

Upstream Uncertainty And Countervailing Power*

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Abstract

Current understanding of bargaining in intermediate goods markets is that (i) efficient bargaining only transfers rents so that retailer size has no retail price implications; and (ii) large buyers secure lower input prices (so called buyer power) if upstream marginal costs are increasing. We show that if there is upstream firm level uncertainty both these headline results fail. Efficient bargaining with any upstream uncertainty yields retail price effects: large buyers wield countervailing power (lower retail prices) if upstream marginal costs are decreasing (not increasing). With enough uncertainty large buyers have buyer power if marginal costs are decreasing. We go on to develop a model of the bargaining interface between competing upstream firms which generates the uncertainty yielding the countervailing power and buyer power results. We use the bargaining interface model to develop a novel theory of waterbed effects; and to deduce long run pressures on upstream technology resulting from downstream consolidation.

Keywords: countervailing power; buyer power; waterbed effects; bargaining interface; input markets; supermarkets; vertical contracts.

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1 Introduction

It is widely accepted that in many intermediate goods markets terms are set through a process of bargaining. And since the emergence of large retail chains it has become common to suppose that the largest retailers enjoy considerable bargaining power which may work to final consumers' advantage.¹ Yet most of the work on such bargaining interfaces begins with the assumption that bargaining is inefficient. Agreement is usually assumed to be over linear per unit prices so that double marginalization is hardwired into these models. Inefficient bargaining is an unpalatable assumption – all parties can gain by separating out profit maximization from the division of surplus. Under *efficient* bargaining the current understanding of the bargaining interface is that (i) the size of the downstream buyer has no retail price implications – there is no countervailing power; and (ii) large buyers secure lower input prices (so called buyer power) if upstream marginal costs are increasing. We extend the standard bargaining interface literature to introduce supplier uncertainty in her final volumes. With any upstream firm level uncertainty buyer size does yield retail price implications – there is countervailing power; and the direction of buyer power is reversed. The uncertainty is shown to be the natural outcome of a new model of a bargaining interface with upstream competition in which contracts might be won or lost. The model gives rise to an original understanding of waterbed effects, in which bargained contracts for all buyers are impacted by a downstream merger or acquisition. Finally our model allows us to deduce the long run pressures on upstream technology resulting from downstream consolidation.

Consider a vertical supply chain consisting of a single upstream supplier (“she”) and multiple downstream retailers. This is the standard textbook setup of the bargaining interface literature (Katz 1987, Chipty and Snyder [CS] 1999 and Inderst and Wey [IW] 2007). If there is no uncertainty for the supplier then, in equilibrium, she will be supplying all the downstream retailers and so knows what her volumes will be. Efficient bargaining requires each retailer to set prices to reflect the marginal costs of production. As this is the same for all the retailers there are no size related retail price effects. That is, without further assumptions, there is no scope for countervailing power here. Further, the per unit input price is a function in this benchmark model of the average cost of production over the relevant range. With no uncertainty bargaining is notionally over the final units the supplier will produce. This generates the result that increasing marginal costs upstream are required for large downstream buyers to wield buyer power.

¹Wal-Mart in the US and Tesco in the UK have reached unprecedented size. In the UK, the groceries market share of the four largest supermarkets is estimated to be 65% (CC 2008, Fig 3.1). In Austria the two largest food retailers alone control more than 65% of the market (‘European Retail Handbook 2003/4’, Mintel).

But now suppose the upstream supplier is subject to uncertainty. Suppose, for example, that she cannot be certain of the volumes each of the buyers will require. Now the total volumes which she will produce are uncertain. Efficient bargaining now links the retail prices with the *expected* marginal cost of production. However this is not now the same for all retailers, and is itself subject to retailer size effects. In negotiation with one buyer, volumes which might be required by other buyers must be under-weighted due to the uncertainty; buyer-specific scale effects are therefore created. As a result countervailing power becomes possible – and who wields it depends both upon buyer size and also the upstream technology. If upstream marginal costs are decreasing then large retailers, by virtue of their size, will strike an efficient supply bargain which results in lower retail prices than for small retailers.

Analogously the per unit input price agreed to through a bargaining interface becomes a function of the *expected* average cost of production. Bargaining is now notionally over a range of production which is itself uncertain. In calculating this range, volumes which might be required by other buyers must again be under-weighted due to the uncertainty; buyer-specific scale effects are therefore once more created. We demonstrate that this reverses the textbook results achieved when there is no upstream uncertainty.

The countervailing power and buyer power results follow from supplier uncertainty. One source for this uncertainty arises in the context of upstream competition. If suppliers cannot be certain, in advance, of which contracts they will win and which lose then uncertainty is created. There is strong empirical evidence for exactly this sort of uncertainty (see the case studies which follow). We extend the benchmark Nash bargaining model to model this competition and so endogenize the uncertainty affecting the suppliers. Thus we present an oligopoly model of an efficient intermediate good bargaining interface in which agreements, and retail prices, depend upon buyer size, the upstream technology and the upstream competition.

When a supplier is subject to uncertainty arising from upstream competition then her expected production volume depends not only upon buyer-specific scale effects, but also upon the distribution of other buyers which might be won. Hence alterations in downstream market structure, say due to downstream consolidation, change the distribution of volumes for the upstream supplier in her negotiations with other downstream retailers. Therefore downstream consolidation has externalities on the bargained agreements between the supplier and non-consolidating downstream firms. This externality is known in some policy circles as a waterbed effect. We are, to the best of our knowledge, the first to build a model of waterbed effects with upstream competition. We demonstrate that under monotonic marginal costs waterbed effects can be either harmful or beneficial – a simple characterization is not possible. But the most plausible cases for upstream technology yield a standard waterbed effect in which non-consolidating downstream

firms suffer from other downstream firms consolidating.

It is standard to take the upstream technology as exogenously given. But under upstream uncertainty, even if the cost of producing the expected volumes is held fixed, the expected upstream profit generated from different technology choices is not independent of the technology. If downstream firms consolidate then expected profits are highest when the upstream selects a technology of decreasing marginal costs. But such a choice of technology itself increases the relative bargaining power of the largest retailers as compared to the smallest.

Many intermediate good markets rely on bargaining, the focus of this paper, rather than auctions or price setting. Grocery supply chains are a prime example. Two major recent reports into the UK supermarket industry, Competition Commission (2000, 2008), do not mention auctions in their chapters on relationships with suppliers, and mention negotiations repeatedly. More generally *The Economist* has reported that business to business deals are predominantly via a negotiated contract and not a spot-market or auction.² The problem cited is that logistics and other details even for otherwise homogeneous goods are too complicated to submit to an auction and that suppliers do not wish their products to be turned into commodities and so avoid taking part in any such auctions if they can.³

Our countervailing power and buyer power results hinge on supplier uncertainty and not on any given model of oligopoly bargaining. We document the presence of such uncertainty through two case studies. The case of liquid milk in the UK is particularly striking. Table 1 demonstrates that though the volume demanded by any buyer (retailer) is very predictable, the upstream suppliers individually have volatile total demand as the supermarkets change their suppliers frequently. Similar output uncertainty has been shown in other supermarket supply chains where it is relatively costless for retailers to switch suppliers; our second case study of private-label carbonated soft drinks (such as cola) confirms this.

Related Literature. The concept of countervailing power, meaning that a large buyer can use its bargaining power to deliver lower retail prices to consumers, was introduced by Galbraith (1952). Since then two main approaches have been followed to model the bargaining power a large buyer might wield. Katz (1987) assumes that buyers have, for some fixed fee, the opportunity to backwards integrate or equivalently source from an unmodelled non strategic exogenous supplier. Horn and Wolinsky (1988) and Dobson and Waterson (1997) postulate instead a Nash bargaining process between the supplier and buyers. Both of these approaches were modeled assuming inefficient bargaining over a linear unit price. In important contributions

²“The problem is that commodities that can be auctioned represent only a tiny fraction of all transactions. An estimated 80-90% of all business goods and services are actually traded through extended term contracts, often lasting for a year or more;” *The Economist* (2000), “Business: The container case,” October 21, 76-78.

³Bajari et al. (2009), Bonaccorsi et al. (2000), and Leffler et al. (2003) confirm the preference for negotiations over auctions in empirical work if sellers are not very numerous or contracts are complicated.

CS and IW extend the Nash bargaining model to the case of efficient contracting confirming the countervailing power irrelevance and buyer power results described above. We extend this benchmark model to allow for uncertainty and so generate our new results. We then endogenize uncertainty through upstream competition.⁴

The empirical evidence on buyer power is limited to the few studies that have had access to proprietary data; these studies suggest that what matters is the combination of buyer size and a choice of suppliers, rather than buyer size alone. This is seen in a recent empirical study by the UK Competition Commission (CC 2008) of prices negotiated between supermarkets and suppliers: buyer power is found to be absent for branded products, where there is a single supplier, but present for private label products, where suppliers compete.⁵ Ellison and Snyder (forthcoming) find qualitatively similar results for the antibiotic drugs market: comparing in-patient and generic drugs they find significant buyer power effects for large buyers in the generic market, where the buyer has a choice of supplier, but not for the in-patient market, where the buyer has no choice. Assuming decreasing marginal costs upstream these empirical results are consistent with our model, with the buyer power effects generated by the output uncertainty implied by upstream competition. Katz (1987) also generates buyer power because of fixed costs of switching to an alternative (non-strategic) supplier. Whether output uncertainty or switching costs is the buyer power mechanism is not identified in these studies. Our mechanism is more likely to apply in cases where suppliers are switched frequently, as this is indicative of low switching costs and high output volatility.

There has been some advance into the modelling of the bargaining interface between multiple upstream suppliers, who are not directly in competition with each other, and downstream buyers. Inderst and Wey (2003) and de Fontenay and Gans (2005) present models of efficient bargaining which deliver the Shapley value as the solution. These models allow for efficient bargaining and consequently retail price effects are absent. Further these models are typically structured so that each supplier supplies each retailer in equilibrium, so uncertainty is absent. By introducing uncertainty we are able to deliver retail price effects. Further we present a bargaining model in which suppliers can either win or lose contracts – the complete network does not arise – as one

⁴The Nash bargaining model is extended to supplier competition by Björnerstedt and Stennek (2007); however as uncertainty is absent its effects cannot be analyzed.

⁵The CC study divides the products into primary-branded goods and other goods. For primary-branded goods, where there is a monopoly owner of any brand in question, the CC discover little if any statistically significant relationship between volume ordered and unit price paid. (Thus, if the costs of supply are likely to be lower for large orders, due for example to logistical efficiencies, this suggests large buyers may be weak against monopoly suppliers, as the bargaining literature would suggest assuming diminishing marginal costs, the weakness being compensated for by lower costs.) For other goods, such as secondary brands and private label goods, order size has a statistically significant effect, such that very large retailers pay approximately 19% less than very small retailers; as these goods are much more readily substituted, the study suggests that competition is generating a buyer power effect. See CC (2008) Appendix 5.3, especially paras 44-45.

would expect when suppliers are in direct competition with each other.

Plan Of The Paper. The standard Nash bargaining model between an upstream supplier and downstream retailers is extended to include upstream uncertainty in Section 2. The countervailing power and buyer power results are established in Section 3. Upstream uncertainty is endogenized through an oligopoly model of bargaining in Section 4 and is shown to yield the same countervailing power and buyer power results. The impact of changes in downstream market structure on all bargained contracts (waterbed effects) is demonstrated in section 5. The effect of uncertainty on upstream investment incentives is analyzed in Section 6. Case study evidence motivating the model is presented in Section 7. We conclude in Section 8 with proofs contained in the appendix.

2 The Model

To demonstrate our results in a simple model consider the polar case of a monopoly upstream supplier supplying a single good. The supplier faces a marginal cost curve of $c(q) : [0, Q] \rightarrow \mathbb{R}_+$ where Q is the maximum possible demand from the downstream buyers. We will analyze two classes of cost functions: increasing and decreasing marginal costs.

There are D downstream buyers indexed by i . Each downstream buyer can convert one unit of input into a unit of output at zero marginal cost. Buyer i is a firm serving z_i representative consumers with residual downward sloping demand curves $q(p)$. Thus if price p_i were set by the firm then volumes $z_i q(p_i)$ would be sold. Equivalently the seller faces an inverse demand curve of $p(q_i/z_i)$.

This formulation for demand implies that there are no competitive externalities between the downstream firms arising from the pricing of the product. This assumption is common to the seminal bargaining interface contributions (CS and IW) and allows us to demonstrate the new insights cleanly. A sufficient condition for this assumption to hold is that the downstream firms are not in competition with each other at all. However such a no competition assumption is not necessary. What is required is that competition between downstream firms over the pricing of the product is minimal; competition can be present over other variables—e.g. supermarkets compete over the whole basket of goods rather than just one product.⁶ Similarly the model applies well to any supply chain where the product under study forms one small part of a larger whole.

We allow bargaining to be sufficiently rich that double marginalization problems can be avoided. Thus negotiations between the buyers and seller are over a total transfer *and* the volume

⁶This follows for all but a few products. The marketing literature refers to these products as “*known value items*.”

to be delivered: $\{T_i, q_i\}$. In common with much of the extant literature (see for example CS) we maintain the bargaining interface paradigm of simultaneous independent pairwise negotiations which are governed by the Nash Bargaining Solution, where the outside option in any negotiation is the existing agreement which is struck with the other parties:

Nash Bargaining Assumption The outcome from negotiations between the seller and the buyers maximizes joint surplus. The seller and buyer split the expected incremental surplus generated from their trade equally.

So far our model qualitatively replicates the standard bargaining interface models (CS and IW). The point of departure comes from the inclusion of upstream uncertainty. During any pairwise negotiations it is not known whether other buyers will place an order or not. We suppose that each buyer ultimately decides to place an order with independent probability α . If $\alpha = 1$ there is no uncertainty and we have the standard bargaining interface model. For α lower than one, the sellers final output is uncertain at the time of negotiation. In this section and the next the uncertainty is exogenous, it will be endogenised later in the paper. The uncertainty might arise if buyers have unpredictable tastes. Alternatively it might represent the chance that a buyer might source the input from some alternative upstream source. We do not need to take a position here on the source of the upstream uncertainty. However its presence has significant effects on the predictions of the bargaining interface model for countervailing power.

Assumption 2 We assume that the revenue function, $qp(q)$ is sufficiently concave to deliver stability of the model in the sense of Dixit (1986).

The stability requirement is that if the volumes agreed between the downstream and upstream were not at their equilibrium levels then a tatonement process of myopically responding to first order conditions for maximizing supplier-buyer profits would return the system to equilibrium. If upstream marginal costs are increasing then it can be shown that any concave revenue function is sufficient. If however upstream marginal costs are decreasing then straightforward (though tedious) algebraic manipulation delivers that we require the slightly stronger condition

$$\frac{d^2}{dq^2} [qp(q)] < \max \{z_i\} \cdot \inf_q \{c'(q)\}. \quad (1)$$

3 Countervailing Power And Buyer Power

This section will answer when, under a bargaining interface, a downstream firm enjoys either countervailing power or buyer power in the face of an upstream supplier with some bargaining power. Recall that in the light of the previous literature we use the term countervailing power to

denote the ability of a downstream firm to achieve lower retail prices when facing a supplier with some bargaining power, while we use buyer power to denote the ability of a downstream firm to achieve lower average input prices, with no retail price implications, when facing a supplier with some bargaining power.

Under the Nash Bargaining Assumption buyer i and the seller will seek to maximize their incremental expected surplus v^i :

$$v^i = q_i p(q_i/z_i) - E_{Q_{-i}} \int_{Q_{-i}}^{Q_{-i}+q_i} c(q) dq$$

where Q_{-i} is the quantity of produce ordered by the other buyers. If there is any uncertainty upstream then Q_{-i} is a random variable. If there is no uncertainty about other buyers' demands then $Q_{-i} = \sum_{j \neq i} q_j$. Under assumption 2 this surplus function is concave in quantities q_i and so has a unique maximizer.

Proposition 1 *With a single dominant supplier upstream:*

1. *[Standard Bargaining Interface] If there is no upstream uncertainty ($\alpha = 1$) then:*
 - (a) *Retail prices set by downstream firms of all sizes are identical whatever the slope of marginal cost.*
 - (b) *Average input prices are lower (higher) for larger buyers if upstream marginal costs are increasing (decreasing).*
2. *[Countervailing Power] If there is any upstream uncertainty, $\alpha < 1$, then retail prices of larger downstream firms are higher (lower) if marginal costs are increasing (decreasing).*
3. *[Buyer Power] If there is sufficient upstream uncertainty, α is sufficiently far below 1, then average input prices are higher (lower) for larger buyers if upstream marginal costs are increasing (decreasing).*

Result 1a highlights that in the standard bargaining interface without upstream uncertainty (see IW for example) there is no retail price effect arising purely from differences in downstream firm size, without assuming exogenous inefficient contracting. The supplier-buyer pair will always wish to set prices to maximize their incremental profit, and with certainty upstream the relevant marginal cost is given by the total volume the supplier is producing across all contracts. And this total volume is the same for each buyer-supplier pair.⁷ Hence, absent exogenous inefficiencies, there is no countervailing power result. Antitrust analysis of input market bargaining

⁷CS note that downstream retail price effects will exist if the downstream firms differ in their efficiency. But such a difference is not bargaining induced.

interfaces have instead made use of models which include exogenous inefficiencies in bargaining (see for example Dobson and Waterson 1997).⁸

The standard bargaining interface analysis (IW and CS for example) generates a clear buyer power prediction (Result 1b): if the supplier's marginal cost is increasing then larger downstream buyers enjoy buyer power. The input price agreed is a function of the average cost of supplying the buyer, calculated incrementally to the other contracts. As the supplier can be certain that she will be serving all the other buyers, the average cost is calculated by averaging over the final units of the supplier's production. So if marginal costs are increasing then the last unit is the most expensive to produce and small buyers face the largest input prices.

Neither of these predictions is robust to upstream uncertainty. Firstly, if there is any upstream uncertainty at all then countervailing power effects are present. These are such that if the seller has decreasing marginal costs retail prices are lower for large buyers (Result 2). The intuition for this is depicted in the left hand panel of Figure 1. With efficient bargaining the retail price depends on the seller's expected marginal cost. Suppose the simultaneous negotiations with buyers 1 and 2 condition on volumes Q^j ordered by remaining buyers $\{3, \dots, D\}$. With no upstream uncertainty ($\alpha = 1$) the seller's marginal cost is the same for both buyers as it is assumed that both contracts are won. However with upstream uncertainty ($\alpha < 1$) a weight of $(1 - \alpha)$ is attached to the other contract not being won. Thus in negotiations with the larger buyer the seller expects a greater output and a lower marginal cost, which implies a lower retail price for the large buyer.

Secondly, if upstream uncertainty is sufficiently great, buyer power effects are reversed (Result 3). This results in the large buyer getting a lower price per unit for the case of decreasing marginal costs, as depicted in the right hand panel of Figure 1. In this figure we again suppose the simultaneous negotiations with buyers 1 and 2 condition on volumes Q^j ordered by other buyers $\{3, \dots, D\}$. Input prices are a function of the average cost of supplying the buyer, given the seller's other orders. For buyer 1 with volume q_1 this is given by the area under the marginal cost curve over the last q_1 units of the seller's output, divided by q_1 . With upstream uncertainty ($\alpha < 1$) a weight of $(1 - \alpha)$ is attached to the other contract (2) *not* being won. It follows that if α is small (there is a large chance of no orders being received from buyer 2), then the possible volume q_2 is under-weighted and the so bargaining is mainly over the average costs incurred from the base of volume Q^j , not $Q^j + q_2$. If marginal costs are decreasing then as more units are ordered above this level their per unit cost falls, and so a larger buyer 1 will secure a lower

⁸The restriction to linear input prices applies also in the seminal Katz (1987) analysis. Though prices here are dictated by the need to match the outside option rather than a given bargaining protocol.

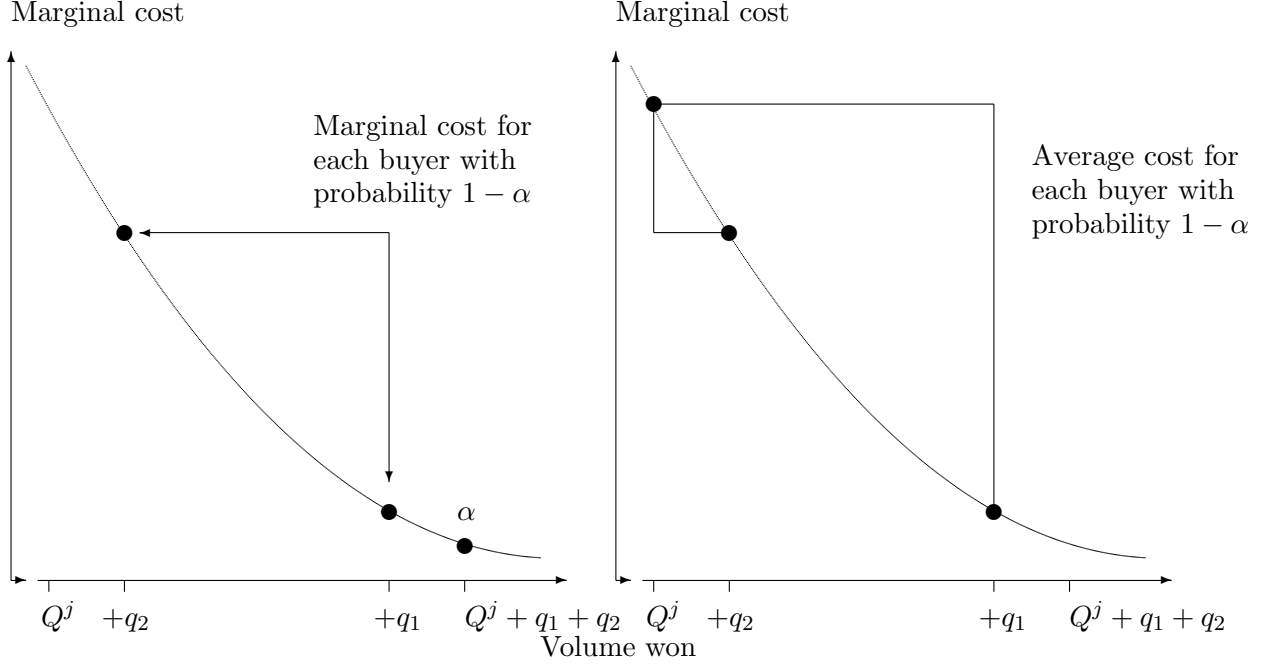


Figure 1: Suppose there are D downstream buyers and Q^j represents some realization of volumes ordered by buyers $\{3, \dots, D\}$. Marginal costs are depicted as declining. The left hand panel shows the expected marginal cost in negotiations with buyers 1 and 2. With probability α both buyers place orders and the marginal cost would be the same. But otherwise the larger buyer has a lower marginal cost. Hence the larger buyer faces a lower expected marginal cost and so retail prices are lower. The right hand panel depicts the same marginal cost curve. The average cost is computed over the buyer's output range. As uncertainty grows, α falls from 1 to 0, the supplier focuses more on the average costs in the event of the other buyer not placing an order. Hence we see that the average cost is lower for the large q_1 and so she receives a lower average input price.

per unit input price than a smaller buyer 2.

4 Endogenous Uncertainty: A Bargaining Model Of Upstream Competition

In the previous section, uncertainty for an upstream monopolist was generated exogenously. Here we offer a bargaining model of upstream competition which generates upstream firm level uncertainty.

We extend the model provided above as follows. Suppose that there are N competing suppliers which produce an identical input with the same marginal cost function $c(\cdot)$. Each of the D downstream firms seek only one upstream supplier for the input under discussion. This simplifies the analysis and is realistic where several firms could supply the product but multi-sourcing is costly e.g. because it increases logistical costs. In addition the buyer will only make

payments to the winning supplier, i.e. we rule out side payments to other potential suppliers.

A buyer is assumed to be able to conduct detailed negotiations with only one supplier at a time. The buyers simultaneously, independently and privately decide on the order of suppliers they wish to negotiate with. We maintain the Nash bargaining assumption.⁹ In the event of a break down of negotiations with the supplier, the buyer can move to the next supplier on her list and so cycle through the suppliers. Should all N suppliers have been cycled through then with probability ρ the buyer is unable to secure the input (or at least to secure it profitably). With probability $1 - \rho$ the buyer cycles back to the first supplier on her list and continues the negotiations in her chosen order. The parameter ρ captures industry-specific (possibly cultural) exogenous features determining the willingness of executives to return to a negotiating partner after a disagreement. In the case of the monopoly supplier of Section 3 $\rho = 1$ so that a break down in negotiations was terminal. With multiple suppliers however a buyer may try to play one off against another and so it is more plausible that a buyer would like to return to a supplier she has previously spurned.

We maintain the assumption that the D buyers Nash bargain with the suppliers simultaneously. They are visited by sales representatives from all N suppliers. The sales representatives for any given supplier operate independently of the other sales representatives of the same supplier and without communication during these simultaneous negotiations. They seek to maximize the expected payoff of their employing firm. This simultaneity assumption renders the bargaining interface tractable. It implies that out of equilibrium play in one set of negotiations cannot affect the other negotiations.

Lemma 1 *An equilibrium of the bargaining interface is for each buyer to randomly select an ordering in which to bargain with all N suppliers. The average per unit transfer price agreed during the ensuing bargaining will be*

$$T_i^1 = \frac{2^N - 1}{2^N - 1 + \rho} E_{Q_{-i}} \int_{Q_{-i}}^{Q_{-i} + q_i} c(q) dq + \frac{\rho}{2^N - 1 + \rho} q_i p(q_i/z_i) \quad (2)$$

Where q_i are the efficient bargained volumes for buyer i .

Proof. First we determine the agreed transfers if all the buyers have as their strategies to randomly order the N suppliers. Let T_i^j denote the transfer i agrees if she reaches the j^{th} supplier on her list. The incremental surplus achieved by buyer i in negotiations with the j^{th} supplier are

$$\left(q_i p(q_i/z_i) - T_i^j \right) - \left(q_i p(q_i/z_i) - T_i^{j+1} \right) = T_i^{j+1} - T_i^j$$

⁹A game theoretic foundation for Nash is offered by Binmore et al. (1986).

The efficient quantity, q_i , is the same with all the suppliers. This is because all the suppliers are homogenous as they have the same probability of winning business from other negotiations. The incremental surplus which accrues to the supplier is

$$T_i^j - E_{Q_{-i}} \int_{Q_{-i}}^{Q_{-i}+q_i} c(q) dq$$

Nash bargaining requires the incremental surplus to be split equally which requires that

$$T_i^j = \frac{1}{2}T_i^{j+1} + \frac{1}{2}E_{Q_{-i}} \int_{Q_{-i}}^{Q_{-i}+q_i} c(q) dq$$

Similar first order conditions will arise from the negotiations with all suppliers except for the N^{th} one. Thus we have

$$T_i^1 = E_{Q_{-i}} \int_{Q_{-i}}^{Q_{-i}+q_i} c(q) dq \cdot \sum_{i=1}^{N-1} \frac{1}{2^i} + \frac{1}{2^{N-1}} T_i^N$$

The negotiations with the N^{th} supplier have the following solution

$$\begin{aligned} T_i^N &= \arg \max_T [(q_i p(q_i/z_i) - T) - (1 - \rho)(q_i p(q_i/z_i) - T_i^1)] \left[T - E_{Q_{-i}} \int_{Q_{-i}}^{Q_{-i}+q_i} c(q) dq \right] \\ \Rightarrow T_i^N &= \frac{1}{2} \left(\rho q_i p(q_i/z_i) + E_{Q_{-i}} \int_{Q_{-i}}^{Q_{-i}+q_i} c(q) dq + (1 - \rho) T_i^1 \right) \end{aligned}$$

Solving for T_i^1 we have

$$T_i^1 \left(1 - \frac{1 - \rho}{2^N} \right) = E_{Q_{-i}} \int_{Q_{-i}}^{Q_{-i}+q_i} c(q) dq \cdot \sum_{i=1}^N \frac{1}{2^i} + \frac{\rho}{2^N} q_i p(q_i/z_i)$$

And rearranging yields (2).

We finally need to check that randomly ordering all the suppliers is equilibrium play. Assuming that the orderings of all the other buyers are random (and private) any reordering by buyer i has no effect on the agreements i can reach, as the probability any supplier sees in winning any other firm's business is unchanged. Thus buyer i does not gain from altering the order of suppliers she will negotiate with and so she is willing to randomize. Hence the buyers independently, randomly and privately ordering all N suppliers is a mixed strategy equilibrium of the bargaining interface. ■

By selecting the mixed strategy equilibrium of our Nash bargaining game we capture upstream uncertainty at the firm level.

Proposition 2 *With N competing upstream homogeneous good suppliers and a bargaining interface with buyers*

- a. *[Countervailing Power] If there is any upstream competition, $N \geq 2$, then retail prices of larger downstream firms are higher (lower) if marginal costs are increasing (decreasing).*
- b. *[Buyer Power] If there is sufficient upstream competition, N large enough, then average input prices are higher (lower) for larger buyers if upstream marginal costs are increasing (decreasing).*

Proof. The strategies of the buyers cause each supplier to be uncertain as to which other contracts she will secure in any given buyer-supplier negotiation. The probability of securing a given contract is $1/N$ and this equates to α in Proposition 1. The multiple suppliers change the division of surplus from $\frac{1}{2}$ each to the downstream firm receiving proportion $(2^N - 1) / (2^N - 1 + \rho)$ (Lemma 1). This alters the proof of Proposition 1 in a trivial way. ■

Upstream competition, as modeled here, causes upstream firm level uncertainty. Competition manifests itself as uncertainty as to which contracts will be won and which lost to rivals. It follows that the results presented in the analysis of uncertainty in Section 3 apply. So with upstream competition *and* efficient bargaining countervailing power effects exist. If the upstream is characterized by decreasing marginal costs of production, large downstream buyers can exploit their buyer-specific scale effects which deliver a lower expected marginal cost. This lowers the retail prices large buyers will set. If upstream competition is sufficiently intense (N large enough) then buyer-specific scale effects become dominant. Hence, if upstream marginal costs are decreasing, the average (as well as marginal) per unit costs of production decline for large buyers. So large buyers wield buyer power by paying lower per unit input prices.

Even though our model mandates sequential negotiation for the buyers, we can capture a wide range of bargaining powers. The bargaining power of the downstream firms versus the upstream suppliers is both endogenously a function of the upstream competition (as measured by N) and exogenously a function of the parameter ρ capturing the willingness to reopen negotiations after a break down. In particular if a buyer was always willing to reopen negotiations with the first supplier then she can in effect play off the suppliers against each other fully and secure the input at the expected cost of supply. (Set $\rho = 0$ in 2). Whatever the bargaining power generated by the model parameters the countervailing power and buyer power results continue to apply.

We conclude that our results are not generated by a particular bargaining protocol which yields too much power to one side or other. Rather the uncertainty we have generated via competition is the route of the results. We will illustrate through a case study in Section 7 that

the uncertainty, and indeed other features of our modeling, are well supported in at least some grocery supply chains.

The mixed strategy equilibrium is not the only one which can be supported. Pure strategy equilibria also exist in which the buyers have a known ordering of suppliers and coordinate with the other downstream firms. In such a setting there is no upstream uncertainty. Such an analysis would return us to the standard bargaining interface results given as Result 1 of Proposition 1. Namely there would be no countervailing power effects and our buyer power result would be reversed. But supplier uncertainty would be reintroduced in pure strategy equilibria by adding incomplete information; for example there could be unpredictable buyer volumes, reflecting preference volatility, or private buyer taste shocks over suppliers, capturing unobserved preferences for supplier differentiation.

5 Waterbed Effects

In this section we analyze how changes in downstream market structure alter the bargained agreements struck between all the buyers, not just those involved in the downstream changes, and the suppliers. To conduct this analysis it is essential that the probability of securing contracts is endogenized. Thus we use the upstream competition model of the previous section.

To make the analysis tractable we restrict attention to the case of completely inelastic buyer demands. This is because without this assumption changes in downstream market structure can create feedback effects in rivals' volumes via the change in the suppliers' expected costs of supply. This restriction is a polar assumption which removes this problem. Our results will go through for markets for which this is a reasonable approximation. This restriction is reasonable for input purchases which are one part of a much larger whole. Salt to trade buyers making ready meals is one example. Car parts for a car manufacturer would be another example. In the case of supermarkets each product forms one part of an overall basket of goods, and consumers decide where to shop based on a basket. Thus the elasticity of demand for a given product type (such as milk or bananas) is typically quite inelastic. The elasticity of demand would be higher if consumers can swap to a rival product of the same type (two brands of yoghurt for example). However this is not the case for many staple, and in particular agricultural, products.¹⁰

Thus we suppose that buyer i seeks q_i units of the input and derives revenue $R(q_i)$ from it. Lemma 1 can be straightforwardly re-written to deliver a bargained transfer price of

$$T_i^1 = \frac{2^N - 1}{2^N - 1 + \rho} E_{Q_{-i}} \int_{Q_{-i}}^{Q_{-i} + q_i} c(q) dq + \frac{\rho}{2^N - 1 + \rho} R(q_i) \quad (3)$$

¹⁰Milk is a seminal such product which is often the focus of antitrust attention. For example the mergers of Arla/Express in the UK and more recently Campina/Friesland under EU jurisdiction.

The restriction to completely inelastic demand has the implication that we will only be able to discuss changes in the average input price enjoyed by suppliers, and not the retail price. Such changes are however relevant to the division of producer surplus and parallel the focus of the existing bargaining interface literature (IW for example). And these considerations are often at the heart of antitrust complaints from firms as to the effects of downstream mergers. An increase in the average input prices payable by a downstream firm can cause the firm to decline to sell the product if fixed costs can no longer be covered. Whether this would be a negative or positive contribution to welfare will depend on whether there is excess, or too little, entry of sellers. It may also depend on distributional considerations an antitrust authority might make (town versus countryside; wealthy area versus deprived area etc.).

5.1 Organic Growth And Its Waterbed

Consider growth by a downstream firm that leaves the size of all other downstream firms unaffected. This might occur, for instance, when a retailer discovers an unserved clientele, or a retailer increases the volume demanded by its existing customers.

Proposition 3 *Suppose there is upstream competition ($N > 1$) and that downstream buyer 1 increases q_1 by organic growth without affecting the volumes demanded by any of the other downstream buyers. Then if upstream marginal costs are increasing (decreasing) then this type of growth causes average input prices for all other downstream firms to increase (decrease).*

For a supplier negotiating a given order of size q with a downstream firm, organic growth by another downstream firm increases the expected total quantity the supplier will win in other orders, which changes the expectation of the average incremental cost of supplying q . Thus input prices fall if there are upstream decreasing marginal costs (an inverse waterbed effect), while input prices move up if there are upstream increasing marginal costs (a standard waterbed effect).

5.2 Downstream Acquisition And Its Waterbed

We capture increases in downstream concentration via acquisition (as opposed to organic growth) as a change in the distribution of volumes sold by each downstream firm, holding total downstream volumes constant. This might happen as a result of a merger of some sales outlets for example. We show that given only the slope of marginal costs a waterbed effect exists - but its direction is ambiguous. One cannot conclude that downstream mergers automatically harm other downstream firms. However if it is known whether the marginal cost curve is concave or convex then crisp predictions can be made.

Proposition 4 *Suppose that two buyers become more asymmetric while holding their combined purchase volumes constant. Suppose also that all other purchase volumes are unaffected and that at least two upstream suppliers compete ($N \geq 2$). Then:*

1. *Increasing (decreasing) upstream marginal costs are compatible with both a standard waterbed effect and an inverse waterbed effect.*
2. *If upstream marginal costs are convex (concave), whether increasing or decreasing, then the increase in downstream asymmetry increases (decreases) the input prices for all other downstream firms.*

To see the result, suppose the downstream firms become more concentrated while the total volumes demanded stay unaffected. This increase in downstream concentration makes things riskier for any supplier: it raises the variance of the supplier's volumes and thus acts as a mean preserving spread of the volumes each supplier expects. The average input price paid by buyer i depends upon the average cost incurred by the supplier in supplying q_i from a (random) volume supplied to other buyers of Q_{-i} . As the variance of Q_{-i} grows, the average cost of the extra q_i units grows if marginal costs are convex. And this results in an increase in the average input price for this buyer. That is a standard waterbed effect results. Analogously if marginal costs were concave then an increase in downstream concentration would result in an inverse waterbed effect. This intuition is presented graphically in Figure 2.¹¹

The first result follows as increasing marginal costs are possible in both a concave and convex way. Hence clear waterbed results are not, it would appear, immediately available. However more can be said as to the plausibility of some cost function shapes. We discuss this in Section 5.3 below.

A corollary of Proposition 4 is that we can predict the effect of a merger of downstream firms on prices paid by other downstream firms.

Corollary 2 *Suppose that two buyers merge while holding their combined purchase volumes constant. Suppose also that all other purchase volumes are unaffected. Then if the upstream marginal cost curve is convex (concave) then the downstream merger increases (decreases) the average input prices for all other downstream firms for any number of competing suppliers $N \geq 2$.*

¹¹Some recent work on waterbed effects is offered by Inderst and Valletti (forthcoming) and Majumdar (2005). Our model however is unique in modelling a bargaining interface rather than relying on the upstream to match an exogenous outside option. Also our analysis affects all retailers, not just those in competition with an expanding buyer.

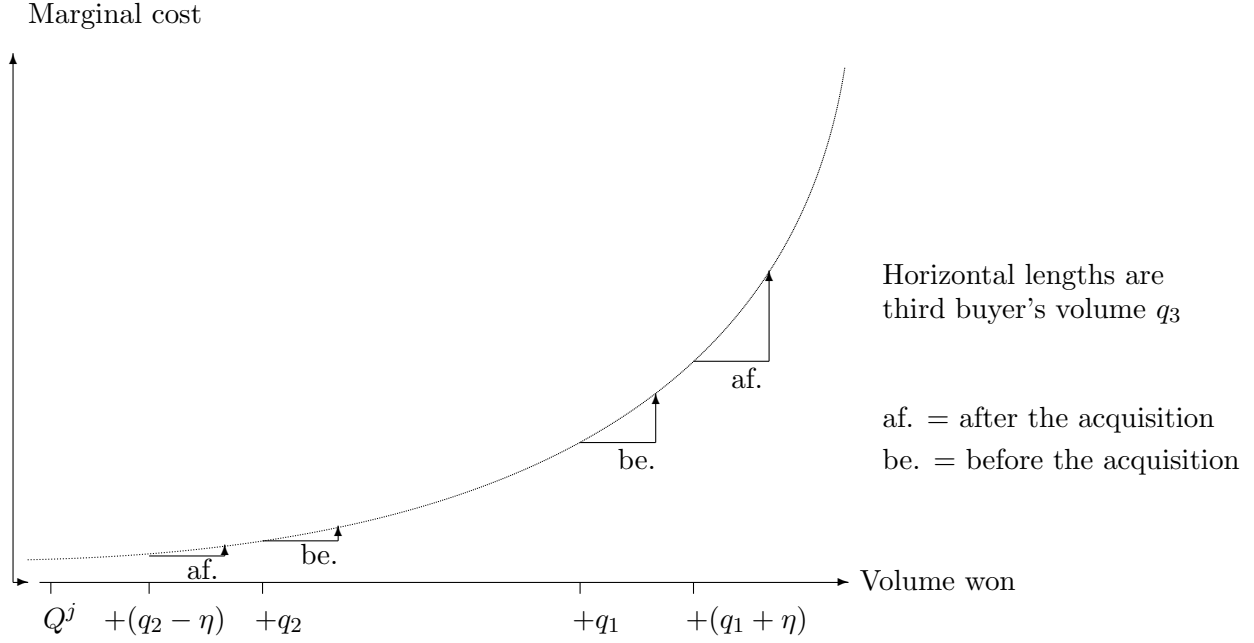


Figure 2: Suppose there are D downstream buyers and Q^j represents some realization of volumes won by some supplier from buyers $\{4, \dots, D\}$. The diagram considers the effect on the average cost of supplying buyer 3 (whose volume is given by the length of the horizontal lines labeled *af.* or *be.*) of the acquisition by buyer 1 of volumes η from 2. The convex shape of marginal costs causes the average cost of supplying 3 if 1 alone is won to increase substantially. Whereas the average cost of supplying 3 if just 2 is won barely changes. Hence the acquisition by 1 of parts of 2 causes the expected average cost of serving 3 to grow. This delivers a standard waterbed effect.

The reasoning is exactly as before: a merger is the logical conclusion of a process by which the smaller downstream firm (q_2) hands all its volume over to the larger firm (q_1).

5.3 The Slope And Curvature Of Marginal Cost

Whether a given cost structure has a convex marginal cost is an empirical question. However a priori the most natural assumption would seem to be one of convex marginal costs; whether increasing or decreasing.

One might take increasing marginal costs in a given industry as the standard textbook view. This would capture that capacity constraints were being approached, or that ramping up production becomes increasingly difficult. This would be most naturally captured by a marginal cost curve which increased at an increasing rate as the ultimate capacity constraint is neared. This is a convex marginal cost curve.

If instead decreasing marginal costs were likely then it would be most natural to expect

marginal costs to *gradually* fall to some constant level as volumes rose.¹² In contrast for the marginal cost function to be concave one would require the unnatural condition that marginal costs collapsed at an ever increasing rate towards 0.

If marginal costs are convex, then Proposition 4 would predict a standard waterbed effect arising from downstream increases in concentration. Other retailers not involved in the concentration increase would see their input prices rise.

6 Incentives to Invest: Endogenous Technology Choice

A concern often raised about downstream buyer power is that it may lower upstream incentives to invest in cost reducing technologies. Clearly if upstream firms extract less profit then their incentives to invest are reduced. This section addresses what endogenous technology choice the suppliers will select.

To analyze cost reducing supply chain investments in the most empirically relevant way we allow rival suppliers to react to any cost reductions. This section therefore uses the *anticipatory equilibrium* described in Mas-Colell, Whinston and Green (1995, Chapter 13D).¹³ This is an appropriate concept here as the innovations employed are typically not covered by patents: rather they are cost reductions due to well understood technology such as larger plants. This means that there is ample opportunity for any supplier to match the investment of a rival supplier. We analyze investments from the position that the upstream firms invest so as to maximize their individual profits in the expectation that profitable investments will be undertaken by all and the upstream market remains symmetric. These assumptions sit well with the UK Grocery Market within which 60% of suppliers to supermarkets conduct innovation to “keep up with the market.”¹⁴

To conduct the analysis of endogenizing technology it is essential that the probability of securing contracts in the bargaining interface is endogenised. Hence we use the upstream competition model of Section 4. As we are analyzing the effect of changes in downstream market structure we again restrict to inelastic downstream demand to avoid intractable feedback effects. Thus the input prices agreed are given by (3).

Suppose that industry demand is normalized to 1. Let there be one large downstream buyer requiring volumes $q_L \in (0, 1)$ and suppose the remaining volume $(1 - q_L)$ is split between D_S equally sized small buyers where the number D_S is large. Suppose that suppliers’ technology is originally given by an increasing marginal cost function $c(q)$. We will consider the family of

¹²The Operations Research literature has noted that economies of scale and scope in delivery would yield such a shape to marginal cost. See Burns et al. (1985).

¹³See also Wilson (1977) for a seminal application of the solution concept to insurance markets.

¹⁴Competition Commission (2008), Appendix 9.2, paragraph 34.

marginal cost functions $\{\tilde{c}(q)\}$ such that the costs of producing the expected quantity $(1/N)$ are held constant: $\int_0^{1/N} \tilde{c}(q) dq = \int_0^{1/N} c(q) dq$.

Proposition 5 *If q_L is sufficiently large then under the anticipatory equilibrium:*

1. *Suppliers prefer the linear cost function from the family $\{\tilde{c}(q)\}$ to the original increasing marginal cost function.*
2. *Further the suppliers prefer any decreasing marginal cost function in $\{\tilde{c}(q)\}$ to the linear cost function of part 1. above.*

Note that the total cost of producing volumes strictly in the range $(0, 1/N)$ is lower with the linear cost function than the decreasing marginal cost technology. And lower still with the benchmark increasing marginal cost technology. Further, if the large buyer is won then she would pay less if the upstream industry selects a decreasing marginal cost technology (Proposition 2). Nevertheless the upstream industry prefers the decreasing marginal cost technology which exacerbates the buyer power of the large buyer.

To understand this note that if the large buyer is large enough the profit or loss generated from that contract, conditional on it being won, is the dominant part of each supplier's expected profit. The bargaining agreement can be interpreted as the buyer paying the proportion $(2^N - 1) / (2^N - 1 + \rho)$ of the expected costs of production and sharing $\rho / (2^N - 1 + \rho)$ of the revenues. As the production technology is altered, holding the size of the large buyer fixed, the revenue share captured by the winning supplier is unchanged. However the winning supplier must bear the remaining proportion $\rho / (2^N - 1 + \rho)$ of any costs. Moving to a decreasing marginal cost technology which holds the cost of producing the expected quantity constant causes the cost of serving a very large buyer to fall. Bargaining ensures that the supplier captures a proportion of these gains.

Thus our model predicts that competing suppliers of a homogeneous good for which buyers have inelastic demand is liable to move endogenously towards decreasing marginal cost technologies. And this itself exacerbates downstream buyer power. As an illustrative example we will consider the UK milk supply chain in the case study which follows. In this industry suppliers to supermarkets have embarked on a process of building superdairies and shutting smaller regional dairies. Concurrently the grocery sector in the UK has seen the emergence of a very few giant stores which dominate competition.

7 Case Study Evidence

To assess the strength of the assumptions underpinning our analysis we consider case study evidence from the UK. Our main case study is the milk supply chain, but we also discuss carbonated soft drinks. We present evidence on whether there is both a bargaining interface and output uncertainty for suppliers; these features generate our core buyer power and countervailing power results in section 3. We also ask whether upstream competition is the source of this uncertainty, and whether the competition takes a form similar to our model in Section 4.

7.1 Milk Supply Case Study

In the case of milk our evidence comes from interviews with industry executives at various stages in the supply chain: buying managers at the major supermarkets, sales directors at milk suppliers, and farmers’ representatives. Fresh milk is homogeneous to consumers.¹⁵ There are three main competing suppliers (processors): Arla, Dairy Crest and Wiseman. The buyers are the four dominant supermarkets – ASDA/Wal-Mart, Morrison, Sainsbury, and Tesco – and some smaller supermarkets.

Bargaining Interface Industry executives told us that bilateral price negotiations are standard, partly because supply requires discussion of various non-price arrangements such as delivery. During these negotiations both parties make offers, as captured by the following quote: “We [the supplier] suggest a pence per liter price X. They [the supermarket] respond by saying that is much too high, we could go to your rivals and get Y. And so it goes on.” The price per liter of milk is agreed in advance and is constant until renegotiation or contract termination. Industry participants informed us that volumes associated with a given contract are accurately predictable so that the negotiations are in effect for a price and a quantity. This suggests that bilateral bargaining is likely to be efficient, avoiding double marginalization. There was no evidence of side payments.¹⁶

Output Uncertainty Our industry sources revealed clear evidence of supplier-level output variation. The first three columns in Table 1 show this: output changes over time for any supplier. Moreover, executives suggested that output was not only fluctuating but also unpredictable for suppliers. It was clear from interviews that the source of the output uncertainty derives from competition between suppliers for buyer contracts. This is supported by Table 1 which shows that output volatility is from supermarket contracts switching between suppliers rather than volatility in the overall demand for milk.¹⁷ Executives told us that a supplier could

¹⁵Organic milk is considered a different market and is supplied by a different supply chain.

¹⁶Published sources such as the KPMG (2003, x178-9) report on the dairy supply chain corroborate these findings.

¹⁷The table is based on more detailed data showing supermarket contract switching.

Volumes Sold to the Largest Four Supermarkets				
(Units: Million Litres Per Year)				
date	Supplier 1	Supplier 2	Supplier 3	Total
12/03	585	690	870	2145
11/04	575	555	1020	2150
1/05	350	835	940	2125
10/05	430	760	920	2110
Data from Industry Sources				

Table 1: Table of Output Variability.

find itself unexpectedly losing or gaining a contract at short notice as a result of supermarkets initiating a re-tendering round so that, during any re-tendering round, which contracts are won and which lost is unclear. Thus contracts are often agreed in the expectation, but not certainty, that other contracts will be won/lost at the same time. Against this lies the fact that not all supermarkets elect to re-tender during a given re-tendering round. Thus the volumes accruing to these contracts would be more certain (though as contracts are rolling the volumes may disappear at an unexpected point in the future).

Evidence supporting the model of Upstream Competition We now examine whether other aspects of our competition model are consistent with evidence from the milk supply chain.

- *Single supplier required* Most of the supermarkets source their milk from only one supplier. Some of the largest supermarkets use two. However this is, we are told, largely for logistical reasons as suppliers are not equally able to deliver to stores in all geographic locations. With more than one supplier some volumes can be transferred at the margin from one supplier to the other, but only to a modest extent.
- *Sequential bargaining* The supermarkets we interviewed reported that typically they focus detailed negotiations with only one supplier in any round.
- *Credible ability to swap suppliers* As milk is supplied in the supermarket’s own packaging it is a private-label product and final consumers would be unaware of any change in the supplier. Empirically, buyers change supplier at short notice.

7.2 Private Label Carbonated Soft Drinks

We now briefly give details from a Competition Commission (2006) investigation into the private label carbonated soft drinks supply chain (eg. colas).¹⁸ The report notes that contracts to supply

¹⁸See in particular paragraphs 5.18 through 5.32 of the Competition Commission (2006) report. We did not conduct any interviews for this supply chain and therefore cover it more briefly.

private label carbonated soft drinks to supermarkets are determined in bilateral negotiations or occasionally e-auctions. Our model is applicable when they use negotiations. Similar to our model of competition, supermarkets face little difficulty in switching suppliers: the CC note that the gap between making the decision to terminate a contract and initiating supply from a rival supplier can be as short as 2 weeks, and often lies between 2 and 12 weeks. The CC point out that although the needs of a large buyer are often divided across more than one seller, there is still considerable volume volatility for the suppliers resulting from the loss of a contract. As an example one of the suppliers reported that in 2005 the net result of a re-tendering round was a drop in volumes of 10%, and this appears to be unpredictable in advance. In sum, supplier output uncertainty characterizes this supply chain.

8 Conclusion

In this paper we analyze the impact of upstream volume uncertainty on the standard bargaining interface model. Without uncertainty, the textbook case, efficient bargaining between a monopoly supplier and multiple buyers results in retail prices independent of buyer size: hence no countervailing power. Buyer power, the ability for a large buyer to secure a lower average input price occurs if the upstream supplier has increasing marginal costs. We show that any uncertainty faced by the upstream supplier significantly impacts these results. Firstly if there is any upstream uncertainty then buyer size has retail price effects – even with efficient bargaining. The efficiently bargained retail price depends upon the expected marginal cost and this now depends on buyer-specific scale effects. Countervailing power goes to the large buyer if the upstream supplier has decreasing marginal costs. Secondly buyer power, if the uncertainty is great enough, accrues to the large buyer if the upstream supplier has decreasing, not increasing, marginal costs.

A compelling source for supplier uncertainty is, we would argue, the possibility that a buyer might decide to source the input from a rival supplier. Our case study evidence supports this claim. We demonstrate that a bargaining interface between competing suppliers and buyers can indeed produce this uncertainty which then yields the new countervailing power and buyer power results. The bargaining model is a simple extension of the standard simultaneous Nash bargaining approach in which the buying firms are assumed to only be able to negotiate with one supplier at a time. In such a setting a mixed strategy equilibrium is for the buyers to randomize as to the order of supplier they will negotiate with. This mixed strategy approach generates the uncertainty for the suppliers as to which contracts they will win. This result applies even if the buyers have so much bargaining power that they can force the agreed input prices to expected average cost.

Therefore our paper describes a new theory of countervailing power: large firms will secure lower retail prices for their consumers if their supplier faces firm level uncertainty and has decreasing marginal costs. And this theory is applicable to a bargaining interface between a competitive upstream seeking to win supply contracts from many downstream buyers. These results were derived allowing downward sloping downstream demands (i.e. not imposing completely inelastic demands).

Building on the bargaining interface model our paper considers the implications across bargained contracts of changes in downstream market structure through acquisitions or organic growth. (Such externalities are sometimes referred to as waterbed effects). We restricted attention to completely inelastic downstream demand, an assumption which is perhaps best for inputs which form one part of a larger whole such as car parts, or staple agricultural products to a supermarket. Any changes in downstream market structure alters the distribution of volumes a (competing) supplier is expecting to win. As the bargained average input price depends upon the expected average cost of supply, downstream market structure changes have externalities on all bargained outcomes. This is a completely novel identification of waterbed effects to our knowledge. If a downstream firm grows organically then suppliers see a right shift in the expected volume distributions. This lowers others' bargained input prices if marginal costs are decreasing. If the downstream becomes more concentrated then suppliers see a mean preserving spread of the volumes they might win. This raises others' bargained input prices if marginal costs are convex.

Extending the analysis of the bargaining interface between competing suppliers we analyze what technology an upstream industry would prefer as downstream consolidation becomes extreme. The limit of downstream consolidation is that a single large buyer is created. Faced with such a buyer, suppliers would prefer a production technology which lowers their costs conditional on winning this buyer, as there is little other business to be won. Such a production function lowers the input price paid by the buyer, but it lowers the costs of production by more as bargaining does not allow all the costs to be passed to the buyer. Such a production function raises the transfer price paid by any small buyers however. Hence downstream consolidation creates pressure for the upstream to move to technology which increases the buyer power of the largest buyers and further weakens the buyer power of the smallest buyers.

It is probably fair to say that no consensus has yet been reached as to how a bargaining interface between competing upstream firms and numerous downstream firms should be modelled. MacDonald and Ryall (2004) and Lippman and Rumelt (2003) writing in the strategy literature have advocated the use of axiomatic bargaining theory. While in IO, game theoretic forms of the Shapley value have been prominent (de Fontenay and Gans 2005). These approaches all offer

no role for uncertainty and (typically) result in a full network of agreements between all suppliers and all buyers. Instead the bargaining formulation we offer is the simplest tractable one which builds on the Nash bargaining assumption common with monopoly upstream suppliers, and allows for suppliers to be uncertain as to which contracts they will win and which lose. Our case study evidence suggests that these features can be important. This bargaining formulation allows us to demonstrate the waterbed results and the endogenously technology choice result. Our countervailing power and buyer power results are even more general. They just hinge on upstream firm level volume uncertainty, and so they would apply to any bargaining interface formulation which generated that uncertainty.

A Technical Proofs

Proof of Proposition 1. We turn first to the standard bargaining interface which removes all uncertainty by setting $\alpha = 1$. Nash bargaining then implies that the volumes secured by buyer i are

$$q_i = \arg \max_q qp(q/z_i) - \left[\int_{Q-i}^{Q-i+q} c(x) dx \right]_{Q-i=\sum_{j \neq i} q_j}$$

The first order condition yields that q_i is the solution to

$$p(q_i/z_i) + (q_i/z_i)p'(q_i/z_i) = c\left(\sum q_j\right)$$

As revenue is concave q_i/z_i is constant across all markets. And so retail prices are $p(q_i/z_i)$ which are also constant across all markets. This delivers 1a.

To prove 1b note that the transfer splits incremental revenues equally so

$$T_i = q_i p(q_i/z_i) - \frac{v^i}{2} = \frac{1}{2} \left[q_i p(q_i/z_i) + \left[\int_{Q-i}^{Q-i+q_i} c(x) dx \right]_{Q-i=\sum_{j \neq i} q_j} \right]$$

Now suppose that $z_1 > z_2$ so that buyer 1 serves a larger market than buyer 2. As q_i/z_i is constant across all markets $q_1 > q_2$. Let $Q = \sum q_j$

$$\begin{aligned} \frac{T_1}{q_1} - \frac{T_2}{q_2} &= \frac{1}{2} \left[\int_{Q-q_1}^Q \frac{c(x)}{q_1} dx - \int_{Q-q_2}^Q \frac{c(x)}{q_2} dx \right] \\ &= \frac{1}{2} \left[\frac{q_1 - q_2}{q_1} \int_{Q-q_1}^{Q-q_2} \frac{c(x)}{q_1 - q_2} dx + \frac{q_2}{q_1} \int_{Q-q_2}^Q \frac{c(x)}{q_2} dx - \int_{Q-q_2}^Q \frac{c(x)}{q_2} dx \right] \end{aligned} \quad (4)$$

Now suppose that marginal costs are increasing then

$$\int_{Q-q_1}^{Q-q_2} \frac{c(x)}{q_1 - q_2} dx < c(Q - q_2) < \int_{Q-q_2}^Q \frac{c(x)}{q_2} dx$$

and so (4) implies that $\frac{T_1}{q_1} - \frac{T_2}{q_2} < 0$ as required.

We now turn to the case of upstream uncertainty. We will first show the results for the case of two downstream buyers, $z_1 > z_2$. The expected surplus for a given buyer-supplier pair is

$$v^i = q_i p(q_i/z_i) - \left\{ \alpha \int_{q_j}^{q_j+q_i} c(q) dq + (1 - \alpha) \int_0^{q_i} c(q) dq \right\}$$

And this is maximized in Nash bargaining. Thus the equilibrium volumes satisfy the first order conditions $v_i^i(q_1, q_2) = 0$. Note that subscripts are used to denote partial differentiation and the superscript identifies which buyer the surplus function belongs to. Dixit (1986) notes that stability of this system is guaranteed if the following second order conditions hold

$$v_{11}^1 < 0, v_{22}^2 < 0 \text{ and } \Delta := v_{11}^1 v_{22}^2 - v_{12}^1 v_{21}^2 > 0 \quad (5)$$

This is delivered by assuming that the revenue function is sufficiently concave (assumption 2).

We first explore the implications for equilibrium volumes under upstream uncertainty. Suppose that z_1 were increased slightly holding z_2 fixed. The outcome on the bargained quantities can be found by implicitly differentiating the first order conditions:

$$\begin{aligned} \begin{bmatrix} v_{11}^1 & v_{12}^1 \\ v_{21}^2 & v_{22}^2 \end{bmatrix} \begin{pmatrix} dq_1 \\ dq_2 \end{pmatrix} &= \begin{pmatrix} -\frac{\partial v_1^1}{\partial z_1} dz_1 \\ 0 \end{pmatrix} \\ \begin{pmatrix} dq_1 \\ dq_2 \end{pmatrix} &= \frac{1}{\Delta} \begin{bmatrix} v_{22}^2 & -v_{12}^1 \\ -v_{21}^2 & v_{11}^1 \end{bmatrix} \begin{pmatrix} -\frac{\partial v_1^1}{\partial z_1} dz_1 \\ 0 \end{pmatrix} = -\frac{\partial v_1^1}{\partial z_1} \cdot \frac{1}{\Delta} \begin{pmatrix} v_{22}^2 \\ -v_{21}^2 \end{pmatrix} dz_1 \end{aligned}$$

To sign this expression note that

$$\frac{\partial^2 v^1}{\partial q_1 \partial z_1} = \frac{\partial}{\partial (q_1/z_1)} \underbrace{\{p(q_1/z_1) + (q_1/z_1) p'(q_1/z_1)\}}_{<0} \cdot \frac{\partial}{\partial z_1} (q_1/z_1) > 0$$

where we have used the fact that revenue is concave. We have $\Delta > 0 > v_{22}^2$ by equation (5). And if revenues are sufficiently concave then $|v_{22}^2| > |v_{21}^2|$, and this is guaranteed by (1). Hence

$$dq_1 - dq_2 = -\frac{\partial v_1^1}{\partial z_1} \cdot \frac{1}{\Delta} (v_{22}^2 + v_{21}^2) dz_1 > 0$$

Therefore increasing z_1 causes equilibrium volumes q_1 to grow relative to q_2 . Therefore firms serving larger markets sell more volume in equilibrium: $z_1 > z_2 \Rightarrow q_1 > q_2$.

To prove result 2 we must consider the impact on the retail prices. The first order conditions for volumes yield

$$[p(q_i/z_i) + (q_i/z_i)p'(q_i/z_i)] = \alpha c(q_j + q_i) + (1 - \alpha)c(q_i)$$

Suppose that marginal costs are increasing then as $q_1 > q_2$

$$\begin{aligned} [p(q_1/z_1) + (q_1/z_1)p'(q_1/z_1)] &= \alpha c(q_2 + q_1) + (1 - \alpha)c(q_1) \\ &> \alpha c(q_2 + q_1) + (1 - \alpha)c(q_2) = [p(q_2/z_2) + (q_2/z_2)p'(q_2/z_2)] \end{aligned}$$

As revenue is concave we must have $(q_2/z_2) > (q_1/z_1)$. Therefore retail prices are higher in market 1.

This gives result 2 when there are 2 buyers. For more buyers suppose that buyers 3 upwards are held at their equilibrium quantities. The method of proof above confirms that $q_1 > q_2$. Then the retail price result holds for any given realization of demand from buyers 3 upwards, and so holds overall.

Turning to result 3 suppose the buyers are ordered so that $z_1 > z_2 > \dots > z_D$. We have seen that this implies $q_1 > q_2 > \dots > q_D$. Let Q_{-12} be the realized demand from buyers 3 to D. Then the transfer price agreed by buyer 1 is half the incremental surplus created and so is given by

$$T_1 = q_1 p(q_1/z_1) - \frac{v^1}{2} = \frac{1}{2} \left[q_1 p(q_1/z_1) + E_{Q_{-12}} \left[\alpha \int_{Q_{-12}}^{Q_{-12}+q_1+q_2} c(x) dx + (1 - \alpha) \int_{Q_{-12}}^{Q_{-12}+q_1} c(x) dx \right] \right]$$

Therefore comparing average input costs yields

$$\frac{T_1}{q_1} - \frac{T_2}{q_2} = \frac{1}{2} \left[\begin{aligned} &p(q_1/z_1) - p(q_2/z_2) \\ &+ E_{Q_{-12}} \left[\begin{aligned} &\alpha \int_{Q_{-12}}^{Q_{-12}+q_1+q_2} \left(\frac{c(x)}{q_1} - \frac{c(x)}{q_2} \right) dx \\ &+ (1 - \alpha) \int_{Q_{-12}}^{Q_{-12}+q_1} \frac{c(x)}{q_1} dx - (1 - \alpha) \int_{Q_{-12}}^{Q_{-12}+q_2} \frac{c(x)}{q_2} dx \end{aligned} \right] \end{aligned} \right]$$

Suppose that marginal costs are increasing. Then $q_1 > q_2$ implies (from result 2) that $p(q_1/z_1) - p(q_2/z_2) > 0$. Further

$$\int_{Q_{-12}}^{Q_{-12}+q_1} \frac{c(x)}{q_1} dx > \int_{Q_{-12}}^{Q_{-12}+q_2} \frac{c(x)}{q_2} dx$$

And so if α is small enough then $\frac{T_1}{q_1} > \frac{T_2}{q_2}$. That is the large buyer pays a higher input price.

This delivers result 3. ■

Proof of Proposition 3. We have from (3) that

$$\frac{\partial}{\partial q_1} \left[\frac{T_i^1}{q_i} \right]_{i \neq 1} = \frac{2^N - 1}{2^N - 1 + \rho} \frac{\partial}{\partial q_1} \left[E_{Q_{-i}} \int_{Q_{-i}}^{Q_{-i}+q_i} \frac{c(q)}{q_i} dq \right]$$

Suppose a supplier is bargaining with buyer 2. Let W_j denote the winning set of contracts for the supplier drawn from the $D - 2$ downstream buyers numbered $\{3, 4, \dots, D\}$. The probability of winning W_j is denoted $f(j)$ and would involve supplying quantity Q^j . Noting that Q^j and $f(j)$ are independent of q_1 we have

$$\begin{aligned} \frac{\partial}{\partial q_1} \left[\frac{T_2^1}{q_2} \right] &= \text{sign} \sum_{j=1}^{2^{D-2}} f(j) \frac{\partial}{\partial q_1} \left\{ \frac{1}{N} \int_{Q^j+q_1}^{Q^j+q_1+q_2} \frac{c(q)}{q_2} dq + \frac{N-1}{N} \int_{Q^j}^{Q^j+q_2} \frac{c(q)}{q_2} dq \right\} \\ &= \text{sign} \sum_{j=1}^{2^{D-2}} f(j) \cdot \frac{1}{Nq_2} [c(Q^j + q_1 + q_2) - c(Q^j + q_1)] \end{aligned}$$

If upstream marginal costs are increasing then the term in square brackets is positive. Hence organic growth by downstream buyer 1 leads to a higher input price for downstream buyer 2. The converse follows identically. ■

Proof of Proposition 4. Suppose there are D downstream firms: buyer 1 is assumed larger than 2 ($q_1 > q_2$). Consider the $D - 3$ downstream firms numbered from 4 to D . A supplier may win any subset of these $D - 3$ firms. Denote the winning set W_j . There are 2^{D-3} possible such winning sets (the power set of $\{4, 5, \dots, D\}$). Denote the probability of winning W_j by $f(j)$ and demand provided to this winning set as Q^j . Now consider some possible realization of W_j and consider the supplier negotiations with buyer q_3 . We have

$$E_{Q_{-3}} \int_{Q_{-3}}^{Q_{-3}+q_3} c(q) dq = \sum_{j=1}^{2^{D-3}} f(j) \left\{ \begin{aligned} &\Pr(\text{win } q_1 \text{ and } q_2) \int_{Q^j+q_1+q_2}^{Q^j+q_1+q_2+q_3} c(q) dq \\ &+ \Pr(\text{win } q_1 \text{ only}) \int_{Q^j+q_1}^{Q^j+q_1+q_3} c(q) dq \\ &+ \Pr(\text{win } q_2 \text{ only}) \int_{Q^j+q_2}^{Q^j+q_2+q_3} c(q) dq \\ &+ \Pr(\text{lose } q_1 \text{ and } q_2) \int_{Q^j}^{Q^j+q_3} c(q) dq \end{aligned} \right\}$$

Suppose that q_1 grows while q_2 shrinks holding the sum of these volumes constant, keeping all other volumes demanded by the $D - 2$ other buyers constant. Using (3) the average input price has the following dependence on q_1 :

$$\frac{\partial}{\partial q_1} \left[\frac{T_3^1}{q_3} \right] = \text{sign} \sum_{j=1}^{2^{D-3}} f(j) \frac{1}{N} \frac{N-1}{N} \left\{ \left[\begin{array}{c} c(Q^j + q_1 + q_3) \\ -c(Q^j + q_1) \end{array} \right] - \left[\begin{array}{c} c(Q^j + q_2 + q_3) \\ -c(Q^j + q_2) \end{array} \right] \right\}$$

If upstream marginal costs $c(\cdot)$ are convex then $q_1 > q_2$ implies that the term in braces is

positive. The case for marginal costs being concave leading to the inverse waterbed effect follows identically. This gives part 2. For part 1 note that increasing marginal costs are possible with either a concave or convex marginal cost curve. ■

Proof of Proposition 5. First note that with enough small buyers the suppliers will, almost surely, receive equal shares of this business and so supply volumes $Q_{-L} = (1 - q_L) / N$ to these small buyers.

Part 1 of Proposition 5

Define a class of marginal cost functions by $g^r(q)$ indexed by r which coincides with the benchmark $c(q)$ when r is 0 and with a linear cost function when $r = 1$:

$$g^r(q) := (1 - r) c(q) + rN \left[\int_0^{1/N} c(x) dx \right]$$

Note that $\int_0^{1/N} g^r(x) dx = \int_0^{1/N} c(x) dx$ for all r so that $g^r(q)$ lies in the family $\{\tilde{c}(q)\}$.

The expected profit of each supplier is the payments from the small buyers, plus the payment from the large buyer when it is won, less the expected costs of production. Using (3) we have

$$\begin{aligned} E(\Pi^{\text{sup}}) &= \frac{2^N - 1}{2^N - 1 + \rho} \cdot \left(\frac{1 - q_L}{N} \right) \left[\frac{N - 1}{N} g^r(Q_{-L}) + \frac{1}{N} g^r(Q_{-L} + q_L) \right] && \text{cost contribution} \\ &+ \frac{1}{N} \frac{2^N - 1}{2^N - 1 + \rho} \cdot \int_{Q_{-L}}^{Q_{-L} + q_L} g^r(q) dq && \text{cost contribution from large buyer} \\ &- \frac{1}{N} \int_0^{Q_{-L} + q_L} g^r(q) dq - \frac{N - 1}{N} \int_0^{Q_{-L}} g^r(q) dq && \text{expected cost} \\ &+ [\text{revenue terms independent of } r] \end{aligned}$$

Differentiation with respect to r and then letting q_L tend to 1 so that Q_{-L} tends to 0 we see that

$$\lim_{q_L \rightarrow 1} \frac{\partial}{\partial r} [E(\Pi^{\text{sup}})] = \frac{1}{N} \cdot \left[\frac{2^N - 1}{2^N - 1 + \rho} - 1 \right] \cdot \int_0^1 \left(-c(q) + N \int_0^{1/N} c(x) dx \right) dq$$

But in part 1 marginal costs are increasing so

$$\begin{aligned} \int_0^{1/N} c(q) dq &< \int_{1/N}^{2/N} c(q) dq < \dots < \int_{(N-1)/N}^1 c(q) dq \\ \Rightarrow \int_0^1 c(q) dq &> N \int_0^{1/N} c(q) dq \end{aligned}$$

Hence $\lim_{q_L \rightarrow 1} \frac{\partial}{\partial r} [E(\Pi^{\text{sup}})] > 0$ at any $r \in [0, 1]$ which implies that if the large buyer is sufficiently big, the industry would rather move to a linear production technology as claimed.

Part 2 of Proposition 5

Now consider *any* decreasing marginal cost technology $\hat{c}(q) \in \{\tilde{c}(q)\}$. Define a new class of cost functions, $\hat{g}^r(q)$, again indexed by r , which move from the linear cost function used in part 1 to the decreasing marginal cost function $\hat{c}(q)$:

$$\hat{g}^r(q) = (1-r)N \int_0^{1/N} c(x) dx + r\hat{c}(q)$$

We proceed exactly analogously to the above working to deduce that

$$\lim_{q_L \rightarrow 1} \frac{\partial}{\partial r} [E(\Pi^{\text{sup}})] = \frac{1}{N} \cdot \left[\frac{2^N - 1}{2^N - 1 + \rho} - 1 \right] \cdot \int_0^1 \left(\hat{c}(q) - N \int_0^{1/N} c(x) dx \right) dq$$

and as $\hat{c}(q)$ is decreasing in q the expression above is positive overall at any $r \in [0, 1]$. Hence, if the large buyer is sufficiently big, the industry would rather move away from the linear production technology and to any decreasing marginal cost technology within $\{\tilde{c}(q)\}$. ■

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