by q, so each party's profit becomes a function of q alone:

$$\text{Monopsonistic } (w = mc(q)) : \quad \pi^u(q) = c'(q)\,q^2, \quad \pi^d(q) = \big(p(q) - c(q) - c'(q)q\big)q, \tag{S.2}$$

$$\text{Monopolistic } (w = mr(q)) : \quad \pi^d(q) = -p'(q)\,q^2, \quad \pi^u(q) = \big(p(q) + p'(q)q - c(q)\big)q. \tag{S.3}$$

We impose the following assumption throughout this section.

Assumption S.1 (Gains from Trade)**.** *Under each conduct model, the set of quantities at which both participation constraints are satisfied is nonempty:*

$$\mathcal{Q}^{ms} \equiv \left\{q > 0 : \big(p(q) - c(q) - c'(q)q\big)q \geq \pi_0^d \ \textit{ and } \ c'(q)q^2 \geq \pi_0^u\right\} \neq \emptyset,$$
$$\mathcal{Q}^{mp} \equiv \left\{q > 0 : -p'(q)q^2 \geq \pi_0^d \ \textit{ and } \ \big(p(q) + p'(q)q - c(q)\big)q \geq \pi_0^u\right\} \neq \emptyset.$$

S.2 First-Order Conditions

Under the simultaneous bargaining models with disagreement payoffs $\pi_0^d \geq 0$ and $\pi_0^u \geq 0$, the maximization problems are:

$$\begin{cases} w = mr(q) & \text{(Input demand)} \\ w = mc(q) & \text{(Input supply)} \\ \max\limits_{w} \ \left[(p(q)q - wq - \pi_0^d)^{\beta} (wq - c(q)q - \pi_0^u)^{1-\beta}\right] & \text{(Bargaining problem)} \\ \max\limits_{w,q} \ \left[(p(q)q - wq - \pi_0^d)^{\beta} (wq - c(q)q - \pi_0^u)^{1-\beta}\right] & \text{(Joint-profit maximization)} \end{cases}$$

For $\beta \in (0, 1)$ and under Assumption S.1, an interior equilibrium satisfies $\pi^d > \pi_0^d$ and $\pi^u > \pi_0^u$ and is characterized by the relevant conduct condition, restated below in terms of the primitives, together with the bargaining first-order condition (B-FOC); the joint-profit maximization problem is characterized by (J-FOC). Both conditions are derived in Section S.4:

$$\begin{cases} w = p'(q)q + p(q) = mr(q) & \text{(Input demand)} \\ w = c'(q)q + c(q) = mc(q) & \text{(Input supply)} \\ \beta\left(\pi^u - \pi_0^u\right) = (1-\beta)\left(\pi^d - \pi_0^d\right) & \text{(B-FOC)} \\ q[p'(q) - c'(q)] + [p(q) - c(q)] = 0 & \text{(J-FOC)} \end{cases}$$

Because the bargaining problem takes the quantity as given, the disagreement payoffs enter (B-FOC) only through the net gains from trade. Solving (B-FOC) for the input price yields

$$w = (1-\beta)\, p(q) + \beta\, c(q) + \frac{\beta\, \pi_0^u - (1-\beta)\, \pi_0^d}{q}, \tag{S.4}$$

which reduces to the familiar weighted average $w = (1-\beta)p(q) + \beta c(q)$ when $\pi_0^d = \pi_0^u = 0$. Note also that (J-FOC) does not involve the disagreement payoffs: joint-profit maximization selects the quantity q^* regardless of (π_0^d, π_0^u).

Substituting the conduct conditions into (B-FOC), the equilibrium-quantity conditions are:

$$F(q,\beta) \equiv (1-\beta)\big[p(q) - c(q)\big]q - c'(q)q^2 - (1-\beta)\,\pi_0^d + \beta\,\pi_0^u = 0 \quad \text{(S-MS-Q-FOC)} \tag{S.5}$$
$$G(q,\beta) \equiv p'(q)q^2 + \beta\big[p(q) - c(q)\big]q + (1-\beta)\,\pi_0^d - \beta\,\pi_0^u = 0 \quad \text{(S-MP-Q-FOC)} \tag{S.6}$$

With $\pi_0^d = \pi_0^u = 0$, dividing by q recovers the conditions $(1-\beta)[p(q)-c(q)] - c'(q)q = 0$ and

$p'(q)q+\beta[p(q)-c(q)] = 0$. These conditions characterize the solution only for $\beta \in (0,1)$; the corner cases $\beta \in \{0,1\}$ are constrained optimization problems, and we restrict attention to $\beta \in (0,1)$ throughout this section.

S.3 Second-Order Conditions

The second-order condition of the bargaining problem is:

$$-\left[\frac{\beta\, q^2}{\left(\pi^d - \pi^d_0\right)^2} + \frac{(1-\beta)\, q^2}{\left(\pi^u - \pi^u_0\right)^2}\right] < 0 \qquad \text{(B-SOC)}.$$

(B-SOC) holds at every point where the net gains from trade are positive, for any disagreement payoffs.

S.4 Derivations of the First- and Second-Order Conditions

For (B-FOC), take the natural logarithm of the bargaining objective:

$$\mathcal{L}(w,q) \equiv \beta \ln\left(p(q)q - wq - \pi^d_0\right) + (1-\beta)\ln\left(wq - c(q)q - \pi^u_0\right). \tag{S.7}$$

Under simultaneous timing, the quantity is taken as given in the bargaining problem, so $d\pi^d/dw = -q$ and $d\pi^u/dw = q$. Differentiating $\mathcal{L}(w,q)$ with respect to w and setting it to zero:

$$\frac{-\beta\, q}{\pi^d - \pi^d_0} + \frac{(1-\beta)\, q}{\pi^u - \pi^u_0} = 0, \tag{S.8}$$

which gives (B-FOC): $\beta(\pi^u - \pi^u_0) = (1-\beta)(\pi^d - \pi^d_0)$. Expanding $\pi^d = (p(q) - w)q$ and $\pi^u = (w - c(q))q$ and solving for w yields Equation (S.4). Differentiating (S.8) once more with respect to w gives (B-SOC):

$$\frac{\partial^2 \mathcal{L}}{\partial w^2} = -\frac{\beta\, q^2}{\left(\pi^d - \pi^d_0\right)^2} - \frac{(1-\beta)\, q^2}{\left(\pi^u - \pi^u_0\right)^2} < 0.$$

For (J-FOC), take the derivative of $\mathcal{L}$ from Equation (S.7) with respect to q:

$$\beta \cdot \frac{p'(q)q + p(q) - w}{\pi^d - \pi^d_0} + (1-\beta) \cdot \frac{w - c'(q)q - c(q)}{\pi^u - \pi^u_0} = 0.$$

By (B-FOC), $\dfrac{\beta}{\pi^d - \pi^d_0} = \dfrac{1-\beta}{\pi^u - \pi^u_0} \equiv \lambda > 0$. Substituting:

$$\lambda\left[\left(p'(q)q + p(q) - w\right) + \left(w - c'(q)q - c(q)\right)\right] = \lambda\left[q\left(p'(q) - c'(q)\right) + \left(p(q) - c(q)\right)\right] = 0,$$

which is (J-FOC).

Finally, for the equilibrium-quantity conditions: under monopsonistic bargaining, substituting the input supply constraint $w = c(q) + c'(q)q$ into (B-FOC) gives $\pi^u = c'(q)q^2$ and $\pi^d = (p(q) - c(q) - c'(q)q)q$, so

$$\beta\left[c'(q)q^2 - \pi_0^u\right] = (1-\beta)\left[\big(p(q) - c(q) - c'(q)q\big)q - \pi_0^d\right],$$

which rearranges to (S-MS-Q-FOC). Under monopolistic bargaining, substituting the input demand constraint $w = p(q) + p'(q)q$ into (B-FOC) gives $\pi^d = -p'(q)q^2$ and $\pi^u = (p(q) + p'(q)q - c(q))q$, so

$$\beta\left[\big(p(q) + p'(q)q - c(q)\big)q - \pi_0^u\right] = (1-\beta)\left[-p'(q)q^2 - \pi_0^d\right],$$

which rearranges to (S-MP-Q-FOC).

S.5 Existence of Equilibrium

Under monopsonistic conduct, an equilibrium (w^e, q^e) of the simultaneous model solves the following system:

$$\begin{cases} w^e = mc(q^e) & (C) \\ w^e \in \arg\max_{w} \left(\pi^d(w, q^e) - \pi_0^d\right)^{\beta}\left(\pi^u(w, q^e) - \pi_0^u\right)^{1-\beta} & (B) \end{cases}$$

That is, (w^e, q^e) is an equilibrium if there is no deviation in w that increases the Nash product given q^e, and the pair lies on the input supply curve. Under monopolistic conduct, the conduct condition (C) is replaced by $w^e = mr(q^e)$. We call an equilibrium *interior* if both net gains from trade are strictly positive: $\pi^d > \pi_0^d$ and $\pi^u > \pi_0^u$.

Proposition S.1 (Existence)**.** *Under simultaneous timing:*
(i) If the upstream marginal cost is constant, $mc'(q) = 0$, the monopsonistic bargaining problem does not have an interior solution for any β and any disagreement payoffs.
(ii) If the downstream marginal revenue is constant, $mr'(q) = 0$, the monopolistic bargaining problem does not have an interior solution for any β and any disagreement payoffs.
(iii) If $mc'(q) > 0$ and $mr'(q) < 0$ and, in addition, $\pi_0^d < \pi^{d*}$ and $\pi_0^u < \pi^{u*}$, interior solutions with quantity in the connected component of the feasible set containing q^* exist for the ranges of β characterized in Lemmas S.1 and S.2 below, and fail to exist outside these ranges. These ranges include $(0, \beta^*]$ under monopsonistic bargaining and $[\beta^*, 1)$ under monopolistic bargaining, where β^* is the bilaterally-efficient bargaining weight characterized in Section S.7.

Proof. We first show parts (i) and (ii). Throughout, we maintain the mild boundary regularity that output generates no revenue and no cost in the limit of zero quantity,

$$\lim_{q\to 0} p(q)\,q = 0 \qquad \text{and} \qquad \lim_{q\to 0} c(q)\,q = 0,$$

which holds, in particular, when the choke price is finite and there is no fixed cost. When $mc'(q) = 0$ (respectively $mr'(q) = 0$), the input supply (respectively input demand) curve is flat: the conduct condition pins down the input price but not the quantity, so the equilibrium conditions of Section S.2 do not characterize a solution, and we argue directly from the constrained bargaining problem.

Monopsonistic bargaining with constant marginal cost ($mc(q) = \bar{c}$):

With constant marginal cost, the input supply curve is flat at $mc(q) = \bar{c}$. Integrating $mc(q) = d(c(q)q)/dq = \bar{c}$ and using the boundary regularity $\lim_{q\to 0} c(q)q = 0$ gives $c(q) = \bar{c}$ for all $q > 0$, so average and marginal cost coincide. Any equilibrium with positive trade must lie on the input supply curve, so $w^e = \bar{c}$, and upstream profit is $\pi^u = (w^e - c(q))q^e = 0$ regardless of the quantity. The upstream net gain from trade is therefore $-\pi_0^u \leq 0$ at every candidate equilibrium, for every $\beta \in (0,1)$ and every configuration of disagreement payoffs. If $\pi_0^u > 0$, the supplier's net gain from trade is strictly negative at every candidate equilibrium, so no equilibrium with positive trade exists. If $\pi_0^u = 0$, the upstream net gain is zero at every candidate equilibrium, so the Nash product is zero and no interior equilibrium exists; degenerate equilibria with a zero Nash product may exist, as in the case without disagreement payoffs (for example, $w^e = \bar{c}$ and $q^e = p^{-1}(\bar{c})$; at that quantity, $\bar{c}$ is the only input price at which both parties weakly gain from trade).

Monopolistic bargaining with constant marginal revenue ($mr(q) = \bar{m}$):

The argument is symmetric. With constant marginal revenue, the input demand curve is flat at $mr(q) = \bar{m}$. Integrating $mr(q) = d(p(q)q)/dq = \bar{m}$ and using the boundary regularity $\lim_{q\to 0} p(q)q = 0$ gives $p(q) = \bar{m}$ for all $q > 0$, so average and marginal revenue coincide. Any equilibrium with positive trade then has $w^e = \bar{m}$, and downstream profit is $\pi^d = (p(q) - w^e)q^e = 0$ regardless of the quantity. The downstream net gain from trade is therefore $-\pi_0^d \leq 0$ at every candidate equilibrium, and by the same argument no interior equilibrium exists for any $\beta \in (0,1)$ and any disagreement payoffs.

Part (iii): Suppose $mc'(q) > 0$ and $mr'(q) < 0$. Fix $\beta \in (0,1)$ and suppose $1-\beta$ (respectively β) is attained by the share function s^{ms} (respectively s^{mp}) of Lemma S.1 (respectively Lemma S.2) at a quantity q in the interior of the feasible set. Set $w = mc(q)$ (respectively $w = mr(q)$). Then (B-FOC) holds by construction, and (B-SOC) holds globally (Section

S.3), so w maximizes the Nash product given q. Moreover, the pair (w, q) lies on the input supply (respectively input demand) curve by construction, so the conduct condition (C) holds. Since the share function equals $1-\beta \in (0,1)$ (respectively $\beta \in (0,1)$) at q and both net gains are nonnegative on the feasible set, both net gains are strictly positive at q, so (w, q) is an interior equilibrium. Conversely, any interior equilibrium satisfies the conduct condition and (B-FOC), hence the share equation. The characterization of the attainable ranges of β, including the claim that they cover $(0, \beta^*]$ and $[\beta^*, 1)$ when $\pi_0^d < \pi^{d*}$ and $\pi_0^u < \pi^{u*}$, is given in Lemmas S.1 and S.2. □

Unlike under sequential timing, where an interior equilibrium exists for every $\beta \in (0,1)$, under simultaneous timing the equilibrium may fail to exist for some values of β, depending on the demand and cost curves and on the disagreement payoffs. The following two lemmas characterize the range of β for which an interior equilibrium (with quantity in the feasible component containing q^*) exists. For each conduct model, define the *share function* implied by (B-FOC): the equilibrium condition $\beta(\pi^u - \pi_0^u) = (1-\beta)(\pi^d - \pi_0^d)$, with profits evaluated along the conduct curve as in Equations (S.2)–(S.3), pins down the bargaining weight as a function of the equilibrium quantity.

Lemma S.1 (Existence Range: Monopsonistic Bargaining)**.** *Assume $mc'(q) > 0$, Assumption S.1, and $\pi_0^d < \pi^{d*}$, $\pi_0^u < \pi^{u*}$. Let $[q_l, q_h]$ denote the connected component of Ω^{ms} containing q^*, and define on it*

$$s^{ms}(q) \equiv \frac{c'(q)\,q^2 - \pi_0^u}{\big(p(q)-c(q)\big)q - \pi_0^d - \pi_0^u} = \frac{\pi^u(q) - \pi_0^u}{\big(\pi^d(q) - \pi_0^d\big) + \big(\pi^u(q) - \pi_0^u\big)}. \tag{S.9}$$

An interior monopsonistic equilibrium with $q \in (q_l, q_h)$ exists at bargaining weight β if and only if $1-\beta$ is in the range of s^{ms} over (q_l, q_h). In particular:

(i) $s^{ms}(q_h) = 1$ and $s^{ms}(q^*) = 1-\beta^*$, where β^* is the bilaterally-efficient bargaining weight of Proposition S.2 below, so an interior equilibrium exists for every $\beta \in (0, \beta^*]$;

(ii) more generally, an interior equilibrium exists for every $\beta \in \big(0, \bar{\beta}^{ms}\big)$, where $\bar{\beta}^{ms} \equiv 1 - \inf_{q\in(q_l,q_h]} s^{ms}(q) \geq \beta^*$ is the upper existence bound for simultaneous monopsonistic bargaining;

(iii) if $\pi_0^d = \pi_0^u = 0$ and Assumption S.2 (stated in Section S.6) holds, then $s^{ms}(q) = \dfrac{c'(q)\,q}{p(q)-c(q)}$ is strictly increasing (its numerator is increasing since $c''(q)q + c'(q) > 0$, and its denominator is positive and decreasing), so $\bar{\beta}^{ms} = 1 - \lim_{q\to 0^+} \dfrac{c'(q)\,q}{p(q)-c(q)}$, recovering the existence range of the model without disagreement payoffs;

(iv) if the upstream participation constraint binds at the lower end of the feasible set ($c'(q_l)q_l^2 = \pi_0^u > 0$) while the downstream constraint is slack there ($\pi^d(q_l) > \pi_0^d$), then $s^{ms}(q_l) = 0$, so

$\bar{\beta}^{ms} = 1$ *and an interior equilibrium exists for every* $\beta \in (0, 1)$.

Proof. Under monopsonistic conduct, $w = mc(q)$ implies $\pi^u(q) = c'(q)q^2$ and $\pi^d(q) = (p(q) - mc(q))q$, with $\pi^d(q) + \pi^u(q) = (p(q) - c(q))q$. Substituting into (B-FOC) and solving for the bargaining weight gives $1 - \beta = s^{ms}(q)$, with s^{ms} as in Equation (S.9). By the argument in part (iii) of Proposition S.1, an interior equilibrium at β exists if and only if $1 - \beta = s^{ms}(q)$ for some q in the interior of the feasible set.

We compute the value of s^{ms} at three points. First, since $mc'(q) > 0$, upstream profit $\pi^u(q) = c'(q)q^2$ is strictly increasing: $\big(c'(q)q^2\big)' = q\big(2c'(q) + c''(q)q\big) = q\, mc'(q) > 0$. Hence the upstream participation constraint cannot bind at the upper end of the feasible set, and at q_h the downstream constraint binds: $\pi^d(q_h) = \pi_0^d$. Substituting into Equation (S.9), the numerator and denominator coincide, so $s^{ms}(q_h) = 1$.

Second, at $q = q^*$: by (J-FOC), $p(q^*) - c(q^*) = q^*\big(c'(q^*) - p'(q^*)\big)$, so $\pi^d(q^*) = \big(p(q^*) - c(q^*) - c'(q^*)q^*\big)q^* = -p'(q^*)(q^*)^2 = \pi^{d*}$ and $\pi^u(q^*) = \pi^{u*}$. Note that $q^* \in (q_l, q_h)$ because $\pi^d(q^*) = \pi^{d*} > \pi_0^d$ and $\pi^u(q^*) = \pi^{u*} > \pi_0^u$. Therefore

$$s^{ms}(q^*) = \frac{\pi^{u*} - \pi_0^u}{S(q^*) - \pi_0^d - \pi_0^u} = 1 - \beta^*,$$

by the formula for β^* in Proposition S.2.

Third, if the upstream constraint binds at q_l with $\pi_0^u > 0$, the numerator of $s^{ms}(q_l)$ is zero while the denominator equals $\pi^d(q_l) - \pi_0^d \geq 0$, so $s^{ms}(q_l) = 0$ whenever $\pi^d(q_l) > \pi_0^d$.

Since s^{ms} is continuous on $(q_l, q_h]$, the Intermediate Value Theorem implies that its range contains every value between any two attained values. Part (i) follows from $s^{ms}(q^*) = 1 - \beta^*$ and $s^{ms}(q_h) = 1$: every $1 - \beta \in [1 - \beta^*, 1)$ is attained in the open interval (q_l, q_h), i.e., every $\beta \in (0, \beta^*]$. Part (ii) follows by the same argument applied to the infimum of s^{ms} (when the infimum is attained in the interior, the endpoint $\beta = \bar{\beta}^{ms}$ is also included). For part (iii), with $\pi_0^d = \pi_0^u = 0$ the share function reduces to $s^{ms}(q) = c'(q)q/(p(q) - c(q))$, the feasible set extends to the left endpoint $q_l = 0$, and the infimum is the stated limit. Part (iv) is immediate from $s^{ms}(q_l) = 0$ and $s^{ms}(q_h) = 1$. □

Lemma S.2 (Existence Range: Monopolistic Bargaining)**.** *Assume* $mr'(q) < 0$*, Assumption S.1, and* $\pi_0^d < \pi^{d*}$*,* $\pi_0^u < \pi^{u*}$*. Let* $[q_l, q_h]$ *denote the connected component of* Ω^{mp} *containing* q^**, and define on it*

$$s^{mp}(q) \equiv \frac{-p'(q)\,q^2 - \pi_0^d}{\big(p(q) - c(q)\big)q - \pi_0^d - \pi_0^u} = \frac{\pi^d(q) - \pi_0^d}{\big(\pi^d(q) - \pi_0^d\big) + \big(\pi^u(q) - \pi_0^u\big)}. \tag{S.10}$$

An interior monopolistic equilibrium with $q \in (q_l, q_h)$ *exists at bargaining weight* β *if and only if*

β is in the range of s^{mp} over (q_l, q_h). In particular:

(i) $s^{mp}(q_h) = 1$ and $s^{mp}(q^*) = \beta^*$, so an interior equilibrium exists for every $\beta \in [\beta^*, 1)$;

(ii) more generally, an interior equilibrium exists for every $\beta \in \big(\underline{\beta}^{mp}, 1\big)$, where $\underline{\beta}^{mp} \equiv \inf_{q\in(q_l,q_h]} s^{mp}(q) \leq \beta^*$ is the lower existence bound for simultaneous monopolistic bargaining;

(iii) if $\pi_0^d = \pi_0^u = 0$ and Assumption S.3 (stated in Section S.6) holds, then $s^{mp}(q) = \dfrac{-p'(q)\,q}{p(q) - c(q)}$ is strictly increasing (its numerator is increasing since $p''(q)q + p'(q) < 0$, and its denominator is positive and decreasing), so $\underline{\beta}^{mp} = \lim_{q\to 0^+} \dfrac{-p'(q)\,q}{p(q) - c(q)}$, recovering the existence range of the model without disagreement payoffs;

(iv) if the downstream participation constraint binds at the lower end of the feasible set ($-p'(q_l)q_l^2 = \pi_0^d > 0$) while the upstream constraint is slack there ($\pi^u(q_l) > \pi_0^u$), then $s^{mp}(q_l) = 0$, so $\underline{\beta}^{mp} = 0$ and an interior equilibrium exists for every $\beta \in (0, 1)$.

Proof. The argument mirrors the proof of Lemma S.1. Under monopolistic conduct, $w = mr(q)$ implies $\pi^d(q) = -p'(q)q^2$ and $\pi^u(q) = (mr(q) - c(q))q$, with $\pi^d(q) + \pi^u(q) = (p(q) - c(q))q$. Substituting into (B-FOC) and solving gives $\beta = s^{mp}(q)$.

Since $mr'(q) < 0$, downstream profit is strictly increasing: $\big(-p'(q)q^2\big)' = -q\big(2p'(q) + p''(q)q\big) = -q\,mr'(q) > 0$. Hence the downstream constraint cannot bind at the upper end of the feasible set, and at q_h the upstream constraint binds: $\pi^u(q_h) = \pi_0^u$, which gives $s^{mp}(q_h) = 1$. At $q = q^*$: $\pi^d(q^*) = \pi^{d*}$ directly, and $\pi^u(q^*) = \big(mr(q^*) - c(q^*)\big)q^* = \big(mc(q^*) - c(q^*)\big)q^* = c'(q^*)(q^*)^2 = \pi^{u*}$, so

$$s^{mp}(q^*) = \frac{\pi^{d*} - \pi_0^d}{S(q^*) - \pi_0^d - \pi_0^u} = \beta^*.$$

If the downstream constraint binds at q_l with $\pi_0^d > 0$, then $s^{mp}(q_l) = 0$ whenever $\pi^u(q_l) > \pi_0^u$. Parts (i)–(iv) then follow from the continuity of s^{mp} and the Intermediate Value Theorem, exactly as in Lemma S.1. □

Remark. In the remainder of this section, when we refer to the equilibrium at a bargaining weight $\beta \in (0, 1)$, we implicitly restrict attention to values of β within the existence ranges characterized in Lemmas S.1–S.2; for brevity, we do not repeat this qualification.

S.6 Output and Buyer Power

We now characterize how the equilibrium output responds to buyer power, measured either by the bargaining weight β or by the disagreement payoffs. Under simultaneous timing, these comparative statics require curvature assumptions on the cost and demand functions, together with a bound on the size of the disagreement payoffs.

Assumption S.2 (Increasing Differences Between Marginal and Average Cost)**.** $c''(q)\, q + c'(q) > 0$.

Assumption S.3 (Decreasing Differences Between Marginal and Average Revenue)**.** $p''(q)\, q + p'(q) < 0$.

Assumption S.2 implies $mc'(q) = c'(q) + \big(c''(q)q + c'(q)\big) > 0$, and Assumption S.3 implies $mr'(q) = p'(q) + \big(p''(q)q + p'(q)\big) < 0$. We need Assumption S.2 only for monopsonistic bargaining and Assumption S.3 only for monopolistic bargaining. Define the curvature terms

$$\Gamma^{ms}(q,\beta) \equiv (1-\beta)\big(c'(q) - p'(q)\big) + c''(q)\, q + c'(q),$$
$$\Gamma^{mp}(q,\beta) \equiv \beta\big(c'(q) - p'(q)\big) - \big(p''(q)\, q + p'(q)\big),$$

which are strictly positive under Assumptions S.2 and S.3, respectively. The bounds on the disagreement payoffs, evaluated at the equilibrium quantity, are:

$$(1-\beta)\,\pi_0^d - \beta\,\pi_0^u \;<\; q^2\,\Gamma^{ms}(q,\beta), \tag{S.11}$$
$$\beta\,\pi_0^u - (1-\beta)\,\pi_0^d \;<\; q^2\,\Gamma^{mp}(q,\beta). \tag{S.12}$$

Theorem S.1 (Output and Buyer Power Under Simultaneous Timing)**.**

(i) Under monopsonistic bargaining, if Assumption S.2 and condition (S.11) hold, the output quantity decreases with the buyer's bargaining weight and the buyer's disagreement payoff, and increases with the supplier's disagreement payoff:

$$\frac{dq^{ms}}{d\beta} < 0, \qquad \frac{dq^{ms}}{d\pi_0^d} < 0, \qquad \frac{dq^{ms}}{d\pi_0^u} > 0.$$

(ii) Under monopolistic bargaining, if Assumption S.3 and condition (S.12) hold, the output quantity increases with the buyer's bargaining weight and the buyer's disagreement payoff, and decreases with the supplier's disagreement payoff:

$$\frac{dq^{mp}}{d\beta} > 0, \qquad \frac{dq^{mp}}{d\pi_0^d} > 0, \qquad \frac{dq^{mp}}{d\pi_0^u} < 0.$$

Proof. Part (i): Monopsonistic bargaining. We apply the Implicit Function Theorem to $F(q,\beta) = 0$ from (S-MS-Q-FOC), treating the disagreement payoffs as parameters.

Step 1: Sign of $\partial F/\partial\beta$. Differentiating Equation (S.5):

$$\frac{\partial F}{\partial \beta} = -\big[p(q) - c(q)\big]q + \pi_0^d + \pi_0^u = -\Big[\big(\pi^d(q) - \pi_0^d\big) + \big(\pi^u(q) - \pi_0^u\big)\Big] < 0,$$

where the inequality holds because both net gains from trade are strictly positive at an interior equilibrium.

Step 2: Sign of $\partial F/\partial q$. Differentiating Equation (S.5):

$$\frac{\partial F}{\partial q} = (1-\beta)\big[p'(q) - c'(q)\big]q + (1-\beta)\big[p(q) - c(q)\big] - c''(q)q^2 - 2c'(q)q.$$

We eliminate $(1-\beta)[p(q) - c(q)]$ using the equilibrium condition (S-MS-Q-FOC) divided by q:

$$(1-\beta)\big[p(q) - c(q)\big] = c'(q)q - \frac{\beta\,\pi_0^u - (1-\beta)\,\pi_0^d}{q}.$$

Substituting and collecting terms:

$$\frac{\partial F}{\partial q} = -q\,\Gamma^{ms}(q,\beta) + \frac{(1-\beta)\,\pi_0^d - \beta\,\pi_0^u}{q}.$$

The first term is strictly negative since $\Gamma^{ms}(q,\beta) > 0$ by Assumption S.2 (as $c'(q) - p'(q) \geq 0$ and $c''(q)q + c'(q) > 0$). The second term has ambiguous sign, but under condition (S.11) it is dominated by the first, so $\partial F/\partial q < 0$.

Step 3: Comparative statics. By the Implicit Function Theorem:

$$\frac{dq^{ms}}{d\beta} = -\frac{\partial F/\partial\beta}{\partial F/\partial q} = -\frac{(-)}{(-)} < 0.$$

For the disagreement payoffs, from Equation (S.5), $\partial F/\partial\pi_0^d = -(1-\beta) < 0$ and $\partial F/\partial \pi_0^u = \beta > 0$, so

$$\frac{dq^{ms}}{d\pi_0^d} = -\frac{-(1-\beta)}{\partial F/\partial q} < 0, \qquad \frac{dq^{ms}}{d\pi_0^u} = -\frac{\beta}{\partial F/\partial q} > 0,$$

using $\partial F/\partial q < 0$ from Step 2.

Part (ii): Monopolistic bargaining. We apply the Implicit Function Theorem to $G(q,\beta) = 0$ from (S-MP-Q-FOC).

Step 1: Sign of $\partial G/\partial\beta$. Differentiating Equation (S.6):

$$\frac{\partial G}{\partial \beta} = \big[p(q) - c(q)\big]q - \pi_0^d - \pi_0^u = \big(\pi^d(q) - \pi_0^d\big) + \big(\pi^u(q) - \pi_0^u\big) > 0,$$

at an interior equilibrium.

Step 2: Sign of $\partial G/\partial q$. Differentiating Equation (S.6):

$$\frac{\partial G}{\partial q} = p''(q)q^2 + 2p'(q)q + \beta\big[p'(q) - c'(q)\big]q + \beta\big[p(q) - c(q)\big].$$

We eliminate $\beta[p(q) - c(q)]$ using the equilibrium condition (S-MP-Q-FOC) divided by q:

$$\beta\big[p(q) - c(q)\big] = -p'(q)q + \frac{\beta\,\pi_0^u - (1-\beta)\,\pi_0^d}{q}.$$

Substituting and collecting terms:

$$\frac{\partial G}{\partial q} = -q\,\Gamma^{mp}(q,\beta) + \frac{\beta\,\pi_0^u - (1-\beta)\,\pi_0^d}{q}.$$

The first term is strictly negative since $\Gamma^{mp}(q,\beta) > 0$ by Assumption S.3. Under condition (S.12), the second term is dominated by the first, so $\partial G/\partial q < 0$.

Step 3: Comparative statics. By the Implicit Function Theorem:

$$\frac{dq^{mp}}{d\beta} = -\frac{\partial G/\partial\beta}{\partial G/\partial q} = -\frac{(+)}{(-)} > 0.$$

From Equation (S.6), $\partial G/\partial\pi_0^d = (1-\beta) > 0$ and $\partial G/\partial\pi_0^u = -\beta < 0$, so

$$\frac{dq^{mp}}{d\pi_0^d} = -\frac{(1-\beta)}{\partial G/\partial q} > 0, \qquad \frac{dq^{mp}}{d\pi_0^u} = -\frac{-\beta}{\partial G/\partial q} < 0,$$

using $\partial G/\partial q < 0$ from Step 2. □

Corollary S.1 (Markups, Markdowns, and the Input Price). *Assume $mc'(q) > 0$ and $mr'(q) < 0$, with $mr(q) > 0$ at the equilibrium quantities.*

(i) Under monopolistic bargaining, the buyer markdown is always zero, $\Delta^d = 0$. Under the conditions of Theorem S.1(ii), the seller markup μ^u decreases with the buyer's bargaining weight and the buyer's disagreement payoff, and increases with the supplier's disagreement payoff.

(ii) Under monopsonistic bargaining, the seller markup is always zero, $\mu^u = 0$. Under the

conditions of Theorem S.1(i), the buyer markdown Δ^d increases with the buyer's bargaining weight and the buyer's disagreement payoff, and decreases with the supplier's disagreement payoff.

(iii) Under the conditions of Theorem S.1, under both conduct models the input price decreases with the buyer's bargaining weight and the buyer's disagreement payoff, and increases with the supplier's disagreement payoff:

$$\frac{dw}{d\beta} < 0, \qquad \frac{dw}{d\pi_0^d} < 0, \qquad \frac{dw}{d\pi_0^u} > 0.$$

Proof. Part (i): Under monopolistic bargaining, the conduct condition imposes $w = mr(q)$, so $\Delta^d = (mr(q) - w)/mr(q) = 0$. The markup is $\mu^u = \big(mr(q) - mc(q)\big)/mc(q) = mr(q)/mc(q) - 1$, which is strictly decreasing in q since $mr'(q) < 0$ and $mc'(q) > 0$. By Theorem S.1(ii), q^{mp} increases with β and π_0^d and decreases with π_0^u; composing with the strict monotonicity of μ^u in q yields the stated signs.

Part (ii): Under monopsonistic bargaining, the conduct condition imposes $w = mc(q)$, so $\mu^u = 0$. The markdown is $\Delta^d = 1 - mc(q)/mr(q)$, which is strictly decreasing in q since $mc(q)/mr(q)$ is strictly increasing in q (mc is strictly increasing and mr strictly decreasing and positive). By Theorem S.1(i), q^{ms} decreases with β and π_0^d and increases with π_0^u; composing yields the stated signs.

Part (iii): Under monopsonistic bargaining, $w = mc(q^{ms})$ with $mc'(q) > 0$, so by the chain rule and Theorem S.1(i), $dw/d\beta = mc'(q)\, dq^{ms}/d\beta < 0$, $dw/d\pi_0^d = mc'(q)\, dq^{ms}/d\pi_0^d < 0$, and $dw/d\pi_0^u = mc'(q)\, dq^{ms}/d\pi_0^u > 0$. Under monopolistic bargaining, $w = mr(q^{mp})$ with $mr'(q) < 0$, so by Theorem S.1(ii), $dw/d\beta = mr'(q)\, dq^{mp}/d\beta < 0$, $dw/d\pi_0^d = mr'(q)\, dq^{mp}/d\pi_0^d < 0$, and $dw/d\pi_0^u = mr'(q)\, dq^{mp}/d\pi_0^u > 0$. □

S.7 The Bilaterally-Efficient Bargaining Weight

Proposition S.2 (Bilaterally-Efficient Buyer Power Under Simultaneous Timing)**.** *Suppose $\pi_0^d < \pi^{d*}$ and $\pi_0^u < \pi^{u*}$. Then there exists a unique bargaining weight*

$$\beta^* = \frac{\pi^{d*} - \pi_0^d}{S(q^*) - (\pi_0^d + \pi_0^u)} = \frac{-p'(q^*)(q^*)^2 - \pi_0^d}{\big(c'(q^*) - p'(q^*)\big)(q^*)^2 - (\pi_0^u + \pi_0^d)} \in (0,1) \tag{S.13}$$

at which the joint-profit maximizing output q^* is an equilibrium output of both the monopsonistic and the monopolistic bargaining model. Under the conditions of Theorem S.1, q^* is the unique equilibrium output of both models at β^*. With zero disagreement payoffs, the formula simplifies to $\beta^* = \dfrac{-p'(q^*)}{c'(q^*) - p'(q^*)}$.

Proof. <u>*Monopsonistic bargaining.*</u> Under the input supply constraint, $w = mc(q)$, so $\pi^u(q) = c'(q)q^2$ and $\pi^d(q) = \big(p(q) - c(q) - c'(q)q\big)q$. At $q = q^*$, (J-FOC) gives $p(q^*) - c(q^*) = q^*\big(c'(q^*) - p'(q^*)\big)$, hence

$$\pi^u(q^*) = c'(q^*)(q^*)^2 = \pi^{u*}, \qquad \pi^d(q^*) = -p'(q^*)(q^*)^2 = \pi^{d*}.$$

Substituting into (B-FOC) at q^*:

$$\beta\left(\pi^{u*} - \pi_0^u\right) = (1-\beta)\left(\pi^{d*} - \pi_0^d\right), \tag{S.14}$$

and solving for β:

$$\beta\big(\pi^{u*} + \pi^{d*} - \pi_0^u - \pi_0^d\big) = \pi^{d*} - \pi_0^d \quad \Longrightarrow \quad \beta^* = \frac{\pi^{d*} - \pi_0^d}{S(q^*) - (\pi_0^d + \pi_0^u)}.$$

The second expression in Equation (S.13) follows from $S(q^*) = \big(p(q^*) - c(q^*)\big)q^* = \big(c'(q^*) - p'(q^*)\big)(q^*)^2$ by (J-FOC).

<u>*Monopolistic bargaining.*</u> Under the input demand constraint, $w = mr(q)$. At $q = q^*$, $w^* = mr(q^*) = mc(q^*)$, so the parties' profits at q^* are identical to the monopsonistic case: $\pi^d(q^*) = \pi^{d*}$ and $\pi^u(q^*) = \pi^{u*}$. Substituting into (B-FOC) yields the same condition (S.14) and hence the same β^*.

<u>*Conditions for $\beta^* \in (0,1)$.*</u> For $\beta^* > 0$: the condition $\pi_0^d < \pi^{d*}$ makes the numerator positive, and together with $\pi_0^u < \pi^{u*}$ it makes the denominator positive (since $\pi_0^d + \pi_0^u < \pi^{d*} + \pi^{u*} = S(q^*)$). For $\beta^* < 1$: the numerator is smaller than the denominator if and only if $\pi_0^u < \pi^{u*}$.

<u>*Uniqueness.*</u> The quantity q^* is the unique solution to $mr(q) = mc(q)$ (as mr is strictly decreasing and mc strictly increasing), and Equation (S.14) maps q^* to a unique β^*. Under the conditions of Theorem S.1, $\partial F/\partial q < 0$ (respectively $\partial G/\partial q < 0$) at every solution of the equilibrium-quantity condition (Step 2 of the proof of Theorem S.1), so the equilibrium quantity at any given bargaining weight is unique; at β^* it therefore equals q^*. □

Remark. When $\pi_0^d > \pi^{d*}$ or $\pi_0^u > \pi^{u*}$, the joint-profit maximizing quantity is not achievable under a linear price contract, because at q^* at least one party would earn strictly less than its disagreement payoff; in that case $q^* \notin \mathcal{Q}^{ms} \cup \mathcal{Q}^{mp}$. As in the sequential analysis, we adopt the corner convention $\beta^* = 0$ (when $\pi_0^d \geq \pi^{d*}$) or $\beta^* = 1$ (when $\pi_0^u \geq \pi^{u*}$); at the equality boundary, the corner value attains q^* exactly.

Corollary S.2 (Properties of β^*). *Under the conditions of Proposition S.2:*

(i) Holding q^* fixed, β^* weakly decreases as the upstream cost curve becomes steeper ($c'(q^*)$

increases) and weakly increases as the downstream inverse demand curve becomes steeper ($-p'(q^*)$ increases).

(ii) *β^* decreases with the downstream disagreement payoff and increases with the upstream disagreement payoff:*

$$\frac{\partial \beta^*}{\partial \pi_0^d} = \frac{-\left(\pi^{u*} - \pi_0^u\right)}{\left[S(q^*) - (\pi_0^d + \pi_0^u)\right]^2} < 0, \qquad \frac{\partial \beta^*}{\partial \pi_0^u} = \frac{\pi^{d*} - \pi_0^d}{\left[S(q^*) - (\pi_0^d + \pi_0^u)\right]^2} > 0.$$

Proof. Write $\beta^* = N/D$ with $N = \pi^{d*} - \pi_0^d = -p'(q^*)(q^*)^2 - \pi_0^d$ and $D = S(q^*) - (\pi_0^d + \pi_0^u) = \left(c'(q^*) - p'(q^*)\right)(q^*)^2 - (\pi_0^d + \pi_0^u)$, with $N, D > 0$ and $N < D$ by Proposition S.2.

Part (i): An increase in $c'(q^*)$, holding q^* and $p'(q^*)$ fixed, increases D and leaves N unchanged, so β^* weakly decreases. For $-p'(q^*)$, write $1/\beta^* = 1 + \left(c'(q^*)(q^*)^2 - \pi_0^u\right)/\left(-p'(q^*)(q^*)^2 - \pi_0^d\right)$: an increase in $-p'(q^*)$ increases the denominator of the second term, so $1/\beta^*$ decreases and β^* increases.

Part (ii): By the quotient rule:

$$\frac{\partial \beta^*}{\partial \pi_0^d} = \frac{(-1)\,D - N\,(-1)}{D^2} = \frac{N - D}{D^2} = \frac{-\left(\pi^{u*} - \pi_0^u\right)}{D^2} < 0, \qquad \frac{\partial \beta^*}{\partial \pi_0^u} = \frac{0 \cdot D - N\,(-1)}{D^2} = \frac{N}{D^2} > 0,$$

where the signs use $\pi_0^u < \pi^{u*}$ and $\pi_0^d < \pi^{d*}$. □

S.8 Determining the Source of Vertical Distortions

As in the main text, we impose that the equilibrium markup and markdown are nonnegative directly in the bargaining problem.

Constraint S.1 (Nonnegative Markup/Markdown Constraint)**.** *The parties bargain over w subject to the constraint that the equilibrium markup and markdown are nonnegative. Under each conduct model, the constrained simultaneous bargaining problem is:*

$$\textit{Monopolistic:} \quad \begin{cases} \max\limits_{w} \; \left(\pi^d - \pi_0^d\right)^{\beta} \left(\pi^u - \pi_0^u\right)^{1-\beta} \quad s.t. \quad w \geq mc(q) \\ w = mr(q) \end{cases}$$

$$\textit{Monopsonistic:} \quad \begin{cases} \max\limits_{w} \; \left(\pi^d - \pi_0^d\right)^{\beta} \left(\pi^u - \pi_0^u\right)^{1-\beta} \quad s.t. \quad w \leq mr(q) \\ w = mc(q) \end{cases}$$

Theorem S.2 (Conduct Selection Under Simultaneous Timing)**.** *Suppose the conditions of Theorem S.1 hold and $\pi_0^d < \pi^{d*}$, $\pi_0^u < \pi^{u*}$, so that $\beta^* \in (0, 1)$. Under the nonnegative* *markup/markdown constraint, the vertical distortion exists only under monopolistic conduct for $\beta \in (0, \beta^*)$ and only under monopsonistic conduct for $\beta \in (\beta^*, 1)$; at $\beta = \beta^*$, neither conduct model generates a distortion.*

Proof. Monopolistic conduct. The conduct condition imposes $w = mr(q)$, so $\Delta^d = 0$ automatically, and the nontrivial constraint is $w \geq mc(q)$, i.e., $mr(q) \geq mc(q)$, which is equivalent to $q \leq q^*$ since mr is strictly decreasing and mc strictly increasing with $mr(q^*) = mc(q^*)$. It is useful to record the unconstrained maximizer of the Nash product given the quantity q^*, which by Equation (S.4) is

$$w^B(q^*, \beta) = (1-\beta)\, p(q^*) + \beta\, c(q^*) + \frac{\beta\, \pi_0^u - (1-\beta)\, \pi_0^d}{q^*};$$

it is strictly decreasing in β, with $\partial w^B / \partial \beta = -\left[S(q^*) - \pi_0^d - \pi_0^u\right]/q^* < 0$, and equals w^* at $\beta = \beta^*$, since (B-FOC) holds at (w^*, q^*) exactly at β^* by Proposition S.2.

- If $\beta \leq \beta^*$: By Theorem S.1(ii), $q^{mp}(\beta)$ is increasing in β, and by Proposition S.2, $q^{mp}(\beta^*) = q^*$. Hence $q^{mp}(\beta) \leq q^*$, so $w = mr(q^{mp}) \geq mr(q^*) = mc(q^*) \geq mc(q^{mp})$: the constraint is slack, and the unconstrained equilibrium—whenever it exists, which by Lemma S.2 is guaranteed for $\beta \in (\underline{\beta}^{mp}, \beta^*]$—prevails with a vertical distortion ($\mu^u > 0$ for $\beta < \beta^*$). For β below the existence range, monopolistic bargaining has no interior equilibrium (with quantity in the feasible component), with or without the constraint: a slack-constraint equilibrium would coincide with the unconstrained one, which fails to exist by Lemma S.2 (β is below the range of the share function s^{mp}), and the binding-constraint candidate (w^*, q^*) requires $w^B(q^*, \beta) \leq mc(q^*)$, which holds only for $\beta \geq \beta^*$.

- If $\beta > \beta^*$: By Lemma S.2, the unconstrained equilibrium exists for every $\beta \in (\beta^*, 1)$ and satisfies $q^{mp}(\beta) > q^*$ by the same monotonicity, implying $w = mr(q^{mp}) < mr(q^*) = mc(q^*) < mc(q^{mp})$, which violates $w \geq mc(q)$. The constraint therefore binds: $w = mc(q)$ together with $w = mr(q)$ forces $q = q^*$ and $w = w^*$. Moreover, (w^*, q^*) is an equilibrium of the constrained problem: for $\beta > \beta^*$, $w^B(q^*, \beta) < w^B(q^*, \beta^*) = w^* = mc(q^*)$, so the unconstrained bargaining optimum violates the constraint $w \geq mc(q^*)$, and by strict concavity of the log Nash objective in w (B-SOC) the constrained optimum given q^* is the corner $w = w^*$; the pair (w^*, q^*) lies on the input demand curve, so the conduct condition holds as well. Both parties earn strictly above their disagreement payoffs at (w^*, q^*) since $\pi^{d*} > \pi_0^d$ and $\pi^{u*} > \pi_0^u$. No distortion: $\mu^u = \Delta^d = 0$.

Monopsonistic conduct. The conduct condition imposes $w = mc(q)$, so $\mu^u = 0$ automatically, and the nontrivial constraint is $w \le mr(q)$, i.e., $mc(q) \le mr(q)$, again equivalent to $q \le q^*$; the function $w^B(q^*, \beta)$ defined above again gives the unconstrained bargaining optimum at q^*.

- If $\beta \ge \beta^*$: By Theorem S.1(i), $q^{ms}(\beta)$ is decreasing in β, and $q^{ms}(\beta^*) = q^*$. Hence $q^{ms}(\beta) \le q^*$, so $w = mc(q^{ms}) \le mc(q^*) = mr(q^*) \le mr(q^{ms})$: the constraint is slack, and the unconstrained equilibrium—whenever it exists, which by Lemma S.1 is guaranteed for $\beta \in [\beta^*, \bar{\beta}^{ms})$—prevails with a vertical distortion ($\Delta^d > 0$ for $\beta > \beta^*$). For β above the existence range, monopsonistic bargaining has no interior equilibrium (with quantity in the feasible component), with or without the constraint: a slack-constraint equilibrium would coincide with the unconstrained one, which fails to exist by Lemma S.1 ($1 - \beta$ is below the range of the share function s^{ms}), and the binding-constraint candidate (w^*, q^*) requires $w^B(q^*, \beta) \ge mr(q^*)$, which holds only for $\beta \le \beta^*$.
- If $\beta < \beta^*$: By Lemma S.1, the unconstrained equilibrium exists for every $\beta \in (0, \beta^*)$ and satisfies $q^{ms}(\beta) > q^*$, implying $w = mc(q^{ms}) > mc(q^*) = mr(q^*) > mr(q^{ms})$, which violates $w \le mr(q)$. The constraint binds: $w = mr(q)$ together with $w = mc(q)$ forces $q = q^*$ and $w = w^*$. Moreover, (w^*, q^*) is an equilibrium of the constrained problem: for $\beta < \beta^*$, $w^B(q^*, \beta) > w^B(q^*, \beta^*) = w^* = mr(q^*)$, so the unconstrained bargaining optimum violates the constraint $w \le mr(q^*)$, and by (B-SOC) the constrained optimum given q^* is the corner $w = w^*$; the pair lies on the input supply curve, so the conduct condition holds as well. Both participation constraints are satisfied strictly at (w^*, q^*). No distortion.

In sum, for $\beta < \beta^*$ monopolistic conduct operates unconstrained (with distortion $\mu^u > 0$) while monopsonistic conduct is constrained to the joint-profit maximizing outcome; for $\beta > \beta^*$ the roles are reversed; and at $\beta = \beta^*$ both models yield q^* with no distortion. □

Remark. When $\pi_0^d \ge \pi^{d*}$ or $\pi_0^u \ge \pi^{u*}$, the corner convention $\beta^* = 0$ or $\beta^* = 1$ applies. If the corresponding inequality is strict, the conduct model whose constraint would bind cannot reach (w^*, q^*), because at q^* one party would earn strictly less than its disagreement payoff; that conduct model then has no equilibrium under the nonnegative markup/markdown constraint, while the other conduct model operates unconstrained at every β, in line with the statement of Theorem S.2 evaluated at the corner value of β^*.

Proposition S.3 (Conduct Identification via the Input Price)**.** *Under the conditions of Theorem S.2:*

(i) Equilibrium output satisfies $q \leq q^*$ under both conduct models, with equality if and only if the markup/markdown constraint binds or $\beta = \beta^*$.

(ii) Under monopolistic bargaining, $w \geq w^*$, with equality if and only if $q = q^*$.

(iii) Under monopsonistic bargaining, $w \leq w^*$, with equality if and only if $q = q^*$.

Therefore, vertical conduct is identified by the sign of $w - w^*$: input prices above w^* are consistent only with monopolistic conduct, and input prices below w^* only with monopsonistic conduct.

Proof. Part (i): When the constraint is slack, the unconstrained equilibrium satisfies $q^{mp}(\beta) \leq q^*$ for $\beta \leq \beta^*$ and $q^{ms}(\beta) \leq q^*$ for $\beta \geq \beta^*$, by the monotonicity of output in β (Theorem S.1) and $q^{mp}(\beta^*) = q^{ms}(\beta^*) = q^*$ (Proposition S.2). When the constraint binds, $q = q^*$ exactly (Theorem S.2).

Part (ii): Under monopolistic bargaining, $w = mr(q^{mp})$. Since $q^{mp} \leq q^*$ by part (i) and $mr'(q) < 0$:

$$w = mr(q^{mp}) \geq mr(q^*) = w^*,$$

with equality if and only if $q^{mp} = q^*$.

Part (iii): Under monopsonistic bargaining, $w = mc(q^{ms})$. Since $q^{ms} \leq q^*$ and $mc'(q) > 0$:

$$w = mc(q^{ms}) \leq mc(q^*) = w^*,$$

with equality if and only if $q^{ms} = q^*$. □

Remark. As in the sequential analysis, $|w - w^*|$ measures the severity of the vertical distortion: under monopolistic bargaining $w - w^* = mr(q^{mp}) - mr(q^*)$ is strictly increasing in the output distortion $q^* - q^{mp}$, and symmetrically under monopsonistic bargaining. Part (i) also provides the testable implication $q \leq q^*$ of the nonnegative markup/markdown constraint under simultaneous timing.