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ABSTRACT

In this paper, we provide a theoretical characterization of the welfare effects of buyer and seller power in vertical relations and introduce an empirical approach for quantifying the contributions of each channel to deadweight loss. Our model accommodates both monopsony distortions from buyer power and double-marginalization distortions from seller power. Rather than imposing a specific form of vertical conduct, we allow it to arise endogenously based on model primitives. We show that the relative elasticity of upstream supply and downstream demand is the key determinant of whether buyer or seller power creates distortions. Applying our framework to coal procurement by power plants in Texas, we find that 83% of the distortion comes from the monopoly power of coal mines, with the remainder attributed to the monopsony power of power plants.

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1 Introduction

There is a growing interest in the buyer power of firms, both in labor markets (Card et al., 2018; Berger et al., 2022; Lamadon et al., 2022; Yeh et al., 2022) and in vertically related industries (Grennan, 2013; Gowrisankaran et al., 2015; Rubens, 2023). This attention is mirrored in policy circles; for instance, the Department of Justice (DOJ) has recently challenged mergers on the grounds of oligopsony concerns (U.S. Department of Justice, 2022), and tackling labor market power has come to the forefront of economic policy-making (The White House, 2023; U.S. Department of Justice and Federal Trade Commission, 2023).

However, the welfare effects of buyer power depend on the specific vertical model one relies on. In one class of models, which we classify as "monopolistic vertical conduct," downstream firms determine input demand given the outcome of input price bargaining (Crawford and Yurukoglu, 2012; Ho and Lee, 2019). In these models, seller power creates deadweight loss through double marginalization, and buyer power can countervail this distortion. In another class of models, which we classify as "monopsonistic vertical conduct," the upstream party chooses how much input to supply given the outcome of the bargaining process (Card et al., 2018; Berger et al., 2022). In these models, buyer power induces deadweight loss by generating input-price markdowns.

In this paper, we provide a theoretical characterization of the welfare effects of buyer and seller power in a unified framework and introduce an empirical approach for quantifying the contributions of each channel to deadweight loss. Our framework nests both monopsonistic and monopolistic vertical models. The key novelty is that we do not impose a specific vertical conduct assumption but instead allow it to arise endogenously based on model primitives. This feature allows us to characterize the conditions under which buyer power and seller power act as countervailing or distortionary.

The starting point of our paper is our result that under increasing upstream marginal cost and decreasing downstream demand, equilibrium exists under both monopsonistic and monopolistic vertical conduct. This contrasts with most empirical IO models studying settings with constant upstream marginal costs, where only monopolistic conduct is possible. Similarly, monopsony models in labor typically feature perfectly elastic downstream demand, where only monopsonistic conduct is possible.[1] However, in industries characterized by increasing upstream cost and decreasing downstream demand, there is no a priori reason why a specific vertical conduct should occur. To address this theoreti-

[1]Recently, monopsony models have been developed in which downstream residual demand is not perfectly elastic, such as Kroft et al. (2020), Rubens (2023), Lobel (2024). We show that in these cases, equilibrium conduct is not necessarily monopsonistic for all values of the bargaining parameter, although it is always monopsonistic at the limit of full buyer power that is assumed in these papers.

cal ambiguity, we develop two microfoundations that empirically identify which form of vertical conduct emerges in equilibrium.

We argue that these settings are common and illustrate the application of our model in three empirical contexts: (i) a manufacturer with increasing marginal costs bargaining with a downstream firm, (ii) a union bargaining with an employer, and (iii) sellers collectively bargaining with a buyer. In these settings, we show how to determine empirically whether the distortion in a vertical relation comes from the buyer's monopoly power or the seller's monopoly power. Moreover, if both distortion types are present in an industry, we decompose the welfare losses into buyer and seller power components. We carry out this decomposition in our main empirical application of coal procurement by power plants.

In its basic form, our theoretical model is a perfect-information bilateral Nash bargaining problem between a single seller ("upstream party") and a single buyer ("downstream party") that bargain over a linear wholesale price, and either the seller chooses how much to supply ("monopsonistic bargaining") or the buyer chooses how much to produce ("monopolistic bargaining"). We refrain from making functional-form assumptions on the demand and cost curves and allow for both simultaneous and sequential timing. We model "buyer power" (β) as the buyer's bargaining ability compared to the seller.

Our first result shows that each type of vertical conduct has an opposite effect of buyer power on downstream output. Under monopolistic bargaining, buyer power increases output by reducing the double-marginalization problem of Spengler (1950). In contrast, under monopsonistic bargaining, buyer power lowers output by leading to a different kind of double marginalization, in which downstream marks down input prices in addition to marking up consumer prices (Robinson, 1933). Although these insights are recognized in the literature, we characterize the exact conditions under a nonparametric framework in a bargaining setting.

To understand their properties, we compare the outcomes of monopsonistic and monopolistic bargaining with the efficient bargaining case, where upstream and downstream bargain over a two-part tariff. We show that for an interior value $\beta^* \in (0, 1)$, both the monopsonistic and monopolistic equilibrium coincide with the efficient-bargaining outcome. Although not immediately obvious, this result is intuitive: at β^*, which we call the 'efficient level of buyer power', the buyer's monopsony power and the seller's monopoly power exactly offset each other, leading to the efficient-bargaining outcome.

We show that β^* is the key parameter determining the welfare effects of buyer and seller power. It is characterized by 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). A higher cost elasticity 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.

We next develop two testable micro-foundations that endogenize vertical conduct and select between monopsonistic and monopolistic equilibria. In our first selection mechanism, we impose a participation constraint that the seller requires a nonnegative markup, and the buyer requires a nonnegative markdown in order to trade. Under these constraints, we show that the equilibrium quantity is unique, and the vertical conduct is either monopsonistic or monopolistic. The type of vertical conduct depends on how the buyer power (β) compares to the efficient level of buyer power (β^*). If buyer power is below β^*, the seller has too much power, resulting in monopolistic vertical conduct. Conversely, if buyer power exceeds β^*, the buyer has too much power, leading to monopsonistic vertical conduct. Thus, buyer power can either be countervailing (increases output) or distortionary (decreases output), depending on how β compares with β^*.

Although the nonnegative markup and markdown constraints are intuitive, they warrant further discussion because even with a negative markup and markdown, firms can still earn positive net profits from inframarginal units due to increasing marginal cost and decreasing demand. Thus, these constraints are more likely to hold when it is infeasible to operate the marginal unit at a loss through transfers between production units. For example, if the seller is a labor union, a negative upstream markup would necessitate transfers among union members to subsidize some workers to accept wages below their reservation wage—a scenario that appears highly implausible. Similarly, if the seller is a multiplant firm, it would require a manager to operate a loss-making plant.

To address cases in which the nonnegative markup and markdown assumption is not necessarily warranted, we develop a second microfoundation to endogeneize vertical conduct. We augment our model to allow firms to either bargain over just the wholesale price or over both the output price and the wholesale price simultaneously (equivalent to a two-part tariff). In this setting, we impose the participation constraint that firms are willing to set linear contracts only if they cannot unilaterally earn higher profits under a two-part tariff. We show that under this participation constraint, one of the firms always has an incentive to choose a linear contract over a two-part tariff. In other words, observing linear price contracts implies by revealed preferences that at least one firm opts not to engage in efficient bargaining, indicating either monopsonistic or monopolistic behavior.

The characterization of vertical conduct as a function of the actual level of buyer power, β, and the efficient level of buyer power, β^*, suggests two empirical strategies for analyzing buyer and seller power. First, β^* can be calculated from the elasticity of upstream cost and downstream demand, and this value can be compared to the actual bargaining weight estimated using a bargaining model. This comparison identifies the nature of the conduct and determines whether seller or buyer power drives distortions. Second, even if estimating the actual bargaining weight is not feasible, β^* can still be readily estimated from cost and demand data. High levels of β^* suggest that the conduct is likely monopsonistic, while low levels of β^* indicate that the conduct is more likely monopolistic.

We show how to implement these empirical strategies in three applications. In our main application, we analyze the wholesale coal procurement by power plants in Texas from 2005 to 2015. Using detailed cost data from coal mines and coal-fired power plants, along with observed wholesale coal and electricity prices, we estimate cost and demand curves on both sides of the market and quantify the relative bargaining power of mines and power plants. Our estimates reveal that 83% is due to monopoly power of coal mines; the remaining 17% arises from the monopsony power of power plants.

The two other empirical examples rely on calibrated applications of our model to estimate β^* rather than fully estimating a bargaining model. First, using estimates of labor supply and demand for U.S. construction workers from Kroft et al. (2020), we examine the effects of potential unionization of labor in this industry. We find that if construction workers were to unionize, the output-maximizing bargaining power of employers would be 0.42, slightly favoring unions over employers. Second, we apply our model to Chinese tobacco farming and manufacturing to examine the potential effects of a farmer cooperative. Using estimates from Rubens (2023), we find that the efficient level of buyer power for cigarette manufacturers would be 0.92, which is close to a one-sided monopsony.

Our paper offers key insights for antitrust policy. In horizontal mergers between either upstream or downstream firms, total and consumer surplus can rise or fall depending on the efficient level of buyer power β^*, which governs whether vertical conduct is monopsonistic or monopolistic. Therefore, our model nests prior analyses of the role that buyer power plays in merger control, with buyer power being pro-competitive in Nevo (2014); Craig et al. (2021); Sheu and Taragin (2021) but anti-competitive in Hemphill and Rose (2018); Berger et al. (2023). Second, in vertical mergers, potential welfare gains through reduced double marginalization depend on the gap between premerger bargaining weights β and β^*, which we characterize and show how to estimate.

We provide four extensions of our theoretical framework. First, we analyze our comparative statics results with respect to disagreement payoffs instead of bargaining weights. We show that most of our results remain robust when the buyer's disagreement payoff is treated as buyer power instead of β. Second, we generalize our model to settings where multiple buyers compete oligopolistically in the downstream market. In this case, increased downstream competition makes vertical conduct more likely to be monopsonistic. Third, we extend our framework to accommodate bilateral negotiations of multiple buyers and sellers by using the extended class of Nash-in-Nash bargaining models with passive beliefs. Fourth, we consider a multi-input downstream production setting, where one input is obtained through bargaining and the other is sourced from a competitive market.

In concluding the introduction, we emphasize that our paper analyzes only the static effects of buyer and seller power while remaining agnostic about potential dynamic effects, such as those relating to innovation or investment incentives. These dynamic effects can influence the net welfare effects of buyer and seller power. Moreover, we do not take a stand on how to weigh the surpluses of upstream and downstream parties in our model; rather, we examine the effects of buyer and seller power on equilibrium output and different welfare metrics.

Contribution to the Literature Our project contributes to four sets of literature. The first one is the literature on market power in vertical relations under bilateral oligopoly. This class of models was implemented in IO to study firm-to-firm bargaining in (Crawford and Yurukoglu, 2012; Grennan, 2013; Gowrisankaran et al., 2015; Crawford et al., 2018; Ho and Lee, 2019), in labor to analyze union-employer wage bargaining (Abowd and Lemieux, 1993; Hosken et al., 2023), and in international trade to study importer-exporter bargaining (Alviarez et al., 2023; Atkin et al., 2024).[2,3] A common feature of these models is that output is determined by the buyers, either directly or indirectly through output prices, which implies that market power distortions are due to seller power.

Second, a distinct literature studies monopsony power in vertical relations while assuming that the *seller*, rather than the buyer, determines output. In these models, the downstream party sets wholesale prices (or wages, in labor applications) while conditioning on an upward-sloping factor supply curve under either monopsonistic competition (Card et al., 2018; Lamadon et al., 2022), oligopsonistic competition (Azar et al., 2022; Berger et al., 2022; Rubens, 2023), or monopsonistic bargaining (Rubens, 2022).[4]

We contribute to these two literatures by endogenizing vertical conduct. Instead of analyzing market power due to monopsony or upstream monopoly power, we consider a unified framework that determines the vertical conduct in equilibrium and decomposes the welfare effects of market power into distortions from seller and buyer power.

[2] An important difference between our paper and Alviarez et al. (2023) is that the "markdown" in our paper is a wedge between the marginal revenue product of an input and the price of that input paid by the buyer, whereas the markdown in Alviarez et al. (2023) means a negative markup of the seller.

[3] Empirical approaches in these literatures often rely on the "Nash-in-Nash" equilibrium notion proposed by Horn and Wolinsky (1988) and micro-founded by Collard-Wexler et al. (2019).

[4] These are the "neoclassical" monopsony models, as opposed to the "dynamic" monopsony models in the search-and-matching tradition (Manning, 2013).

Third, we contribute to models of countervailing power (Galbraith, 1954; Iozzi and Valletti, 2014; Loertscher and Marx, 2022), for which empirical evidence was documented in Gowrisankaran et al. (2015); Barrette et al. (2022).[5] We advance this literature by developing a model that identifies the conditions under which buyer power is countervailing or distortionary. In complementary and independent research, Avignon et al. (2024) derive similar theoretical results within a bargaining framework where the upstream firm also exercises monopsony power, which introduces a novel "double markdownization" phenomenon. Other differences include our consideration of both simultaneous and sequential timing assumptions, a different approach to endogenizing vertical conduct, and bringing our model to the data.

Fourth, we contribute to the literature testing vertical conduct (Berto Villas-Boas, 2007; Bonnet and Dubois, 2010; Atkin et al., 2024). Differently from these papers, vertical conduct is an equilibrium outcome in our model instead of a primitive assumed to be fixed.

The rest of this paper is structured as follows. In Section 2, we present the setup of our model. Section 3 compares the welfare effects of buyer power between monopolistic and monopsonistic bargaining models while taking vertical conduct as given. Section 4 endogenizes vertical conduct. Section 5 generalizes the basic model with four extensions. In Section 6, we empirically implement our model in two calibrated applications: labor unions and farmer cooperatives. In Section 7, we carry out a fully estimated empirical application in the context of coal procurement of power plants in Texas. Section 8 concludes. All proofs are included in Appendices A, B, and C.

2 Model Setup

2.1 Primitives: Costs, Demand, and Payoffs

We consider a simple bilateral bargaining problem where an upstream firm U sells a quantity q of a good to a downstream firm D at a wholesale price w, using a linear price contract. The downstream firm D then sells this good directly to consumers at no additional cost. D faces an inverse demand curve $p(q)$, with $p'(q) \leq 0$. U produces output at a per-unit cost $c(q)$, with $c'(q) \geq 0$. We denote the downstream profit as $\pi^d(w,q) \equiv \big(p(q) - w\big)q$ and upstream profit as $\pi^u(w,q) \equiv \big(w - c(q)\big)q$. We assume that $p(q) > c(q)$ in an interval $(0, \bar{q})$ with $p(\bar{q}) = c(\bar{q})$ to guarantee gains from trade. We denote upstream marginal cost as $mc(q) \equiv \frac{\partial(c(q)q)}{\partial q}$ and downstream marginal revenue as $mr(q) \equiv \frac{\partial(p(q)q)}{\partial q}$. For expositional purposes, we set the disagreement payoffs of both buyers and sellers to zero, which we later relax in Section 5.

[5] In contrast to models of countervailing power that rely on incomplete information bargaining, such as Loertscher and Marx (2022), we model countervailing power in a complete information setup.

2.2 Relevance of Allowing for Increasing Marginal Costs

Our key departure from the prior empirical bargaining literature is that we allow for increasing marginal costs of U, in contrast to, for instance, Grennan (2013), Crawford et al. (2018), and Ho and Lee (2019). Allowing for increasing marginal costs is important for understanding vertical relationships across various industries. Below, we highlight three vertical environments where increasing marginal costs matter and our model applies.

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

A long tradition of research has examined wage bargaining and labor unions (Ashenfelter and Johnson, 1969; Card, 1986; Abowd and Lemieux, 1993; Lee and Mas, 2012). In these applications, the upstream entity is a labor union bargaining over wages with a downstream employer. The upstream marginal costs correspond to workers' reservation wages, i.e., their outside employment opportunities. Any heterogeneity in these reservation wages results in an upward-sloping labor supply curve faced by the employer. In Section 6, we provide an example in the context of U.S. construction workers.

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

When an upstream party collectively bargains on behalf of multiple suppliers with a downstream buyer, heterogeneity in supplier costs creates an upward-sloping supply curve. Agricultural cooperatives, which are prevalent in both the US and developing countries, are an example of this structure (Cook, 1995; Banerjee et al., 2001; Ito et al., 2012). In Section 6, we provide an example in the context of agricultural cooperatives in Chinese tobacco markets.

Example 3. ***Firm-Level Increasing Marginal Costs:*** *Individual suppliers with increasing marginal costs at the firm level.*

In Examples 1 and 2, the aggregation of individual atomistic production units generates increasing marginal costs for the negotiator. There are also instances where an individual input producer bargains with a downstream buyer and faces increasing marginal costs due to decreasing returns-to-scale technology. Most production function estimates support decreasing returns to scale, particularly in the short term when capital is fixed (Olley and Pakes, 1996; Collard-Wexler and De Loecker, 2015; De Loecker and Scott, 2022). Moreover, even firms with constant marginal costs at the plant level can experience increasing marginal costs at the *firm level* when operating multiple plants with heterogeneous costs.[6] In Section 6, we illustrate this category in the context of coal production.

[6] Also, any monopsony power of the upstream firm over its own input market leads to increasing marginal costs.

2.3 Behavior: Monopolistic vs. Monopsonistic Bargaining

We consider two behavioral models of vertical conduct. In the first type, which we coin "monopolistic bargaining," D makes an output decision q, and U and D bargain over the wholesale price w to maximize a Nash product[7]:

$$\begin{cases} \max\limits_{q} \pi^d(w,q) \\ \max\limits_{w} [(\pi^d(w,q))^{\beta}(\pi^u(w,q))^{1-\beta}] \end{cases} \quad \text{s.t.} \quad \pi^d \geq 0, \pi^u \geq 0 \tag{1}$$

We denote the solution to this problem (q^{mp}, w^{mp}). A second type of vertical conduct, which we coin "monopsonistic bargaining," involves U choosing how much output to supply while bargaining over the wholesale price with D:

$$\begin{cases} \max\limits_{q} \pi^u(w,q) \\ \max\limits_{w} [(\pi^d(w,q))^{\beta}(\pi^u(w,q))^{1-\beta}] \end{cases} \quad \text{s.t.} \quad \pi^d \geq 0, \pi^u \geq 0 \tag{2}$$

We denote the solution to this problem as (q^{ms}, w^{ms}). In the remainder of the paper, we refer to the bargaining weight of the buyer, β, as "buyer power" and $1-\beta$ as "seller power."

Note that under monopsonistic bargaining, "U chooses output" should not be interpreted as contracts in which upstream firms directly control downstream output levels, as in resale price maintenance contracts. Instead, upstream firms choose how much input they are willing to supply to D, which in turn constrains how much output D can sell.[8] The "U chooses output" model is relevant in the presence of increasing upstream marginal costs: with constant marginal costs, the upstream firm would supply an infinite amount of goods as long as the wholesale price exceeds marginal cost. In contrast, increasing marginal costs create a well-defined profit-maximization problem with an interior solution.

We discuss two versions of our model that differ in terms of the timing assumptions: a simultaneous bargaining model and a sequential bargaining model.

Definition 1. *Under "Simultaneous Bargaining," quantity choices by either U or D occur simultaneously while wholesale prices are being bargained over.*

- Stage 0: U and D observe $c(.), p(.), \beta$.

[7] The model can be readily extended to settings where downstream firms choose a price (p) instead of a quantity (q), a more common assumption in empirical bargaining models for industries with product differentiation.
[8] This assumption can be extended by letting upstream choose a quantity that is an input to downstream production; we provide this extension in Section 5.4.

- Stage 1: U and D bargain over w, and either U or D chooses q.

Definition 2. *Under "Sequential Bargaining," U and D bargain over a wholesale price, after which either U or D chooses an output quantity.*

Given that firms are forward-looking, they internalize the relationship between wholesale prices and output, $q(w)$, when bargaining over w.

- Stage 0: U and D observe $c(.), p(.), \beta$.
- Stage 1: U and D bargain over w.
- Stage 2: Either U or D chooses $q(w)$.

Both types of timing assumptions are widely used in the literature.[9] Simultaneous models have been employed in several studies, including Ho and Lee (2017) and Crawford et al. (2018). The sequential model resembles various vertical models in the literature, such as the bargaining model in Crawford and Yurukoglu (2012) and the right-to-manage models of union-labor bargaining (Leontief, 1946; Abowd and Lemieux, 1993).

Assuming that the second-order conditions hold, the first-order conditions of these problems are given by

$$p'(q)q + p(q) = w \qquad \text{(D-FOC)} \qquad (3)$$

$$c'(q)q + c(q) = w \qquad \text{(U-FOC)} \qquad (4)$$

$$\beta \frac{\partial \pi^d}{\partial w} \pi^u + (1-\beta) \frac{\partial \pi^u}{\partial w} \pi^d = 0 \qquad \text{(B-FOC)} \qquad (5)$$

for $\beta \in (0,1)$.[10] The monopolistic bargaining model solution is characterized by (D-FOC) and (B-FOC), and the monopsonistic bargaining model solution is characterized by (U-FOC) and (B-FOC).[11,12]

Our bargaining models, in the case of perfect buyer and seller power, nest several classical models. With perfect buyer power ($\beta = 1$), the sequential model collapses to the classical monopsony model of Robinson (1933), in which sellers decide how much to supply at each possible wholesale price and buyers unilaterally set wholesale prices

[9] See Lee et al. (2021) for a comprehensive discussion of these timing assumptions and their implications.

[10] The second-order conditions specify that upstream and downstream profits are bounded under the monopsonistic and monopolistic conduct models, respectively. This implies that $mc'(q) \geq 0$ and $mr'(q) \leq 0$.

[11] Appendices A.1 and B.1 detail the closed-form solutions of these first-order conditions for the simultaneous and sequential versions of the model, respectively

[12] The FOCs above only characterize the solutions to the monopolistic and monopsonistic bargaining models for $\beta \in (0,1)$. At the limiting cases for $\beta = 0$ and $\beta = 1$, these models must be solved as constrained optimization problems, as the nonnegative profit constraints become binding. In Appendix D.1, we show that this increases the range of bargaining parameters for which a solution exists to $\beta \in (0,1]$ and $\beta \in [0,1)$ for the simultaneous monopoly and monopsony bargaining models, respectively.

conditional on this factor supply curve. In contrast, monopolistic conduct with sequential bargaining at perfect seller power, $\beta = 0$, collapses to the successive monopoly model of Spengler (1950) with complete double marginalization. The remaining limit cases represent scenarios where one party makes a take-it-or-leave-it (TIOLI) offer.[13]

2.4 Benchmark: Efficient Bargaining

We consider the "efficient-bargaining" problem as a benchmark against the monopsonistic and monopolistic bargaining models. Under efficient bargaining, upstream and downstream firms negotiate over both wholesale price and quantity:

$$\max_{w,q}[(\pi^d(w,q))^\beta(\pi^u(w,q))^{1-\beta}] \tag{6}$$

This corresponds to a scenario where the parties maximize their joint profit. The efficient-bargaining quantity q^* from this problem is simply the quantity such that upstream marginal cost equals downstream marginal revenue: $mc(q^*) = mr(q^*)$. We use this model as a reference point for the monopsonistic and monopolistic bargaining models and as a means to assess their deadweight loss relative to efficient bargaining.

2.5 Sources of Market Power in Vertical Relations

Since we do not take a stance on vertical conduct, two sources of market power in a vertical relation can generate distortion in our model: a markup of the seller and a markdown of the buyer. As usual, we define the markup as the wedge between the wholesale price w and the marginal cost of the seller, and the "markdown" as the wedge between the marginal revenue of the buyer and the wholesale price[14]:

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

We also have buyer's markup as an additional source of market power; however, it is present regardless of the vertical conduct. Throughout the paper, we distinguish different sources of market power in vertical relation by referring to the seller's markup as "upstream monopoly power," and the buyer's markdown as "downstream monopsony power".[15]

[13] See Table OA-1 for a summary of the limit cases of both models.

[14] We write the markdown this way in contrast to the often-used formula $(w - mr(q))/(mr(q))$ so that higher markdowns imply more monopsony power, similarly to higher markups implying more monopoly power.

[15] The buyer's markup is due to monopoly power of the buyer on the final goods market, and it appears in both monopolistic and monopsonistic bargaining models.

3 Welfare Effects of Buyer and Seller Power

In this section, we first analyze the existence of monopsonistic and monopolistic conduct under different assumptions about cost and demand curves to determine in which empirical settings these conducts are possible. We then characterize the effects of buyer power on output, consumer surplus, and total welfare separately under monopolistic and monopsonistic bargaining. In the next section, we unify both conducts and jointly examine their welfare effects by introducing endogenous vertical conduct.

3.1 Equilibrium Existence

We show the existence of equilibrium in monopsonistic and monopolistic bargaining by focusing on two special cases commonly used in the literature: constant marginal cost and constant marginal revenue.

Proposition 1. *Under both simultaneous and sequential timing assumptions*

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

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

(iii) In all other cases, both the monopolistic and monopsonistic bargaining problems have an interior solution for $\beta \in (0, 1)$.[16]

The intuition for Proposition 1 is straightforward: if upstream marginal costs are constant, the first-order condition (FOC) for U's output choice in the monopsonistic model becomes undefined when the wholesale price exceeds the marginal cost; U would be willing to supply an infinite quantity of output. Similarly, in the monopolistic model, if marginal revenue is constant, D would be willing to sell an infinite quantity if the wholesale price is below the downstream price, resulting in unbounded profits for D.

Given Proposition 1, we assume in the remainder of this section that $mc'(q) > 0$ when analyzing monopsonistic bargaining and $mr'(q) < 0$ when analyzing monopolistic bargaining, as these models would otherwise not be well-defined.

3.2 Output and Buyer Power

We characterize the relationship between output q and buyer power β in monopsonistic and monopolistic bargaining. To do so, we introduce two additional properties of the cost

[16] In the simultaneous bargaining models, a solution may fail to exist for some interior values of β depending on the demand and cost curves. We characterize the β range for which a solution may exist for the simultaneous models in Appendix D.2, but for simplicity, we use the $\beta \in (0, 1)$ for the remainder of the paper. If necessary, one can replace these bounds with those derived in Appendix D.2.

and demand curves.

Property 1. *Increasing Difference Between Marginal and Average Costs:* $\frac{d(mc(q)-c(q))}{dq} > 0$

Property 2. *Decreasing Difference Between Marginal and Average Revenue:* $\frac{d(mr(q)-p(q))}{dq} < 0$

These properties govern the curvature of the cost and demand curves. They are weaker assumptions than the convexity of the average cost and the concavity of demand, but they imply that upstream marginal costs are weakly increasing, $mc'(q) \geq 0$, and that downstream marginal revenue is weakly decreasing, $mr'(q) \leq 0$.[17] In addition, we assume that $p(q)$ and $c(q)$ are thrice continuously differentiable functions.

Lemma 1. *If Property 1 holds, in simultaneous monopsonistic bargaining, the equilibrium quantity* q^{ms} *is decreasing and the buyer markdown* Δ^d *are increasing with* β*, that is* $dq^{ms}/d\beta < 0$ *and* $d\Delta^d/d\beta > 0$*.*

Lemma 1 establishes that output decreases with buyer power under monopsonistic bargaining. Figure 1(a) provides the key intuition behind this result. In monopsonistic bargaining, the output is decided by U, which implies that $q(w)$ is an input *supply* curve. An increase in buyer power β leads to movements along this input supply curve by lowering the wholesale price. This, in turn, reduces output and increases the markdown.

The "Increasing Difference Between Marginal and Average Costs" assumption in Property 1 is a necessary condition for Lemma 1 to hold globally. The intuition is that, in the monopsonistic model, marginal cost determines the quantity decision, while average cost governs the upstream firm's profit and its participation constraint. If marginal cost rises more slowly than average cost, a more powerful buyer might prefer a higher wholesale price since the resulting increase in quantity could compensate for higher costs while still maximizing the Nash product. Property 1 prevents this scenario.

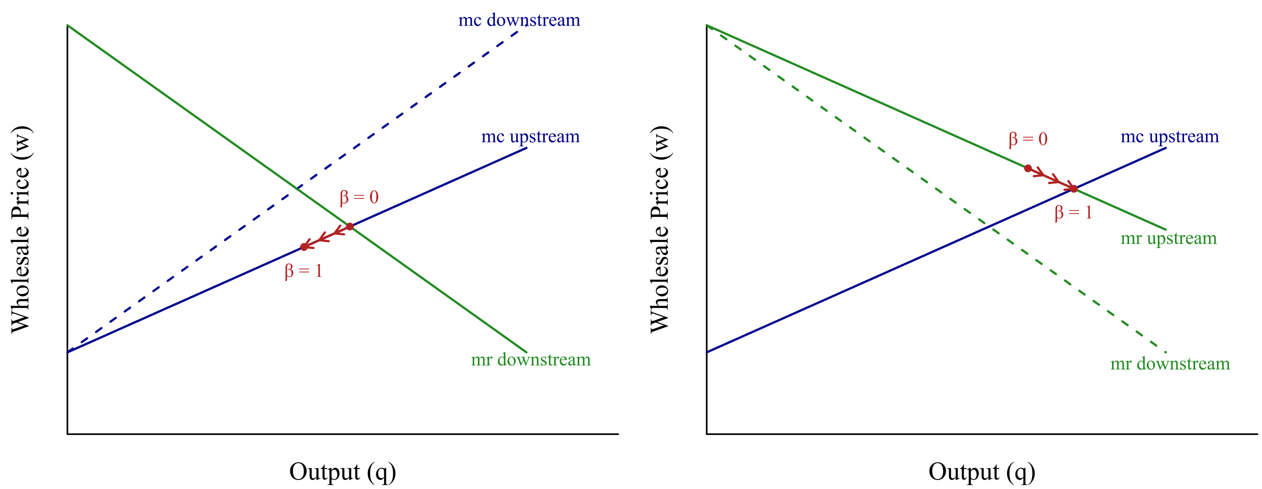
Lemma 2. *If Property 2 holds, in simultaneous monopolistic bargaining, the equilibrium quantity* q^{mp} *and the upstream markup* μ^u *are increasing with* β*; that is,* $dq^{mp}/d\beta > 0$ *and* $d\mu^u/d\beta > 0$*.*

Lemma 2 states that output increases with buyer power under monopolistic bargaining. Unlike the monopsonistic case, monopolistic bargaining implies that output gets decided by D, so the relationship between wholesale prices and output $q(w)$ is an input *demand* curve, as seen in Figure 1(b). Consequently, an increase in β induces movements along this input demand curve, reducing the seller's markup and increasing output.

Moving to the sequential bargaining cases, we show that these results hold under sequential bargaining under additional assumptions.

[17] See Lemma OA-6 in Appendix D.3 for this result.

Figure 1: Illustration of the Effects of Buyer Power on Output (Intuition)



(a) Monopsonistic Conduct **(b)** Monopolistic Conduct

Notes: This figure illustrates how buyer power affects output under two market structures: monopsonistic bargaining (Panel (a)) and monopolistic bargaining (Panel (b)). For monopsonistic bargaining, increased buyer power β moves output along the marginal cost curve, while for monopolistic bargaining, it shifts output down the marginal revenue curve.

Lemma 3. *Lemma 1 extends to sequential bargaining models under the additional assumptions that* $mc''(q) \geq 0$ *and positive markdown* $\Delta^d \geq 0$.

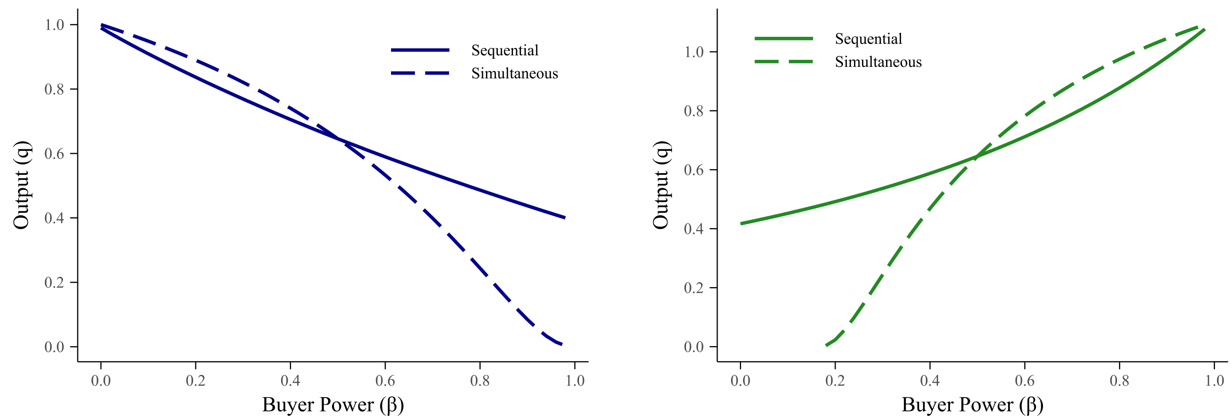
Lemma 4. *Lemma 2 extends to sequential bargaining models under the additional assumptions that* $mr''(q) \leq 0$ *and positive upstream markup* $\mu^u \geq 0$.

Since the bargaining problem in the sequential model internalizes the quantity choice that involves cost (monopsonistic) and demand (monopolistic) curves, additional restrictions on the third derivatives are necessary to obtain these results.

To illustrate our findings, we simulate data using log-linear upstream cost and downstream demand curves and solve the simultaneous and sequential bargaining models for both types of vertical conduct.[18] The resulting output-buyer power relationships are shown in Figure 2(a), for monopsonistic conduct, and Figure 2(b), for monopolistic conduct. Under monopsonistic bargaining, output decreases with buyer power in both simultaneous and sequential timing, whereas the opposite is true under monopolistic bargaining.

[18]We use the cost curve $c(q) = \frac{1}{1+\psi} q^{\psi}$ and demand curve $p(q) = q^{1/\eta}$, where the marginal cost elasticity is ψ and the downstream demand elasticity is η. Under these functional forms, the simultaneous bargaining model yields analytical solutions, which we derive in Appendix D.4. We set the marginal cost elasticity to $\psi = 1/4$ and the demand elasticity to $\eta = -6$. The sequential bargaining model, however, does not have closed-form solutions, so we solve it numerically using first-order conditions.

Figure 2: Illustration of the Effects of Buyer Power on Output (Simulation)



(a) Monopsonistic Conduct **(b)** Monopolistic Conduct

Notes: This figure presents numerical simulation results showing how output varies with buyer power under monopolistic and monopsonistic bargaining. Under monopsonistic conduct (Panel (a)), output decreases with buyer power in both sequential and simultaneous models, while under monopolistic conduct (Panel (b)), output increases. The simultaneous monopolistic bargaining model does not have a solution for $\beta < 1/6$, as we prove in Appendix D.5.

3.3 Buyer Power vs. Monopsony Power

In the literature, the terms *buyer power* and *monopsony power* are often used interchangeably. To clarify the conceptual distinctions between these concepts, we derive the following corollary from Lemmas 1–4.

Corollary 1. *Under monopolistic bargaining, downstream markdown is always zero, so the buyer has no monopsony power. Under monopsonistic bargaining, upstream markup is always zero, so the seller has no monopoly power.*

Under monopolistic bargaining, while there may be buyer power ($\beta > 0$), the buyer markdown is zero, which follows from FOC (3). Hence, there is no monopsony distortion in this model. Similarly, under monopsonistic bargaining, even with seller power ($1-\beta > 0$), the seller markup is always zero, which follows from FOC (4). Hence, there is no double-marginalization distortion. Monopsony power thus 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.

3.4 Characterization of the Efficient Level of Buyer Power

After establishing the relationship between output and buyer power across vertical conducts, we analyze their efficiency properties by comparing each conduct to the efficient-bargaining problem over the two-part tariff given in Equation (6).

Proposition 2. *There exists a bargaining parameter* $\beta^* = \dfrac{-p'(q^*)}{c'(q^*) - p'(q^*)} \in (0, 1)$ *at which the monopsonistic bargaining model, the monopolistic bargaining model, and the efficient-bargaining models imply an identical equilibrium output in both simultaneous and sequential models. We denote* β^* *as the "efficient level of buyer power."*

This proposition shows that at β^*, output under the monopolistic and monopsonistic conduct coincides and is equal to the level that would be reached under efficient bargaining. This property arises because β^* is the level of buyer power such that the buyer's monopsony power and the seller's monopoly power exactly offset each other, resulting in an outcome with neither monopsony nor upstream monopoly distortions. Moreover, this property holds under both simultaneous and sequential timing assumptions, so β^* is the bargaining power where equilibrium coincides under different timing assumptions.

Since downstream monopsony power is determined by the curvature of the cost curve and upstream monopoly power by the curvature of the demand curve, β^* depends on these functions in an intuitive way, as we specify in the next corollary.

Corollary 2. *The efficient level of buyer power* β^* *weakly decreases with the elasticity of upstream marginal costs and weakly decreases with the elasticity of downstream demand.*

As the elasticity of upstream costs increases, the potential for monopsony power grows. To counterbalance this effect, the seller requires greater bargaining power, which results in a lower value of β^*. Similarly, if downstream demand becomes more inelastic, the scope for upstream monopoly power increases, so the buyer needs more bargaining power to countervail the potential upstream monopoly power, increasing β^*.

Looking at a few special cases is useful to compare our model to existing models in the vertical relations literature.

Corollary 3. *If upstream marginal costs are constant, the efficient level of buyer power is one* ($\beta^* = 1$). *If downstream demand is fully elastic, the efficient level of buyer power is zero* ($\beta^* = 0$).

As was stated earlier, bargaining models in the empirical IO literature commonly focus on settings with constant upstream marginal costs. In these models, output is maximized (and joint profit maximization is achieved) if all bargaining power goes to D. In contrast, classical monopsony models often assume that downstream demand is fully elastic, in which case the output is maximized if U has full bargaining power.

3.5 Total and Consumer Surplus Under Monopolistic and Monopsonistic Conduct

Thus far, our analysis has focused on the effects of buyer power on output q. We now turn to examining the welfare implications of buyer power under monopolistic and monopsonistic bargaining. We define consumer surplus as $CS(\beta) \equiv \int_0^{q(\beta)} \big(p(h) - p(q(\beta))\big) dh$ and total surplus as the sum of consumer surplus, upstream profit, and downstream profit.

Proposition 3. *Consumer surplus is maximized at $\beta = 1$ under monopolistic conduct and at $\beta = 0$ under monopsonistic conduct.*

Proposition 3 is intuitive: because consumer surplus increases monotonically with output, the level of buyer power that maximizes output also maximizes consumer surplus. Under monopolistic bargaining, this occurs at the corner solution with full buyer power, whereas under monopsonistic bargaining, it occurs with full seller power.

Proposition 4. *Total surplus is maximized at $\beta^\dagger$, with $\beta^* < \beta^\dagger \leq 1$ under monopolistic bargaining and $\beta^\dagger = 0$ under monopsonistic bargaining.*

Proposition 4 is novel: in bargaining models with constant marginal costs, both consumer surplus and total surplus are maximized at full buyer power. However, with increasing marginal costs, this result no longer holds. At full buyer power, wholesale and downstream prices can fall below the marginal cost, as the upstream firm may still earn positive profits even when the wholesale price is below the marginal cost. In this case, there is socially inefficient overproduction at full buyer power, and the total-welfare-maximizing bargaining parameter lies between β^* and 1.

Under monopsonistic bargaining, total welfare is maximized with full seller power. In this scenario, the monopsony model simplifies to the seller making a TIOLI offer to the downstream firm, leaving the downstream firm with zero profits. The final goods price p then equals the wholesale price w, which equals upstream marginal costs under monopsonistic bargaining. As a result, prices equate to marginal costs, which maximizes total welfare.

4 Endogenous Vertical Conduct

In Section 3, we demonstrated that with increasing upstream marginal costs and decreasing downstream marginal revenue, both monopsonistic and monopolistic conduct exist across a range of bargaining parameters but yield opposing output and welfare effects. Hence, the welfare implications of buyer power depend on the type of vertical conduct, for which researchers typically have no ex-ante information. In this section, we provide two micro-foundations that determine which type of vertical conduct arises in equilibrium.

4.1 Selecting Conduct: Nonnegative Markup and Markdown

We start by specifying a participation constraint that pins down vertical conduct, and that can be used in both the simultaneous and sequential bargaining models.

Participation Constraint 1. *D only participates in bargaining if the resulting markdown is nonnegative,* $\Delta^d \geq 0$*. U only participates in bargaining if the resulting markup is nonnegative,* $\mu^u \geq 0$*.*

This condition states that both firms participate in the bargaining process only when their respective outcomes are nonnegative: the upstream firm requires a nonnegative markup, and the downstream firm requires a nonnegative markdown. As markups and markdowns vary with β, Participation Constraint 1 introduces an equilibrium selection rule.

Theorem 1. *Under Participation Constraint 1, for any bargaining parameter* β*, either the monopsonistic or the monopolistic bargaining equilibrium exists, but not both. Specifically, the monopsonistic equilibrium exists if* $\beta \geq \beta^*$*, while the monopolistic equilibrium exists if* $\beta \leq \beta^*$*.*

Theorem 1 shows that the type of vertical conduct occurring in equilibrium depends on how the bargaining parameter β compares to the efficient level of buyer power β^*. When $\beta \geq \beta^*$, the upstream markup becomes negative in monopolistic bargaining, requiring the equilibrium to take the form of monopsonistic vertical conduct. Conversely, when $\beta \leq \beta^*$, the downstream markdown becomes negative in monopsonistic bargaining, requiring monopolistic vertical conduct in equilibrium. Thus, the assumption of nonnegative markups and markdowns provides a selection rule between the two vertical conduct types.[19]

We illustrate this selection rule in the decision tree of Figure 3 for simultaneous bargaining. The nonnegative markup and markdown assumption can be imposed as a participation constraint at the end of the decision tree by stating that one of the two agents in the model refuses to trade if their markup or markdown is negative. This implies that for a given level of the bargaining parameter, either monopsonistic or monopolistic conduct exists.

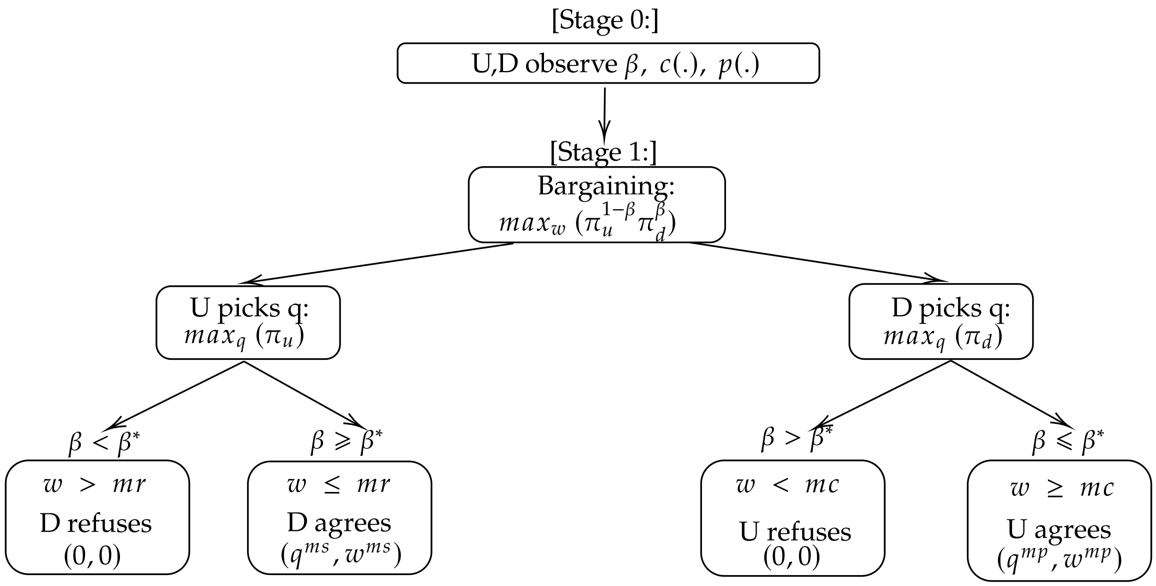
Theorem 1 leads to one of the central findings of the paper: an increase in buyer power creates monopsony distortion (reducing output) when $\beta > \beta^*$, but counteracts upstream market power (increasing output) when $\beta < \beta^*$. Conversely, an increase in seller power causes monopoly distortion when $\beta < \beta^*$, but offsets monopsony power when $\beta > \beta^*$.

Corollary 4. *An increase in buyer power* β *lowers output if* $\beta > \beta^*$ *but increases output if* $\beta < \beta^*$ *in both simultaneous and sequential models.*

In Figure 4(a), we combine Figures 1(a) and 1(b) to illustrate the Λ-shaped relationship between output and buyer power that follows from Corollary 4. From $\beta = 0$ to β^*, the

[19] The positive markup and markdown constraints imply that the restrictions imposed in Lemmas 3 and 4 are never binding.

Figure 3: Decision Tree: Participation Constraint 1



Notes: This decision tree illustrates the bargaining game under the conduct selection rule in Section 4.1.

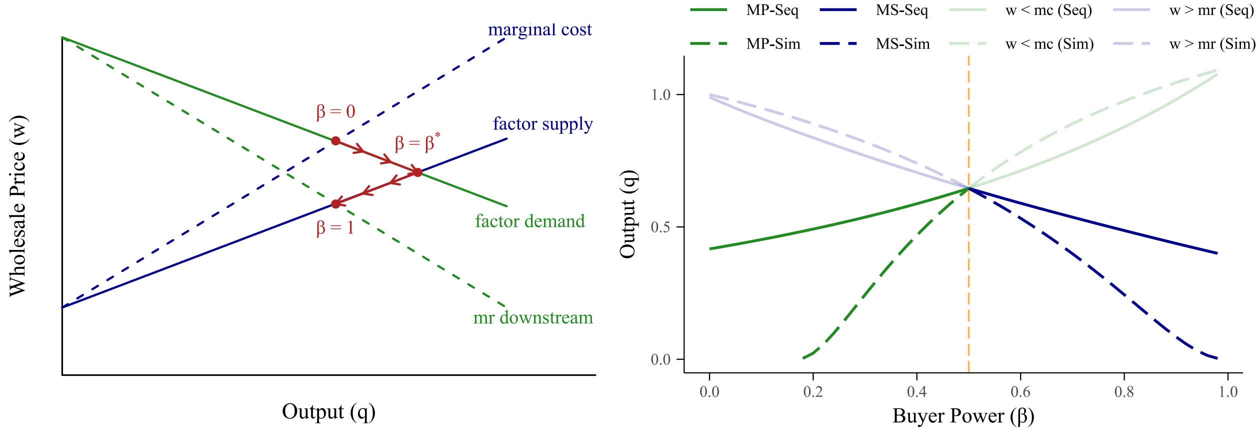
conduct is monopolistic bargaining, with the input price-output relationship tracing the input demand curve. In this range, increasing buyer power transitions the outcome from successive monopoly to efficient bargaining. Once $\beta > \beta^*$, the vertical conduct shifts to monopsony, and the relationship between input price and output follows a factor supply curve. Further increases in buyer power result in movement along this supply curve, progressing from the efficient-bargaining outcome toward classical monopsony at $\beta = 1$.

We illustrate the first conduct selection rule by reusing the numerical example from Section 3. In Figure 4(b), we indicate the eliminated points at which $w < mc$ and at which $w > mr$ as the shaded blue and green lines. In line with Theorem 1, this generates a Λ-shaped relationship between output and buyer power.

Discussion of the Nonnegative Markups and Markdowns Constraint

Even with a negative upstream markup, the upstream party can still earn positive profits from trading due to its inframarginal production units; a negative markup merely indicates that the marginal production unit operates at a loss. Similarly, the downstream party can realize gains from trade under negative markdowns, again due to its inframarginal units. Therefore, whether the nonnegative markup and markdown assumptions are reasonable depends on the feasibility of internal transfers within parties. For example, in the case of labor unions, given in Example 1, nonnegative markup is likely to hold: it seems highly unrealistic for unions to subsidize some workers to accept wages below their reservation

Figure 4: The Effects of Buyer Power on Output With Endogenous Conduct



(a) Intuition **(b)** Simulation

Notes: This figure illustrates the relationship between buyer power (β) and output (q) in models with endogenous conduct under different timing assumptions. Panel (a) provides the intuition, showing how equilibrium wholesale price (w) and quantity are determined by the input supply and input demand curves. Panel (b) presents numerical simulation results for simultaneous and sequential bargaining. As buyer power (β) increases, output behavior diverges depending on whether the wholesale price is less than or greater than marginal cost ($w < mc$) or marginal revenue ($w > mr$). The orange dashed line indicates the threshold of β^*, where the relationship transitions.

wage. In the context of wholesale price bargaining between multi-establishment firms, as in Example 3, it is plausible that plant managers would resist overseeing loss-making production units.

Testing the Vertical Conduct Selection Rules

While the realism of the nonnegative markups and markdowns constraint depends on the context, a key advantage is its empirical verifiability. In Proposition 5 below, we show that the weakly positive markup and markdown restriction in Participation Constraint 1 ensures that equilibrium output is bounded from above by the efficient-bargaining output level, q^*. This property can be empirically tested by examining whether observed output levels fall below the equilibrium output level predicted by efficient bargaining.

Proposition 5. *The restrictions $\mu^u \geq 0$ and $\Delta^d \geq 0$ ensure that equilibrium output is always smaller than or equal to the efficient-bargaining output level q^*.*

4.2 Selecting Conduct: Incentive Compatibility of Linear Pricing

The sequential bargaining model has the benefit of offering a different participation constraint that does not directly impose nonnegative markups and markdowns. We introduce the possibility that firms bargain efficiently by setting a nonlinear wholesale price contract, such as a two-part tariff. Such a nonlinear price contract would lead firms to reach an efficient-bargaining solution if it is incentive-compatible.

Participation Constraint 2. *D and U choose q unilaterally only if they cannot earn higher profits by bargaining over (q, w) instead:*

$$\begin{cases} \pi_u^{ms}(q^{ms}, w^{ms}) & \geq \pi_u^j(q^*, w^*) \\ \pi_d^{mp}(q^{mp}, w^{mp}) & \geq \pi_d^j(q^*, w^*) \end{cases}$$

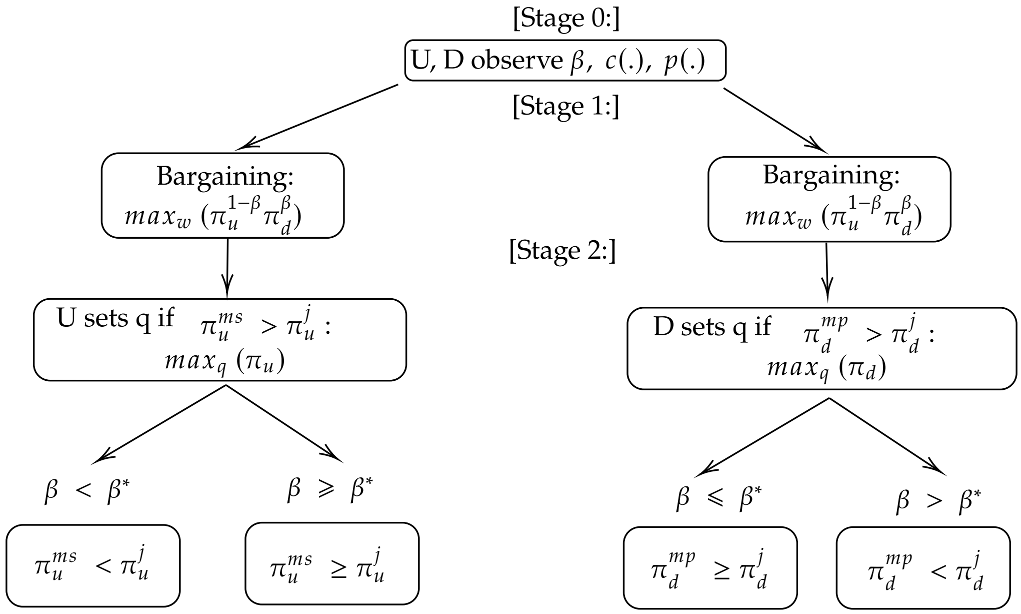
where π_u^j and π_d^j correspond to upstream and downstream profit under efficient bargaining. Participation Constraint 2 states that U and D are willing to commit to making an output choice in Stage 2 only if the resulting profit surpasses the profit they would earn under efficient-bargaining (i.e., the profit they would earn when *not* setting output unilaterally, but by joint bargaining over output and wholesale prices). The resulting decision tree is visualized in Figure 5.

Theorem 2. *Under Participation Constraint 2, for any β, either the monopsonistic or the monopolistic bargaining equilibrium exists, but not both. Specifically, the monopsonistic equilibrium exists if $\beta \geq \beta^*$, while the monopolistic equilibrium exists if $\beta \leq \beta^*$.*

Theorem 2 implies, by revealed preference, that if we observe a linear price contract, then our conduct selection criterion is satisfied: if $\beta < \beta^*$, the upstream firm determines output, whereas if $\beta > \beta^*$, the downstream firm determines output. If $\beta = \beta^*$, neither party has the incentive to determine output, and firms simply maximize joint profits.

The finding that firms are unwilling to unilaterally move to joint profit maximization under the sequential model has a broader implication for full-information vertical bargaining models, given that a key criticism of this class of models is that linear pricing behavior is not Pareto-optimal if nonlinear pricing is possible (Lee et al., 2021). In our model, the reason why firms do not bargain efficiently can be explained by a holdup problem due to a lack of commitment. Under commitment, profit maximization could be reached at any stage of the model and would be Pareto-optimal: both firms could become better off by moving to joint profit maximization and transferring profits. However, we assume that the bargaining weights β are predetermined and fixed and that firms cannot commit to choosing output ex-ante. Either party could try to convince the other party not to set quantities in the second stage by bargaining less aggressively in the first stage, but the inability to commit to this prevents such agreements from happening in our model. This holdup rationalization of linear price contracts has similarities to prior work on vertical contracts, such as Iyer and Villas-Boas (2003), in which shocks in between the time of signing the contract and delivery induce firms not to negotiate over two-part tariffs.

Figure 5: Decision Tree: Participation Constraint 2



Notes: This decision tree illustrates the bargaining game under the conduct selection rule in Section 4.2.

4.3 Welfare Effects of Buyer and Seller Power Under Endogenous Vertical Conduct

Now that we have developed an integrated framework that nests both monopolistic and monopsonistic bargaining models, we apply our framework to address the key question of this paper, namely to understand the extent to which welfare losses from market power in vertical relations are due to buyer power and to seller power. We continue the analysis of welfare that was introduced in Section 3.5, but we introduce our notion of endogenous vertical conduct to this welfare analysis.

Under both of our conduct selection criteria, vertical conduct is monopolistic if $\beta < \beta^*$ and monopsonistic if $\beta > \beta^*$. Hence, a monopolistic distortion will exist for low levels of β relatively to β^*, and a monopsonistic distortion will exist for high levels of β. To identify both the level of total market power distortions and the extent to which it is caused by buyer and/or seller power, we need to know the level of buyer power β, which can be estimated, and the efficient level of buyer power β^*, which can be computed by cost and demand estimates. Therefore, the determinants of the efficient level of buyer power analyzed in Section 3.4 play a crucial role for understanding the sources of market power distortions. All else equal, a more inelastic downstream demand implies that monopolistic conduct becomes more likely, requiring higher levels of buyer power to reach the efficient bargaining benchmark, whereas a more inelastic upstream cost implies that monopsonistic conduct is more likely, requiring more seller power instead.

Proposition 6. *Under either conduct selection criteria from Participation Constraint 1 or Participation Constraint 2, both consumer surplus and total surplus are maximized at the efficient level of buyer power β^*.*

For consumer surplus, this proposition is trivial because consumer surplus is monotonically increasing in output, and output was already shown to be maximized at the efficient level of buyer power in Corollary 4. For total surplus, we note that the bargaining parameters that maximized total surplus under monopolistic and monopsonistic conduct in Proposition 4 are ruled out by both Constraints 1 and 2, as either the markdown or markup are negative under those bargaining parameter values. As a result, under both the monopolistic and the monopsonistic bargaining models, total surplus is maximized at the efficient level of buyer power β^*.[20]

4.4 Implications for Antitrust Policy

Our results have important implications for understanding the effects of both horizontal and vertical mergers.

Horizontal Merger Policy

Assume that a horizontal merger between downstream firms increases downstream bargaining ability.[21] Under monopolistic bargaining on the wholesale market, increased buyer power due to the downstream merger reduces downstream marginal costs, thereby increasing output and both consumer and total welfare. Hence, all else equal, the regulator is more likely to approve the merger in the presence of this bargaining effect, as discussed in Grennan (2013), Nevo (2014), and Sheu and Taragin (2021). However, under monopsonistic bargaining, horizontal mergers have the opposite welfare effect, as discussed in Berger et al. (2023): the associated increase in buyer power now *reduces* output and both consumer and total welfare.

Our model provides insight into when downstream mergers create either distortionary or countervailing effects. Let β^0 represent premerger buyer power and β^1 represent postmerger buyer power. Our model implies that if $\beta^0 < \beta^1 \leq \beta^*$, monopolistic bargaining occurs both pre- and postmerger, and the merger increases output due to countervailing force. This should make regulators more lenient. However, if $\beta^0 > \beta^*$, vertical conduct is

[20] The results in this paper analyze partial equilibria. In models that consider the welfare effects of monopoly or monopsony power in general equilibrium, the relevant object to characterize inefficiency is usually not the level, but the dispersion of the markups and/or markdowns Atkeson and Burstein (2008); Berger et al. (2022). In the context of our model, this implies that welfare would be a function of the dispersion of markups for any bargaining relationships in which $\beta < \beta^*$, and of markdowns in any relationships in which $\beta > \beta^*$.

[21] In Section 5, we consider the more widely used case in which bargaining ability is invariant but the relative disagreement payoff of downstream compared to upstream increases, which leads to the same implications.

monopsonistic, and a horizontal merger between downstream firms decreases output due to increasing monopsony power. This should induce regulators to be less lenient about the merger. If $\beta^0 < \beta^*$ but $\beta^1 > \beta^*$, vertical conduct changes after the merger, and the net effect of the merger on output can be positive or negative depending on the relative size of the monopsony and monopoly distortions. A parallel analysis applies to upstream mergers.

Our analysis ideally requires knowledge of both the premerger level of buyer power β and the efficient level of buyer power β^*. However, even in the absence of β, which is nontrivial to estimate (as doing so requires observing wholesale prices and/or quantities), β^* can be readily estimated using only cost and demand function primitives and can still be useful. A high β^* would suggest that increased buyer power likely raises output, while a low β^* would indicate the opposite. As a result, the estimate of β^* can serve as a screening tool without requiring the estimation of a full bargaining model. In our empirical applications, we illustrate these two alternative ways of using our model: in Section 6, we estimate only β^*, whereas in Section 7, we estimate both β^* and β.

Vertical Merger Policy

In vertical mergers, our model is useful for quantifying potential welfare effects from elimination of double marginalization (Chipty, 2001; Crawford et al., 2018; Luco and Marshall, 2020). As discussed in Section 3, under a fixed model of vertical conduct, consumer surplus is maximized at the corner solutions $\beta = 0$ or $\beta = 1$. However, when taking into account endogenous vertical conduct, the picture changes: the welfare gains from vertical integration increase with the distance between the initial bargaining parameter and the output-maximizing bargaining parameter, $|\beta - \beta^*|$. As a result, similar to horizantal merger analysis, the knowledge of β and β^* allows one to quantify the potential benefits of vertical mergers.

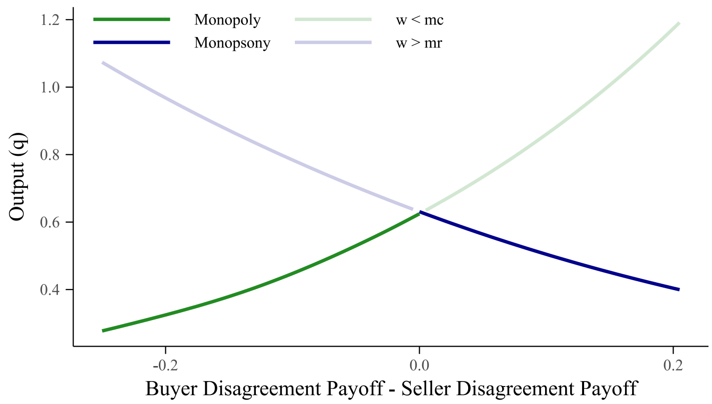
5 Extensions

This section extends our model along several dimensions. We perform comparative statics based on disagreement payoffs rather than bargaining weights, introduce competition among buyers, consider settings involving multiple buyers and sellers, and analyze the model when downstream firms utilize multiple inputs.

5.1 Nonzero Disagreement Payoffs

In our main results, we conducted comparative statics with respect to the bargaining parameter β, while keeping disagreement payoffs fixed and normalized to zero. However, in horizontal merger analysis with bargaining, it is more likely that a merger alters firms'

Figure 6: Output and Relative Outside Options



Notes: This figure illustrates the relationship between output (q) and the relative outside options, represented as the difference between the buyer's disagreement payoff and the seller's disagreement payoff. The blue line represents the simultaneous monopolistic bargaining case, while the red line represents the simultaneous monopsonistic bargaining case. Output increases in monopolistic bargaining as the buyer's relative disagreement payoff improves, while in monopsonistic bargaining, output decreases as the seller's relative disagreement payoff becomes stronger.

outside options instead of their bargaining weights (Hemphill and Rose, 2018). To accommodate this, we incorporate nonzero disagreement payoffs into the bargaining problem as follows:

$$\max_{w}[(p(q)q - wq - o^{d}q)^{\beta}(wq - c(q)q - o^{u}q)^{1-\beta}].$$

Here, o^d and o^u represent the per-unit profits that downstream and upstream firms can earn in the event of a disagreement. The following theorem analyzes how equilibrium output changes with o^d and o^u.

Theorem 3. *Under monopolistic bargaining, output increases with the buyer's disagreement payoff and decreases with the seller's disagreement payoff, $dq/do^d > 0$ and $dq/do^u < 0$. Under monopsonistic bargaining, output decreases with the buyer's disagreement payoff and increases with the seller's disagreement payoff, $dq/do^d < 0$ and $dq/do^u > 0$.*

See Appendix E.1 for the proof. Theorem 3 establishes that the comparative statics of output with respect to the bargaining weight in the previous section also hold when output is expressed as a function of the buyer's disagreement payoff. We demonstrate this in Figure 6 using the same numerical example as before.[22] A higher buyer disagreement payoff increases output under the monopolistic model but decreases it under the monopsonistic model. When we apply our conduct selection rule of nonnegative markups and markdowns, we observe a similar Λ-shaped relationship between disagreement payoff

[22]See Appendix E.1 for details on extending the log-linear model to incorporate nonzero disagreement payoffs.

and output. In this case, there exists an output-maximizing disagreement payoff, with the conduct determined by whether the actual disagreement payoff is above or below this optimal level.

5.2 Multiple Buyers That Compete Downstream

Our baseline model examined a single supplier selling to a single buyer. This framework extends naturally to settings with multiple competing buyers by incorporating their residual downstream demand.

As an example, we develop a Cournot model where multiple downstream firms compete oligopolistically in their product market and present a numerical implementation in Appendix E.2. In contrast to the single-buyer case, where the downstream firm makes decisions based on the market-level demand elasticity $-\eta$, firms now optimize with respect to a *residual* demand elasticity under oligopolistic competition. As a result, a higher number of competing firms in the downstream market leads to more elastic residual demand and a lower efficient level of buyer power β^*. This suggests that increased competition in the downstream market makes monopsonistic conduct in the wholesale market more likely, as the range of β for which equilibrium conduct is monopsonistic becomes wider.

5.3 Multiple Buyers and Sellers

In most industries, upstream and downstream markets comprise multiple firms engaging with various counterparts. Our framework extends to these settings through the passive-belief assumption, commonly used in the "Nash-in-Nash" approach of Horn and Wolinsky (1988). This assumption states that firms expect all other equilibrium outcomes to remain unchanged regardless of the outcome of their current negotiation.[23] Within this framework, one can calculate the gains from trade by conditioning on the equilibrium outcomes of other negotiations to operationalize our model. Our empirical application in Section 7 examines such a setting.

5.4 Multi-Input Downstream Production Function

In our model, we assumed that the downstream firm operates with a single-input production function, simply selling the input in the downstream market after applying a markup. In Appendix E.3, we extend this framework to accommodate a multi-input downstream production function. We show that the bargaining problem remains largely similar, with a few modifications. In monopsonistic bargaining, the upstream firm's output choice no longer directly determines the downstream output level. Instead, it affects the

[23] For extensions of this assumption, see Ho and Lee (2019).

downstream output through a monotone function, as the downstream firm can partially substitute other inputs to adjust its production. Similarly, in monopolistic bargaining, the downstream firm's output choice no longer directly dictates the upstream quantity but influences it through a monotone input demand function.

The multi-input production function introduces an additional parameter that influences the model's comparative statics: the elasticity of substitution between inputs. As the elasticity of substitution approaches zero, the production function converges to a Leontief form, establishing a one-to-one relationship between upstream and downstream outputs—effectively equivalent to our baseline model. Conversely, as the elasticity of substitution increases, the connection between upstream and downstream outputs weakens, reducing the influence of buyer and seller power within the vertical chain.

6 Empirical Illustrations: Labor Unions and Farmer Cooperatives

To quantify the total distortions from market power and decompose these into monopsony- and monopoly-induced welfare losses, one needs to estimate both the actual level of buyer power β and the efficient level of buyer power β^*. In addition to cost and demand data, which are needed to estimate β^*, wholesale price data is required for estimating β. Whereas this data is readily available in many labor applications in the form of wage data in employer-employee datasets, transaction-level wholesale prices are less often observed in IO applications.[24]

However, even if transaction-level wholesale prices are unobserved, our model can be used to study the sources of market power distortions, as the efficient level of buyer power can still be estimated using the cost and demand primitives. To illustrate this, we analyze two case studies by calibrating our model using prior estimates from the literature: labor unions in the U.S. construction industry and farmer cooperatives in the Chinese tobacco industry. The details of these empirical applications are provided in Appendix F.

6.1 Labor Unions

A natural application of our model is collective wage bargaining, as introduced in Example 1. Given the growing empirical evidence of monopsony power in labor markets (Card et al., 2018; Berger et al., 2022; Lamadon et al., 2022; Yeh et al., 2022), an important question is whether labor unions can effectively counteract such power. To provide insights into this question, we calibrate a first-order approximation of our model using estimates from Kroft et al. (2020), who study the U.S. construction industry under monopsonistic competition

[24] However, the increased availability of administrative firm-to-firm transaction data make transaction-level wholesale prices increasingly observed.

Table 1: Calibrated Empirical Applications

Industry	Sources	ψ	η	β^*
U.S. construction workers	Kroft et al. (2020)	0.29	-7.30	0.42
Chinese tobacco farmers	Rubens (2023), Ciliberto and Kuminoff (2010)	1.904	-1.14	0.92

for workers, which implies that $\beta = 1$ according to our notation.[25] This assumption is plausible in this setting because only 10% of U.S. construction workers are represented by a labor union, according to the Bureau of Labor Statistics (BLS).[26]

However, suppose that construction workers were fully unionized. To what extent would this countervail employer monopsony power, and what level of union bargaining power would maximize total output? The answer depends critically on β^*, which we derive in Appendix D.4 using a log-linear approximation of our model:

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

where η is the own-price elasticity of downstream demand and ψ the inverse elasticity of labor supply. Using the estimated values for these two primitives from Kroft et al. (2020) given in Table 1, we calculate the efficient level of buyer power β^* to be 0.42.

This estimate suggests that collective wage bargaining requires careful consideration as a solution to countervail employer monopsony power. If the resulting labor union became too powerful—which would occur at a union bargaining weight exceeding 0.58 (1-β^*)—it would replace the downstream monopsony distortion with an upstream monopoly distortion through double marginalization by the labor union.

6.2 Farmer Cooperatives

As a second illustration of our model, we consider the seller cooperatives discussed in Example 2. We apply our model to the context of Chinese tobacco farmers selling to cigarette manufacturers, leveraging supply elasticities estimated by Rubens (2023), in which the model is estimated under the oligopsony assumption ($\beta = 1$). This assumption is reasonable in this context, as a concentrated group of cigarette manufacturers purchases tobacco leaves from many small farmers.

[25] For a full estimation of a bargaining model within a specific union-employer bargaining context, see Angerhofer et al. (2024).

[26] https://www.bls.gov/news.release/pdf/union2.pdf.

A natural question arising in this setting is how the introduction of a farmers' cooperative, bargaining collectively with cigarette manufacturers, would affect outcomes. To determine the efficient-bargaining parameter for this example, we use leaf supply elasticities estimated by Rubens (2023) and cigarette demand elasticities from Ciliberto and Kuminoff (2010), as shown in Table 1. Despite the highly inelastic supply from farmers, we estimate the efficient level of buyer power of $\beta^* = 0.92$, which is close to the unilateral monopsony case of $\beta = 1$. This indicates that near-complete monopsony power represents the welfare-maximizing bargaining weight in this industry, at least when abstracting from other inefficiencies of monopsony power, such as cost misallocation (Rubens, 2023). The key factor driving this high efficient level of buyer power is the inelastic demand for cigarettes, which is unsurprising given the addictive nature of the product.[27]

7 Empirical Application: Coal Procurement

In contrast to the analysis in the previous section, where we only estimated β^*, we now turn to an application that estimates actual buyer power β within a bargaining model alongside β^*. We analyze coal procurements of power plants from mining firms while allowing for (i) rich heterogeneity in cost elasticities, demand elasticities, and bargaining parameters, (ii) multiple sellers and buyers, and (iii) oligopolistic competition in the downstream electricity market. For mining cost, we estimate the marginal cost of individual mines and aggregate them at the firm-level, representing an example of multiunit suppliers discussed in Example 3. In modeling electricity markets, we closely follow the classic papers in the literature (Wolfram, 1999; Borenstein and Bushnell, 1999; Borenstein et al., 2002; Puller, 2007). The main objective of the model is to decompose the total welfare losses from market power into monopolistic and monopsonistic distortions.

7.1 Data Sources and Summary Statistics

Our empirical setting is the Texas ERCOT (Electric Reliability Council of Texas) market, which has been previously studied in the IO literature (Hortaçsu and Puller, 2008; Hortaçsu et al., 2019). The ERCOT market offers three key advantages: (i) it operates independently with no trade between regions, (ii) most power plants are deregulated, and (iii) hourly price and generation data are readily accessible. We limit our sample to the 2005–2015 period, as this timeframe has a stable market share of coal power plants (≈20%) and largely

[27] Other studies estimating cigarette demand elasticities, such as Liu et al. (2015) and Lopez and Pareschi (2024), report elasticities below one. These estimates are inconsistent with our model of static profit maximization, as they imply that manufacturers would be pricing on the inelastic portion of the demand curve. Applying our efficient level of buyer power formula in such cases would yield an efficient level of buyer power above one, which lies outside the bargaining range considered in our model.

Table 2: Summary Statistics

	Upstream	**Downstream**
	Panel A. Unit Characteristics	
Number of units (plant or mine)	25	9
Number of firms	9	3
Number of units per firm	2.51	2.88
Avg. number of trade partners	22.09	2.65
Avg. share of largest partner	0.42	0.53
	Panel B. Transaction Characteristics	
Average FOB price (per MMBtu)	-	0.85
Contract duration (years)	-	1.42
Share of spot-market transactions	-	0.04
Share of railroad transportation	-	0.77

precedes the significant wave of coal-mine closures that began in the early 2010s.

We combine data from Velocity Suite, CostMine, the BLS, and the Mine Safety and Health Administration (MSHA). Velocity Suite compiles data from various sources for the power industry; CostMine provides engineering estimates of mining costs; the BLS provides wage data; and MSHA provides information on mine characteristics and production. We describe these sources in detail in Appendix G.1.

Table 2 presents summary statistics describing vertical market structure in the dataset. Nine mining firms that operate 25 mines sell coal to three power-generation firms with nine power plants. On average, mining firms deal with 22.09 partners, including some that are not in ERCOT, while power firms engage with a more limited network of just 2.65 partners. These interactions are primarily governed by medium-term contracts, with an average duration of 1.42 years.

7.2 Model Primitives

Our empirical framework involves estimating a bargaining model between coal-mining firms ('upstream') and power-generating firms ('downstream'). We begin by estimating the model's key primitives: the cost curves for mining firms, power firms, and the residual electricity demand faced by power firms. We then analyze the bargaining model. The primitives and bargaining model are estimated each year separately, but we omit year subscripts to keep the notation simple. A summary table of notation used in the model is provided in Table OA-2.

7.2.1 *Cost Curve of Mining Firms*

Each upstream mining firm u has a portfolio of n_u coal mines, indexed by i, that have marginal costs c_{iu} and capacity k^c_{iu}. We assume that within a mine, marginal cost is constant and determined by mine characteristics and labor costs.

To estimate mine-level marginal costs, we first specify their production function. A mine i owned by firm u produces q^c_{iu} short tons of coal using l_{iu} hours of labor and m_{iu} amount of intermediate inputs according to the following production function:

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

where ω_{iu} is mine productivity. This specification accommodates production heterogeneity through the parameter $\gamma_{\theta(iu)}$, which determines the labor-materials ratio as a function of mine type θ based on capacity, vein thickness, and mining technology. It also assumes that labor and intermediate inputs are perfect complements—a reasonable assumption given the limited substitution possibilities between them in coal production in the short run (Byrnes et al., 1988).

Denoting hourly labor wages as w^l_{iu} and material unit costs as p^m_{iu}, the marginal cost c_{iu} is equal to average costs as long as capacity $\bar{q}_{iu}$ is not reached:

$$c_{iu} = \frac{w^l_{iu} l_{iu} + p^m_{iu} m_{iu}}{q^c_{iu}} \quad \text{if} \quad q^c_{iu} \leq k^c_{iu}, \tag{7}$$

To estimate marginal costs, we use the Coal Cost Guide, published by an industry research firm CostMine, to obtain the engineering estimates of labor-to-material-cost ratios for various mine types θ, as $\overline{\gamma}_{\theta(iu)} = \frac{p^m_{iu} m_{iu}}{w^l_{iu} l_{iu}}$.[28] Then, the marginal cost expression becomes

$$c_{iu} = w^l_{iu} \frac{l_{iu}}{q^c_{iu}}(1 + \overline{\gamma}_{\theta(iu)}) \quad \text{if} \quad q^c_{iu} \leq k^c_{iu}, \tag{8}$$

which can be estimated using wage and labor data. This expression provides the marginal cost in terms of unit weight. However, it is useful to distinguish coal quantity by weight and heat content (measured in millions of British thermal units, or MMBtu), as heat content mainly determines coal's value as an input in electricity generation. To convert between weight and heat content, we introduce a mine-specific conversion factor λ_{iu} such that $q_{iu} = \lambda_{iu} q^c_{iu}$ and $k_{iu} = \lambda_{iu} k^c_{iu}$. The value of λ_{iu} depends on the coal type and mining area, serving as an important source of heterogeneity across mines. With this conversion, we

[28] The coal Cost Guide has been used in the mining engineering literature (Shafiee and Topal, 2012).

define quantities and marginal costs in terms of MMBtu for the rest of the paper.

Using individual mine marginal costs, the firm-level cost curve can be constructed by taking the cumulative production cost after ordering mines from lowest to highest cost. In particular, we obtain the following cost function at the firm level:

$$C_u(Q, c_u, k_u) = \begin{cases} \sum_{i=1}^{n_u} c_{iu} \max\left\{0, \min\left[k_{iu}, Q - \sum_{l=1}^{i-1} k_{lu}\right]\right\}, & \text{if } 0 \le Q \le \sum_{i=1}^{n_u} k_{iu}, \\ \infty, & \text{if } Q > \sum_{i=1}^{n_u} k_{iu} \end{cases}$$

where the vector $c_u := \{c_{iu}\}_{i=1}^{n_u}$ is such that $c_{1u} \le c_{2u} \le \cdots \le c_{n_u u}$ and k_u is the vector of mine capacities.

7.2.2 Cost Curve of Power Firms

A downstream power firm d operates a portfolio of n_d generation assets. Each asset j is characterized by a constant marginal cost c_{jd} and a capacity k_{jdt}. The capacity can be time-varying due to the intermittency of renewable energy sources across seasons and hours of the day. We therefore define capacity values for each hour type t, which captures specific combinations of month, hour of day, and weekend/weekday status.

The marginal cost of generation units depends on fuel prices and their efficiency, which is measured by the heat rate for fossil fuel generators. We define marginal costs as follows:

$$c_{jd} = \begin{cases} (w_d + \kappa_{jd}) h_{jd} & \text{if coal} \\ w^g h_{dj} & \text{if gas} \\ 0 & \text{if nuclear and renewables} \end{cases}$$

where h_{jd} is the (inverse) heat rate of generation unit j, w^g is the natural gas prices that are common across natural gas generators, and w_d is the weighted average FOB coal price negotiated by firm d. We also add the per MMBtu transportation cost κ_{jd} from the basin firm d operates to generator j if the generation is a coal generator.[29] We assume the heat rate of generators is constant within a year, which we calculate by dividing the total heat input by the total electricity generation in a given year.[30]

[29] By treating transportation costs κ_{jd} as exogenous, we do not explicitly model railroad firms as a third agent in the value chain. Prior research has found the market power of railroad companies to be important in coal procurement markets (Preonas, 2023). In the context of our model, the upstream agents can be viewed as jointly representing coal firms and railroad operators rather than solely coal firms. For instance, if coal firms and railroad companies would bargain efficiently, one can view upstream as a joint-profit-maximizing entity that combines the mining firms and railroad companies. As a result, the statements about double marginalization by coal firms can be alternatively interpreted as double marginalization arising from railroad companies' market power.

[30] We calculate the marginal cost using coal prices from the transaction data, transportation costs, and the

To calculate the time-varying capacity k_{jdt}, we cannot rely solely on the nameplate capacity, as fossil-fuel power plants are subject to maintenance downtime, and renewable energy sources experience intermittency. Instead, we compute a capacity factor for each unit. For fossil-fuel units, we derive fuel-type-specific capacity factors using Generating Availability Data System (GADS) data. For renewables, we calculate the capacity factor by averaging production for a given hour type and dividing it by the nameplate capacity.

Using unit-level capacity and cost data, firm-level cost of d in hour t is constructed by arranging all generators in ascending order of marginal cost and then calculating the cumulative production cost. Specifically, the cost curve is expressed in the following form:

$$C_{dt}(Q, c_d, k_{dt}) = \begin{cases} \sum_{j=1}^{n_d} c_{jd} \max\left\{0, \min\left[k_{jdt}, Q - \sum_{l=1}^{j-1} k_{ldt}\right]\right\}, & \text{if } 0 \leq Q \leq \sum_{j=1}^{n_d} k_{jdt}, \\ \infty, & \text{if } Q > \sum_{j=1}^{n_d} k_{jdt} \end{cases}$$

where the vector $c_d := \{c_{jd}\}_{j=1}^{n_d}$ is such that $c_{1d} \leq c_{2d} \leq \cdots \leq c_{n_d d}$ and k_{dt} is the vector of generator capacities.

7.2.3 *Downstream Electricity Demand*

We model competition in the electricity market using a Cournot framework following the prior literature (Borenstein and Bushnell, 1999; Borenstein et al., 2002). In this model, regulated firms and small firms act as price takers, while larger firms behave strategically. Since both demand and available capacity vary hourly, we estimate separate Cournot models for each hour type t. In this model, the demand curve faced by strategic firms is given by

$$Q_t(P) = Q_t^D - Q_t^{\text{fr}}(P)$$

where Q_t^D denotes the inelastic demand during hour t and $Q_t^{\text{fr}}(P)$ denotes the quantity supplied by the competitive fringe firms at a price P. Let $P_t(Q)$ denote the inverse demand curve of strategic firms, so the profit function of downstream firm d at hour t is given by:

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

heat rate. In this calculation, we assume that if there are multiple coal suppliers, the coal is blended across suppliers without a specific order of use.

with Q_{-dt} representing the production of all other strategic firms except d. The annual profit function can be obtained by aggregating hourly profits:

$$\pi^d(Q_d, C_d) = \sum_t f_t \pi_t^d(Q_{dt}, C_{dt})$$

Here f_t is the frequency of the hour type t; Q_d is a vector of quantities, $Q_d = \{Q_{dt}\}_{t=1}^{n_t}$; and C_d is the set of cost functions, $C_d = \{C_{dt}\}_{t=1}^{n_t}$.

7.2.4 Upstream Profit

Each upstream firm u has a set of buyers given by D_u, where a quantity q_{ud} is traded with each partner u at a price w_{ud}. The upstream firm's profit function is simply the total revenue obtained from these transactions minus the total cost of production:

$$\pi^u(w_u, q_u) = \sum_{d \in D_u} w_{ud} q_{ud} - C_u \left(\sum_{d \in D_u} q_{ud} \right)$$

Here, w_u and q_u represent the vector of all prices and quantities for firm u.

7.3 A Bargaining Model of Mining Firms and Power-Plant Owners

We specify a model of bargaining between mining and power firms that negotiate over a linear price annualy. We adopt the sequential timing assumption introduced in Section 2, as it permits the equilibrium to exist for all β values. Under this assumption, the upstream firm chooses how much coal to supply in the monopsonistic bargaining and the downstream firm how much coal to demand in the monopolistic bargaining after observing the wholesale price. We also maintain the passive-belief assumption, so u and d condition on all other bargaining outcomes when negotiating over the wholesale price.

Empirical evidence supports our assumptions of annual contract durations and linear price contracts. As shown in Table 2, the average contract duration is 1.42 years, making annual negotiation a reasonable approximation of actual contract terms. Regarding linear pricing, while our transaction data do not directly reveal contract types, we have access to historical contract data from 1980 to 2000. Figure OA-2, constructed from this data, reveals that the share of linear price contracts increased from 3% in 1979 to over 75% by 2000.[31] Assuming this trend continued beyond 2000, it is likely that linear price contracts represent the majority of contracts during our sample.

[31] Coal contracts can take several forms, including base price plus escalation, market-indexed pricing, cost-plus contracts, and linear price contracts (Kozhevnikova and Lange, 2009).

Our assumptions also allow us to abstract from the holdup problem, as analyzed in the seminal paper by Joskow (1985). Since the 1970s and 1980s, when Joskow's study was conducted, coal markets have undergone significant transformations driven by technological advancements and regulatory reforms. First, the introduction of scrubbers has made coal more homogenous for power plants, which mitigates the coal specificity that led to investment holdup. Second, environmental and railroad regulatory changes have reduced coal specificity by incentivizing boiler upgrades and improving access to more coal markets (Ellerman et al., 2000).[32] Overall, these developments have significantly reduced the prevalence of long-term contracts, which were historically the primary mechanism for mitigating investment holdup.

In what follows, we first define the firms' individual optimization problem under monopolistic and monopsonistic bargaining in Stage 2, and then we introduce the bargaining problem of Stage 1.

Firms' Problem in Monopolistic Bargaining

Under monopolistic bargaining, the downstream firm d takes input prices as given, which affects its cost curve C_{dt}, and chooses the level of production every hour to maximize profit:

$$Q_{dt}^{\text{mp}}(C_{dt}) = \arg\max_{Q_{dt}} \left[P_t(Q_{-dt} + Q_{dt})Q_{dt} - C_{dt}(Q_{dt}) \right]. \tag{9}$$

Let $q_{udt}^{mp}(C_{dt}, w_{ud})$ be the factor demand from upstream firm u to production of $Q_{dt}^{\text{mp}}(C_{dt})$. This factor demand comes from the electricity generation from coal units in producing $Q_{dt}^{\text{mp}}(C_{dt})$. Given this, we can write the annual factor demand of d from u as

$$q_{ud}^{mp}(w_{ud}) = \sum_t f_t q_{udt}(C_{dt}).$$

For the mining firm, the passive-beliefs assumption means firm u assumes that coal shipments to all partners except d are fixed and predetermined. Thus, in monopolistic bargaining, u supplies the quantity demanded by d using production from its lowest-cost available mines.[33]

[32] Due to the 1990 Clean Air Act Amendment, plants acquired new technologies that allowed them to boil lower-sulfur-content coal, which made them more flexible in their coal-type burning requirements, as suggested by Ellerman et al. (2000). Kacker (2014) finds that in the 1990 Clean Air Act Amendment Phase I, power plants forced to switch technology were more likely to write shorter-term contracts and choose fixed-price contracts than those not forced to switch. Moreover. the 1980 Railroad Reform reduced transportation costs, favoring heterogeneous coal-type price reductions at the power-plant gate, including lower-sulfur coal.

[33] This assumption would be violated if mining firms recognized that selling to d increases costs for all other firms they supply. However, we believe that passive beliefs are a reasonable first-order approximation, since upstream firms typically sell to many downstream firms.

Firms' Problem in Monopsonistic Bargaining

Under monopsonistic bargaining, the upstream firm takes $\{w_{ul}\}_{l \neq d}$ and $\{q_{ul}\}_{l \neq d}$ as given and decides how much to supply to firm d with the following optimization problem:

$$q^{\text{ms}}_{ud}(C_u, w_{ud}) = \arg\max_{q_{ud}} \Big\{ w_{ud}\, q_{ud} \; - \; \Big[C_u\Big(\sum_{l \neq d} q_{ul} \; + \; q_{ud}\Big) \; - \; C_u\Big(\sum_{l \neq d} q_{ul}\Big)\Big]\Big\}.$$

The solution to this problem is $q_{ud} = (C'_u)^{-1}(w_{ud}) - \sum\limits_{l \neq d} q_{ud}$, meaning that firm u supplies to firm d up to a quantity such that its marginal cost equals the wholesale price w_{ud}.

For the downstream firm, the quantity decision of u does not directly determine its production due to the multi-input nature of electricity generation, as in Extension 5.4. Thus, firm d solves the following problem:

$$Q^{ms}_{dt}(q_{ud}) = \underset{\tilde{Q}_{dt}}{\text{argmax}} \;\; P_t(Q_{-dt} + Q_{dt})Q_{dt} - C^{-u}_{dt}(Q_{dt}) \quad \text{s.t.} \quad Q_{dt} = \tilde{Q}_{dt} + Q_{udt}(q_{ud}), \qquad (10)$$

where $Q_{udt}(q^{ms}_{ud})$ is the electricity generation from q^{ms}_{ud}—that is, the quantity supplied from u—and $C^{-u}_{dt}(Q_{dt})$ is the cost function after taking out the generation capacity that is used to generate Q_{udt}. In other words, firm d takes the electricity generation from coal supplied by u as given and maximizes its profit.

Gains From Trade

Next, we calculate the gains from trade for the upstream and downstream firms. The annual profit of firm u, if we exclude partner d, is given by

$$\pi^u_{-d}(w_u, q_u) = \sum_{l \in \mathcal{D} \setminus \{d\}} w_{ul} q_{ul} - C_u\left(\sum_{l \in \mathcal{D} \setminus \{d\}} q_{ul}\right)$$

Here, we assume that the upstream firm does not sell the quantity q_{ud} in the event of a disagreement. With this, the gain from trade for firm u with d is given by:

$$\begin{aligned} \text{GFT}^u_{ud} = \pi^u - \pi^u_{-d} &= \left[\sum_{l \in \mathcal{D}} w_{ul} q_{ul} - C_u(Q_u)\right] - \left[\sum_{l \in \mathcal{D} \setminus \{d\}} w_{ul} q_{ul} - C_u(Q_{-d})\right] \\ &= w_{ud} q_{ud} - \left[C_u(Q^{-d}_u + Q_{ud}) - C_u(Q^{-d}_u)\right], \end{aligned}$$

where Q^{-d}_u denotes the total quantity that is sold to partners other than d.

For the downstream firm, a disagreement in bargaining primarily affects its cost function. We assume that in the event of a disagreement, firm d turns to the spot market instead of sourcing the coal from firm u. In the spot market, both price levels and volatility impact firm profitability, as firms generally dislike price uncertainty (Jha, 2022).[34] We denote d's cost function from disagreement with u as $C_{dt}^{-u}(Q)$, which can be obtained by replacing the wholesale price w_{ud} with the price in the spot market.[35] Therefore, the profit function in case of a disagreement is given by:

$$\pi_{-ut}^{d}(Q_{dt}) = P_t(Q_{-dt} + Q_{dt})Q_{dt} - C_{dt}^{-u}(Q_{dt})$$

Let $\bar{Q}_{dt}^{-u}$ be the solution to maximizing this profit. The gain from trade is given by

$$\text{GFT}_{ud}^{d} = \sum_t w_t \Big(\big[P_t(Q_{-dt} + Q_{dt})Q_{dt} - C_{dt}(Q_d)\big] - \big[P_t(Q_{-dt} + \bar{Q}_{dt}^{-u})\bar{Q}_{dt}^{-u} - C_{dt}^{-u}(\bar{Q}_{dt}^{-u})\big]\Big)$$

With these objects, we can represent the monopsonistic bargaining problem as follows:

$$\begin{cases} \max\limits_{w_{ud}} \Bigg\{ \Big[w_{ud}\, q_{ud}^{ms}(w_{ud}) - \Big(C_u\big(Q_{-d} + q_{ud}^{ms}(w_{ud})\big) - C_u\big(Q_{-d}\big)\Big)\Big]^{1-\beta} \\ \qquad\qquad \times \Big[\sum_t w_t \Big(\big[P_t\big(Q_{-dt} + Q_{dt}^{ms}\big)\, Q_{dt}^{ms} - C_{dt}\big(Q_d^{ms}\big)\big] - \big[P_t\big(Q_{-dt} + \bar{Q}_{dt}^{-u^*}\big)\, \bar{Q}_{dt}^{-u} - C_{dt}^{-u}\big(\bar{Q}_{dt}^{-u}\big)\big]\Big)\Big]^{\beta} \Bigg\} \\ Q_{dt}^{ms}(q_{ud}) = \underset{\tilde{Q}_{dt}}{\text{argmax}}\ \ P_t(Q_{-dt} + Q_{dt})Q_{dt} - C_{dt}^{-u}(Q_{dt}) \qquad \text{where} \quad Q_{dt} = \tilde{Q}_{dt} + Q_{udt} \\ q_{ud}^{ms}(C_u, w_{ud}) = \underset{q_{ud}}{\text{argmax}}\ \ \sum w_{ud} q_{ud} - C_u\left(\sum q_{ud}\right) \end{cases}$$

Similarly, we can write the monopolistic bargaining problem as follows:

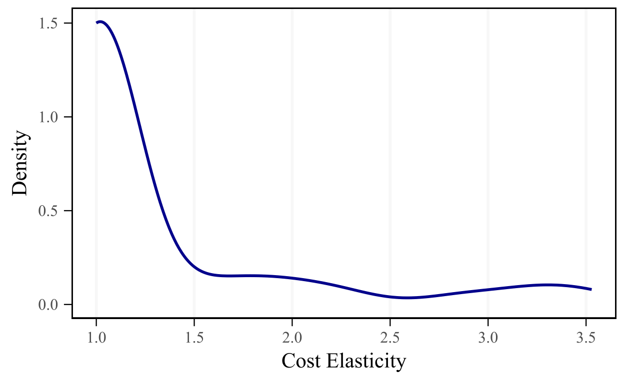
$$\begin{cases} \max\limits_{w_{ud}} \Bigg\{ \Big[w_{ud}\, q_{ud}^{mp}(w_{ud}) - \Big(C_u\big(Q_{-d} + q_{ud}^{mp}(w_{ud})\big) - C_u\big(Q_{-d}\big)\Big)\Big]^{1-\beta} \\ \qquad\qquad \times \Big[\sum_t w_t \Big(\big[P_t\big(Q_{-dt} + Q_{dt}^{mp}\big)\, Q_{dt}^{mp} - C_{dt}\big(Q_d^{mp}\big)\big] - \big[P_t\big(Q_{-dt} + \bar{Q}_{dt}^{-u}\big)\, \bar{Q}_{dt}^{-u} - C_{dt}^{-u}\big(\bar{Q}_{dt}^{-u}\big)\big]\Big)\Big]^{\beta} \Bigg\} \\ Q_{dt}^{\text{mp}}(C_{dt}), q_{ud}^{mp}(w_{ud}) = \arg\max\limits_{Q_{dt}}, q_{ud}\, [P_t(Q_{-dt} + Q_{dt})Q_{dt} - C_{dt}(Q_{dt})] \end{cases}$$

The solutions (w_{dt}, Q_{dt}) to these problems characterize the equilibrium in monopsonistic and monopolistic bargaining, respectively.

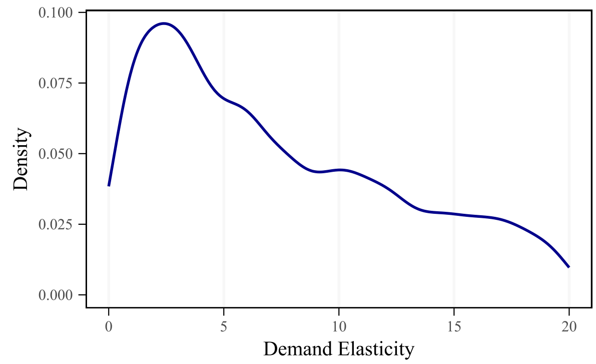
[34] As Jha (2022) notes, "plant managers may pay a premium for contract coal because delivery is guaranteed. In contrast, plant managers have no assurance that they will find a spot supplier to purchase coal from every month."

[35] See Appendix G.5. for the implementation with disagreement payoffs.

Figure 7: Distribution of Cost and Demand Elasticity



(a) Upstream Cost Estimates



(b) Dowstream Demand Estimates

Notes: Panel (a) presents kernel density estimates of the distribution of the elasticity of marginal cost (the elasticity of $\partial(c(q)q)/\partial q$)). Panel (b) presents kernel density estimates of the distribution of the elasticity of demand (the elasticity of $p^{-1}(q)$). Each observation corresponds to a mining firm-year in Panel (a) and an hour-type power firm in Panel (b).

7.4 Estimation and Results

We solve the model for each contracting pair (mining and power firms) each year. We first estimate the primitives, the residual electricity demand of the downstream firm, and the cost of the upstream firm to form payoff functions. Then, we solve for equilibrium quantities and wholesale prices (p, w) under both monopsonistic and monopolistic bargaining for each $\beta \in (0, 1)$. We estimate β as the value of the bargaining parameter that rationalizes the observed quantity under each vertical conduct and then apply our conduct selection rule. See Appendix G.7 for the detailed implementation of our estimation algorithm.

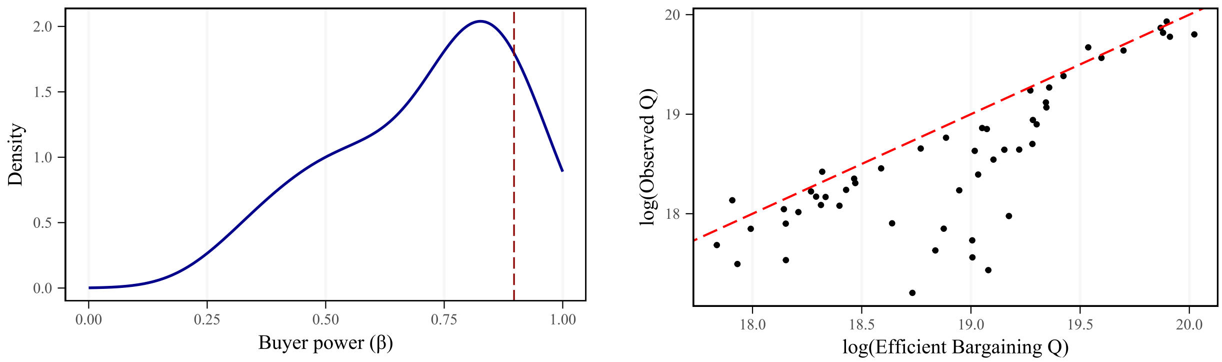
Cost and Demand Elasticity Estimates

We present the distribution of marginal cost elasticity estimates for each mine-year in Figure 7(a). These estimates show a notable concentration at or near one, which indicates approximately constant marginal cost curves, while the rest of the distribution ranges from 1.5 to 3.5. This heterogeneity in the mining cost elasticity comes primarily from the mine's location: mines in Wyoming and Montana are predominantly surface mines with large capacities and relatively flat marginal cost curves, while mines in Appalachia are mainly underground mines with smaller capacities and steeper marginal cost curves.

We present the distribution of residual demand elasticity estimates in Figure 7(b), with each observation corresponding to an hour-firm pair.[36] The elasticity estimates exhibit a

[36]Since demand is estimated nonparametrically from the cost curves of both fringe and strategic firms, we report the elasticities at the observed output levels for each hour.

Figure 8: Bargaining Model Estimates



(a) Buyer Power Estimates **(b)** Comparison to Efficient Bargaining

Notes: Panel (a) shows kernel density of buyer power estimates (β) across each buyer-seller pair, with the red dashed line marking the average of the efficient level of buyer power β^*. Panel (b) compares the logarithm of observed coal-transaction quantities (q), in log MMBtu, to the logarithm of the joint-profit-maximizing coal transaction (q^*) across each buyer-seller pair. The red dashed line represents the 45-degree line.

wide range, though most are concentrated between 1 and 4. This variation in elasticities primarily reflects the shape of the fringe firms' supply curve, which varies depending on the time of day and season. The average of our elasticity estimates aligns with Puller (2007), who reports a residual demand elasticity of 2.33 in the California electricity market.

These cost and demand estimates are the key inputs to understanding whether buyer or seller power is likely to be a source of inefficiency. As shown in Section 3, the efficient level of buyer power that maximizes total output decreases with the upstream cost elasticity and with the downstream demand elasticity. The presence of many mining firms with close to constant returns to scale suggests that seller power is likely to be the source of distortion in many bargaining pairs.

Bargaining Parameter Estimates

We estimate a separate bargaining parameter for each buyer-seller-year and report the distribution of these estimates in Figure 8(a). The distribution is heavily skewed toward one, meaning power plants have relatively more bargaining power than the mining firms they buy from. The average efficient level of buyer power, indicated by the dashed red line, lies around 0.9. While the estimated bargaining parameters are below the efficient level, they are not significantly far from it, suggesting the scope of distortion in this market is relatively small.

Next, we apply our conduct selection criteria of nonnegative markup and markdown. Theorem 1 in Section 4 shows that vertical conduct is monopsonistic if the bargaining weight exceeds β^* and monopolistic otherwise. Applying this rule to the bargaining weight estimates in Figure 8(a), we find that two bargaining relationships exhibit monopsonistic conduct, while the remaining relationships are monopolistic. This suggests that most output distortion arises from seller power rather than buyer power, resulting in double marginalization.

Finally, we test whether our conduct selection criteria are supported by the data by leveraging its falsifiable implication developed in Section 4: observed output quantities should be lower than the joint-profit-maximizing output. Figure 8(b) compares the observed quantities with the efficient-bargaining quantities calculated from the model for each trading relationship in the data. With few exceptions, observed output is consistently below the joint-profit-maximizing levels, providing empirical support for our conduct selection criterion.

7.5 Decomposing Welfare Effects Into Monopolistic and Monopsonistic Conduct

In this section, we quantify total welfare loss and decompose it into components attributable to monopsony power and monopoly power. Since short-run electricity demand is inelastic, welfare effects in electricity markets arise primarily from allocative inefficiency rather than lost output (Borenstein et al., 2002). Specifically, monopoly and monopsony distortions lead strategic firms to produce less than they would in the absence of vertical distortions, shifting production to higher-cost fringe firms. Accordingly, we measure welfare loss as the additional output produced by higher-cost fringe firms due to double marginalization or monopsony power.

To decompose the total welfare effects into monopsony and monopoly sources, for every trading relationship in the data, we calculate the differences between the observed and output-maximizing output levels in Figure 8(b). We then aggregate these differences by multiplying them by market prices separately across trading pairs for both the monopolistic and monopsonistic conduct cases. This gives us both the total underproduction of strategic producers compared to a competitive benchmark and a decomposition of this amount into a monopsonistic and monopolistic distortion.

The results are summarized in Table 3. We estimate the total misallocated quantity in the ERCOT market to be 5.11% of total fuel-generation expenditures. While this figure is relatively small, it is not surprising given that the estimated bargaining weights are close to the efficient levels. In terms of sources, 82.71% of the welfare loss is attributed to double marginalization resulting from the monopoly power of coal mining firms, while the remaining portion is due to the monopsony power of power companies. In this market, an increase in buyer power would be countervailing, whereas an increase in seller power would be further distortionary.

Table 3: Decomposing Welfare Losses From Market Power

Misallocation	% of Coal Expenditure
Total misallocated output	5.11 %
Decomposition:	*% of Total Loss*
Due to monopsony	17.29%
Due to monopoly	82.71%

Notes: This table decomposes the total misallocation due to market power (additional output produced by fringe firms compared to a competitive wholesale coal market) into its components: losses due to monopsony and monopoly power.

8 Concluding Remarks

Vertical relationships between buyers and sellers are studied in a variety of settings to quantify market distortions, from healthcare markets to labor unions, under monopsony/oligopsony and double-marginalization settings. In this paper, we provide a unified framework that nests both monopolistic and monopsonistic vertical conduct that are commonly used in the literature. We show that with increasing upstream marginal costs and decreasing downstream marginal revenues, both conduct types lead to a solution with distinct welfare implications. We demonstrate how to determine which type of vertical conduct emerges based on the relative bargaining positions of buyers and sellers and the underlying primitives of cost and demand functions.

We illustrate our model using various empirical settings that feature increasing upstream marginal costs, including labor unions, farmer cooperatives, and suppliers with decreasing returns to scale. In our main empirical application, we use the model to quantify the sources of deadweight loss in the coal procurement of power plants in Texas. We find that inefficiencies mostly stem from double marginalization due to coal-mine monopoly power rather than from the monopsony power of power plant companies.

Insights from this paper inform antitrust policy. In horizontal merger analysis, we characterize the conditions under which changes in concentration in upstream and downstream markets are distortionary or countervailing. In monopolistic conduct, increased buyer power counteracts double marginalization and increases welfare, while in monopsonistic conduct, increased buyer power enhances monopsony distortions and reduces welfare. For vertical mergers, our framework provides a systematic way to evaluate efficiency claims about eliminating double marginalization by quantifying the gap between current and efficient levels of buyer power.

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Welfare Effects of Buyer and Seller Power

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Appendix

Contents

A Proofs for Results Under the Simultaneous Model

A.1 Summary of First-Order Conditions

Under the simultaneous bargaining models, the maximization problems are given by:

$$\begin{cases} \max_q p(q)q - wq & \text{(Downstream's problem)} \\ \max_q wq - c(q)q & \text{(Upstream's problem)} \\ \max_w [(p(q)q - wq)^\beta (wq - c(q)q)^{1-\beta}] & \text{(Bargaining problem)} \\ \max_{w,q} [(p(q)q - wq)^\beta (wq - c(q)q)^{1-\beta}] & \text{(Joint profit maximization)} \end{cases} \tag{OA.1}$$

These objective functions correspond to the following FOCs, for which we provide the proofs in Section A.2:

$$\begin{cases} w = p'(q)q + p(q) & \text{(D-FOC)} \\ w = c'(q)q + c(q) & \text{(U-FOC)} \\ w = (1-\beta)\, p(q) + \beta\, c(q) & \text{(B-FOC)} \\ q[p'(q) - c'(q)] + [p(q) - c(q)] = 0 & \text{(J-FOC)} \end{cases} \tag{OA.2}$$

Based on these FOCs, the equilibrium quantities are given by:

$$\begin{cases} (1-\beta)[c(q) - p(q)] - p'(q)q = 0 & \text{(MP Bargaining)} \\ (1-\beta)[p(q) - c(q)] - c'(q)q = 0 & \text{(MS Bargaining)} \\ q\,[p'(q) - c'(q)] + [p(q) - c(q)] = 0 & \text{(Joint Max.)} \end{cases}$$

A.2 Derivations of FOCs Under Simultaneous Bargaining

D-FOC and U-FOC are straightforward and therefore omitted.

A.2.1 B-FOC

Take the natural logarithm of the objective function:

$$\mathcal{L}(w) \equiv \beta \ln(p(q)q - wq) + (1-\beta) \ln(wq - c(q)q) \tag{OA.3}$$

Taking the derivative of $\mathcal{L}(w)$ with respect to w and setting it to zero gives

$$\beta \cdot \frac{-q}{p(q)q - wq} + (1-\beta) \cdot \frac{q}{wq - c(q)q} = 0.$$

Solving for w gives $w = (1-\beta)p(q) + \beta c(q)$.

A.2.2 J-FOC

Take the derivative of $\mathcal{L}(w)$ from Equation (OA.3) with respect to q:

$$\beta \cdot \frac{p'(q)q + p(q) - w}{p(q)q - wq} + (1-\beta) \cdot \frac{w - c'(q)q - c(q)}{wq - c(q)q} = 0.$$

Substitute $w = (1-\beta)p(q) + \beta c(q)$ from (B-FOC) above:

$$\beta \cdot \frac{p'(q)q + p(q) - [(1-\beta)p(q) + \beta c(q)]}{p(q)q - [(1-\beta)p(q) + \beta c(q)]q} + (1-\beta) \cdot \frac{[(1-\beta)p(q) + \beta c(q)] - c'(q)q - c(q)}{[(1-\beta)p(q) + \beta c(q)]q - c(q)q} = 0$$

The numerator and denominator for both terms above simplify to:

$$\frac{p'(q)q + \beta[p(q) - c(q)]}{q[p(q) - c(q)]} + \frac{(1-\beta)(p(q) - c(q)) - c'(q)q}{q(p(q) - c(q))} = 0.$$

This expression results in the joint profit maximization FOC (J-FOC):

$$q[p'(q) - c'(q)] + [p(q) - c(q)] = 0.$$

A.3 Proof of Proposition 1 for the Simultaneous Model

Proposition 1. If the upstream marginal cost is constant, $mc'(q) = 0$, the monopsonistic bargaining problem does not have an interior solution. If the downstream marginal revenue is constant, $mr'(q) = 0$, the monopolistic bargaining problem does not have an interior solution. In all other cases, both the monopolistic and monopsonistic bargaining problems have an interior solution within the ranges of β specified in Appendix D.2.

Proof. Note that the second-order conditions for either bargaining model do not hold under the assumptions of this proposition since the profit function of upstream is unbounded for $w > c$ when marginal cost is constant, and the profit of downstream is unbounded for $p < w$ when marginal revenue is constant. As a result, the first-order conditions cannot be relied on to find an equilibrium pair (w^*, q^*), and we must consider each of the maximization programs in cases. We will provide the proof separately for monopsonistic and monopolistic bargaining.

Monopsonistic Bargaining:

The equilibrium (w^*, q^*) maximizes the objective functions below in the monopsonistic bargaining.

$$\begin{cases} \max\limits_{q} \pi^u(w^*, q) \quad (U) \\ \max\limits_{w} \pi^b(w, q^*, \beta) \quad (B) \end{cases} \qquad \text{s.t} \quad \pi^u(w,q) \geq 0, \quad \pi^d(w,q) \geq 0$$

where $\pi^b(w, q, \beta) \equiv (\pi^d(w,q))^\beta(\pi^u(w,q))^{1-\beta}$. For any β, (w^*, q^*) is an equilibrium if there is no other w such that $\pi^d(w, q^*) > \pi^d(w^*, q^*)$ and there is no other q such that $\pi^b(w^*, q, \beta) > \pi^b(w^*, q^*, \beta)$. Our result follows from analyzing the equilibrium under different β values.

Case I: $\beta \in (0,1)$

We will show that under constant upstream marginal cost, the equilibrium for $\beta \in (0,1)$ is $w^* = c$ and $q^* = p^{-1}(c)$. The profit functions are given by

$$\pi^d(w,q) = \big(p(q) - w\big)q \quad \text{and} \quad \pi^u(w,q) = \big(w - c\big)q.$$

Observe that at (w^*, q^*) we have that $\pi^d(w^*, q^*) = 0$ and $\pi^b(w^*, q^*, \beta) = 0$.
First we will verify that $(c, p^{-1}(c))$ is indeed an equilibrium. Consider a deviation of $\tilde{q}$ from q^*. Observe that for any such deviation, the $\pi^u = 0$, so there is no profitable deviation.

Now, consider a deviation of $\tilde{w} > c$ from w^*. Observe that since $p(q^*) = w$, such a deviation does not satisfy the participation constraint because $\pi^d(\tilde{w}, q^*) = \big(p(q^*) - \tilde{w}\big)q < 0$.

Next, consider a deviation of $\tilde{w} < c$ from w^*. Observe that since $w^* = c$, such a deviation does not satisfy the participation constraint because $\pi^u(\tilde{w}, q^*) = \big(\tilde{w} - c\big)q^* < 0$. This proves that $w^* = c$ and $q^* = p^{-1}(c)$ is indeed an equilibrium.

We now show that there is no other equilibrium by considering cases separately.

(i) Suppose $\bar{w} = c$ and $\bar{q} < q^*$ is an equilibrium. Consider a deviation from this equilibrium such that $\tilde{w} = c + \epsilon$, $\epsilon < p(\bar{q}) - p(q^*)$. Noting that $\tilde{w} = p^* + \epsilon$, the profit functions are given by

$$\pi^u(\tilde{w}, \bar{q}) = \big(c + \epsilon - c\big)\bar{q}^* > 0 \quad \text{and} \quad \pi^d(\tilde{w}, \bar{q}) = \big(p(\bar{q}) - (p(q^*) + \epsilon)\big)\bar{q} > 0.$$

Therefore, $\pi^b(\tilde{w}, \bar{q}) > \pi^b(\bar{w}, \bar{q})$, which means that there is a profitable deviation such that $(\bar{w} = c, \bar{q} < q^*)$ cannot be an equilibrium. We can also eliminate $(\bar{w} = c, \bar{q} > q^*)$ as a potential equilibrium since it does not satisfy the participation constraint of upstream.

(ii) Suppose $(\bar{w} > c, \bar{q})$ is an equilibrium, where $\bar{q} \in (0, p^{-1}(\bar{w}))$. In this case, $\tilde{q} = p^{-1}(\bar{w})$ is a profitable deviation for U

$$\pi^u(\tilde{w}, \tilde{q}) = (\tilde{w} - c)\tilde{q} > (\tilde{w} - c)\bar{q} = \pi^u(\tilde{w}, \bar{q})$$

because $\bar{q} > \tilde{q}$ and $\pi^d(\tilde{w}, \tilde{q}) = 0$ still satisfies the participation constraint of the downstream.

(iii) Now suppose that $(\bar{w} > c, p^{-1}(\bar{w}))$ is an equilibrium. Note that $\pi^d = \pi^b = 0$ in this case. Consider a deviation $\tilde{w} = \bar{w} - \epsilon$ where $\epsilon < \bar{w} - c$. We can write the profit functions as

$$\begin{aligned} &\pi^u(\tilde{w}, \bar{q}) = (\tilde{w} - c)\tilde{q} > 0, \\ &\pi^d(\tilde{w}, \bar{q}) = (p(\bar{q}) - (\bar{w} - \epsilon))\bar{q} = (\bar{w} - (\bar{w} - \epsilon))\bar{q} > 0. \end{aligned}$$

This deviation is profitable because $\pi^b > 0$. Therefore, $(\bar{w} > c, \bar{q} = p^{-1}(\bar{w}))$ cannot be an equilibrium.

(iv) We can directly eliminate any case $(\tilde{w} < c, \tilde{q})$ because it does not satisfy the participation constraint of upstream, and we can also eliminate any case $(\tilde{w} > c, \tilde{q} > p^{-1}(\tilde{w}))$ because it does not satisfy the participation constraint of downstream. This concludes the proof.

Case II: $\beta = 1$

We will show that if $\beta = 1$, there is a continuum of equilibria given by $w^* = c$ and $q^* \in [0, p^{-1}(c)]$. The equilibrium (w^*, q^*) should solve the following problems:

$$\begin{cases} \max\limits_{q} \pi^u(w^*, q) & (U) \\ \max\limits_{w} \pi^d(w, q^*) & (D) \end{cases} \qquad \text{s.t} \quad \pi^u(w, q) \geq 0, \quad \pi^d(w, q) \geq 0.$$

First we verify that $w^* = c$ and $q^* \in [0, p^{-1}(c)]$ is indeed an equilibrium. Consider a deviation of $\tilde{w} > c$ from w^*. This will reduce the downstream profit for any q

$$\pi^d(\tilde{w}, q) = (p(q) - \bar{w})q \ > \ (p(q) - w^*)q = \pi^d(\tilde{w}, q)$$

Thus, there is no profitable deviation from $w^* = c$ for any q. Similarly, when $w = c$, the profit function of U is always zero regardless of q, so there is a profitable deviation from q^*, and any q that satisfies the participation constraint is an equilibrium. Therefore, $w^* = c$

and $q^* \in [0, p^{-1}(c)]$ is an equilibrium.

Next, we will show that no other equilibria exist. Suppose $(\bar{w} > c, \bar{q})$ is an equilibrium for any $\bar{q}$. We cannot have $\bar{q} < p^{-1}(\bar{w})$, because then $\tilde{q} = p^{-1}(\bar{w})$ will be a profitable deviation for upstream. Similarly, we cannot have $\bar{q} > p^{-1}(\bar{w})$ because that would violate the participation constraint of downstream. Therefore, we only consider $(\bar{w} > c, \bar{q} = p^{-1}(\bar{w}))$ as a potential equilibrium.

Note that at $(\bar{w} > c, q = p^{-1}(\bar{w}))$, we have $\pi^d = 0$. Now, consider a deviation $\tilde{w} = \bar{w} - \epsilon$ such that $\epsilon < \bar{w} - c$. The downstream profit, in this case, is positive:

$$\pi^d(\tilde{w}, \bar{q}) = (p(\bar{q}) - \tilde{w})\tilde{q} = (\bar{w} - \tilde{w})\bar{q} > 0.$$

Thus, there is a profitable deviation, and $(\bar{w} > c, q = p^{-1}(\bar{w}))$ cannot be an equilibrium. Finally, as an equilibrium candidate, $\tilde{w} < c$ violates the participation constraint of upstream, so it cannot be an equilibrium.

Case III: $\beta = 0$

We will show that if $\beta = 0$, there is a continuum of equilibria given by $\beta = 0$, which is $(w^* > c, p^{-1}(w^*))$. The equilibrium (w^*, q^*) should solve the following problems:

$$\begin{cases} \max\limits_{q} \pi^u(w^*, q) & (U) \\ \max\limits_{w} \pi^u(w, q^*) & (D) \end{cases} \qquad \text{s.t } \pi^u(w, q) \geq 0 \qquad \pi^d(w, q) \geq 0$$

For any q, D is maximized at $w = p(q)$ subject to the participation constraint. Similarly for any w, (U) is maximized at q such that $w = p(q)$ to make participation constraint binding. Therefore, w is indeterminate in this case, so any $w \geq c$ with $q = p^{-1}(w)$ is an equilibrium.

Monopolistic Bargaining:

When marginal revenue is constant, $p(q) = p$, the equilibrium for monopolistic bargaining for different β values is given by

$$\begin{cases} (w^* = p,\ q^* = c^{-1}(p)) & \text{if } \beta \in (0, 1) \\ (w^* = p,\ q^* \in [0, c^{-1}(p)]) & \text{if } \beta = 0 \\ (w^* \leq p,\ c^{-1}(w^*)) & \text{if } \beta = 1. \end{cases}$$

We omit the proofs for these results as they follow in a very similar manner to the proof for the cases above for the monopsonistic bargaining model. Note that for all β values in both monopsonistic and monopolistic bargaining, either the downstream profit or upstream profits are zero. This proves that no interior equilibrium exists.

What's left to show is that if $mc'(q) > 0$, and $mr'(q) < 0$, equilibrium exists for an interior solution within the β ranges specified in the proposition in both monopsonistic and monopolistic bargaining. The existence of an equilibrium under monopsonistic and monopolistic bargaining follows from Lemmas OA-1 and OA-2, respectively. □

A.4 Proof of Lemma 1

Lemma 1. If Property 1 holds, the equilibrium quantity q^{ms} is decreasing and the buyer markdown Δ^d is increasing with β under simultaneous monopsonistic bargaining model, that is $dq^{ms}/d\beta < 0$ and $d\Delta^d/dq^{ms} > 0$.

Proof. This result follows from an application of the Implicit Function Theorem. Note the first-order condition for U in the monopsonistic bargaining problem shown in A.2. Substituting w from (U-FOC) into (B-FOC), we have

$$c'(q)q = (1-\beta)[p(q) - c(q)].$$

Put $F(q, \beta) \equiv (1-\beta)[p(q) - c(q)] - c'(q)q$, and observe that $F(q, \beta) = 0$. As assumed in Section 2, we consider an interval $(0, \bar{q})$ such that $p(q) > c(q)$ for all $q \in (0, \bar{q})$. Hence,

$$\frac{\partial F(q, \beta)}{\partial \beta} = c(q) - p(q) < 0$$

We verify that $\partial F/\partial q < 0$. Indeed, from our assumption of strict increasing differences combined with the model in Section 3, we have

$$\frac{\partial F(q, \beta)}{\partial q} = (1-\beta)\underbrace{[p'(q) - c'(q)]}_{\leq 0} - \underbrace{[c''(q)q + c'(q)]}_{>0} < 0$$

By the Implicit Function Theorem,

$$\frac{dq}{d\beta} = -\frac{\partial F/\partial \beta}{\partial F/\partial q} < 0$$

which concludes the proof that $\frac{dq^{ms}}{d\beta} < 0$.

Next, consider the markdown $\Delta^d(q) = 1-w/mr(q)$. Differentiating with respect to β yields:

$$\frac{d}{d\beta}\Delta^d(q) = -\frac{\frac{dw}{d\beta}mr(q) - w\frac{d\big(mr(q)\big)}{d\beta}}{(mr'(q))^2} = -\frac{\frac{dq}{d\beta}\left(\frac{dq}{dw}\right)^{-1}mr(q) - w\frac{d\big(mr(q)\big)}{dq}\frac{dq}{d\beta}}{(mr'(q))^2}.$$

Note that $mr'(q) = (p''(q)q + 2p'(q)) < 0$ by assumption. We already showed that $\frac{dq}{d\beta} < 0$ and $\frac{dq}{dw} > 0$ from Lemma 1. Therefore, $\frac{d}{d\beta}\Delta^d(q)$ is positive and markdown is increasing with β. □

A.5 Proof of Lemma 2

Lemma 2. If Property 2 holds, the equilibrium quantity q^{mp} and the upstream markup μ^u under simultaneous monopolistic bargaining is increasing with β, that is $dq^{mp}/d\beta > 0$ and $d\mu^u/d\beta > 0$.

Proof. This result follows from an application of the Implicit Function Theorem. Note the first-order condition for D in the monopolistic bargaining problem shown in A.2. Substituting w from (D-FOC) into (B-FOC), we have

$$p'(q)q = \beta[c(q) - p(q)].$$

Put $F(q,\beta) \equiv p'(q)q - \beta[c(q) - p(q)]$, and observe that $F(q,\beta) = 0$. As assumed in Section 2.1, we consider an interval $(0,\bar{q})$ such that $p(q) > c(q)$ for all $q \in (0,\bar{q})$. Hence,

$$\frac{\partial F(q,\beta)}{\partial \beta} = p(q) - c(q) > 0.$$

We verify that $\partial F/\partial q < 0$. Indeed, from our assumption of strict decreasing differences combined with the model in Section 2.1, we have

$$\frac{\partial F(q,\beta)}{\partial q} = \underbrace{p''(q)q + p'(q)}_{<0} + \beta\underbrace{[p'(q) - c'(q)]}_{\leq 0} < 0.$$

By the Implicit Function Theorem,

$$\frac{dq}{d\beta} = -\frac{\partial F/\partial \beta}{\partial F/\partial q} > 0,$$

which concludes the proof that $\frac{dq^{mp}}{d\beta} > 0$.

Next, consider upstream markup as $\mu^u(q) = w/mc(q) - 1$. Differentiating with respect to β yields:

$$\frac{d}{d\beta}\mu^u(q) = \frac{\frac{dw}{d\beta}mc(q) - w\frac{d(mc(q))}{d\beta}}{(d(mc(q))/d\beta)^2} = -\frac{\frac{dq}{d\beta}\left(\frac{dq}{dw}\right)^{-1} mc(q) - w\frac{d(mc(q))}{dq}\frac{dq}{d\beta}}{(d(mc(q))/d\beta)^2}$$

$mc' = (c''(q)q + 2c'(q)) < 0$ by assumption. We already showed that $\frac{dq}{d\beta} < 0$ and $\frac{dq}{dw} > 0$. Therefore, $\frac{d}{d\beta}\mu^s(q)$ is positive, and markdown increases with β. □

A.6 Proof of Proposition 2 for the Simultaneous Model

Proposition 2. There exists a bargaining parameter $\beta^* = \dfrac{-p'(q^*)}{c'(q^*) - p'(q^*)} \in (0,1)$ at which the monopsonistic bargaining model, the monopolistic bargaining model, and the efficient-bargaining models imply an identical equilibrium output in both simultaneous and sequential models. We denote β^* as the "efficient level of buyer power."

Proof. We proceed by showing that the joint-profit-maximizing quantity q^* is the optimal output under both monopolistic and monopsonistic bargaining when buyer power is β^*. From (J-FOC) as described in Section A.2, we know that q^* uniquely satisfies

$$q^*[p'(q^*) - c'(q^*)] + [p(q^*) - c(q^*)] = 0.$$

Rewriting this gives the equation:

$$p(q^*) - c(q^*) = -q^*[p'(q^*) - c'(q^*)]. \tag{OA.4}$$

First, consider monopolistic bargaining. The equilibrium output in the monopoly model satisfies

$$p'(q^{mp})q^{mp} = \beta[p(q^{mp}) - c(q^{mp})],$$

and solving for β yields

$$\beta^{mp} = -\frac{q^{mp} \cdot p'(q^{mp})}{p(q^{mp}) - c(q^{mp})}.$$

When $\beta^{mp} = \beta^*$, we have

$$\frac{-p'(q^*)}{c'(q^*) - p'(q^*)} = -\frac{q^{mp} \cdot p'(q^{mp})}{p(q^{mp}) - c(q^{mp})}.$$

This equation is satisfied for $q^{mp} = q^*$ which can be seen by substituting Equation (OA.4) into the denominator of the righthand side above:

$$\begin{aligned}\frac{-p'(q^*)}{c'(q^*) - p'(q^*)} &= -\frac{q^{mp} \cdot p'(q^{mp})}{-[p'(q^{mp}) - c'(q^{mp})]q^{mp}} \\ &= \frac{-p'(q^{mp})}{c'(q^{mp}) - p'(q^{mp})}.\end{aligned}$$

Now, consider the monopsonistic problem. The equilibrium output in the monopsony model satisfies

$$c'(q^{ms})q^{ms} = (1-\beta)[p(q^{ms}) - c(q^{ms})],$$

and solving for β yields

$$\beta^{ms} = 1 - \frac{c'(q^{ms})q^{ms}}{p(q^{ms}) - c(q^{ms})}.$$

As above, we set $\beta^{ms} = \beta^*$, which gives the relationship

$$\frac{-p'(q^*)}{c'(q^*) - p'(q^*)} = 1 - \frac{c'(q^{ms})q^{ms}}{p(q^{ms}) - c(q^{ms})}.$$

This relation is satisfied when $q^{ms} = q^*$, which can be seen by substituting Equation (OA.4) into the denominator in the right-hand side of the relation above:

$$\begin{aligned}\frac{-p'(q^*)}{c'(q^*) - p'(q^*)} &= 1 - \frac{c'(q^{ms})q^{ms}}{-[p(q^{ms}) - c(q^{ms})]q^{ms}} \\ &= \frac{-p'(q^{ms})}{c'(q^{ms}) - p'(q^{ms})}.\end{aligned}$$

We conclude then that under buyer power β^*, the efficient output q^* is optimal under all bargaining regimes. □

B Proofs for Results Under the Sequential Model

B.1 Summary of First-Order Conditions

Under the sequential bargaining models, the maximization problems are given by:

$$
\begin{cases}
\max\limits_{q^d} \; p(q^d)\, q^d - w\, q^d & \text{(Downstream's problem)} \\
\max\limits_{q^u} \; w\, q^u - c(q^u)\, q^u & \text{(Upstream's problem)} \\
\max\limits_{w} \; \left[\left(p\left(q^d(w)\right)\, q^d(w) - w\, q^d(w)\right)^{\beta} \left(w\, q^d(w) - c\left(q^d(w)\right)\, q^d(w)\right)^{1-\beta} \right] & \text{(MP bargaining problem)} \\
\max\limits_{w} \; \left[\left(p\left(q^u(w)\right)\, q^u(w) - w\, q^u(w)\right)^{\beta} \left(w\, q^u(w) - c\left(q^u(w)\right)\, q^u(w)\right)^{1-\beta} \right] & \text{(MS bargaining problem)}
\end{cases}
$$

The corresponding first-order conditions, shown in Section B.2, are:

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

Equilibrium quantities are given by:

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

B.2 Derivation of FOCs Under Sequential Bargaining

B.2.1 U-B-FOC

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

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

Note the following intermediate derivatives:

<u>Derivative of $[p(q) - w]\, q$:</u>

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

<u>Derivative of $[w - c(q)]\, q$:</u>

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

Differentiating both sides of U-FOC, $w = c(q) + c'(q)\, q$ 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:

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

and plugging in $\frac{dq}{dw}$:

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

From U-FOC, substitute $w = c(q) + c'(q)q$:

$$N_1 = -q + ([p(q) - c(q)] + [p'(q)q - c'(q)q]) \frac{1}{2c'(q) + c''(q)q}$$

$$D_1 = [p(q) - w]\, q = ([p(q) - c(q)] - c'(q)q)\, q = \left([p(q) - c(q)]q - c'(q)q^2\right)$$

$$N_2 = q + (c'(q)q - c'(q)q) \frac{1}{2c'(q) + c''(q)q} = q$$

$$D_2 = [w - c(q)]\, q = c'(q)q^2$$

After simplifying, substitute terms back into to yield the final form of (U-B-FOC):

$$\beta \left(\frac{-q + ([p(q) - c(q)] + [p'(q)q - c'(q)q]) \frac{1}{2c'(q) + c''(q)q}}{[p(q) - c(q)] - c'(q)q} \right) + (1 - \beta) \left(\frac{1}{c'(q)} \right) = 0$$

□

B.2.2 *D-B-FOC*

Proof. Calculate $\frac{dq}{dw}$ using $w = p(q) + p'(q)q$:

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

Substitute $\frac{dq}{dw}$ and $w = p(q) + p'(q)q$ into the FOC:

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

From U-FOC, substite $w = p(q) + p'(q)q$:

$$N_1 = -q + ([p(q) - c(q)] + [p'(q)\, q - c'(q)\, q]) \frac{1}{2\, p'(q) + p''(q)\, q}$$

$$D_1 = [p(q) - w]\, q = ([p(q) - c(q)] - c'(q)\, q)\, q = \left([p(q) - c(q)]\, q - p'(q)\, q^2\right)$$

$$N_2 = q + (c'(q)\, q - c'(q)\, q) \frac{1}{2\, c'(q) + c''(q)\, q} = q$$

$$D_2 = [w - c(q)]\, q = p'(q)\, q^2$$

After simplifying, plug the terms back into the equation to yield the final form of (D-B-FOC):

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

□

B.3 Proof of Proposition 1 for the Sequential Model

Proposition 1. If the upstream marginal cost is constant, $mc'(q) = 0$, the monopsonistic bargaining problem does not have an interior solution. If the downstream marginal revenue is constant, $mr'(q) = 0$, the monopolistic bargaining problem does not have an interior solution. In all other cases, both the monopolistic and monopsonistic bargaining problems have an interior solution within the ranges of β specified in Appendix D.2.

Proof. Since second-order conditions do not hold in this case, we cannot use first-order conditions to derive an equilibrium pair (w^*, q^*). Therefore, we will directly work with the maximization programs under each bargaining model. We split each problem into multiple cases.

Monopsonistic Bargaining:

The equilibrium (w^*, q^*) maximizes the objective functions in the monopsonistic bargaining.

$$\begin{cases} \max\limits_{q} \pi^u(w^*, q) & (U) \\ \max\limits_{w} \pi^b(w, q^*, \beta) & (B) \end{cases} \quad \text{s.t } \pi^u(w,q) \geq 0 \qquad \pi^d(w,q) \geq 0$$

The subgame-perfect equilibrium $(w^*, q^*(w^*))$ is determined by backward induction. Specifically, for a given w, in the second stage, the upstream firm solves (U), yielding the best-response function $q^*(w)$. In the first stage, anticipating $q^*(w)$, the parties solve (B). Therefore, for any β, $(w^*, q^*(w^*))$ is a subgame-perfect equilibrium if there is no other w such that $\pi^b(w, q^*(w), \beta) > \pi^b(w^*, q^*(w^*), \beta)$, and $q^*(w)$ is indeed the maximizer of (U). We analyze equilibrium under different β values.

Case I: $\beta \in (0, 1)$

If the marginal cost is constant, the equilibria for $\beta \in (0,1)$ in the sequential monopsony model are $w^* > c$ and $q^*(w)$:

$$q^*(w) = \begin{cases} 0, & w < c, \\ p^{-1}(w), & c < w, \\ [0, p^{-1}(w)], & c = w, \end{cases}$$

where $q^*(w)$ is the trivial reaction function of upstream when marginal cost is constant. Now, we must show that any w such that $w \geq c$ is an equilibrium. This follows because $\pi^b = 0$ for any value of w since when $\pi^u = 0$ and $\pi^d = 0$ when $w = c$ and $w > c$, respectively. Therefore, there is no profitable deviation.

Case II: $\beta = 1$

If marginal cost is constant, there are two equilibria for $\beta = 1$ in the sequential monopsony model:

$$q_1^*(w) = \begin{cases} 0, & w < c, \\ p^{-1}(w), & c < w, \\ (0, p^{-1}(w)), & c = w. \end{cases} \quad w_1^* = c \quad \text{and} \quad q_2^*(w) = \begin{cases} 0, & w < c, \\ p^{-1}(w), & c < w, \\ p^{-1}(w), & c = w. \end{cases} \quad w_2^* \geq c$$

(i) Observe that in the first equilibrium $\pi^d(q_1^*, w_1^*) > 0$. This is an equilibrium because any deviation from $w_1^* = c$ to $\tilde{w} > c$ gives the downstream zero profit. Moreover, upstream profit is zero at $w = c$ for any value of q. Therefore, there is a profitable deviation for the upstream.
(ii) At $q_2^*(w)$ the downstream profit is always zero so any w is an equilibrium.

Case III: $\beta = 0$

If marginal cost is constant for $\beta = 0$, thenequilibrium is given by:

$$q_1^*(w) = \begin{cases} 0, & w < c, \\ p^{-1}(w), & c < w, \\ (0, p^{-1}(w)), & c = w. \end{cases} \quad w_1^* = \text{argmax}_w \ (w - c)p^{-1}(w).$$

When $w = c$, upstream profit is zero, which cannot be an equilibrium since $w > c$ leads to positive profit for the upstream. For $w > c$, the best response in the second stage is given by $p^{-1}(w)$, which leads to the profit function $(w - c)p^{-1}(w)$. The equilibrium w maximizes this profit function.

Monopolistic Bargaining:

Equilibrium under monopolistic bargaining is given below. Since the proofs closely follow the proofs of monopsonistic bargaining, they are omitted.

Case I: $\beta \in (0, 1)$

$$q^*(w) = \begin{cases} 0, & p < w, \\ c^{-1}(w), & p > w, \\ [0, c^{-1}(w)], & p = w. \end{cases} \quad w^* < p.$$

Case II: $\beta = 1$

$$q_1^*(w) = \begin{cases} 0, & p < w, \\ c^{-1}(w), & p > w, \\ (0, c^{-1}(w)), & p = w. \end{cases} \qquad w_1^* = p \qquad \text{and} \qquad q_2^*(w) = \begin{cases} 0, & p < w, \\ c^{-1}(w), & p > w, \\ c^{-1}(w), & p = w. \end{cases} \qquad w_2^* \le p.$$

Case II: $\beta = 0$

$$q_1^*(w) = \begin{cases} 0, & p < w, \\ c^{-1}(w), & p > w, \\ (0, c^{-1}(w)]), & p = w. \end{cases} \qquad w_1^* = \text{argmax}_w \ (p - w)c^{-1}(w).$$

Note that for all β values in both monopsonistic and monopolistic bargaining, either the downstream profit or upstream profits are zero. This proves that no interior equilibrium exists.

What's left to show is that if $mc'(q) > 0$, and $mr'(q) < 0$, equilibrium exists for an interior solution within the β ranges specified in the proposition in both monopsonistic and monopolistic bargaining. This result follows from Lemma OA-5. □

B.4 Proof of Lemma 3

Lemma 3: Lemma 1 extends to sequential bargaining models under the additional assumptions that $mc''(q) \ge 0$ and positive markdown $\Delta^d \ge 0$.

Proof. We start by proving $\frac{dq}{d\beta} < 0$. The first-order condition (D-B-FOC) is given by

$$f(\beta, q) = (1-\beta)\left(\frac{1}{c'(q)}\right) + \beta\left(\frac{\overbrace{-q + \left(\overbrace{[p(q) - c(q)] + [p'(q)\,q - c'(q)\,q]}^{B(q)}\right)\overbrace{\frac{dq}{dw}}^{s(q)}}^{N(q)}}{\underbrace{[p(q) - c(q)] - c'(q)\,q}_{D(q)}}\right) = 0.$$

By the Implicit Function Theorem, we have

$$\frac{dq}{d\beta} = -\frac{\frac{\partial f}{\partial \beta}}{\frac{\partial f}{\partial q}} = -\frac{-\frac{1}{c'(q)} + \frac{N(q)}{D(q)}}{(1-\beta)\left(-\frac{c''(q)}{[c'(q)]^2}\right) + \beta\frac{N'(q)D(q) - N(q)D'(q)}{[D(q)]^2}} \tag{OA.5}$$

where we define the following functions:

$$
\begin{aligned}
B(q) &= [p(q) - c(q)] + [p'(q)q - c'(q)q] \\
N(q) &= -q + (B(q))\, s(q) \\
D(q) &= [p(q) - c(q)] - c'(q)q > 0 \\
D'(q) &= p'(q) - 2c'(q) - c''(q)q < 0 \\
B'(q) &= [p'(q) - c'(q)] + [p''(q)q + p'(q)] - [c''(q)q + c'(q)] < 0 \\
s(q) &= \frac{dq}{dw} = \frac{1}{2c'(q) + c''(q)q} > 0 \\
s'(q) &= -\frac{3c''(q) + c'''(q)q}{(2c'(q) + c''(q)q)^2} < 0
\end{aligned}
$$

The function $s(q)$ is positive by our assumptions on the cost function. From $p'(q) \leq 0$, we deduce $D'(q) < 0$. Next, $B'(q)$ is negative since our assumptions on cost and revenue are such that $p'(q) - c(q) \leq 0$ and the remaining terms sum to a value strictly less than zero as a result of Properties 1 and 2. Furthermore, $s'(q)$ is negative since we assumed $mc''(q) \geq 0$. Finally, $D(q) > 0$ because $D(q) = p(q) - w$ with $w = c'(q)\, q + c(q)$, and the participation constraint ensures that $p(q) \geq w$. Now, observe that the (U-B-FOC) can be written as

$$
f(\beta, q) = (1-\beta)\left(\frac{1}{c'(q)}\right) + \beta\left(\frac{N(q)}{D(q)}\right) = 0 \tag{OA.6}
$$

Using this equation, we can solve for $N(q)/D(q)$ as follows:

$$
\frac{N(q)}{D(q)} = -\frac{1-\beta}{\beta}\frac{1}{c'(q)}.
$$

Substituting this equation into $\frac{\partial f}{\partial \beta}$ in Equation (OA.5), we obtain:

$$
\frac{\partial f}{\partial \beta} = -\frac{1}{c'(q)} + \frac{N(q)}{D(q)} = -\frac{1}{\beta c'(q)}
$$

Substituting this equation, $\frac{dq}{d\beta}$ now becomes:

$$
\frac{dq}{d\beta} = -\frac{-\frac{1}{\beta c'(q)}}{(1-\beta)\left(-\frac{c''(q)}{[c'(q)]^2}\right) + \beta\frac{N'(q)D(q) - N(q)D'(q)}{[D(q)]^2}}.
$$

Further manipulating this equation, and using the signs that we identified above, we obtain:

$$\frac{dq}{d\beta} = -\frac{\frac{\partial f}{\partial \beta}}{\frac{\partial f}{\partial q}} = -\frac{\overbrace{-\frac{1}{\beta c'(q)}}^{(-)}}{\underbrace{(1-\beta)\left(-\frac{c''(q)}{[c'(q)]^2}\right)}_{(-)} + \beta\frac{N'(q)}{D(q)} - \beta\underbrace{\frac{N(q)}{D(q)}}_{(-)}\underbrace{\frac{D'(q)}{D(q)}}_{(-)}}.$$

The only remaining term is $N'(q)/D(q)$. We already know that $D(q) > 0$, so this sign depends on the sign of $N'(q)$, which is written as

$$N'(q) = -q + B'(q)s(q) + B(q)s'(q).$$

Since $s(q) > 0$ and $B'(q) < 0$, the second term is negative. Since $s'(q) < 0$, we need to show that $B(q) > 0$ to prove that $N'(q) < 0$. $B(q)$ can be written as

$$B(q) = [p(q) - c(q)] + [p'(q)q - c'(q)q].$$

From (U-FOC), we have $w = c'(q)(q) + c(q)$, so we can write $B(q)$ as

$$B(q) = (p(q) - p'(q)q - w) = mr(q) - w.$$

By our assumption that $(mr(q) - w) > 0$, we have $B(q) > 0$ and $N'(q) < 0$. This implies that $\frac{dq}{d\beta} < 0$. The proof of $d\Delta^d/d\beta > 0$ is identical to the proof of Lemma 1 and is therefore omitted.

□

B.5 Proof of Lemma 4

Lemma 4: Lemma 2 extends to sequential bargaining models under the additional assumptions that $mr''(q) \leq 0$ and positive upstream markup $\mu^u \geq 0$.

Proof. Note that (D-B-FOC) can be written as

$$f(\beta, q) = \beta\left(\frac{1}{p'(q)}\right) + (1-\beta)\left(\frac{q + (p(q) - c(q) + p'(q)q - c'(q)q)\cdot\frac{1}{2p'(q) + p''(q)q}}{[p(q) - c(q) + p'(q)q]}\right) = 0$$

By the Implicit Function Theorem,

$$\frac{dq}{d\beta} = -\frac{\frac{\partial f}{\partial \beta}}{\frac{\partial f}{\partial q}} = -\frac{\frac{1}{p'(q)} - \frac{N(q)}{D(q)}}{\beta\left(-\frac{p''(q)}{[p'(q)]^2}\right) + (1-\beta)\frac{N'(q)D(q)-N(q)D'(q)}{[D(q)]^2}}, \tag{OA.7}$$

where the preceding functions are defined as:

$$\begin{aligned}
B(q) &= [p(q) - c(q)] + [p'(q)q - c'(q)q] \\
N(q) &= q + (B(q))\, s(q) \\
D(q) &= [p(q) - c(q)] - p'(q)q < 0 \\
D'(q) &= c'(q) - 2p'(q) - p''(q)q > 0 \\
N'(q) &= 1 + B'(q)s(q) + B(q)s'(q) \\
B'(q) &= 2[p'(q) - c'(q)] + q[p''(q) - c''(q)] < 0 \\
s(q) &= \frac{dq}{dw} = \frac{1}{2p'(q) + p''(q)q} < 0 \\
s'(q) &= -\frac{3p''(q) + qp'''(q)}{(2p'(q) + qp''(q))^2} > 0
\end{aligned}$$

The quantity $D(q)$ is negative because $w = p'(q)\,q + p(q)$, so $D(q) = w - c(q)$, and the participation constraint ensures that $D(q) < 0$. Next, $D'(q)$ is non-negative since $c'(q) \geq 0$ and $(2\,p'(q) + p''(q)\,q) < 0$ by our assumption on marginal revenue. Furthermore, $B'(q)$ is negative because $(2\,c'(q) + c''(q)\,q) > 0$ while $(2\,p'(q) + p''(q)\,q) < 0$. We also have $s(q) < 0$ and $s'(q) > 0$ by our assumption on marginal revenue and that $mr''(q) \leq 0$.

Now, observe that the (U-B-FOC) can be written as

$$f(\beta, q) = \beta\left(\frac{1}{p'(q)}\right) + (1-\beta)\left(\frac{N(q)}{D(q)}\right) = 0 \tag{OA.8}$$

Using this, we can solve for $N(q)/D(q)$ as follows:

$$\frac{N(q)}{D(q)} = -\frac{\beta}{1-\beta}\frac{1}{p'(q)}$$

Substituting this equation into $\frac{\partial f}{\partial \beta}$ in Equation (OA.5) we obtain

$$\frac{\partial f}{\partial \beta} = \frac{1}{p'(q)} - \frac{N(q)}{D(q)} = \frac{1}{(1-\beta)p'(q)}$$

Substituting this equation, $\frac{dq}{d\beta}$ now becomes

$$\frac{dq}{d\beta} = -\frac{\frac{1}{(1-\beta)p'(q)}}{\beta\left(-\frac{p''(q)}{[p'(q)]^2}\right) + (1-\beta)\frac{N'(q)D(q)-N(q)D'(q)}{[D(q)]^2}}$$

Rewriting the above, we have

$$\frac{dq}{d\beta} = -\frac{\frac{\partial f}{\partial \beta}}{\frac{\partial f}{\partial q}} = -\frac{\overbrace{\frac{1}{(1-\beta)p'(q)}}^{(-)}}{\underbrace{\beta\left(-\frac{p''(q)}{[p'(q)]^2}\right)}_{(+)} + \beta\frac{N'(q)}{D(q)} - \beta\underbrace{\frac{N(q)}{D(q)}}_{(+)}\underbrace{\frac{D'(q)}{D(q)}}_{(-)}}$$

We have left to determine the sign of $N'(q)/D(q)$. We already know that $D(q) < 0$, so this sign depends on the sign of $N'(q)$, which is written as

$$N'(q) = 1 + B'(q)s(q) + B(q)s'(q)$$

Since $s(q) < 0$ and $B'(q) < 0$, the second term is positive. Since $s'(q) > 0$, we need to show that $B(q) > 0$ to prove that $N'(q) > 0$. $B(q)$ is written as

$$B(q) = [p(q) - c(q)] + [p'(q)q - c'(q)q]$$

From (D-FOC), we have $w = p'(q)(q) + p(q)$, so we can write $B(q)$ as

$$B(q) = (p(q) - p'(q)q - w) = w - mc(q)$$

By our assumption, $(w - mc(q)) > 0$, so $B(q) > 0$ and $N'(q) > 0$. Therefore, $\frac{dq}{d\beta} > 0$. The proof of $\frac{d}{d\beta}\mu^u < 0$ is identical to the proof in Lemma 2 and is therefore omitted. □

B.6 Proof of Proposition 2 for the Sequential Model

Proposition 2. There exists a bargaining parameter $\beta^* = \dfrac{-p'(q^*)}{c'(q^*) - p'(q^*)} \in (0, 1)$ at which the monopsonistic bargaining model, the monopolistic bargaining model, and the joint-profit-maximization models imply an identical equilibrium output in both simultaneous and sequential models. We denote β^* as the '"efficient level of buyer power."

Proof. For monopsonistic conduct, substituting (J-FOC) into monopsony FOC

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

we obtain:

$$\frac{\beta}{p'(q)}+\frac{1-\beta}{c'(q)}=0.$$

This equation holds at $\beta=\dfrac{-p'(q)}{c'(q)-p'(q)}$, which concludes the proof for monopsonistic bargaining.

For monopsonistic conduct, substitutin(J-FOC) into monopsony FOC,

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

we obtain

$$\frac{\beta}{qp'(q)}+\frac{1-\beta}{c'(q)q}=0.$$

This equation holds at $\beta=\dfrac{-p'(q)}{c'(q)-p'(q)}$, which concludes the proof for monopolistic bargaining. □

C Proofs of Other Results

C.1 Proof of Corollary 1

Corollary 1: Under monopolistic bargaining, downstream markdown is always zero, so the buyer has no monopsony power. Under monopsonistic bargaining, upstream markup is always zero, so the seller has no monopoly power.

Proof. $\mu^p = 0$ follows immediately from the FOC of the monopsonistic bargaining problem, which implies that $w(q) = mc(q)$. $\mu^w = 0$ follows immediately from the FOC of the monopolistic bargaining problem, which implies that $w(q) = mr(q)$.

□

C.2 Proof of Corollary 2

Corollary 2. The efficient level of buyer power β^* weakly decreases with the elasticity of upstream marginal costs and decreases with the elasticity of downstream demand.

Proof. Given that $-p'(q^*) \geq 0$, an increase in $c'(q^*)$ weakly increases the denominator of β^* so β^* is weakly decreasing with $c'(q^*)$. Observe that $1/\beta^* = 1 - c'(q^*)/p'(q^*)$. Since $c'(q^*)/p'(q^*) \leq 0$, $1/\beta^*$ is weakly decreasing with $p'(q^*)$, which implies that β^* is weakly increasing with $p'(q^*)$. □

C.3 Proof of Corollary 3

Corollary 3. If upstream marginal costs are constant, the efficient level of buyer power is one ($\beta^* = 1$). If downstream demand is fully elastic, the efficient level of buyer power is zero ($\beta^* = 0$).

Proof. This immediately follows from substituting $c'(q^*) = 0$ into $\beta^* = \frac{-p'(q^*)}{c'(q^*)-p'(q^*)}$ and from substituting $p'(q^*) = 0$ into $\beta^* = \frac{-p'(q^*)}{c'(q^*)-p'(q^*)}$. □

C.4 Proof of Proposition 3

Proposition 3: Consumer surplus is maximized at $\beta = 1$ under monopolistic conduct, and at $\beta = 0$ under monopsonistic conduct.

Proof. First, consider monopolistic conduct. As is proven in Appendices D.1.5 and D.1.1, at $\beta = 1$ we have that $w(\beta = 1) = c(q(\beta = 1)) = mr(q(\beta = 1))$. Achieving any $\tilde{q} > q(\beta = 1)$ requires a wholesale price $\tilde{w} < c(\tilde{q})$. This leads to negative profits of upstream, and hence, violates the participation constraint for upstream.

Second, consider monopsonistic conduct. As is proven in Appendices D.1.7 and D.1.3, at $\beta = 0$ we have that $p(\beta = 0) = mc(q(\beta = 0)) = w(\beta = 0)$. Achieving any $\tilde{q} > q(\beta = 0)$ requires a wholesale price $\tilde{p} < w(\tilde{q})$. This leads to negative profits of downstream, and hence, violates the participation constraint for downstream. □

C.5 Proof of Proposition 4

Proposition 4: Total surplus is maximized at $\beta^\dagger$, with $\beta^* \leq \beta^\dagger \leq 1$ under monopolistic bargaining, and $\beta^\dagger = 0$ under monopsonistic bargaining.

Proof. Total welfare is maximized if prices are equal to marginal costs. Let $q^\dagger$ be the total-welfare maximizing output level:

$$p(q^\dagger) = mc(q^\dagger).$$

First, consider monopsonistic bargaining. As shown in Appendix D.1.4, $\beta = 0$ results in the condition $p = mc$. This is the first-best any planner could achieve, so total welfare is maximized at this point. Second, consider monopolistic bargaining. At $\beta = \beta^*$, $mr(q^*) = mc(q^*)$. Given that prices are set by downstream at a markup above marginal costs, this implies that $p > mc$ at the joint-profit-maximization level of buyer power β^*:

$$p(\beta = \beta^*) = mc(q^*) + \mu(q^*).$$

As is proven in Appendix D.1.1, at $\beta = 1$ we have that $mr(q(\beta = 1)) = c(q(\beta = 1))$. Hence, prices are above average costs:

$$p(q(\beta = 1)) = c(q(\beta = 1)) + \mu(q(\beta = 1)).$$

Let $b(q(\beta = 1)) = mc(q(\beta = 1)) - c(q(\beta = 1))$. It follows that there are three possibilities:

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

First, if $b(q(\beta = 1)) = \mu(q(\beta = 1))$, $\beta = 1$ maximizes total welfare and leads to the first-best solution $p(q(\beta = 1)) = mc(q(\beta = 1))$. Second, if $b(q(\beta = 1)) < \mu(q(\beta = 1))$, prices are still too high at $\beta = 1$, as $p(q(\beta = 1)) > mc(q(\beta = 1))$. However, given that $\beta = 1$ is the highest possible value of β, welfare is maximized at this value. Third, if $b(q(\beta = 1)) > \mu(q(\beta = 1))$, 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, this implies that total welfare is maximized at $\beta^* < \beta < 1$.

□

C.6 Proof of Theorem 1

Theorem 1. Under Participation Constraint 1, for any β, either the monopsonistic or the monopolistic bargaining equilibrium exists, but not both. Specifically, the monopsonistic equilibrium exists if $\beta \geq \beta^*$, while the monopolistic equilibrium exists if $\beta \leq \beta^*$.

Proof. First, consider the monopsonistic bargaining model. It follows from U-FOC that $w = mc(q)$, so the restriction $w \geq mc(q)$ is satisfied at any β. At $\beta = \beta^*$, the monopsonistic bargaining model equates joint profit maximization, so $mc(q(\beta^*)) = mr(q(\beta^*))$. Hence, $w(\beta^*) = mr(q(\beta^*))$.

Consider $\beta = \beta^* - \epsilon$, for $\epsilon > 0$. Given that $\frac{\partial q}{\partial \beta} < 0$, that $mc'(q) > 0$, and that $w(q) = mc(q)$, it follows that $\frac{\partial w}{\partial \beta} < 0$. This implies that $w(\beta^* - \epsilon) > mr(q(\beta^*)$.

From Lemma 1, $q(\beta^* - \epsilon) > q(\beta^*)$. Given Property 2, $mr'(q) < 0$, then $mr(q(\beta^* - \epsilon)) < mr(q(\beta^*))$. It follows that

$$w(\beta^* - \epsilon) > mr(q(\beta^* - \epsilon)).$$

Hence, the wholesale price markdown is negative (wage is above marginal revenue product of downstream) in the monopsonistic bargaining model if $\beta < \beta^*$.

Analogously, it follows straightforwardly that markdowns are positive for values of $\beta > \beta^*$ in the monopsonistic model:

$$w(\beta^* + \epsilon) < mr(q(\beta^* + \epsilon)).$$

Second, consider the monopolistic bargaining model. The restriction $w \leq mr(q)$ is always satisfied under monopolistic conduct, because D-FOC implies that $w = mr(q)$. Consider a $\beta = \beta^* + \epsilon$, for $\epsilon > 0$.

Following the same logic as above, at $\beta = \beta^*$, we have $w(\beta^*) = mc(q(\beta^*))$. Given that $\frac{\partial w}{\partial \beta} < 0$, it follows that $w(\beta^* + \epsilon) < mc(q(\beta^*))$.

Lemma 2 implies that $q(\beta^* + \epsilon) > q(\beta^*)$. Increasing marginal costs imply that $mc(q(\beta^* + \epsilon) > mc(q(\beta^*))$. It follows that

$$w(\beta^* + \epsilon) < mc(q(\beta^* + \epsilon)).$$

Hence, seller markups are negative in the monopolistic bargaining model if $\beta > \beta^*$.

Again, it is straightforward to repeat the same argument to show that markups are positive as soon as $\beta < \beta^*$ in the monopolistic bargaining model:

$$w(\beta^* - \epsilon) > mc(q(\beta^* - \epsilon))$$

□

C.7 Proof of Corollary 4

Corollary 4. An increase in buyer power β lowers output if $\beta > \beta^*$ but increases output if $\beta < \beta^*$ in both simultaneous and sequential models.

Proof. This follows immediately from Theorem 1, Lemmas 2 and 4, and Lemmas 1 and 3. □

C.8 Proof of Proposition 5

Proposition 5. The restrictions $\mu^u \geq 0$ and $\Delta^d \geq 0$ ensure that equilibrium output is always smaller than or equal to the efficient-bargaining output level q^*.

Proof. First, suppose $q > q^*$ and monopsonistic conduct applies. Given Lemma 1, this holds if and only if $w(q) > w(q^*)$. The first-order condition for joint profit maximization implies that $w(q^*) = mr(q^*)$, hence $w(q) > mr(q^*)$. Under the assumption that property 2 holds, this implies that $mr'(q) < 0$, so $w(q) > mr(q)$. Hence, the markdown is negative for any value of $q > q^*$ under monopsonistic conduct.

Second, suppose $q > q^*$ and monopolistic conduct applies. Given Lemma 2, this holds if and only if $w(q) < w(q^*)$. The first-order condition for joint profit maximization implies that $w(q^*) = mc(q^*)$. Given assumption 1, $mc'(q) > 0$, which means that $w(q) < mc(q)$. Hence, the supplier markup is negative for any $q > q^*$ under monopolistic conduct. □

C.9 Proof of Theorem 2

Theorem 2. Under Participation Constraint 2, for any β, either the monopsonistic or the monopolistic bargaining equilibrium exists, but not both. Specifically, the monopsonistic equilibrium exists if $\beta \geq \beta^*$, while the monopolistic equilibrium exists if $\beta \leq \beta^*$.

Proof. Suppose $\beta < \beta^*$ and consider the case of monopsonistic conduct where U chooses output. From Theorem 1, this implies that $\beta < \beta^* \Leftrightarrow w(\beta) < mc(\beta)$. Hence, upstream profits decrease in output for $\beta < \beta^*$ in the monopsonistic model:

$$\frac{\partial \pi_u^{ms}}{\partial q} < 0 \Leftrightarrow \beta < \beta^*$$

Given Lemma 1, this equation can be rewritten as

$$\frac{\partial \pi_u^{ms}}{\partial \beta} > 0 \Leftrightarrow \beta < \beta^*.$$

At $\beta = \beta^*$, firms maximize joint profits, so upstream receives a profit π_u^j. It follows that

$$\pi_u^{ms} < \pi_u^j \Leftrightarrow \beta < \beta^*.$$

Alternatively, suppose $\beta > \beta^*$ and D chooses output, which is the monopolistic conduct case. Similar to the reasoning above, Theorem 1 implies that $w(\beta) > mr(\beta)$ in this case. Hence, buyer profits increase if output falls:

$$\frac{\partial \pi_d^{mp}}{\partial q} < 0 \Leftrightarrow \beta > \beta^*$$

$$\frac{\partial \pi_d^{mp}}{\partial \beta} < 0 \Leftrightarrow \beta > \beta^*$$

At $\beta = \beta^*$, downstream obtains the joint-profit-maximization profit π_d^j. It follows that

$$\pi_d^{mp} < \pi_d^j \Leftrightarrow \beta > \beta^*$$

□

C.10 Proof of Proposition 6

Proposition 6: Under either conduct selection criteria from Participation Constraint 1 or Participation Constraint 2, both consumer surplus and total surplus are maximized at the efficient level of buyer power β^*.

Proof. As was proven in C.4, consumer surplus is monotonically increasing in output. Proposition 5 states that under our conduct selection criteria, output is maximized at $\beta = \beta^*$. Hence, consumer surplus is maximized at $\beta = \beta^*$.

Turning to total surplus, Proposition 4 states that under monopolistic competition, the bargaining parameter $\beta^\dagger$ that maximizes total surplus satisfies

$$\beta^\dagger \in (\beta^*, 1).$$

However, Theorems 1 and 2 rule out that any $\beta > \beta^*$ can be an equilibrium under monopolistic conduct. Hence, $\beta^\dagger = \beta^*$ under monopolistic conduct.

Similarly, Proposition 4 states that under monopsonistic competition, it holds that

$$\beta^\dagger \in (0, \beta^*)$$

Again, Theorems 1 and 2 rule out that any $\beta < \beta^*$ can be an equilibrium under monopsonistic conduct. Hence, $\beta^\dagger = \beta^*$ under monopsonistic conduct. It follows that $\beta^\dagger = \beta^*$ under both monopolistic and monopsonistic conduct, so total surplus is maximized at β^*. □

D Other Theory Results

D.1 Limit Cases for β

We solve each version of the model (monopolistic-monopsonistic and simultaneous-sequential) 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 stated in the main text. These results are summarized in Table OA-1.

The most important takeaways from this appendix are that (i) the sequential monopsony has a solution at $\beta = 0$ using the constrained optimization problem but not using the FOCs, and (ii) the sequential monopoly model has a solution at $\beta = 1$ using the constrained optimization problem, but not using the FOCs. Hence, the participation constraints $\pi^d \geq 0$ and $\pi^u \geq 0$ are only binding in these two instances.

D.1.1 Simultaneous Monopoly, $\beta = 1$

We solve the constrained optimization problem faced by downstream:

$$\begin{cases} \max_q \pi^d(w, q) \\ \max_w \pi^d(w, q) \ \text{ s.t } \ \pi^u(w, q) \geq 0. \end{cases}$$

In this scenario, the downstream makes a TIOLI offer to the upstream, which results in the wholesale price being set equal to the upstream's average cost:

$$\max_{w,q} \pi^d(w, q) \qquad \Rightarrow \qquad \text{mr}(q) = c(q), \quad w = c(q).$$

This corner solution is identical to the solution obtained from the FOC:

$$c(q) = p'(q)q + p(q) \qquad \Rightarrow \qquad \text{mr}(q) = c(q), \ \ w = c(q).$$

D.1.2 Simultaneous Monopoly, $\beta = 0$

We solve the constrained optimization problem faced by downstream:

$$\begin{cases} \max_q \pi^d(w, q) \\ \max_w \pi^u(w, q) \ \text{ s.t } \ \pi^u(w, q) \geq 0. \end{cases}$$

This yields no solution:

$$\max_q \pi^d(w, q), \ \max_w \pi^u(w, q) \qquad \Rightarrow \qquad w = p(q), \ \text{mr}(q) = p(q)$$

Working out the first-order conditions does not yield a solution either:

$$p(q) = p'(q)q + p(q) \qquad \Rightarrow \qquad w = p(q),\ \text{mr}(q) = p(q)$$

D.1.3 *Simultaneous Monopsony, $\beta = 1$*

$$\begin{cases} \max_q \pi^u(w, q) \\ \max_w \pi^d(w, q) \ \text{ s.t } \ \pi^u(w, q) \geq 0. \end{cases}$$

The constrained profit-maximization problem yields no solution:

$$\max_q \pi^u(w, q),\ \max_w \pi^d(w, q) \qquad \Rightarrow \qquad w = c(q),\ \text{mc}(q) = w$$

The FOCs don't yield a solution either:

$$c(q) = c'(q)q + c(q) \qquad \Rightarrow \qquad w = c(q),\ \text{mc}(q) = c(q)$$

D.1.4 *Simultaneous Monopsony, $\beta = 0$*

$$\begin{cases} \max_q \pi^u(w, q) \\ \max_w \pi^u(w, q) \ \text{ s.t } \ \pi^d(w, q) \geq 0. \end{cases}$$

Solving the constrained profit-maximization problem implies a TIOLI offer being made by upstream, which results in the wholesale price being set equal to the downstream price:

$$\max_q \pi^u(w, q),\ \max_w \pi^d(w, q) \qquad \Rightarrow \qquad w = p(q),\ \text{mc}(q) = p(q)$$

The FOC results in the same condition:

$$p(q) = c'(q)q + c(q) \qquad \Rightarrow \qquad w = p(q),\ \text{mc}(q) = p(q)$$

D.1.5 *Sequential Monopoly, $\beta = 1$*

$$\begin{cases} \max_q \pi^d(w, q) \\ \max_w \pi^d(w, q) \ \text{ s.t } \ \pi^u(w, q) \geq 0. \end{cases}$$

The solution based on constrained profit-maximization is

$$\max_{w,q} \pi^d(w,q) \qquad \Rightarrow \qquad \mathrm{mr}(q) = c(q),\ w = c(q)$$

Using the FOCs does not yield a solution:

$$c(q) = p'(q)q + p(q) \qquad \Rightarrow \qquad \mathrm{mr}(q) = w,\ 1/(p'(q)q) = 0$$

D.1.6 Sequential Monopoly, $\beta = 0$

$$\begin{cases} \max_q \pi^d(w,q) \\ \max_w \pi^u(w,q) \ \text{ s.t } \ \pi^d(w,q) \geq 0. \end{cases}$$

The solution based on constrained profit-maximization is full double marginalization:

$$\max_q \pi^d(w,q),\ \max_w \pi^u(w,q) \qquad \Rightarrow \qquad \mathrm{mr}(q) = w$$

The FOC results in the same condition:

$$c(q) = p'(q)q + p(q) \qquad \Rightarrow \qquad \mathrm{mr}(q) = w$$

D.1.7 Sequential Monopsony, $\beta = 1$

$$\begin{cases} \max_q \pi^u(w,q) \\ \max_w \pi^d(w,q) \ \text{ s.t } \ \pi^u(w,q) \geq 0. \end{cases}$$

The solution based on constrained profit-maximization is the classical monopsony outcome:

$$\max_q \pi^u(w,q),\ \max_w \pi^u(w,q) \qquad \Rightarrow \qquad w = mc(q)$$

The FOC results in the same condition:

$$c(q) = p'(q)q + p(q) \qquad \Rightarrow \qquad \mathrm{mc}(q) = w$$

D.1.8 Sequential Monopsony, $\beta = 0$

$$\begin{cases} \max_q \pi^u(w,q) \\ \max_w \pi^u(w,q) \ \text{ s.t } \ \pi^d(w,q) \geq 0. \end{cases}$$

The solution based on constrained profit maximization is a TIOLI offer by upstream, which results in $mc(q) = p(q)$:

$$\max_q \pi^u(w, q),\ \max_w \pi^u(w, q) \qquad \Rightarrow \qquad w = p(q),\ mc(q) = p(q)$$

The first-order condition does not yield a solution:

$$c(q) = p'(q)q + p(q) \qquad \Rightarrow \qquad \mathrm{mc}(q) = w,\ 1/(s'(q)q) = 0$$

D.2 Auxiliary Lemmas on Equilibrium Existence

In this appendix, we discuss the existence and unicity of the monopolistic and monopsonistic equilibrium in both the simultaneous and sequential bargaining models.

D.2.1 Equilibrium Existence in the Simultaneous Model

In Lemmas OA-1 and OA-2, we find that in the simultaneous bargaining model, the monopsonistic and monopolistic equilibria both exist and are unique for a different range of buyer power values.

Lemma OA-1. *Assume that $mc'(q) > 0$. In the simultaneous monopsony model, equilibrium exists and is unique in the following β range:*

$$\beta \in [0, 1 - \lim_{q \to 0^+} s(q))$$

where $s(q) = \frac{c'(q)q}{p(q)-c(q)}$ which is bounded below by 0.

Proof. In the simultaneous monopsony model, combining (U-FOC) and (B-FOC) gives

$$1 - \beta = \frac{c'(q)q}{p(q) - c(q)} \tag{OA.9}$$

So, β can take any value in support of $s(q)$. Note that $s(q) > 0$ because $p(q) - c(q) > 0$ and $c'(q) > 0$. Since $c'(q) > 0$ and $p(q) - c(q)$ is decreasing with q, the $\min_q s(q) = \lim_{q \to 0^+} s(q)$. Therefore, the maximum value β could take in the monopsony model is

$$1 - \lim_{q \to 0^+} s(q)$$

Similarly since $c'(q) > 0$ and $q > 0$ and there exists $\bar{q}$ such that $p(q) = c(q)$, $s(q)$ can be arbitrarily large $\max_q s(q) > 1$. Combining these two observations derives the bound for β

$$\beta \in [0, 1 - \lim_{q \to 0^+} s(q))$$

Moreover, since $s(q)$ is a continuous function, there exists q that satisfies Equation (OA.9) for all β in the range given above. This proves the existence of equilibrium for all β values.

□

Lemma OA-2. *Assume that $mr'(q) < 0$. In the simultaneous monopoly model, equilibrium exists only in the following β range:*

$$\beta \in (\lim_{q \to 0^+} s(q), 1]$$

where $s(q) = \frac{p'(q)\, q}{p(q) - c(q)}$. This interval does not include 0.

Proof. In the simultaneous monopoly model, combining (D-FOC) and (B-FOC) gives

$$\beta = -\frac{p'(q)\, q}{p(q) - c(q)} \tag{OA.10}$$

So, β can take any value in support of $s(q)$. Note that $s(q) > 0$ because $p(q) - c(q) \geq 0$ and $p'(q) \leq 0$. Since $p'(q) \leq 0$ and $p(q) - c(q)$ is decreasing with q, the $\min_q s(q) = \lim_{q \to 0^+} s(q)$. Therefore, the maximum value β could take in the monopoly model is

$$\lim_{q \to 0^+} s(q)$$

Similarly since $p'(q) \leq 0$ and $q > 0$ and there exists $\bar{q}$ such that $p(\bar{q}) = c(\bar{q})$, $s(q)$ can be arbitrarily large, which impies that $\max_q s(q) > 1$. Combining these two observations derives the bound for β

$$\beta \in (\lim_{q \to 0^+} s(q), 1]$$

Moreover, since $s(q)$ is a continuous function, there exists q that satisfies Equation (OA.10) for all β in the range given above. This proves the existence of equilibrium for all β values. □

D.2.2 Equilibrium Existence in the Sequential Model

Lemma OA-3. *The solution to the sequential monopoly model, characterized by its FOCs approaches as $\beta \to 1$ to the solution of the constraint-optimization problem at $\beta = 1$.*

Proof. Define

$$A(q) \equiv \frac{1}{p'(q)} \quad \text{and} \quad B(q) \equiv \frac{N(q)}{D(q)} = \frac{q + [\, p(q) - c(q) + p'(q)\, q - c'(q)\, q\,]\, \frac{1}{2\,p'(q) + p''(q)\, q}}{\underbrace{p(q) - c(q) + p'(q)\, q}_{D(q)}}.$$

The equation of interest 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 $\pm\infty$ (unless $p'(q) = \infty$, which we rule out). Thus, $B(q)$ must also become unbounded in magnitude. If the nominator of $B(q)$ is finite, the denominator of $B(q)$ must vanish. Since

$$B(q) \;=\; \frac{N(q)}{D(q)} \quad \text{with} \quad D(q) \;=\; p(q) - c(q) \;+\; q\, p'(q),$$

the only way $B(q)$ goes to infinity is if $D(q)$ vanishes. Hence, as $\beta \to 1$, we have

$$p(q) \;-\; c(q) \;+\; q\, p'(q) \;=\; 0,$$

which corresponds to the solution given in the constraint-optimization problem. □

Lemma OA-4. *The solution to the sequential monopsony model, characterized by its FOCs approaches as $\beta \to 0$ to the solution of the constraint-optimization problem at $\beta = 0$.*

Proof. Define

$$A(q) \;=\; \frac{1}{c'(q)} \quad \text{and} \quad B(q) \;=\; \frac{N(q)}{D(q)} \;=\; \frac{-\,q \;+\; \Big([p(q) - c(q)] \;+\; [\,p'(q)\, q - c'(q)\, q\,]\, \frac{1}{2\, c'(q) + c''(q)\, q}\Big)}{\underbrace{p(q) \;-\; c(q) \;-\; c'(q)\, q}_{D(q)}}.$$

The equation of interest is

$$(1-\beta)\, A(q) \;+\; \beta\, B(q) \;=\; 0.$$

Rewrite β as ε. Then, the equation becomes

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

As $\varepsilon \to 0$ (i.e., $\beta \to 0$), the multiplier $\frac{\varepsilon}{1-\varepsilon}$ tends to 0. If $A(q) \neq 0$ is finite, we must have $B(q)$ become unbounded (go to $\pm\infty$) in order to satisfy the above equality. This implies that as $\beta \to 0$, we have

$$p(q) - c(q) - q\, c'(q) = 0,$$

which corresponds to the solution given in the constraint-optimization problem. □

Lemma OA-5. *If $mc'(q) > 0$ and $mr'(q) < 0$ for both sequential monopolistic and monopsonistic bargaining problems, there exists a solution for $\beta \in [0, 1]$. The solution is interior for $\beta \in (0, 1)$.*

Proof. For the monopsony model, we show in Section D.1.7 that the solution to the sequential monopsony model exists for $\beta = 1$, and this solution coincides with the solution given by FOCs. Moreover, in Section D.1.8 we show that the solution to the sequential monopsony model exists for $\beta = 0$. Lemma OA-4 shows that the solution from FOC as $\beta \to 0$ corresponds to the solution obtained in Section D.1.8. Therefore, the solution to FOC converges to the corner cases of $\beta = 0$ and $\beta = 1$. The continuity of the FOCs implies that the solution exists for any $\beta \in (0, 1)$. Since this solution is given by the FOC, it is in the interior.

For the monopoly model, we show in Section D.1.6 that the solution to the sequential monopoly model exists for $\beta = 0$, and this solution coincides with the solution given by FOCs. Moreover, in Section D.1.5 we show that the solution to the sequential monopoly model exists for $\beta = 1$. Lemma OA-3 shows that the solution from FOC as $\beta \to 1$ corresponds to the solution obtained in Section D.1.5. Therefore, the solution to FOC converges to the corner cases of $\beta = 0$ and $\beta = 1$. The continuity of FOCs implies that the solution exists for any $\beta \in (0, 1)$. Since this solution is given by the FOC, it is in the interior. □

D.3 Auxiliary Lemma on Cost and Revenue Functions

Lemma OA-6. *The condition $c''(q)q + c'(q) > 0$ is equivalent to $\frac{\partial(mc(q)-c(q))}{\partial q} > 0$. The condition $p''(q)q + p'(q) < 0$ is equivalent to $\frac{\partial(mr(q)-p(q))}{\partial q} < 0$*

Proof. Consider the term $c''(q)q + c'(q)$:

$$c''(q)q + c'(q) = \frac{\partial\big(c'(q)q\big)}{\partial q}.$$

Given $c(q) = C(q)/q$. We can write $c'(q)q$ as

$$\begin{aligned} c'(q)q &= \frac{C'(q)q - C(q)}{q^2}q \\ &= C'(q) - \frac{C(q)}{q} \\ &= \text{M.cost} - \text{Avg.cost}. \end{aligned}$$

So, $c''(q)q + c'(q) > 0$ corresponds to the condition that the difference between marginal and average costs increases with q. Since $c'(q) \geq 0$, $c''(q)q + c'(q) > 0$ implies that $mc(q)$ is increasing with q.

Next, consider the term $p''(q)q + p'(q)$:

$$p''(q)q + p'(q) = \frac{\partial\big(p'(q)q\big)}{\partial q}.$$

The difference between marginal and average revenue is

$$\frac{\partial(p(q)q)}{\partial q} - p = p'(q)q + p(q) - p(q) = p'(q)q.$$

Hence, if $p''(q)q + p'(q) < 0$, this implies that the difference between marginal and average revenue decreases with q. Since $p'(q) \leq 0$, $p''(q)q + p'(q) < 0$ implies that $mr(q)$ is decreasing with q. □

D.4 Loglinear Version of the Model

We solve the simultaneous bargaining model with log-linear costs and demand:

$$c(q) = \frac{1}{1+\psi} q^{\psi} \tag{OA.11}$$

$$p(q) = q^{\frac{1}{\eta}} \tag{OA.12}$$

Solving the first-order condition for output in the monoponistic conduct case (U-FOC) results in the factor supply curve $w = q^{\psi}$. Solving the first-order condition for output in the monopolistic conduct case (D-FOC) 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 problem (B-FOC) and setting it equal to the monopsonistic and monopolistic cases to find the intersection of the two output-buyer power curves results in the output-maximizing bargaining parameter

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

Equilibrium existence under monopolistic bargaining

Solving the first-order conditions for the monopolistic bargaining problem, $q(\beta)$, is given by

$$q^{mpl} = (\frac{\psi+1}{\beta\eta}) + 1 + \psi)^{\frac{1}{\psi - \frac{1}{\eta}}}.$$

Given that $\psi - \frac{1}{\eta} = \frac{5}{12} < 1$ in our numerical example, equilibrium existence requires

$$(\frac{\psi+1}{\beta\eta}) + 1 + \psi > 0.$$

Hence, it must hold that

$$\beta > \frac{-1}{\eta}.$$

In our numerical example, this condition is satisfied for $\beta > \frac{1}{6}$, so the monopolistic equilibrium is defined only for this range of bargaining parameters.

Equilibrium existence under monopsonistic bargaining

Solving the FOCs of the monopsonistic bargaining model delivers the following $\beta(q)$ relationship:

$$\beta = \frac{q^{\psi} - q^{\frac{1}{\eta}}}{q^{\frac{1}{\eta}} + \frac{q^{\psi}}{1+\psi}}.$$

Given that $\psi > 0$ and $\eta < 0$, output is well-defined for any $\beta > 0$. Hence, the monopsonistic equilibrium always exists for the range of bargaining parameters we consider.

D.5 Limits in the Numerical Example

When we apply the bounds for existence from proposition OA-2, the limit of the monopoly model corresponds to

$$\lim_{q \to 0^+} -\frac{p'(q)\, q}{p(q) - c(q)} = \lim_{q \to 0} \frac{\frac{1}{\eta} q^{\frac{1}{\eta}}}{q^{\frac{1}{\eta}} - \frac{1}{1+\psi} q^{\psi}}.$$

Using l'Hôpital's rule, this limit can be found as

$$\lim_{q \to 0^+} -\frac{\frac{1}{\eta} q^{\frac{1}{\eta}}}{q^{\frac{1}{\eta}} - \frac{1}{1+\psi} q^{\psi}} = -\frac{1}{\eta}.$$

Since we set $\eta = -6$, the limit is $1/6$.

In the monopsony model, the upper bound is given by the limit:

$$\lim_{q \to 0^+} \frac{c'(q)\, q}{p(q) - c(q)} = \lim_{q \to 0} \frac{\frac{\psi}{1+\psi} q^{\psi}}{q^{\frac{1}{\eta}} - \frac{1}{1+\psi} q^{\psi}}$$

Using l'Hôpital's rule, this limit can be found as

$$\lim_{q \to 0^+} = \frac{\frac{1}{\eta} q^{\frac{1}{\eta}}}{q^{\frac{1}{\eta}} - \frac{1}{1+\psi} q^{\psi}} = 0$$

E Extension Details

E.1 Nonzero Disagreement Payoffs

Theorem 3. Under monopolistic bargaining, output increases with the buyer's disagreement payoff and decreases with the seller's disagreement payoff, $dq/do^d > 0$ and $dq/do^u < 0$. Under monopsonistic bargaining, output decreases with the buyer's disagreement payoff and increases with the seller's disagreement payoff, $dq/do^d < 0$ and $dq/do^u > 0$.

Proof. With the disagreement payoffs, the firms' optimization problem becomes

$$\begin{cases} \max_q p(q)q - wq & \text{(Downstream's problem)} \\ \max_q wq - c(q)q & \text{(Upstream's problem)} \\ \max_w [(p(q)q - wq - o^d q)^\beta (wq - c(q)q - o^u q)^{1-\beta}] & \text{(Bargaining problem)} \end{cases} \tag{OA.13}$$

which leads to the following FOCs

$$\begin{cases} w = p'(q)\, q + p(q) & \text{(D-FOC)} \\ w = c'(q)\, q + c(q) & \text{(U-FOC)} \\ w = (1-\beta)\left[p(q) - o^d\right] + \beta\left[c(q) + o^u\right] & \text{(B-O-FOC)} \end{cases} \tag{OA.14}$$

(B-O-FOC) and (U-FOC) imply that

$$(1-\beta)[p(q) - c(q)] = c'(q)q + (1-\beta)o^d - \beta o^u.$$

(B-O-FOC) and (D-FOC) imply that

$$\beta[c(q) - p(q)] = p'(q)q + (1-\beta)o^d - \beta o^u.$$

First, consider the monopsony case. Using the Implicit Function Theorem, dq/do^u and dq/do^d can be obtained as

$$\frac{dq}{do^u} = -\frac{dF/do^u}{dF/dq} = -\frac{\beta}{s'(q)} \quad \text{and} \quad \frac{dq}{do^d} = -\frac{dF/do^d}{dF/dq} = \frac{(1-\beta)}{s'(q)},$$

where

$$F(q, o^u, o^d) = \underbrace{(1-\beta)[p(q) - c(q)] - c'(q)q}_{s(q)} - (1-\beta)o^d + \beta o^u.$$

$s'(q)$ is given by

$$s'(q) = (1-\beta)(p'(q) - c'(q)) - [c''(q)q + c'(q)].$$

We have $c''(q)q + c'(q) > 0$ by assumption. $p'(q) \leq 0$ and $c'(q) \geq 0$, therefore $s'(q) < 0$. Hence, this proves that in the monopsony model, $dq/do^d < 0$ and $dq/do^u > 0$.

Second, consider the monopoly model. The Implicit Function Theorem gives

$$\frac{dq}{do^u} = -\frac{dF/do^u}{dF/dq} = -\frac{\beta}{s'(q)} \quad \text{and} \quad \frac{dq}{do^d} = -\frac{dF/do^d}{dF/dq} = \frac{(1-\beta)}{s'(q)},$$

where

$$F(q, o^u, o^d) = \underbrace{\beta[c(q) - p(q)] - p'(q)q}_{s(q)} - (1-\beta)o^d + \beta o^u.$$

$s'(q)$ is given by

$$s'(q) = \beta[c'(q) - p'(q)] - [p''(q)q + p'(q)].$$

We have $c'(q) \geq 0$, $p'(q) \leq 0$ and $(p''(q)q - p'(q)) < 0$, so $s'(q) > 0$. This proves that under monopolistic conduct, $dq/do^d > 0$ and $dq/do^u < 0$. □

For the simple functional forms $c(q) = \frac{1}{1+\psi}q^{\psi}$ and $p(q) = q^{\frac{1}{\eta}}$, we obtain Equation (OA.15) for the monopolistic model, and Equation (OA.16) for the monopsonistic model:

$$q^{\frac{1}{\eta}}(1 - \beta - (\frac{1+\eta}{\eta})) + \frac{\beta}{1+\psi}q^{\psi} - ((1-\beta)o^d - \beta o^u) = 0 \tag{OA.15}$$

$$q^{\frac{1}{\eta}}(1-\beta) + (\frac{\beta}{1+\psi} - 1)q^{\psi} - ((1-\beta)o^d - \beta o^u) = 0 \tag{OA.16}$$

Neither of these equations has a closed-form solution. Hence, we numerically solve these equations for q at given values of η, ψ, and β. We calibrate $\eta = -10$ and $\psi = 0.25$, as before. We express q as a function of the difference between the outside option of the buyer compared to the outside option of the seller, $z - y$. We let this difference in disagreement payoffs be uniformly distributed on the interval $[-1/4, 1/4]$.

E.2 Cournot Competition

Let there be firms $j = 1, ..., J$, with $\sum_{j=1}^{J} q_j = Q$. The firms' optimization problem becomes

$$\begin{cases} \max_{q_j} p(Q)q_j - wq_j & \text{(Downstream's problem)} \\ \max_{q_j} wq_j - c(q_j)q_j & \text{(Upstream's problem)} \\ \max_{w} [(p(Q)q_j - wq_j)^{\beta}(wq_j - c(q_j)q_j)^{1-\beta}] & \text{(Bargaining problem)} \end{cases} \tag{OA.17}$$

Compared to the single-buyer version of the model, in which $-\eta$ was the firm-level price elasticity of demand, $-\eta$ is now the market-level price elasticity of demand. In the Cournot case, the residual price elasticity of demand at the firm level becomes $\frac{\eta}{s_j}$, with $s_j = \frac{q_j}{Q}$. Hence, the more competing firms there are in the downstream market, the more elastic residual demand becomes, and the lower the efficient level of buyer power β^*. This implies that the more competitive the downstream market becomes, the more likely it is that the wholesale market is monopsonistic; the range of bargaining parameters for which equilibrium conduct is monopsonistic increases.

Numerical Example

We simulate the same parametric version of our model used earlier, but with multiple buyers that compete downstream, à la Cournot. We keep $\psi = 0.25$ but now set the market-level elasticity $\eta = -3$, which implies that firm-level demand elasticities are between -3 (if there is a single downstream firm) to -12 (if there are four equally sized downstream firms). Figure OA-3 shows the resulting output-buyer power graphs when there are one to four firms per downstream market. As competition increases, residual demand faced by the buyers becomes more elastic. Hence, the efficient level of buyer power decreases, and monopsonistic competition is the equilibrium form of vertical conduct for an increasing range of relative bargaining abilities.

E.3 Multi-Input Downstream Production

E.3.1 Monopoly

In this section, we show how to adjust the bargaining model in the case of a multi-input production function for the downstream firm. 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 term for productivity. Assume that for the input x_2, the downstream firm negotiates based on monopsonistic bargaining, and it takes the price of x_1 as given. In monopolistic bargaining, the downstream firm takes the price w_2 as given and finds the profit-maximizing quantity. We can write the firm's demand for x_2 as a function of target output quantity q:

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

The CES function leads to the following cost function:

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

Taking the derivative to find the marginal cost,

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

which is the same as the average cost $c_d(w_2)$. With these objects, we can write the firm's maximization problems as

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

These problems resemble the problem in the paper with the following exceptions: w_2 in the upstream firm's maximization problem shows up in $c_d(w_1, w_2)$ instead of as a simple linear function in w_2. Similarly, q in the downstream firm's problem shows up as $x_2(q)$ instead of as a simple linear function. Since $c_d(w_1, w_2)$ 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.

E.3.2 Monopsony

Now we will consider the monopsony model. In the monopsony model, the production function remains the same, but since the input x_2 is determined by the upstream firm, the downstream firm will take x_2 as given. Therefore, the firm will solve a constrained optimization problem:

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

This will lead to a conditional factor demand conditional on x_2:

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

Similarly, we obtain a conditional cost function:

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

Denote the average cost as $c_q(q, w_2) = C_d(q, w_2)/q$. Taking the derivative to find the marginal cost,

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

Given x_2, the firm will set marginal cost to marginal revenue:

$$c_u'(q, x_2) = p'(q)q + p(q).$$

Let the solution to this problem be $q_d(x_2)$. Now, we can write the firms' maximization problems as

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

These problems resemble the problem in the paper with the following exceptions: w_2 in the downstream firm's maximization problem shows up as $c_d(w_2)$ instead of as a simple linear function w_2. Similarly, q in the downstream problem appears as $q_d(x_2)$ instead of as a linear function x_2. In this case, we do not see any change in the upstream firm's cost function. Since both $c_d(w_2)$ and $q_d(x_2)$ are monotone functions, they do not change the basic mechanisms of the model.

F Empirical Application Appendix: Unions and Cooperatives

F.1 Labor Unions Application

In our labor unions application, we rely on the estimates for labor supply and demand for U.S. construction workers from Kroft et al. (2020).

Given that their labor supply model is log-linear, it has the same functional form as our numerical example from Appendix D.4. Using their notation of firms being indexed as j, wages W_j and number of workers L_j, their inverse labor supply curve at the firm level is

$$W_{jt} = L_{jt}^{\theta} U_{jt}.$$

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 θ 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 on the short term, we treat capital as fixed, which results in output being proportional to the labor input. Translating their notation into the notation of Appendix D.4, we have that $\eta = -\frac{1}{\epsilon}$ and $\psi = \theta$.

We use the β^* formula applied to the loglinear example, as worked out in Appendix D.4. Using the notation from Kroft et al. (2020), this gives

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

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 $\theta = 0.286$ from Table 2, Panel A. Plugging these into the β^* formula above results in $\beta^* = 0.417$.

F.2 Farmer Cooperatives Application

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 demand residual 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:

$$\frac{MRPM}{P^M} = 1 + \psi.$$

Using the preferred GMM specification in the third column of Table 1, Panel B, 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 $\bar{P}_t$, and the inverse demand elasticity as ϵ:

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

As an estimate of the cigarette demand elasticity $\frac{-1}{\epsilon}$, 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, given that this is one of the two preferred specifications that relies on GMM. Using the formula above results in $\beta^* = 0.916$. Alternatively, using the other GMM specification (in column 7) of $\frac{1}{\epsilon} = 1.11$ results in a very similar efficient level of buyer power of $\beta^* = 0.933$.

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 Velocity and one from the Mine Safety and Health Administration (MSHA). The MSHA data provides information on mine characteristics, including mine type, depth, production technology, number of employees, and total production. The Velocity data offers ownership information. While ownership details are also available in the MSHA data, we found it to be unreliable due to the lack of unique owner IDs, inconsistent spellings, and unaccounted ownership changes.

Coal-Mine Cost Data. We purchased cost information for coal mines from the 2019 Coal Cost Guide published by Costmine Intelligence. This comprehensive guide provides detailed data on operating costs, capital costs, labor requirements, and equipment expenses for different mining technologies used in the United States and Canada. It includes information on surface and underground mining methods, processing costs, and transportation costs. Additionally, the guide offers insights into regional variations in mining expenses, coal quality adjustments, and other factors that impact overall production costs. We combine this data with data from BLS data to obtain wage information for coal mine workers at the zip-code and county levels.

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 data sources 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 the 60-Day SCED Disclosure Report provided by ERCOT.

Coal Transaction Data[2005-2015]. 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. 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 Generation Construction

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.

G.3 Capacity Estimation

Power Plants

We calculate these 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 with the nameplate capacity provides the effective of the generator by hour type.

Coal Mines

Data on coal mine capacity are collected by the EIA and has been used in prior research. However, the EIA no longer makes this data available to researchers. Consequently, we infer mine capacity from production data. For each year, we define a mine's capacity as the maximum historical production observed at that mine 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 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 cost per MMBtu, we multiply the inverse of the heat rate by the per-MMBtu cost of coal.

To convert coal quantities from short tons to MMBtu, we calculate an annual conversion factor by dividing the total coal production (in short tons) by the total heat content of coal produced during the same year. This conversion factor is then assumed to remain constant throughout the year.

G.5 Disagreement Payoff Estimation

Coal Mines

We assume that the disagreement payoff of mining firms equals the profit from sales to all other firms, implying that if a negotiation fails, the coal mine will not produce the quantity that is negotiated. We think this assumption is reasonable because for mining firms, each transaction is small relative to total capacity as mining firms transact with many partners.

Power Plants

For power companies, the assumption of no production in the event of a disagreement is unrealistic, as coal power plants contribute significantly to the total capacity of power firms and require substantial upfront capital investments. Thus, it is more reasonable to assume that coal power generators would continue operating even if negotiations fail. In such cases, we assume that the power company would procure coal from the spot market. However, the spot market is volatile, and delivery is not guaranteed. Given the assumption that power companies are risk-averse, as supported by Jha (2022), it is necessary to account for disutility from uncertainty. To address this, we calculate the yearly mean spot price of coal sold from the same basin and coal type, along with its standard deviation. Using a reduced-form approach, we model risk aversion by assuming that power plants perceive the effective spot market coal price as the mean spot price plus one standard deviation.

G.6 Cournot Demand Estimation Details

As described in the main text, we assume a Cournot competition model with strategic 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 power plants and firms whose total capacity is below 5% are fringe firms in a given year. With these assumptions, modeling downstream competition requires the consumer demand and supply of fringe firms every hour type.

We assume that total demand is fully inelastic in the short run and calculate the inelastic demand by averaging the actual observed demand in 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 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, where each strategic firm faces a residual demand curve determined by the industry demand minus observed generation from other strategic firms.

G.7 Estimation Algorithm

Consider a grid of potential wholesale coal prices, denoted by $[0, \bar{w}]$. The following steps outline a procedure to compare the resulting equilibria across these different prices:

Monopsony

1. First, calculate how much quantity will be supplied by the upstream firm at any price w. Denote this $q^{ms}(w)$
2. Calculate upstream profit as a function of w and $q^{ms}(w)$
3. Calculate downstream profit as a function of w and $q^{ms}(w)$. Doing this is a bit nuanced. To find the downstream profit, we need to construct the cost curve of the downstream firm for a given $q^{ms}(w)$. Since in the monopsony model, the upstream firm chooses the quantity; we assume that the downstream firm will use that quantity in production. The way we operationalize this is as follows:

    - We construct the supply curve of all other power plants in the power company's portfolio. We take that as given, and it is not affected by the negotiation between coal mines and the power company.
    - We also take as given the prices and quantities, if any. This, together with the bullet above, constructs the supply curve from all inputs other than the one negotiated with the mining company.
    - We assume that the quantity supplied by u, $q^{ms}(w)$, is allocated to each coal generator in the portfolio of the power company proportionally to their capacity. For example, the

downstream quantity is 100 tons, and we have two coal power plants, A and B, whose capacity is 50 tons and 200 tons, respectively, we assume that 20 tons will go to plant A and 80 tons will go to plant B. This will matter to the extent that plant A's heat rate is different than that of plant B. If their heat rates are the same, this is without loss of generality.

- We further assume that the coal quantity is distributed uniformly throughout each hour of the day. For example, there are 8,760 hours in a given year, so plant A will have 20/8,760 tons of coal to use in a given hour. This assumption ignores the optimal intertemporal allocation of limited coal quantity over the course of the year. For example, if coal is limited, Plant A might want to use all of it when the price is high.
- With these steps, we now have the tons of coal allocated to each plant in a given hour. The downstream firm takes as given that the allocated coal is used for electricity generation under any market conditions. Then, it optimizes the production of a la Cournot competition for the rest of its portfolio.

4. Now we have the profits as a function of wholesale prices for both parties. Construct the Nash product.
5. For each β, find w that maximizes the Nash product. This gives us $q^{ms}(\beta)$ and $w^{ms}(\beta)$.

Monopoly

1. In the monopoly setting, calculate how much quantity will be demanded by the downstream firm. To find this quantity, take w as given and construct the downstream firm's supply curve. Solve for the Cournot model to calculate the quantity produced by firm d and the corresponding coal input demand of d from u, $q^{mp}(w)$.
2. Given $q^{mp}(w)$ and w, find the upstream profit.
3. Construct the Nash product:
4. For each β, find w that maximizes the Nash product, which gives us $q^{mp}(\beta)$ and $w^{mp}(\beta)$.

Use the intersection of $q^{mp}(\beta)$ and $w^{mp}(\beta)$ to find β^* and q^*. Eliminate β^{ms} and β^{mp} values such that $q^{mp}(\beta)$ and $w^{mp}(\beta)$ are above q^* to apply our conduct criteria. Finally, find the β value and vertical conduct that rationalize realized quantity q and wholesale price w in the data.

H Additional Tables

Table OA-1: Summary of limit cases for β

Case	Equilibrium Condition		Explanation	
	FOC	Cons. Max	FOC	Cons. Max
Sim. MP, $\beta = 1$	$mr(q) = c(q)$	$mr(q) = c(q)$	(D-TIOLI)	(D-TIOLI)
Sim. MP, $\beta = 0$	–	–	–	–
Sim. MS, $\beta = 1$	–	–	–	–
Sim. MS, $\beta = 0$	$mc(q) = p(q)$	$mc(q) = p(q)$	(U-TIOLI)	(U-TIOLI)
Seq. MP, $\beta = 1$	–	$mr(q) = c(q)$	–	(D-TIOLI)
Seq. MP, $\beta = 0$	$mr(q) = w$	$mr(q) = w$	(D.M)	(D.M)
Seq. MS, $\beta = 1$	$mc(q) = w$	$mc(q) = w$	(C.M)	(C.M)
Seq. MS, $\beta = 0$	–	$mc(q) = p(q)$	–	(U-TIOLI)

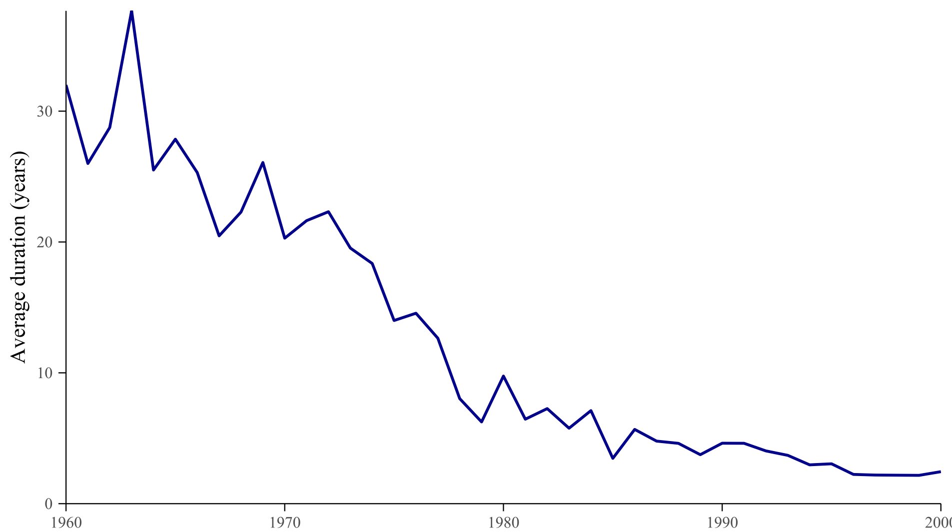
Notes: This table summarizes the equilibrium of monopsonistic and monopolistic bargaining in the limit cases separately using FOCs and from the constraint maximization problems. We use the following abbreviations: "D-TIOL" (downstream take-it-or-leave-it) and "U-TIOL" (upstream take-it-or-leave-it), "D.M." (double marginalization), "C.M." (classical monopsony). "–" denotes that equilibrium does not exist.

Table OA-2: Key Notation Used in the Model

Mining	
q_i^c	Coal-mine *i* output (short tons)
l_i	Labor hours used at mine *i*
m_i	Intermediate inputs at mine *i*
$\theta(i)$	Mine type for mine *i*
$\gamma_{\theta(i)}$	Labor-material ratio by mine type
ω_i	Mine *i* productivity shifter
h_i	Hourly wage at mine *i*
p_i^m	Material cost at mine *i*
λ_i	Coal-weight-to-MMBtu conversion
c_i	Marginal cost at mine *i*
c_{iu}	Mine *i* cost in upstream *u*
k_{iu}	Capacity of mine *i* in upstream *u*
c_u	Vector of costs for upstream *u*
k_u	Vector of capacities for upstream *u*
$C_u(Q)$	Upstream cost curve
Q_u	Total coal output of upstream *u*
Power	
Q_t^D	Electricity demand in hour *t*
Q_t^{fr}	Fringe supply in hour *t*
Q_t^{st}	Strategic supply in hour *t*
P_t	Price of electricity in hour *t*
c_{jd}	Marginal cost of generator *j* in *d*
k_{jdt}	Capacity of generator *j* in hour *t*
$C_{dt}(Q_{dt})$	Downstream cost function
Q_{-dt}	Output of other downstream firms
Bargaining	
D_u	Set of downstream partners of *u*
q_{ud}	Quantity traded between *u* and *d*
w_{ud}	Coal price between *u* and *d*
π_u	Profit function of upstream *u*
π_{dt}	Period-*t* profit of downstream *d*
Q_{dt}^{ms}	Monopsonistic downstream quantity
Q_{dt}^{mp}	Monopolistic downstream quantity
β	Bargaining power parameter
Q_{-d}	Total coal output to other partners
$\bar{Q}_{dt}^{-u^*}$	Disagreement output without upstream *u*

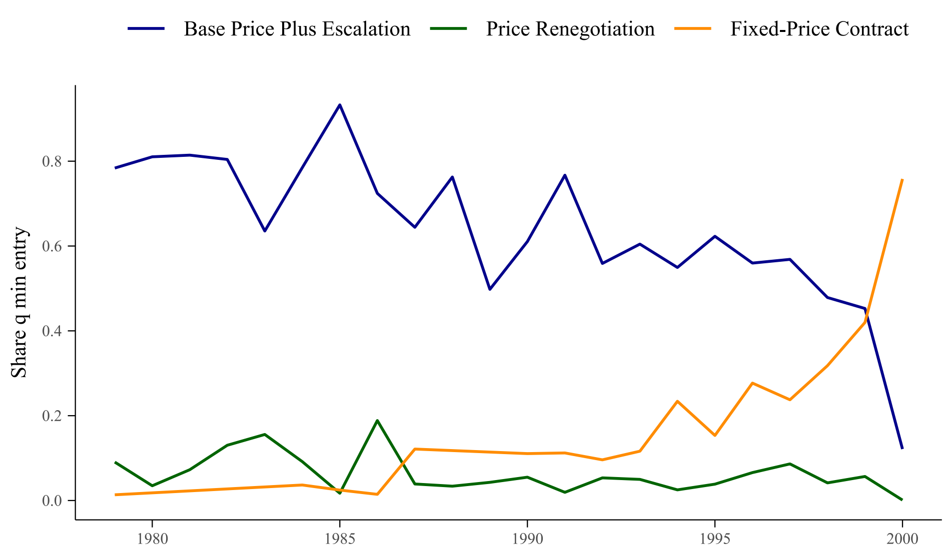
I Additional Figures

Figure OA-1: Average Contract Duration by Signing Year



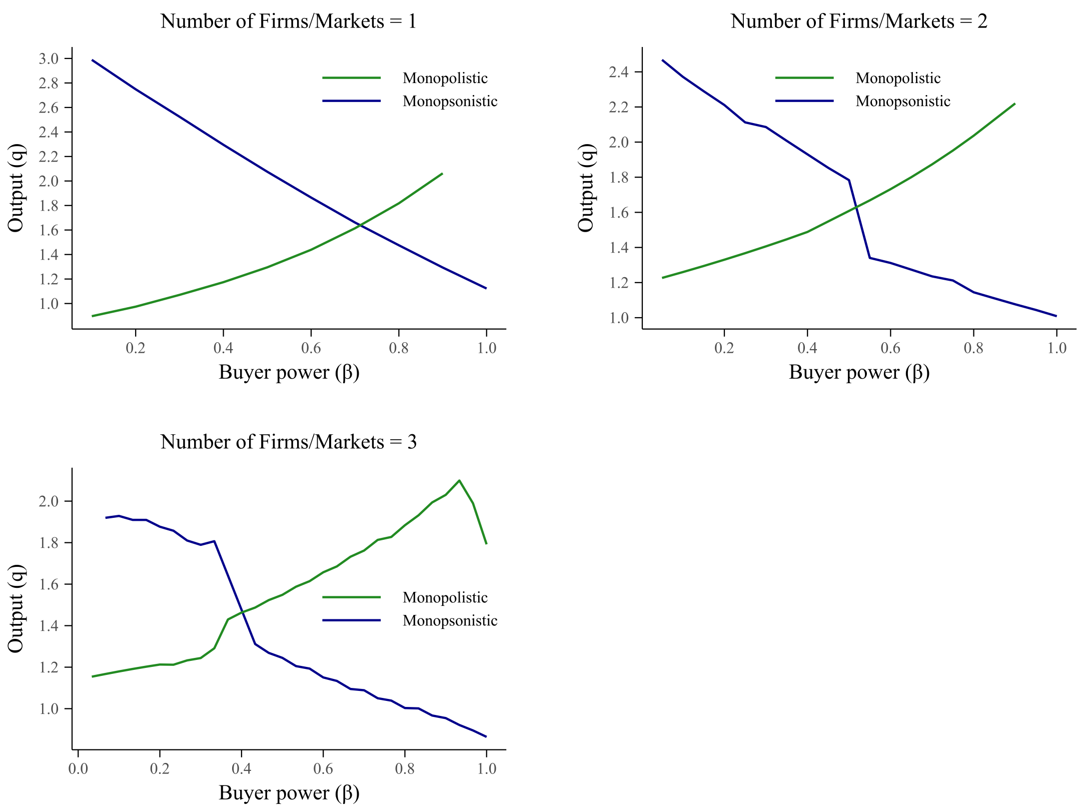
Notes: This figure presents the average duration of contracts (in years) by the year that the contract was signed. These data are drawn from EIA's Coal Transportation Rate Database for the years 1979-2000 as described in G.1. Signing years prior to 1979 are present due to the associated contract's overlap with the period of the data.

Figure OA-2: Contract Type Shares by Signing Year



Notes: This figure presents the Share of coal quantity shipped by by year and contract type. These contracts represent the three main types present in EIA's Coal Transportation Rate Database for the years 1979-2000 as described in G.1.

Figure OA-3: Cournot Competition



Notes: This figure presents numerical simulation results showing the relationship between output (q) and buyer power (β) when there are one to three firms in each downstream market. The residual demand faced by buyers becomes more elastic as competition increases.