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UPSTREAM COMPETITION AND DOWNSTREAM BUYER POWER

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Abstract

It is often claimed that large buyers wield buyer power. Existing theories of this effect generally assume upstream monopoly. Yet the evidence is strongest with upstream competition. We show that upstream competition can yield buyer power for large buyers by generating supplier-level volume uncertainty—a feature that emerges from case study evidence of upstream competition—so the negotiated price depends on the seller's cost *expectation*. By analyzing the effect of market structure changes on seller cost expectations the paper gives insights on three key policy-relevant questions around buyer power: (i) who wields it and under what circumstances (ii) does a downstream merger alter the buyer power of other buyers (so-called waterbed effects); and (iii) how are the incentives to invest in upstream technology altered by the creation of large downstream firms?

Keywords: Buyer power; Waterbed effects; Bargaining in the supply chain; Milk; Private-Label; Supermarkets.

JEL numbers: L13, L42, L66

1 Introduction

Do large buyers wield buyer power? Does the growth of large buyers affect the prices paid by small buyers? These questions have grown in importance recently, partly as a result of the increases in retail concentration which have taken place in several economies with the emergence of large retail firms such as Wal-Mart, Carrefour, and Tesco.[1] They are also very prominent

[1]In the UK, the groceries market share of the four largest supermarkets is estimated to have risen from approximately 50% in 2002 to 65% now (CC 2008, Fig 3.1). In Austria the two largest food retailers together control more than 65% of the market ('European Retail Handbook 2003/4', Mintel).

in the healthcare industry in the US. It is often expected that large buyers should be strong buyers but the empirical evidence does not support the contention that size itself matters. This paper argues that upstream competition and its associated uncertainty are key ingredients which determine the consequences of large buyers on negotiated prices.

With an upstream monopoly the existing theory is mixed on the question of who wields buyer power.[2] Katz (1987) creates buyer power by supposing that downstream firms can sponsor upstream entry. The cost of so doing is spread across more units when contemplated by a large downstream firm and so this firm extracts a lower price from the incumbent upstream monopolist. However a criticism of this theory is that introducing entry against an upstream rival may be prohibitively costly and beyond the reach of even the largest downstream buyers. If buyers cannot sponsor entry then the bargaining literature, Chipty and Snyder (1999) and Inderst and Wey (2007), shows that large buyers are actually *weak* buyers, in the case of an upstream technology exhibiting economies of scale. In effect, the large buyer must shoulder more of the inframarginal costs.[3,4]

There is in fact only limited evidence of buyer power with an upstream monopoly. In contrast, when there is competition upstream, the evidence is stronger. This contrast is evident in a recent empirical study by the UK Competition Commission (CC), which uses a unique dataset of per unit prices negotiated between supermarkets and suppliers over a number of years for a wide range of grocery products.[5] The 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, 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. Ellison and Snyder (2001) find qualitatively

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[2]For a full survey see Inderst and Shaffer (2006). The first papers to analyze buyer seller relationships adopting a bargaining interface were Dobson and Waterson (1997) and von Ungern Sternberg (1996). See also MacDonald and Ryall (2004) and references therein.

[3]See Chipty and Snyder (1999) and Inderst and Wey (2007). The reason for large buyers to be weak buyers is that a monopoly supplier is certain of their total volumes in equilibrium. Hence a large buyer bargains over relatively more of the monopoly supplier's final units. Thus, if there are economies of scale the average cost of supplying the buyer is relatively larger (as the supplier's total cost function is concave) than that for a small buyer.

[4]A further source of buyer power with an upstream monopolist is found in De Graba (2003) which notes that a risk averse monopolist would offer lower take it or leave it prices to large buyers whose valuation is unknown so as to lower the risk of the buyer not purchasing.

[5]See CC (2008) Appendix 5.3, especially paras 44-45.

similar results for the antibiotic drugs market. Comparing in-patent 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-patent market, where the buyer has no choice. These authors note that the buyer power literature cited above fails to explain this effect.[6] Finally, Sorenson (2003), in a study of insurance companies purchasing hospital services, finds support for the hypothesis that supplier competition reduces prices but finds no effect of buyer size, whether or not competition is present.

The contribution of this paper is to provide a theory, grounded in case study evidence, which explains the link between buyer size and buyer power when upstream competition and its associated uncertainty is present. The theory also allows us to explore the impact of changes in market structure on input prices for all buyers (so-called waterbed effects[7]) and on upstream innovation incentives.[8]

The hypothesis offered in this paper is as follows. Upstream competition creates volume uncertainty at the firm level for the competing suppliers. The average price per unit at which a supplier will agree to supply a product will depend upon the seller's expected average incremental cost of supplying the buyer. Except in the special case of constant marginal costs, the average incremental cost of supply will depend on the supplier's final volume. As the supplier's final volume is uncertain, so too is the average incremental cost of supplying the buyer at the time the price is agreed. During a negotiation with a large buyer the possible cost implications of business from other buyers are partially discounted as a result of the uncertainty induced by upstream competition: the cost implication of the business of the current buyer is weighted more. With upstream economies of scale a supplier expects a lower average incremental cost of supplying large buyers, hence they receive lower prices.[9] If upstream technology is instead characterized by decreasing returns to scale then the logic would be reversed. This source of buyer power is our first contribution.

Our second contribution is the insight that the distribution of volumes won under upstream competition is a function of downstream market structure. Hence alterations of downstream market structure change the risk profile of volumes for every upstream seller. This creates a link between downstream mergers and the input price for all buyers (via the shape of the upstream cost functions). This link is referred to in European policy circles as a waterbed effect. Up to

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[6]A possible explanation is found in Snyder (1996), which allows buyer size to affect upstream collusion.

[7]See for example Competition Commission (2003), especially paragraph 2.218, and Competition Commission (2000, paragraphs 11.113-11.117). For discussion of other countries, see Dobson and Waterson (1999, Table 2). See Inderst (2007) for a discussion of the policy literature on waterbed effects.

[8]Smith and Thanassoulis (forthcoming) describe the supermarket supply chain in greater detail and compare the differing market outcomes for primary-branded versus other goods.

[9]Inderst and Shaffer (2007) note that downstream mergers across markets can bring suppliers into competition with each other which, in their model, leads to lower input prices if buyers threaten to delist some of the suppliers. This is a very different effect to the one we describe.

now there has been very little theoretical work that establishes a source of waterbed effects.[10] We characterize when waterbed effects are present and when they will be of a standard type: increases in downstream concentration disadvantaging smaller downstream buyers. This is also of important policy relevance as the possibility arises that smaller buyers will be forced to exit the market.

The third main contribution is to explore the suppliers' incentive to innovate by lowering their costs. This addresses a third current policy concern that large buyers may impede the incentives of their suppliers to innovate. We show that the presence of large buyers creates a preference for technologies which increase the large buyers' buyer power and result in higher prices for smaller buyers. Thus, a vicious circle is created for the smaller buyers.

This paper develops these hypotheses though a model of a bargaining interface between multiple suppliers competing to supply a homogeneous good to multiple downstream buyers. That is we have a model of contract negotiation and not a model of procurement auctions or a model of upstream price setters. The evidence that negotiations are a very common form of contracting is strong. For instance, two major recent reports into the supermarket industry, Competition Commission (2000, 2008), do not mention auctions even once 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.[11] 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. These arguments are in line with theoretical insights of Goldberg (1977) and Manelli and Vincent (1995). A number of recent empirical studies for specific industries (see Bajari et al (2008), Bonaccorsi et al (2000), and Leffler et al (2003)) confirm the preference for negotiations over auctions if sellers are not very numerous or contracts are complicated.

The model we offer is built upon a suite of interviews we conducted with buying and selling executives in a supermarket supply chain—that for milk—as well as further case studies. These investigations highlighted the importance of uncertainty created by upstream competition, which arises as a supplier does not know in advance which buyers will approach and complete deals with her. We capture this source of uncertainty in a tractable static bargaining framework. In our model each downstream buyer wishes to source an input from one of the competing

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[10]Some recent work with an upstream monopoly has given support for a waterbed effect which derives from downstream competition effects. See Inderst (2007) and Majumdar (2005). However there is to our knowledge no work with upstream competition.

[11]"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.

upstream suppliers. As in the case study evidence, the uncertainty for the suppliers is generated by not knowing which total set of contracts will be won when any individual contract is being negotiated. The model then captures the interaction of this uncertainty with the production cost and downstream market structure to generate the predictions.[12]

The rest of this paper is as follows. Two case studies are offered in Section 2. The formal model and a motivating example is introduced in Section 3. Section 4 explores when buyer power will exist. Sections 5 and 6 analyze the effect of changes in market structure on bargained prices and social efficiency—the analysis of waterbed effects. Section 7 analyzes upstream investment incentives. Section 8 analyzes the robustness of the main results. Section 9 concludes.

2 Supermarket Procurement Case Studies

An important class of applications for the model is supermarket procurement of products where there are several potential suppliers, e.g. fresh produce, secondary brands, and private-label goods. To ensure a solid justification for our modeling choices we have researched two case studies: the liquid milk market and the market for private-label Carbonated Soft Drinks. In both cases the bargaining environment is very similar and motivates the model developed in the paper.

2.1 Case 1: Bargaining in the UK Liquid Milk Supply Chain[13]

Our main case study concerns the UK liquid milk market. Here we conducted interviews with a number of buying managers at major UK supermarkets and a number of sales directors at UK milk suppliers.

The UK milk supply chain provides a good example of upstream competition. The product is homogeneous to consumers[14] and there are three main competing suppliers (known as milk processors), Arla, Dairy Crest and Wiseman. The buyers are the four dominant supermarkets— ASDA/Wal-Mart, Morrison, Sainsbury, and Tesco—and some smaller supermarkets.[15]

The main features of the supermarket-supplier interface relayed to us by the industry executives are as follows: The standard supply contract in the industry is a rolling one in which

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[12]Inderst and Wey (2007) and Dobson and Waterson (1997) consider simultaneous bargaining but with a monopoly supplier. That surplus shape due for example, to variable marginal costs, will alter the bargained outcome has been shown in Horn and Wolinsky (1988) and Stole and Zwiebel (1996). Supplier competition is modelled in Inderst and Wey (2003), de Fontenay and Gans (2005), Inderst (2006) and Björnerstedt and Stennek (2007); however as uncertainty is absent from these models, its effects cannot be analyzed.

[13]We would like to thank all the industry executives who allowed us to interview them and released the facts which we report below.

[14]Organic milk is considered a different market and is supplied by a different supply chain.

[15]One industry source estimates that as of October 2006, the top 4 supermarkets sold 61% of the liquid milk produced in the UK. The rest is sold by smaller chain stores, doorstep delivery, and convenience stores.

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.

supermarkets need offer only 3 months notice of termination. The price per litre of milk is agreed in advance and is constant until renegotiation or contract termination. The executives we interviewed did not suggest that these standard features of the contracts varied by size of supermarket buyer. Renegotiation or termination of contracts does not happen at predictable times, nor in some dynamic order. Instead any or all supermarkets can seek to terminate and change suppliers at any given point in time. As a result, during a renegotiation phase a supplier may lose some of her existing contracts while gaining new ones. We do not observe the times that renegotiation occurs without a change in the supplier. However times when renegotiation resulted in one or more of the largest five supermarkets terminating an existing contract were provided to us by one industry participant. These times confirm the unpredictability of renegotiation phases. Supermarkets have relative ease in switching suppliers as the milk is supplied in their own supermarket packaging. Thus milk is a private-label product and final consumers would be unaware of any change in the identity of milk supplier. Finally capacity constraints are not binding.[16]

The industry participants we interviewed informed us that the volumes associated with a given contract are very accurately predictable.[17] However as contracts can be won and lost the total volumes actually supplied by a given supplier are volatile. As Table 1 shows supplier-level volatility is a result of competition between the three main suppliers rather than volatility in the total demand for milk.

Though the product is homogeneous, supply requires the inter-working of complicated supply chain arrangements and so supermarkets do engage in negotiations with a supplier: auctions or

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[16]We were told that suppliers were not restricted by binding capacity constraints either at the level of the processing plant or at the level of the farmers producing milk. At the level of the processing plant this is because of the modular design of modern dairies, which allows rapid capacity adjustment should new contracts be won. At the level of the farmers this is because liquid milk commands a price premium over its alternative uses (cheese and butter) and so the farmers supplying a processor can substitute immediately towards milk if that processor were to win a large supermarket contract.

[17]The exception is that milk sales become less predictable in the few days running up to Christmas.

	Supplier 1	Supplier 2	Supplier 3	Total
Supermarket 1		15.66	9.10	
Supermarket 2	5.08	5.61		
Supermarket 3			10.79	
Supermarket 4		1.69	2.96	
Supermarket 5	4.66		4.66	
Supermarket 6	1.90			
Supermarket 7	1.38			
Other buyers	19.37	9.21	7.94	
Total	*32.38*	*32.17*	*35.45*	*100.00*

Table 2: Table of Market Shares in October 2006.

arms length contracting are not possible. During these negotiations both parties make offers. This process was 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.*"

Supermarkets either source from just one supplier, or divide their needs into two distinct geographical contracts and use one supplier for each of these contracts. The division is usually on a North-South basis in Great Britain so that in these cases contracts are again over discrete quantities. In October 2006 the supermarket contracts of the largest supermarkets were given by the figures in Table 2 (normalized into market shares).

From the case study we have reported we draw the following conclusions:

1. Supermarkets regularly and unilaterally start new procurement rounds at unpredictable points in time.

2. Suppliers face uncertainty regarding current tender successes and losses of existing contracts when negotiating for any given contract.

3. Negotiations are over a per unit price taking as given the required quantities.

These insights are consistent with published sources. The KPMG (2003, §178-9) report into the dairy supply chain corroborates the fact that supermarkets initiate retendering rounds with prices per unit being negotiated, and notes that this format is common across supermarket supply negotiations. The Competition Commission (2003, §5.97) merger investigation also confirms that the supermarkets were aware of their importance in the supply chain and seek to "play off the major processors [suppliers] against each other. [The national retailers] have the ability to switch volumes easily between suppliers".

2.2   Case 2: Procurement of Private-Label Carbonated Soft Drinks

The procurement process for milk appears to be shared by other supermarket private-label goods. In support of this we offer a short case study of the private-label carbonated soft drinks supply business drawn from the Competition Commission (CC) report into the proposed merger of two suppliers.[18]

The CC report notes that the standard contracts to supply private-label carbonated soft drinks to supermarkets are rolling and sometimes not even written down. They 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. Prices are agreed at the beginning of a contract and are constant until contract renegotiation or termination. Supermarkets face little difficulty in switching suppliers and competition between suppliers is intense. Supermarkets use negotiation to secure the lowest possible prices. Due to the ease of retendering and switching suppliers the CC note that there is little competitive advantage to being the incumbent supplier.[19] Instead competition begins afresh in each retendering round. The CC point out that contracts are generally not subdivided so that there is a winner takes all approach to supply. This creates volume volatility for the suppliers. However carbonated soft drinks requires large volumes for suppliers to generate profits. As an example one of the merger parties reported that in 2005 the net result of a retendering round was a drop in volumes of 10%. This resulted in decreases in gross margins of approximately one-fifth and operating margins of nearly one half.

The facts of the private label carbonated soft drinks supply business tally with those of milk and provide strong support for the conclusions drawn from the milk case study.

3   The Model

This section proposes a model of upstream-downstream bargaining. Although the model is motivated by the case studies in the previous section, it applies to other supplier-buyer situations with upstream competition (some of which are noted in the introduction) where the effect of competition is to create output uncertainty for the suppliers. We assume throughout that all suppliers and buyers are risk neutral.

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[18]See in particular paragraphs 5.18 through to 5.32 of the Competition Commission (2006) report.

[19]The Competition Commission explicitly noted the lack of incumbency advantage during a renegotiation round in Carbonated Soft Drinks. In milk we have reported that multiple buyers can and do renegotiate or recontract at unpredictable points in time which would act to limit the value of any incumbent contract.

3.1 Industry Configuration

Suppose there are U upstream firms in competition to supply a homogeneous input to down-stream firms. These upstream firms all have access to the same technology and so have the same total cost function: a firm supplying q units incurs total cost $C(q) : [0, Q] \to \mathbb{R}_+$ where Q is the maximum possible demand from the downstream buyers. We normalize so that zero production is costless, $C(0) = 0$. The cost function is assumed twice differentiable and strictly increasing in quantity. We consider two classes of cost functions: concave and convex. Concave cost functions imply that average costs decline as volumes grow (increasing returns to scale), the opposite is true for convex cost functions. There are no binding capacity constraints: all upstream firms could in principle supply the entire market demand of Q.

Downstream there are D buyers labeled $i \in \{1, 2, \dots, D\}$. Buyer i seeks the fixed quantity q_i units of the input and bargains over a per-unit price t_i. The input price t_i is assumed not to influence the downstream firm's revenues. Thus the model we propose implies the retailer does not optimize against t_i the bargained linear price when setting the retail price. The fixed demand assumption is not essential, though it does simplify the analysis allowing us to highlight the role that contract uncertainty plays in the bargaining stance of suppliers.[20] The framework extends to endogenize downstream firms' demands without altering the results, as we have done in other work (see Section 8.3).

We use the term *incremental costs* to refer to the extra costs incurred by the supplier to supply a specific buyer. Thus if q is sought by a buyer given a baseline output x that would be supplied in the absence of the buyer the incremental cost is $C(x + q) - C(x)$. Average incremental costs denoted $I_q(x)$ are the cost per unit of producing q more units from a base level of x units of production:

$$I_q(x) := \frac{C(x + q) - C(x)}{q} \text{ and } q \in \{q_1, q_2, \dots, q_D\}. \tag{1}$$

The 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.

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[20]A constant q_i is consistent with the volume being the efficient output when optimizing against expected marginal cost (i.e. avoiding double marginalization). Even in (inefficient) settings where output is optimised against intermediate price it is consistent with a setting where the input is a sufficiently small part of a final product with Leontief production technology, such as the supply of e.g. salt to trade buyers, a standard component in the automotive supply chain, etc.

3.2 Introducing Upstream Volume Uncertainty—A Motivating Example

One of the main results of this paper is that upstream volume uncertainty generated by upstream competition creates buyer power for large buyers when sellers have economies of scale, and buyer power for small buyers when sellers have increasing returns to scale. This subsection provides a motivating example of this effect for the case of economies of scale.

To abstract from industry-level volatility normalize the volumes the downstream industry requires to 1. Suppose also that an upstream supplier has quadratic total cost function $C(Q) = Q(2-Q)$ which has increasing returns to scale over the feasible range. During a procurement round the supplier is negotiating with a downstream buyer who requires fixed volumes q. The per unit input price which will be agreed is assumed to be a monotonic function of the firm's expectation of its average incremental costs of supply, $I_q(x)$ where x is the volume won from other buyers.

Case 1: Upstream Monopolist. If q is won from the buyer then the supplier will supply the whole industry. Failure to secure the contract would mean supplying the remaining volume $1-q$. Thus average incremental cost is deterministic and increasing in q:

$$\begin{bmatrix} \text{Average Incremental} \\ \text{Cost} \end{bmatrix} = \frac{C(1) - C(1-q)}{q} = \frac{1 - (1-q)(1+q)}{q} = q$$

so that larger buyers pay more per unit.[21]

Case 2: Upstream Competition. Upstream competition means that the supplier will win baseline orders for some volume $x \in [0, 1-q]$. However at the time of negotiation x is uncertain. Suppose that the expected fraction of the remaining volume won is λ. Then $E(x) = \lambda(1-q)$ and the expected average incremental cost is:

$$\begin{bmatrix} \text{Expected Average} \\ \text{Incremental Cost} \end{bmatrix} = E_x \left\{ \frac{C(q+x) - C(x)}{q} \right\} = E_x[2 - q - 2x]$$
$$= 1 + (1-q)[1 - 2\lambda].$$

If upstream competition is such that the proportion of the industry business expected to be won is less than 50% then $\lambda < \frac{1}{2}$ and larger buyers now pay less per unit. The intuition is that upstream competition causes the supplier to discount the other volumes which could be won and so the economies of scale achievable with the current buyer dominate.

The above example is for the case of increasing returns to scale. In the case of decreasing returns to scale the same intuition applies and the result is reversed: the smaller buyer pays less

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[21]This replicates the insight of Inderst and Wey (2007) and Chipty and Snyder (1999).

per unit.

The example indicates the effect of upstream uncertainty arising from competition. This example is incomplete as the monotonic link between expected average incremental cost and the negotiated per unit input price is not modelled. We now model this link explicitly.

3.3 Upstream Volume Uncertainty—A Bargaining Model

We first define the ultimate disagreement outcome. If the downstream buyer should ultimately fail to agree with any of the U upstream suppliers then she can source the input at a "high" price of κ per unit. (High means $\kappa > C'(q)$ for all $q \in [0, Q]$). This could be through importing from a different geographical market for example.

We assume for convenience that any idiosyncratic taste shocks between suppliers and buyers are negligible so that the U upstream firms are symmetric as far as a downstream buyer is concerned. Each buyer determines the order to negotiate with the upstream firms. The buyer negotiates with one supplier at a time, approaching initially the first supplier on its list.

The negotiation between buyer and any supplier takes the form of a full information alternating offer no discounting bargaining game as in Binmore et al. (1986).[22] That is, the two parties make alternating offers and after each offer there exists a small exogenous probability ε that the bargaining irretrievably breaks down.

As Binmore et al. (1986) show, the solution is that the parties evenly split the joint surplus from the relationship relative to their respective alternatives when bargaining breaks down.[23] In our model the supplier's alternative is to forgo the sales to that buyer. But for the buyer the alternative is to bargain with the next supplier on the list.

The negotiation with the next supplier takes the same form as the negotiations with the first. However, the buyer is now in the weaker position of having one fewer potential supplier on its list. The buyer moves sequentially through the whole of its list of U suppliers until agreement is reached. At each point the bargaining supplier knows how many other suppliers are still sourcing possibilities for the buyer. If no agreement is reached with any supplier the ultimate outside option for the buyer is to source at (the expensive) κ.

The overall solution to the game is built up by iteration through the U upstream firms in the buyer's list and the buyer's ultimate outside option of κ per unit. The overall solution is given by an equal split between buyer and supplier of the gains from trade in excess of the value

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[22]As Binmore et al. (1986) note their model is a way of providing a micro-foundation for the Nash bargaining solution in which parties split the gains evenly. The results of our model are therefore consistent with any model generating the Nash bargaining solution.

[23]The 50-50 rule is not essential however. Had the probabilities of breakdown been ε_U when an upstream firm proposes and ε_D otherwise the split of the gains from trade above the outside options would be split according to the ratio of ε_U to ε_D.

which would be enjoyed if the buyer moves on and bargains with the second supplier, with one fewer supplier remaining.[24] Thus we capture the idea that should negotiations with U_1 break down the downstream firm will be able to go to U_2 and derive a known surplus, so if U_1 is to win the business it must offer a price lower than U_2 will. However U_1 still has some bargaining power because the buyer's position is weakened when it then has one fewer potential supplier remaining.

Before introducing multiple downstream buyers, we first solve this model for a simple intuition-building case of a single buyer.

3.3.1 Case of a Single Buyer

Consider the case of a single downstream buyer seeking q units. If a supplier finds it is chosen for negotiations then it knows its total volume q exactly. Solving the bargaining game in this context leads to the following result:

Lemma 1 *The price per unit agreed by the downstream firm which seeks q units of input when it has u upstream firms left to bargain with, including the firm with whom it is currently negotiating, is given by*

$$t\left(u\right) = \frac{1}{2^u}\kappa + \frac{C\left(q\right)}{q}\left[1 - \frac{1}{2^u}\right] \tag{2}$$

The agreed price per unit exceeds average costs $C\left(q\right)/q$ by an amount which depends upon the number of suppliers and the ultimate outside option facing the downstream firm: to obtain supply at price κ once negotiations have broken down with all u remaining suppliers.

Proof. Binmore et al. (1986, p185) note that the outcome of bargaining without time preferences between the two parties is given by the Nash Bargaining Solution with the disagreement point set equal to the payoffs which would ensue should the bargaining process break down. Here this implies that the parties split the gains from trade, in excess of what each could get in the event of a breakdown, equally between them. Thus suppose the downstream firm has n upstream firms left to negotiate with. The extra surplus available from dealing with the nth supplier as opposed to the $(n-1)^{th}$ is $q\left[t\left(n-1\right) - t\left(n\right)\right]$. Next consider the upstream firm when there are n suppliers (including herself) left for this downstream firm to approach. Should agreement be reached at input price $t\left(n\right)$ then profits of the supplier are $qt\left(n\right) - C\left(q\right)$. Her profits in the event of this bargain breaking down are 0. The Binmore et al. (1986) bargaining game requires the gains from trade to be equal as the size of the profit to be split is unaffected

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[24]The backwards iteration through the buyer's disagreement alternatives is related to the approach in Stole and Zweibel (1996) who examine bargaining over labor inputs. In Stole and Zweibel a buyer aiming to employ a given number n of workers has an immediate alternative of employing (n-1), and the iteration backwards to n=0. In our model the buyer seeks only a single seller, and iterates through alternative sellers until there are none left.

by the agreed price and so we have the difference equation

$$q\left[t\left(n-1\right)-t\left(n\right)\right]=qt\left(n\right)-C\left(q\right)$$

where $t\left(0\right)=\kappa$. The solution is given in the lemma. ∎

Lemma 1 shows how with a single buyer the input price agreed varies with the suppliers' average costs of supplying the buyer and the number of competing suppliers. We now develop the full bargaining model with multiple buyers.

3.3.2   The Full Bargaining Model

The full bargaining model introduces supplier uncertainty about total volumes, which was identified as key in our case studies. To capture this simply and tractably we assume that all D buyers conduct negotiations for the required inputs simultaneously using the sequential scheme detailed above. Each supplier is represented by separate sales agents in each of the D possible negotiations. There is no information transfer between the different negotiations and so each of the D sequences of negotiations happen independently of each other. The sales agents maximize their firm's expected profits. If a sales agent is negotiating with a buyer they therefore know how many other suppliers this buyer could potentially source from should negotiations break down; the sales agent does not however know which of the other $D-1$ buyers might have concluded agreements with their company for its supply. Thus total volumes are uncertain mirroring the insights from the case studies.

We focus on the buyers' mixed strategy equilibrium in which each buyer randomises as to what order to approach the suppliers. This rules out equilibria in which the buyers coordinate their purchases to remove any uncertainty for the upstream suppliers – we discuss this further below. By the assumption of symmetry between suppliers, each supplier therefore views her probability of winning any other given contract as $\frac{1}{U}$.[25]

Given our model, the same proof used to derive Lemma 1 yields the following:

Lemma 2 *The price per unit agreed by a downstream firm of type i which seeks q_i units of input when it has u upstream firms left to bargain with is given by*

$$t_i\left(u\right)=\frac{1}{2^u}\kappa+\frac{\Delta C_i}{q_i}\left[1-\frac{1}{2^u}\right]=\frac{\Delta C_i}{q_i}+\frac{1}{2^u}\left[\kappa-\frac{\Delta C_i}{q_i}\right] \tag{3}$$

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[25]This symmetry assumption is not essential. All the results would follow if the suppliers were differentiated, resulting in other probabilities of winning any given contract, as long as the probabilities of winning a contract decline as the upstream competition increases.

where

$$\Delta C_i = E \left(total\ cost \left| \begin{array}{c} win\ contract \\ with\ type\ i \end{array} \right. \right) - E \left(total\ cost \left| \begin{array}{c} lose\ contract \\ with\ type\ i \end{array} \right. \right)$$

Using (3) we see that the agreed price per unit for buyer i exceeds the expected average incremental costs $\Delta C_i / q_i$ of supplying i by an amount which depends upon the number of suppliers and the ultimate outside option κ. Thus the expression is identical to the expression (2) for the case of a single buyer, except that the supplier now takes an *expectation* of the average incremental costs of supplying buyer i. This expectation can be expressed using the notation in (1) as follows

$$\frac{\Delta C_i}{q_i} = E_{q_{-i}} \left[I_{q_i} \left(q_{-i} \right) \right]$$

where q_{-i} is the random variable denoting volumes won from the $D - 1$ buyers other than i.

Note that average incremental cost is a function both of the size q_i of the buyer (which is known) and of the output q_{-i} the supplier wins from all other negotiations (which is uncertain). Therefore, the seller's expectation of average incremental costs depends not just on the size of the buyer but also, by standard risk theory, on the mean and spread of the output she might win in other negotiations and the curvature of the average incremental cost function (1) in that output. The mean and spread of the output from other buyers is determined by downstream (and upstream) market structure. The results in the rest of the paper build on these insights.

The robustness of this model is explored in Section 8 where the effect of generalizing to allow for downstream coordination, dynamic contracting, auctions and endogenous downstream demand are all explored. As long as upstream volume uncertainty remains then our results continue to hold, as indicated in the motivating example in Section 3.2 which did not rely on a specific bargaining model. We therefore offer this model as an analytically tractable way of studying the key features of buyer-seller relationships that emerged from the case studies: competing suppliers, bargaining, and uncertainty over which contracts will be won.

4   The Effect Of Buyer Size On Buyer Power

We have noted that supplier certainty and increasing returns to scale hands the greatest buyer power to small buyers (e.g. Chipty and Snyder (1999), Inderst and Wey (2007)), a result which sits at odds with policy discussion in many industries. The motivating example in Section 3.2 found the opposite: with increasing returns and upstream competition the large buyers have buyer power. In this section we establish the result for the full bargaining model, considering both increasing returns to scale and decreasing returns to scale cases.

Theorem 1 *Let there be D buyers indexed by i. Buyer i seeks to purchase q_i units. Suppose that $q_1 > q_2$.*

1. *With concave total costs (increasing returns to scale), the larger downstream buyer ($i = 1$) receives a lower input price than the smaller buyer if U is sufficiently large.*

2. *With convex total costs (decreasing returns to scale), the smaller downstream buyer ($i = 2$) receives a lower input price than the larger buyer if U is sufficiently large.*

3. *For the family of quadratic costs, $U > 2$ is sufficient to give the buyer power result.*

4. *In general a sufficient (but not necessary) condition for the buyer power result to hold is that*

$$U > 1 + \max \left\{ \frac{\inf C''(\cdot)}{\sup C''(\cdot)}, \frac{\sup C''(\cdot)}{\inf C''(\cdot)} \right\} \ \text{ with } \sup \text{ and } \inf \text{ found over } q \in [0, Q]$$

This bound is tight for the family of quadratic costs.

The proof of this result is given in the Appendix. Here we provide an intuitive derivation of the result using Figure 1, drawn for the case of concave costs. Consider first the $D - 2$ buyers labeled by $i \in \{3, 4, \ldots, D\}$. A given supplier might win any subset of these $D - 2$ buyers. In particular let W_j be the subset won so $W_j \subseteq \{3, 4, \ldots, D\}$. Suppose that winning W_j results in total volumes demanded of Q^j. Taking as given any realization of Q^j we consider the supplier's bargaining stance when her sales agents are negotiating with two buyers: buyer 1 and buyer 2. To explore the effect of asymmetries suppose that $q_1 > q_2$ so firm 1 is the larger buyer of the two. Figure 1 shows the supplier depicted with increasing returns to scale (concave total cost functions) with volumes supplied measured upwards from Q^j, i.e. upwards from the realization of the other successful contracts that we take as given. The two gradients drawn on the total cost function in the graph to the left give the average incremental cost of supplying the large buyer, buyer 1, conditional on the outcome of the simultaneous negotiations with the other buyer 2 (and vice versa in the diagram to the right). If $U > 2$ then there is a greater chance of losing as opposed to winning the other contract. In this case the supplier puts more weight on the steeper of the two gradients. That is, a supplier sees losing a given contract as more likely than winning it and therefore is more concerned about average incremental costs taking volumes Q^j as its reference point. Thus the effect of competition is to introduce uncertainty which causes the supplier to discount the possibility of success in the other independent negotiations. With this reference point and increasing returns to scale the larger buyer can be supplied at a lower expected average incremental cost.

15

It is intuitive from the diagram that the result is reversed if the cost function is convex.

As the preceding logic is true for any realization of other victories W_j, the larger buyer is offered a lower input price per unit. So the large buyer negotiates a preferential deal: i.e. we have *buyer power*. Chipty and Snyder (1999) get the opposite result because they assume a monopoly supplier and in each negotiation there is no uncertainty as to whether the other buyer is served, so that all the probability weight is attached to the flatter of the two gradients and in that case (as the diagram shows) higher average incremental costs are anticipated when bargaining with the large buyer.
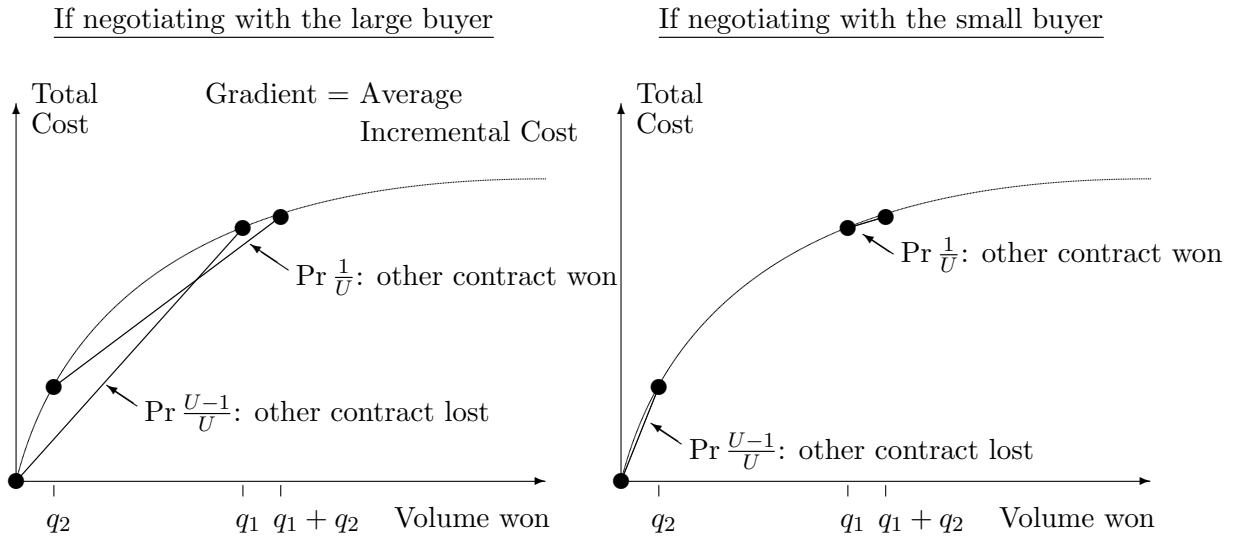

Figure 1: U upstream suppliers compete to supply one large buyer (requiring volume q_1) and one small buyer (volume q_2). A given supplier is depicted with increasing returns to scale (concave total cost functions). The supplier takes as given some realization of other contracts won from the other $D-2$ buyers yielding volumes Q^j - we normalize this point to the origin of the graph. The gradients drawn on the total cost function give the anticipated average incremental cost conditional on the outcome of possible negotiations with the other buyer. If $U > 2$ then there is a greater chance of losing as opposed to winning the other contract. In this case more weight ($\Pr \frac{U-1}{U}$) is put on the steeper of the two gradients. The graph therefore shows that when bargaining with the large buyer, lower average incremental costs are anticipated than when bargaining with the small buyer. So the large buyer negotiates a preferential deal.

In summary, when suppliers have increasing returns to scale a large contract has a lower expected average incremental cost than a small contract, and larger buyers wield buyer power. Identical reasoning for the case of the upstream firms having decreasing returns to scale would yield that smaller buyers receive lower input prices.

The above intuition captures the reasoning behind the proof of parts 1 and 2 of Theorem 1. The remaining parts of the Theorem give the number of upstream firms U needed for the buyer power results to hold. Part 3 states that for the family of quadratic costs, $U > 2$ is sufficient. Part 4 gives a sufficient condition for the general class of cost functions being considered. The theorem has particular relevance when $\max \left\{ \frac{\inf C''(\cdot)}{\sup C''(\cdot)}, \frac{\sup C''(\cdot)}{\inf C''(\cdot)} \right\}$ is not too far from 1: in this case more than 2 upstream competitors is sufficient to deliver larger buyers wielding buyer power if there are economies of scale upstream. This will be the case if the rate of change of marginal cost is not widely varying across the output range. To see why this condition is sufficient suppose that C'' fluctuates between very different values. It would then be possible for a supplier to be in a position where the winning of some other contract, though unlikely at a probability of $\frac{1}{U}$, would alter average incremental costs so substantially that the possibility heavily influences negotiations with other buyers. This possibility becomes more remote as U rises. However we also note that the buyer power result involves averaging across possible final volumes, so as long as any points at which marginal costs change abruptly are limited then one would expect the buyer power result to survive.

Thus we have concrete results that predict large buyers wielding buyer power when the upstream technology exhibits economies of scale, and small buyers wielding buyer power when it exhibits diseconomies of scale. Whether economies of scale are present or significant in any given industry is ultimately an empirical question. [26],[27]

5   Changes in Downstream Concentration: Effects on Prices and Welfare

In this section we extend the analysis to consider the effect of changes in downstream market structure on the prices paid by all buyers. We examine changes that increase buyer size inequality.

In public policy discussions it has been suggested that the emergence of a large buyer with buyer power may result in input prices being pushed up for other smaller buyers, with detrimental effects for their viability. This is sometimes called a waterbed effect. The idea has suffered from a lack of theoretical foundation. For instance, if a supplier could have increased

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[26]When logistics form a substantial part of the costs of supplying a good economies of scale due to economies of density are likely, according to the Operations Research literature (see, for example, Burns et al. 1985).

[27]It is possible that economies of scale may give way at high volume levels to decreasing returns to scale due, for example, to capacity constraints. In such settings the total cost function would initially be concave and then subsequently convex. Theorem 1 wouldn't apply directly – though the intuition underlying it is clear. If the probability of winning enough contracts to push a supplier onto the decreasing returns part of their cost function was low then it would be given little weight in the strategic considerations and large buyers would wield buyer power.

prices to smaller buyers why did it refrain initially, i.e. before the large buyer emerged? And if upstream firms compete then how would they coordinate this price increase? In this section we provide the first analysis of these so-called waterbed effects with competing non-collusive upstream suppliers.

For a supplier negotiating a given order of size q, the waterbed effects in our model are derived from the effect of the change to downstream market structure on the supplier's expectation of average incremental cost, $I_q(x)$. ($I_q(x)$ was introduced in equation (1)). Since a change in downstream market structure changes the probability distribution of x, the total quantity the supplier wins in other orders, it therefore changes the supplier's expectation of $I_q(x)$.

Most of the policy attention to waterbed effects has been given to the case where small buyers end up paying higher prices. However it is possible they end up paying lower prices. We call the first a standard waterbed effect and the second an inverse waterbed effect.

In the next two subsections we consider the effect of two alternative downstream concentration change scenarios: the organic growth of a large firm, and downstream merger. These scenarios have different implications for the distribution of x and both are relevant for public policy. In the final subsection we consider the welfare effects of changes to downstream market structure.

5.1 Downstream Organic Growth

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. We obtain the result that with increasing returns to scale this type of growth causes a fall in the prices to all other downstream firms. With decreasing returns the opposite happens.

Theorem 2 *Suppose that downstream buyer 1 were to increase q_1 by organic growth without affecting the volumes demanded by any of the other downstream buyers $i \in \{2, 3, \ldots, D\}$. Then*

1. *With concave total costs (increasing returns to scale), all other buyers receive a lower input price, for any number of suppliers, as a result of buyer $1's$ organic growth.*

2. *With convex total costs (decreasing returns to scale), all other buyers receive a higher input price, for any number of suppliers, as a result of buyer $1's$ organic growth.*

The proof of this result is in the appendix. The intuition is very simple. For a supplier negotiating a given order of size q with a downstream firm, organic growth by another downstream firm increases the expected value of the total quantity x the supplier will win in other orders,

18

which changes the expectation of the average incremental cost $I_q(x)$ of supplying q. This effect outweighs any risk-enhancing effect of a change in concentration. Thus input prices fall if there are upstream economies of scale (an inverse waterbed effect), while input prices move up if there are upstream decreasing returns to scale (a standard waterbed effect).

5.2 Downstream Growth by Acquisition

We now consider the effect on input prices of an increase in downstream concentration holding total downstream output constant. This might happen as a result of merger of some sales outlets for example. A waterbed effect again exists, though its direction now depends upon the concavity or convexity in total supplier output of the average incremental cost function $I_q(x)$.

Suppose that downstream firm 1 is larger than downstream firm 2 $(q_1 > q_2)$. Now 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. This increases concentration downstream by making the downstream demand more asymmetric. We seek to understand how the input prices of the $D-2$ other retailers would be affected.

Theorem 3 *Suppose that two buyers become more asymmetric while holding their combined purchase volumes constant. Suppose also that all other purchase volumes are unaffected. Then:*

1. *If average incremental costs are convex $\left(I_q'' > 0\right)$ then the increase in downstream asymmetry raises the input prices for all other downstream firms (a standard waterbed effect), for any number of competing suppliers $U \geq 2$.*

2. *If average incremental costs are concave $\left(I_q'' < 0\right)$ then the increase in downstream asymmetry lowers the input prices for all other downstream firms (an inverse waterbed effect), for any number of competing suppliers $U \geq 2$.*

The intuition behind this result is readily explained. Before doing so we note that the condition that average incremental costs are convex (concave) in the supplier's total output is a generalization of marginal costs being convex (concave).[28] Thus Theorem 3 applies more broadly than when marginal costs are convex or concave.

To see the result, suppose the downstream firms become more concentrated while the total volumes demanded stay unaffected. The expected volume a supplier will win is $\frac{Q}{U}$ (by symmetry each supplier believes they have as good a chance of winning contracts as any other supplier). However, an increase in downstream concentration makes things riskier for any supplier: it raises

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[28] $I_q'' = \frac{1}{q}\left[C''(x+q) - C''(x)\right] = C'''(x+\tilde{q})$ for some $\tilde{q} \in [0, q]$ by a Taylor expansion. Therefore $C''' \gtreqless 0 \Rightarrow I_q'' \gtreqless 0$.

the variance of the supplier's volumes and thus acts as a mean preserving spread of the volumes each supplier expects. If average incremental costs are convex (whether increasing or decreasing) then the mean preserving spread has the effect of increasing the expected average incremental cost, which results in an increase in the input price for all buyers not involved in the acquisition. (For those involved in the acquisition there are also the effects of Theorem 1). Thus, there is a standard waterbed effect which is depicted graphically in Figure 2. By the same reasoning if average incremental costs are concave then there is an inverse waterbed effect—i.e. an increase in downstream concentration lowers the input price for all buyers.
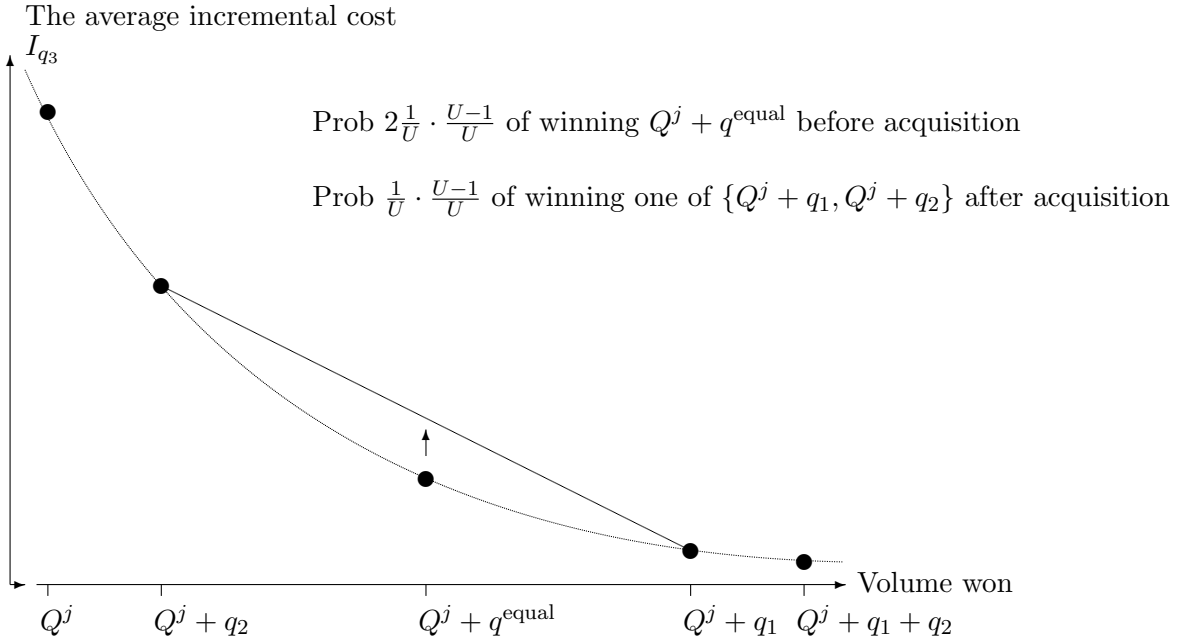
The average incremental cost

I_{q_3}

Prob $2\frac{1}{U} \cdot \frac{U-1}{U}$ of winning $Q^j + q^{\text{equal}}$ before acquisition

Prob $\frac{1}{U} \cdot \frac{U-1}{U}$ of winning one of $\{Q^j + q_1, Q^j + q_2\}$ after acquisition

Volume won

Q^j $Q^j + q_2$ $Q^j + q^{\text{equal}}$ $Q^j + q_1$ $Q^j + q_1 + q_2$

Figure 2: Suppose there are D downstream buyers and Q^j represents some realisation of volumes won by some supplier from buyers $\{4, \ldots, D\}$. Suppose initially buyers 1 and 2 require equal volumes of q^{equal}; subsequently buyer 1 acquires some of 2 so that $q_1 > q_2$. The graph depicts the average incremental cost for a given supplier of serving buyer 3, I_{q_3}, which is assumed convex. The downstream acquisition doesn't alter the probability with which the supplier will win both 1 and 2 or neither. However the volumes won if only the business of one of 1 or 2 is won undergoes a mean preserving spread; and so the expected average incremental costs of serving buyer 3 rise. Hence buyer 3 receives a higher transfer price as a result of the acquisition by 1 of part of 2: the standard waterbed effect.

A corollary of Theorem 3 is that we can predict the effect of a merger of downstream firms on prices paid by other downstream firms.

Corollary 1 *Suppose that two buyers merge while holding their combined purchase volumes constant. Suppose also that all other purchase volumes are unaffected. Then:*

1. *If average incremental costs are convex then the downstream merger raises the input prices for all other downstream firms (a standard waterbed effect), for any number of competing suppliers $U \geq 2$.*

2. *If average incremental costs are concave then the downstream merger lowers the input prices for all other downstream firms (an inverse waterbed effect), for any number of competing suppliers $U \geq 2$.*

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).

Whether a given cost structure has a convex average incremental cost is an empirical question. If there were increasing returns to scale the most natural assumption would be one of convex decreasing marginal costs which implies convex average incremental costs (see footnote 28): then marginal costs would *gradually* fall to some constant level as volumes rose. In contrast for the marginal cost function to be concave $(C''' < 0)$ one would require the unnatural condition that marginal costs collapsed at an ever increasing rate towards 0. If marginal costs (and so average costs) are convex as this reasoning would suggest, then an increase in downstream concentration would lead, by Theorem 3, to a standard waterbed effect: other retailers not involved in the concentration increase would see their input prices rise.[29,30]

5.3   The Welfare Effects of Increases in Downstream Concentration

In this subsection we consider the effect on welfare of changes in downstream concentration. One welfare effect is immediate from the waterbed analysis: if downstream concentration were to increase, small buyers may experience a standard waterbed effect: that is their input prices rise (Theorem 3). If the smaller downstream firms are then unable to cover their fixed costs they may be forced to exit the market. This reflects a standard concern in policy circles, for which our model provides a foundation.[31]

There is however a second effect of downstream concentration arising from the cost of manufacture of the input, as long as all downstream firms remain active:

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[29]Upstream increasing returns to scale is also the setting in which the merging firms will command buyer power. In this case the most natural form of waterbed effect from merger would be of a standard kind: any merger raising input prices for third parties while lowering them for the merging party.

[30]Inderst (2007) and Majumdar (2005) have developed a model with an upstream monopolist which generates waterbed effects. However upstream competition is not analysed. Further our results involve a completely different mechanism to that found by Inderst (2007): we do not require for smaller firms to be able to integrate backwards and the mechanism we have described would affect all small retailers, not just those in competition with an expanding buyer.

[31]The direction of the welfare effect depends on the social value of the smaller firms.

Theorem 4 *Suppose that, holding downstream volumes constant, two downstream buyers become more asymmetric. (Perhaps through a merger or by the larger buyer purchasing some sales outlets from the smaller buyer). Then:*

1. *If upstream firms have concave total cost functions (increasing returns to scale) then the increase in downstream concentration raises expected welfare by resulting in more efficient (lower cost) production.*

2. *If upstream firms have convex total cost functions (decreasing returns to scale) then the increase in downstream concentration lowers expected welfare by resulting in less efficient (higher cost) production.*

The driving force behind this result is the insight that an increase in downstream concentration, coupled with active upstream competition, leads to an increase in risk faced by the suppliers. The constant level of total downstream market demand means that expected volumes are unchanged by the change in concentration. However, the increase in downstream asymmetry creates a mean preserving spread of the distribution of final volumes: the expectation is the same but more weight is pushed towards extreme outcomes. Thus each supplier has a greater chance of winning big volumes but also a greater chance of winning very small volumes. If total costs are concave (increasing returns to scale) then the expected total cost falls. Thus, in expectation, consumers are all served but the industry costs are brought down and so welfare overall is enhanced. Similarly if the upstream total cost is convex the reverse holds.

From the upstream firms' point of view the market with large buyers is characterized by greater volume uncertainty. This has driven many of the results in this section.

6   The Effect of a Change in *Upstream* Concentration

We now turn our attention from buyer concentration to supplier concentration. Our particular interest is whether an increase in the number of suppliers benefits large buyers more than small buyers. The following result is available:

Theorem 5 *As the number of suppliers (U) increases:*

1. *The absolute input price differential between large and small buyers grows if the upstream firms have convex declining marginal costs (increasing returns to scale), and if U is sufficiently large.*

2. *The absolute input price differential between large and small buyers shrinks if the upstream firms have concave increasing marginal costs (decreasing returns to scale), and if U is sufficiently large.*

To see the intuition for this result, suppose there are upstream economies of scale and note that if supplier numbers increase then a supplier's chances of securing any given other contract decline. In particular, when negotiating with the smaller buyer the chances of securing a given large contract are only $\frac{1}{U}$ and this falls as the number of competing suppliers increases. The supplier therefore puts more weight on lower volumes. To ascertain the magnitude of this effect for the large and small buyers we now turn to the assumption that marginal costs are convex (and so average incremental costs are convex by footnote 28). If average incremental costs are convex declining a small reduction in volumes has a bigger effect on the expected average incremental costs at low volumes than at high volumes. Hence the reduction in expected volumes pushes expected average incremental costs up more when negotiating with a small buyer than with a large buyer: and so increasing supplier numbers is much more harmful to the small than the large buyers. The reasoning for part 2, convex total cost functions, is analogous.

To conclude this section we turn our attention to the question of whether an increase in the number of suppliers unambiguously leads to lower input prices for downstream buyers. The answer is not necessarily. Consider an increase in supplier numbers. Recall that we impose that suppliers are symmetric. For any buyer of given size, this has two effects on the actual level of the input prices. First, in Lemma 2 it increases the number of upstream firms left to bargain with before sourcing at the expensive marginal cost of κ. Thus input prices fall towards the expected average incremental cost ($\frac{\Delta C_i}{q_i}$ in equation (3)). This effect is always negative pushing down on input prices. Second, as the number of suppliers rises, each supplier expects to serve smaller total volumes for the reasons outlined in the proof of Theorem 5. This either increases or decreases expected average cost per unit, depending on the direction of returns to scale. Therefore with increasing returns to scale, smaller total volumes increase expected average costs so the two effects push in opposite directions with ambiguous effects for input prices. With decreasing returns to scale in upstream production smaller volumes reduce expected average costs so the two effects work in the same direction, and input prices fall as supplier numbers rise.

7   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.[32] This section addresses what endogenous technology choice the

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[32]However the empirical evidence that increases in downstream concentration choke off upstream innovation is not strong. For example, in their comprehensive analysis of the UK groceries market the Competition Commission note that R&D spending on food production in the UK has been trending upwards. Competition Commission (2008), Appendix 9.2, Figure 6 and paragraph 30.

suppliers will select. To analyse 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).[33] 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 analyse 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.[34] These assumptions sit well with the UK Grocery Market within which 60% of suppliers to supermarkets conduct innovation to "keep up with the market."[35]

In this section we show that as buyer concentration increases a competitive supplier would prefer to switch from convex costs to linear costs and from linear costs to concave costs. This result is perhaps particularly surprising given that firms actively seek technology yielding upstream economies of scale which will (a) only be realized if they were to win a big contract and (b) result in the large buyers paying less (Theorem 1). The result also creates a potential new concern for welfare: a move to upstream economies of scale will make small buyers weak buyers who pay more for the input and could be driven out of business.

Theorem 6 *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 D_S is large. Suppose that suppliers' technology is given by a convex (decreasing returns to scale) cost function $C(q)$ with $C(0) = 0$. Normalizing all costs so that zero production is costless, if q_L is sufficiently large then under the anticipatory equilibrium:*

1. *Suppliers prefer the linear cost function which preserves the cost of producing the expected volumes, $\frac{1}{U}$, at $C\left(\frac{1}{U}\right)$ to the convex cost function (decreasing returns to scale) benchmark.*

2. *Further the suppliers prefer* any *concave cost function (increasing returns to scale) which preserves the cost of producing the expected volumes, $\frac{1}{U}$, at $C\left(\frac{1}{U}\right)$ to the linear cost function of part 1. above.*

Note that the total cost of producing volumes in the range $\left(0, \frac{1}{U}\right)$ is lower with the linear cost function than the concave one, and lower still with the benchmark convex cost function.

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[33]For example, Mas-Colell et al. note that Wilson (1977) has applied these ideas in the context of insurance markets.

[34]If one firm lowers her costs others would wish to emulate as competition for the supply of a homogeneous product would reward any supplier with a lower cost than any of her rivals.

[35]See Competition Commission (2008), Appendix 9.2, paragraph 34.

Thus if suppliers should win less than $\frac{1}{U}$ their costs will be lowest with the benchmark convex production technology. Further if U is large then the probability of winning the large buyer is small.

The proof is provided in the appendix. Here we explain the two main forces driving Theorem 6.

The first is that expected costs are reduced if the production technology becomes more concave. This follows as a bigger main buyer (larger q_L) corresponds to a mean preserving spread of likely business. As suppliers are symmetric, each supplier ex ante expects to supply $\frac{1}{U}$ units, and by assumption the cost for this is independent of the technology. However, as q_L increases there are increasing probabilities of either supplying very little or (less likely) supplying a great deal. If costs are concave then the greater the size of the buyer, and thus the greater the mean preserving spread, then the lower are the expected total costs.

Against this we must consider the second force: the effect on bargained input prices of a switch to a linear and thence to a concave production technology shape. The effect on input prices from the small buyers is to increase them as the cost function becomes more concave—however this effect becomes small as the large buyer becomes a bigger and bigger part of the market. The upstream competition causes these input prices to be determined mostly by the marginal cost at low volumes, and this rises as the technology moves to one of upstream economies of scale (holding average production costs constant).

The input prices from the large buyer, on the other hand, are unambiguously smaller under a concave cost function, for the same reasons. So expected prices per unit decline with the big buyer if we have concave production costs. But these falls are *more than* made up for in lower expected costs if the buyer is big enough. This is because the ultimate outside option for the buyers of having to pay κ per unit of input places a lower bound on how far the input prices can fall. This reduces the effect of the technology on the bargained input price; there is no similar dampening of the expected cost reduction. Thus, the suppliers would rather be more efficient in supplying the large buyer and accept lower input prices.

In the previous literature the shape of the cost function is often treated as exogenous. A notable exception to this is in Inderst and Wey (2007) who show that as buyer concentration increases, a monopoly supplier would prefer to switch from convex costs to linear costs.

The result that increasing downstream concentration will push upstream technology towards economies of scale has, for example, resonance in the UK milk supply (where the dominance of large buyers has increased). In this industry suppliers to supermarkets have embarked on a process of building superdairies and shutting smaller regional dairies. This move to superdairies was initiated by Wiseman and quickly copied by her rivals. These superdairies create a need for

large volumes to achieve low marginal costs. Our analysis therefore predicts that this endogenous technology development has exacerbated the buyer power differential between large and small buyers.

8   Robustness of the Bargaining Model

The bargaining model is deliberately simple to allow the insights to be displayed cleanly. However, this then raises the question of how the results might be altered if the model assumptions are changed. We here describe four possible relaxations: downstream coordination, dynamic contracting, auctions, and endogenous downstream demand.

8.1   Downstream Dynamic Contracting and Buyer Coordination

In the case of upstream technology having economies of scale two related robustness issues should be discussed. First, if contracting were sequential, so that all subsequent buyers know which supplier wins the first contract, then, leaving all other model features unaltered, the first buyer would recognize that she was critical to the supplier securing the full industry profit and so she could extract most of this profit herself through a very low per unit price.[36] Second, in a static setting, in addition to the mixed strategy equilibrium studied, coordination equilibria also exist in which buyers all play a pure strategy and coordinate their purchase decisions on a single supplier.

For both the sequential and the simultaneous coordination cases, the uncertainty in supplier volumes, which was a key feature of our case studies and has motivated our model, has been removed (in the sequential case supplier volumes are deterministic after the first contract is agreed). However, supplier uncertainty can be reintroduced into the model, with some loss of simplicity, by allowing buyers to have private idiosyncratic taste shocks over suppliers. This approach is common in the structural empirical literature and designed to capture unobserved preferences of buyers for supplier differentiation, e.g. differential ability to deliver milk to particular quality specifications.

With private idiosyncratic taste shocks, a sequential version of our bargaining model would then yield the following two insights. First, securing one contract makes it more likely, but not certain, that further contracts will be secured. This is the coordination effect that dynamic bargaining creates. The likelihood of raised profits for the supplier will result in lower per unit prices for the first buyer contracting, whether she were a large or a small buyer. Thus this is 'first

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[36]Arguably, in this case, as the first buyer secures all the rents, one would expect buyers to prefer to be first, and this would return us to the position of buyers contracting at the same time, as in our model.

buyer power' and not 'large buyer power'.[37] The second effect created in this dynamic context parallels that described in Figure 1. Because of the idiosyncratic taste shock, when negotiating with one buyer the supplier is uncertain of which subsequent contracts she will win. As a result, she would therefore put some weight on losing the other contracts. The greater the competition upstream the greater the weight placed on losing the subsequent contracts. Hence though the probabilities associated with losing a contract would not be $\frac{U-1}{U}$ as depicted in Figure 1, they would be large if upstream competition was great. Therefore the supplier bargaining with a buyer would discount other contracts and so consider the buyer's business as incremental—i.e. bargaining would be related to the steeper average incremental cost curves of Figure 1 and large buyers would still wield buyer power if there were upstream economies of scale.

Similarly, in the simultaneous coordination case, the introduction to the model of idiosyncratic taste shocks would again re-introduce upstream volume uncertainty and so the results we have found would continue to apply.

Therefore our results continue to hold under all equilibria with dynamic contracting and buyer coordination provided the suppliers' uncertainty about final volumes is preserved—most naturally by idiosyncratic tastes between suppliers.

8.2 Empirical Relevance of an Auction Model

A further question is why the buyers don't use reverse auctions. One response to this is empirical. Our case studies into the procurement of relatively homogeneous products found that the buyers used negotiations. This appears to be widespread for supermarket procurement: it is informative that in the Competition Commission reports into the grocery sector (2000, 2008), the chapters dealing with supplier relationships make no mention of auctions, while aiming to cover the full range of supermarket supply relationships in considerable depth. Thus for an important class of applications auctions appear not to be used.

To understand why auctions are not used an empirical literature has developed analyzing the choice between negotiations and reverse auctions. This highlights the empirical conditions under which negotiations are revealed to be preferred to auctions. This literature finds that negotiations are preferred when there are few suppliers, there are issues other than price such as quality, and where contractual design is incomplete. (See for example Bajari et al. (2008), Leffler et al. (2007), and Bonaccorsi et al. (2003)). According to *The Economist*, for example, these apply in the vast majority of circumstances, (see note 11). In the case of milk, executives noted that supply contracts required agreeing more than just price: the logistics of supply, what

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[37]However if large buyers go first and are followed by small buyers then the result would be observationally equivalent to large buyer power.

to do in unexpected circumstances, marketing support and other factors were also discussed. Thus at some point a supermarket will be negotiating with just one supplier and (as is common to all negotiations) the deal cannot be agreed until all parts are in place. Therefore in our model the price agreed could be seen as representing the outcome of a more involved negotiation including logistics and marketing as well as price.

These empirical studies provided support for theoretical work that highlighted the adverse selection considerations that weigh against using auctions (see Goldberg (1977) and Manelli and Vincent (1995)). In particular, Manelli and Vincent (1995) note that in a large class of cases, auction mechanisms for procurement will be worse than sequentially offering a contract to each supplier until one accepts, with the ordering of suppliers chosen at random. This applies if the suppliers have private information about the costs to them of supplying a given level of 'quality', and this quality is not contractible. One aspect of quality in the case of procurement for items such as milk is the probability that supply will be interrupted. The interviews we conducted with buying executives highlighted this as of key concern. As this probability is not contractible Manelli and Vincent's work suggests this is one reason why auctions would be dominated by sequential mechanisms. We could include such private quality variables into our model of bargaining to justify not modelling an auction explicitly, but this would involve a considerable increase in the complexity of the exposition. The insights would be unchanged however as the uncertainty as to upstream volumes at the firm level is preserved.

8.3 The Effect of Endogenous Downstream Demand

A virtue of the model is that it is extendable to the case of endogenous downstream demand. This theoretical extension is presented in a companion piece of work, in which we take the model to demand and pricing data from the UK milk supply chain and assess how profit splits would vary in response to market structure changes and other counterfactual changes.[38]

If one extends the model so that negotiations are over a two part tariff with downstream buyers competing then, under standard assumptions, there is efficient bilateral bargaining. Further the buyer power result we have described applies as it stands. The waterbed effects we describe are complicated slightly as changes in downstream market structure alter the volumes each firm demands which create secondary buyer power effects.

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[38]See Manachotphong, Smith and Thanassoulis (2009).

9 Conclusions

This paper examines negotiated contracts between upstream suppliers competing to supply a homogeneous product to downstream buyers. With upstream competition, suppliers are likely to face uncertain output as which contracts are won in any procurement round is uncertain. We offer a formal analysis motivated by two case studies of different private-label supermarket procurement processes. The model allows us to demonstrate the link between supplier output uncertainty (created by competition) and downstream buyer power and waterbed effects.

Our results help clarify the concerns competition authorities often voice regarding: some buyers wielding buyer power; creating waterbed effects; and distorting upstream investment incentives.

We interviewed industry executives and conducted case studies with a view to appropriately modeling the bargaining interface between upstream suppliers and downstream buyers. Our approach differs to an influential strand of the Strategy Literature in which authors such as MacDonald and Ryall (2004) and Lippman and Rumelt (2003) have advocated the use of axiomatic bargaining theory as a mechanism for exploring the bargaining interface between firms. These authors emphasize that axioms allow one to abstract from specific bargaining game forms. Such an axiomatic approach is not without modeling choices, as these authors acknowledge, as there are multiple axioms that can be picked. Leading candidate solutions are the core and the Shapley value. In the context of homogeneous good supply chains both of these approaches lead to problems. As suppliers are substitutable and without capacity constraints the core would yield the suppliers no return at all as competition would collapse to the Bertrand extreme. The Shapley approach can be justified by a non-cooperative game (de Fontenay and Gans 2005) however this requires suppliers to receive payments even if not supplying the homogeneous good.[39] More intuitively one could see the Shapley value as capturing expected bargaining power, but this masks which buyers wield buyer power and under what circumstances. Our approach is instead to seek to understand the drivers of buyer power by making modeling choices as to the bargaining while seeking to justify the choices we have made.

The fact that relationships can be broken readily and suppliers changed quickly in the case studies we offer is clearly not a feature of every supply chain. In celebrated work Asanuma (1989) and Milgrom and Roberts (1992) document longer and more stable relationships between suppliers and car manufacturers in Japan: a system of relationships known as Kyohokai. These relationships prevent suppliers holding up the car manufacturers with higher than expected costs by linking future contracts to keeping costs low now. The case studies we report did not

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[39]These payments are not for nothing in return. The payments would be required to ensure that a supplier who was unsuccessful would be willing to remain available should the other supplier try to renegotiate terms.

have this feature. In the private label supply chains the prices were set at the start, and not at the end, of the contract. Thus the scope for hold up is heavily reduced. Further the extent of buyer specific investment is limited as the Competition Commission explicitly report (2006, para 5.21) in relation to Carbonated Soft Drinks. As these hold-up issues become less important the buyers focus more on extracting the lowest possible prices and hence seek to use threats to leave suppliers at short notice to push prices down.

In a homogeneous supply market one might conclude that there is very little suppliers can do to escape the forces of competition we have modeled. The best examples for our framework have involved supply chains in which final consumers were indifferent between suppliers of the input, e.g. pharmaceuticals, salt, milk, and other private label or secondary branded products. However there are cases where a supplier has been able to differentiate itself to *final* consumers; notably Intel and silicon chips.[40] Silicon chips must conform to a standard architecture and so are, in principle, substitutable. Intel has a number of competitors yet in 2006 controlled over 80% of the market in laptops and over 60% of the market in desktops.[41] How bargaining in the supply chain adapts to the evolution of a consumer branded supplier is an extension which is worthy of future research.

A   Proofs Omitted From the Main Text

Proof of Theorem 1.   Consider the $D - 2$ retailers indexed by $i \in \{3, 4, \ldots, D\}$. There are 2^{D-2} possible subsets of these firms. Index each of these subsets by j. Let $f(j)$ be the probability an upstream supplier sees of winning exactly subset j from these $D - 2$ possible buyers. Let the total demand supplied by this supplier when serving subset j be Q^j. Now consider a supplier negotiating with buyer $i = 1$. We have

$$
E\left(\text{costs}|\,\text{win } q_1\right) \;=\; \sum_{j=1}^{2^{D-2}} f\left(j\right) \left\{\Pr\left(\text{win } q_2\right) C\left(Q^j + q_1 + q_2\right) + \Pr\left(\text{lose } q_2\right) C\left(Q^j + q_1\right)\right\}
$$

$$
E\left(\text{costs}|\,\text{lose } q_1\right) \;=\; \sum_{j=1}^{2^{D-2}} f\left(j\right) \left\{\Pr\left(\text{win } q_2\right) C\left(Q^j + q_2\right) + \Pr\left(\text{lose } q_2\right) C\left(Q^j\right)\right\}
$$

Combining we have

$$
\Delta C_1 = \sum_{j=1}^{2^{D-2}} f\left(j\right) \left\{\frac{1}{U}\left[C\left(Q^j + q_1 + q_2\right) - C\left(Q^j + q_2\right)\right] + \frac{U-1}{U}\left[C\left(Q^j + q_1\right) - C\left(Q^j\right)\right]\right\} \quad (4)
$$

---

[40]For further discussion see Duguid (2006).
[41]Source: http://pcpitstop.com/research/cpuintel.asp

Now we repeat for the negotiation with buyer 2 and using Lemma 2 we establish that

$$t_1(U) < t_2(U) \Leftrightarrow \frac{\Delta C_1}{q_1} < \frac{\Delta C_2}{q_2}$$

which is true if (but not only if)

$$\frac{1}{U} \underbrace{\left[\frac{C\left(Q^j + q_1 + q_2\right) - C\left(Q^j + q_2\right)}{q_1} \right]}_{(I)} + \frac{U-1}{U} \underbrace{\left[\frac{C\left(Q^j + q_1\right) - C\left(Q^j\right)}{q_1} \right]}_{(II)} \tag{5}$$
$$< \frac{1}{U} \underbrace{\left[\frac{C\left(Q^j + q_1 + q_2\right) - C\left(Q^j + q_1\right)}{q_2} \right]}_{(III)} + \frac{U-1}{U} \underbrace{\left[\frac{C\left(Q^j + q_2\right) - C\left(Q^j\right)}{q_2} \right]}_{(IV)}$$

Increasing Returns to Scale (Concave Costs)

If the total cost function is concave then we have $(II) < (IV)$ as the chord on the cost curve between Q^j and $Q^j + q$ becomes less steeply sloped as q increases. Therefore we have $\frac{\Delta C_1}{q_1} < \frac{\Delta C_2}{q_2}$ if U is sufficiently large. This implies that larger buyers get lower input prices as required.

Now consider quadratic costs of $C(q) = q(b - aq)$ with $a, b \geq 0$ and $\frac{b}{2a} \geq Q$ so that the cost function is increasing in the range $q \in [0, Q]$. The incremental cost of q units is $\frac{C(x+q) - C(x)}{q} = b - aq - 2ax$ so that (5) can be rewritten

$$a\left(1 - \frac{2}{U}\right) q_2 < a\left(1 - \frac{2}{U}\right) q_1 \Leftrightarrow U > 2 \text{ as } a > 0$$

Decreasing Returns to Scale (Convex Costs)

If the total cost function is convex then we have $(II) > (IV)$ as the chord on the cost curve between Q^j and $Q^j + q$ becomes more steeply sloped as q increases. Therefore the opposite inequality to (5) holds and we have $\frac{\Delta C_1}{q_1} > \frac{\Delta C_2}{q_2}$ if U is sufficiently large. This implies that smaller buyers get lower input prices as required.

With the quadratic cost function $C(q) = q(b - aq)$ with $a \leq 0 \leq b$ so that the cost function is increasing in the range $q \in [0, Q]$ the incremental cost of q units is $\frac{C(x+q) - C(x)}{q} = b - aq - 2ax$ so that using (5) we have

$$\frac{\Delta C_1}{q_1} > \frac{\Delta C_2}{q_2} \Leftarrow a\left(1 - \frac{2}{U}\right) q_2 > a\left(1 - \frac{2}{U}\right) q_1 \Leftrightarrow U > 2 \text{ as } a < 0$$

Thus we have parts 1, 2 and 3 of the Theorem. For part 4 of the theorem suppose that costs

are concave so that $C'' < 0$. In this case a sufficient condition for (5) to be true is if

$$\frac{1}{U}\frac{\partial}{\partial q}\left[\frac{C\left(\tilde{Q}\right) - C\left(\tilde{Q} - q\right)}{q}\right] < -\frac{U-1}{U}\frac{\partial}{\partial q}\left[\frac{C\left(Q^j + q\right) - C\left(Q^j\right)}{q}\right] \text{ with } \tilde{Q} = Q^j + q_1 + q_2$$

$$\text{and } q \in [q_2, q_1]$$

as in this case (II) shrinks below (IV) faster than (I) rises above (III). This condition is satisfied if

$$\frac{1}{U}\left\{-qC'\left(\tilde{Q} - q\right) + C\left(\tilde{Q}\right) - C\left(\tilde{Q} - q\right)\right\} > \frac{U-1}{U}\left\{qC'\left(Q^j + q\right) - C\left(Q^j + q\right) + C\left(Q^j\right)\right\}$$

$$\parallel \qquad\qquad\qquad\qquad\qquad\qquad \parallel$$

$$\frac{1}{U}\int_{z=\tilde{Q}-q}^{\tilde{Q}}\left(\tilde{Q} - z\right)C''\left(z\right)dz \qquad\qquad \frac{U-1}{U}\int_{z=Q^j}^{Q^j+q}\left(z - Q^j\right)C''\left(z\right)dz$$

$$\parallel \qquad\qquad\qquad\qquad\qquad\qquad \parallel$$

$$\frac{1}{U}\int_{w=0}^{q}wC''\left(\tilde{Q} - w\right)dw \qquad\qquad \frac{U-1}{U}\int_{w=0}^{q}wC''\left(w + Q^j\right)dw$$

Hence (5) holds if

$$\int_{w=0}^{q}w\left[\frac{U-1}{U}C''\left(w + Q^j\right) - \frac{1}{U}C''\left(\tilde{Q} - w\right)\right]dw < 0 \text{ with } \tilde{Q} = Q^j + q_1 + q_2$$

$$\text{and } q \in [q_2, q_1]$$

We assumed that $C'' < 0$ and so a sufficient (but not necessary) condition for the above inequality to hold is

$$\frac{U-1}{U}\sup C'' - \frac{1}{U}\inf C'' < 0 \Rightarrow U > 1 + \frac{\inf C''}{\sup C''}$$

which gives the required condition. If costs are convex then analogous reasoning to determine when the opposite inequality to (5) holds gives the required result. ∎

Proof of Theorem 2. Using (3) we have $\frac{\partial}{\partial q_1}t_2\left(U\right) =_{\text{sign}} \frac{\partial}{\partial q_1}\frac{\Delta C_2}{q_2}$. Let W_j denote the winning set drawn from the $D-2$ downstream buyers numbered $\{3, 4, \ldots, D\}$. The probability of winning W_j is denoted $f\left(j\right)$ and would involve supplying quantity Q^j. Now apply the decomposition for $\frac{\Delta C_2}{q_2}$ found by applying (4). Noting that Q^j and $f\left(j\right)$ are independent of q_1 we have

$$\frac{\partial}{\partial q_1}t_2\left(U\right) =_{\text{sign}} \sum_{j=1}^{2^{D-2}}f\left(j\right)\frac{\partial}{\partial q_1}\left\{\begin{array}{l}\frac{1}{U}\left[\frac{C\left(Q^j + q_1 + q_2\right) - C\left(Q^j + q_1\right)}{q_2}\right] \\ +\frac{U-1}{U}\left[\frac{C\left(Q^j + q_2\right) - C\left(Q^j\right)}{q_2}\right]\end{array}\right\}$$

$$=_{\text{sign}} \sum_{j=1}^{2^{D-2}}f\left(j\right)\cdot\frac{1}{Uq_2}\left[C'\left(Q^j + q_1 + q_2\right) - C'\left(Q^j + q_1\right)\right]$$

If upstream total costs are concave (increasing returns to scale) then the term in square brackets is negative. That is with increasing returns to scale organic growth by downstream buyer 1 leads

to a lower input price for downstream buyer 2. If upstream total costs are convex (decreasing returns to scale) then the term in square brackets is positive. Hence we have the desired result as concerns the input price of other buyers. ∎

Proof of Theorem 3. 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 $\{4, 5, \ldots, D\}$). 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. By Lemma 2 the input price is proportional to $\Delta C_3 / q_3$ where ΔC_3 is the difference in the expected costs incurred when q_3 is won versus not. Now note that

$$
E\left(\text{costs} \mid \text{win } q_3\right) = \sum_{j=1}^{2^{D-3}} f(j) \left\{
\begin{array}{l}
\Pr\left(\text{win } q_1 \text{ and } q_2\right) \cdot C\left(Q^j + q_1 + q_2 + q_3\right) \\
+ \Pr\left(\text{win } q_1 \text{ only}\right) \cdot C\left(Q^j + q_1 + q_3\right) \\
+ \Pr\left(\text{win } q_2 \text{ only}\right) \cdot C\left(Q^j + q_2 + q_3\right) \\
+ \Pr\left(\text{lose } q_1 \text{ and } q_2\right) \cdot C\left(Q^j + q_3\right)
\end{array}
\right\}
$$

Hence we have

$$
\frac{\Delta C_3}{q_3} = \sum_{j=1}^{2^{D-3}} f(j) \left\{
\begin{array}{l}
\frac{1}{U^2}\left[I_{q_3}\left(Q^j + q_1 + q_2\right)\right] + \left(\frac{U-1}{U}\right)^2 \left[I_{q_3}\left(Q^j\right)\right] \\
+ \left(\frac{1}{U}\right)\left(\frac{U-1}{U}\right)\left[I_{q_3}\left(Q^j + q_1\right) + I_{q_3}\left(Q^j + q_2\right)\right]
\end{array}
\right\}
$$

Using the fact that $q_1 + q_2$ is constant by assumption we have

$$
\frac{\partial}{\partial q_1} t_3(U) =_{\text{sign}} \sum_{j=1}^{2^{D-3}} f(j) \left(\frac{1}{U}\right)\left(\frac{U-1}{U}\right) \left\{\frac{\partial}{\partial q_1}\left[I_{q_3}\left(Q^j + q_1\right) + I_{q_3}\left(Q^j + q_2\right)\right]\right\}
$$

If I_{q_3} is convex then $q_1 > q_2$ implies that $I'_{q_3}\left(Q^j + q_1\right) > I'_{q_3}\left(Q^j + q_2\right)$ which implies that the term in braces is positive. This gives part 1 of the Theorem in which the increase in downstream concentration leads to a standard waterbed effect. The case for $I''_{q_3} < 0$ leading to the inverse waterbed effect follows identically. ∎

Proof of Theorem 4. Suppose there are D downstream firms: buyer 1 is assumed larger than 2 $(q_1 > q_2)$. Let $f(j)$ capture the probability of winning any given combination of the $D - 2$ retailers numbered from 3 to D. The volumes supplied to these buyers in this case would be Q^j.

The expected costs for a supplier (EC) are then given by

$$EC = \sum_{j=1}^{2^{D-2}} f(j) \left\{ \begin{array}{l} \Pr\left(\text{win } q_1 \text{ and } q_2\right) C\left(Q^j + q_1 + q_2\right) \\ + \Pr\left(\text{win } q_1 \text{ only}\right) C\left(Q^j + q_1\right) \\ + \Pr\left(\text{win } q_2 \text{ only}\right) C\left(Q^j + q_2\right) \\ + \Pr\left(\text{lose both } q_1 \text{ and } q_2\right) C\left(Q^j\right) \end{array} \right\}$$

Using fact that $q_1 + q_2$ is constant by assumption we have

$$\frac{\partial}{\partial q_1} EC =_{\text{sign}} \sum_{j=1}^{2^{D-3}} f(j) \left(\frac{1}{U}\right) \left(\frac{U-1}{U}\right) \left\{ C'\left(Q^j + q_1\right) - C'\left(Q^j + q_2\right) \right\}$$

As $q_1 > q_2$ by assumption then if total costs are concave $(C'' < 0)$ then the brace above is negative: that is total expected costs decline. As downstream volumes are unaffected this is a positive contribution to welfare. The result for convex total costs upstream follows identically. ∎

Proof of Theorem 5. Suppose $q_1 > q_2$ and that $q_D = \min\{q_3, \ldots, q_D\}$. Using (3) note that the difference in input prices agreed by large versus small buyers is given by

$$t_2(U) - t_1(U) = \underbrace{\left[1 - \frac{1}{2^U} \right]}_{(\dagger)} \underbrace{\left[\frac{\Delta C_2}{q_2} - \frac{\Delta C_1}{q_1} \right]}_{(\ddagger)}$$

It is immediate that $(\dagger)$ is increasing in U. We therefore turn to $(\ddagger)$. Let $f(j)$ be the probability of winning the set of buyers W_j out of the $D-2$ buyers numbered from 3 to D, with associated volume Q^j. Note that $f(j)$ can be decomposed into a probability of winning $|W_j|$ buyers from the $D-2$, which depends on the number of competing suppliers U, multiplied by the probability of winning exactly the set W_j conditional on having won $|W_j|$ buyers, which doesn't depend on U. That is, using (4) and letting $z_U \sim \text{Bin}\left(D-2, \frac{1}{U}\right)$ we have

$$\frac{\Delta C_2}{q_2} - \frac{\Delta C_1}{q_1} = \sum_{n=0}^{D-2} z_U(n) \left\{ \sum_{W_j : |W_j| = n} \Pr\left(\text{winning } W_j | \text{won } n \text{ buyers}\right) \cdot H\left(Q^j\right) \right\} \tag{6}$$

$$\text{with } H\left(Q^j\right) = \frac{1}{U} \left[\frac{C\left(Q^j + q_1 + q_2\right) - C\left(Q^j + q_1\right)}{q_2} - \frac{C\left(Q^j + q_1 + q_2\right) - C\left(Q^j + q_2\right)}{q_1} \right]$$
$$+ \frac{U-1}{U} \left[\frac{C\left(Q^j + q_2\right) - C\left(Q^j\right)}{q_2} - \frac{C\left(Q^j + q_1\right) - C\left(Q^j\right)}{q_1} \right]$$

Focus on $(\ddagger)$ and therefore on (6). Consider first the case of concave costs (decreasing marginal costs). In this case the $\frac{1}{U}$ term in $H\left(Q^j\right)$ is negative while the $\frac{U-1}{U}$ term in $H\left(Q^j\right)$ is positive.

Therefore as U increases, more weight is put on the positive term suggesting that $H(Q^j)$ rises. However, altering the number of suppliers also alters the probability of winning a contract and so alters the random variable z_U. Now recall that $z_U \sim Bin\left(D-2, \frac{1}{U}\right)$. As U increases the probability of success falls and so a standard result for the Binomial distribution has the random variable z_U putting increasing weight on low numbers of successes: that is $z_{\underline{U}}$ first order stochastically dominates $z_{\overline{U}}$ if $\underline{U} < \overline{U}$. Overall therefore we can only unambiguously conclude that (‡) is increasing in U if the braced term in (6) is weakly decreasing in the number of successes, n.

First note that as the number of buyers won (n) rises, the expected volumes delivered also rises in a first order stochastically dominant way. To see this let $G_n(\tilde{q})$ be the probability of delivering volumes up to $\tilde{q}$ if n buyers are won from the set $\{q_3, \dots, q_D\}$. We aim to show that $G_{n+1}(\tilde{q}) \leq G_n(\tilde{q})$. This is true as:

$$
\begin{aligned}
G_{n+1}(\tilde{q}) \;\leq\;& \Pr\left(\text{deliver volumes } \leq \tilde{q}\,\middle|\,\text{win } n+1 \text{ buyers but one is } q_D\right) \\
\leq\;& \Pr\left(\text{deliver volumes } \leq \tilde{q}\,\middle|\,\begin{array}{c}\text{win } n+1 \text{ buyers but one is } q_D \\ \text{and } q_D \text{ is set to } 0\end{array}\right) \\
=\;& \Pr\left(\text{deliver volumes } \leq \tilde{q}\,\middle|\,\text{win } n \text{ buyers from } \{q_3, \dots, q_{D-1}\}\right) \\
\leq\;& \Pr\left(\text{deliver volumes } \leq \tilde{q}\,\middle|\,\begin{array}{c}\text{win any } n \text{ buyers} \\ \text{from } \{q_3, \dots, q_D\}\end{array}\right) = G_n(\tilde{q})
\end{aligned}
$$

We can rewrite (6) as

$$
\frac{\Delta C_2}{q_2} - \frac{\Delta C_1}{q_1} = \sum_{n=0}^{D-2} z_U(n) \cdot E_{G_n(q)}(H(q))
$$

where E denotes the expectation operator. Suppose that $H(Q^j)$ were declining in volumes. Then as $G_{n+1} \leq G_n$ the expected value of $H(Q^j)$ would be lower with $n+1$ downstream buyers won than with n as volumes would be higher with greater numbers of victories. Thus $E_{G_n(q)}(H(q))$ would be decreasing in n. But as z_U stochastically dominates z_{U+1}, $\frac{\Delta C_2}{q_2} - \frac{\Delta C_1}{q_1}$ would be increasing in the number of competitors U.

The final step of the proof is therefore to show that convex marginal costs $(C''' > 0)$ implies that $H(Q^j)$ is declining in volumes. If U is sufficiently large then the requirement is to show that

$$
\frac{C'(Q^j + q_2) - C'(Q^j)}{q_2} < \frac{C'(Q^j + q_1) - C'(Q^j)}{q_1}
$$

As $q_1 > q_2$ this follows if C' is convex as required. Hence we have the result that if marginal costs are convex declining then increasing numbers of suppliers helps large buyers more than

small ones.

We finally turn to the case of increasing marginal costs so that $C'' > 0$. For large U we have $\frac{\Delta C_2}{q_2} < \frac{\Delta C_1}{q_1}$ and so $t_1(U) - t_2(U)$ is increasing in U if C' is concave by identical reasoning. ∎

Proof of Theorem 6. We begin the proof by establishing that if the number of small buyers is large enough then the volumes suppliers will win from small buyers is known. To see this, consider the demand from the D_S small firms, each requiring output $q_S = \left(\frac{1-q_L}{D_S}\right)$. The total volume these buyers demand from a given supplier is a random variable given by $v_S = \left(\frac{1-q_L}{D_S}\right) w_S$ where $w_S \sim Bin\left(D_S, \frac{1}{U}\right) \approx N\left(\frac{D_S}{U}, D_S \frac{U-1}{U^2}\right)$ as for large D_S we can use the normal approximation to the Binomial distribution. Hence

$$
v_S \sim N\left(\frac{1-q_L}{U}, \frac{(1-q_L)^2}{D_S}\frac{U-1}{U^2}\right)
$$

But as D_S becomes large by the law of large numbers the variance of v_S vanishes so that $\lim_{D_S \to \infty} v_S = \frac{1-q_L}{U}$. That is, with enough small buyers the suppliers will, almost surely, receive equal shares of this business and so supply volumes $\frac{1-q_L}{U}$ to these small buyers.

Part 1 of Theorem 6

We define a class of cost functions, $G^r(q)$ indexed by r which coincides with the benchmark $C(q)$ when r is 0 and with a linear cost function when $r = 1$:

$$
G^r(q) := (1-r)C(q) + rUC\left(\frac{1}{U}\right)q
$$

Note that $G^r(0) = 0$ and $G^r\left(\frac{1}{U}\right) = C\left(\frac{1}{U}\right)$ so that the cost of producing the expected volume of $\frac{1}{U}$ remains constant at $C\left(\frac{1}{U}\right)$. We wish to show that the expected profits of the suppliers grows as r grows if the large buyer is sufficiently large. To this end we consider the expected average incremental cost of dealing with a large and a small buyer:

$$
\frac{\Delta G_L^r}{q_L} = \frac{G^r\left(q_L + \frac{1-q_L}{U}\right) - G^r\left(\frac{1-q_L}{U}\right)}{q_L} = (1-r)\left[\frac{C\left(q_L + \frac{1-q_L}{U}\right) - C\left(\frac{1-q_L}{U}\right)}{q_L}\right] + rUC\left(\frac{1}{U}\right)
$$

$$
\frac{\Delta G_S^r}{q_S} = \frac{U-1}{U}\frac{\partial G^r}{\partial q}\left(\frac{1-q_L}{U}\right) + \frac{1}{U}\frac{\partial G^r}{\partial q}\left(q_L + \frac{1-q_L}{U}\right)
$$

$$
= (1-r)\left[\frac{U-1}{U}C'\left(\frac{1-q_L}{U}\right) + \frac{1}{U}C'\left(q_L + \frac{1-q_L}{U}\right)\right] + rUC\left(\frac{1}{U}\right)
$$

We also establish the expected costs of each supplier as

$$
\begin{aligned}
E\left(\text{costs}\right) \;=\;& \frac{U-1}{U} G^r \left(\frac{1-q_L}{U}\right) + \frac{1}{U} G^r \left(q_L + \frac{1-q_L}{U}\right) \\
\;=\;& (1-r)\left[\frac{U-1}{U} C\left(\frac{1-q_L}{U}\right) + \frac{1}{U} C\left(q_L + \frac{1-q_L}{U}\right)\right] + rC\left(\frac{1}{U}\right)
\end{aligned}
$$

Now note that each supplier's expected profits are given by

$$
E\left(\Pi^{\text{sup}}\right) = \frac{1}{U}\left[q_L t_L + (1-q_L) t_S\right] - E\left(\text{costs}\right) \;\text{ with } t_S,\ t_L \text{ given by (3)}
$$

and so we have

$$
\begin{aligned}
\frac{\partial}{\partial r}\left[E\left(\Pi^{\text{sup}}\right)\right] \;=\;& \frac{1}{U}\left(1 - \frac{1}{2^U}\right)\left\{q_L \frac{\partial}{\partial r}\frac{\Delta G_L^r}{q_L} + (1-q_L)\frac{\partial}{\partial r}\frac{\Delta G_S^r}{q_S}\right\} - \frac{\partial}{\partial r}E\left(\text{costs}\right) \\
\;=\;& \frac{1}{U}\left(1 - \frac{1}{2^U}\right)\left\{\begin{array}{c} UC\left(\frac{1}{U}\right) - C\left(q_L + \frac{1-q_L}{U}\right) + C\left(\frac{1-q_L}{U}\right) \\ -\frac{U-1}{U}(1-q_L)C'\left(\frac{1-q_L}{U}\right) - \frac{1}{U}(1-q_L)C'\left(q_L + \frac{1-q_L}{U}\right)\end{array}\right\} \\
& -C\left(\frac{1}{U}\right) + \frac{U-1}{U}C\left(\frac{1-q_L}{U}\right) + \frac{1}{U}C\left(q_L + \frac{1-q_L}{U}\right)
\end{aligned}
$$

Now let q_L become large and, using the fact that $C(0) = 0$ we see that

$$
\lim_{q_L \to 1}\frac{\partial}{\partial r}\left[E\left(\Pi^{\text{sup}}\right)\right] = \frac{1}{U}\frac{1}{2^U}\left[C(1) - UC\left(\frac{1}{U}\right)\right] \tag{7}
$$

But the benchmark cost function, $C(\cdot)$ is convex by assumption and so $C\left(\frac{1}{U}\right) < \frac{1}{U}C(1) + \left(1 - \frac{1}{U}\right)C(0) = \frac{1}{U}C(1)$. Hence $\lim_{q_L \to 1}\frac{\partial}{\partial r}\left[E\left(\Pi^{\text{sup}}\right)\right] > 0$ 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 Theorem 6

Now consider any concave (increasing returns to scale) cost function which leaves the cost of producing $\frac{1}{U}$ units unchanged at $C\left(\frac{1}{U}\right)$. We denote this candidate concave cost technology as $\hat{C}(q)$.[42] We now 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 concave cost function $\hat{C}(q)$:

$$
\hat{G}^r(q) = (1-r)UC\left(\frac{1}{U}\right)q + r\hat{C}(q)
$$

again note that $\hat{G}\left(\frac{1}{U}\right) = C\left(\frac{1}{U}\right)$ so that the cost of producing the ex ante expected volumes of

---

[42]Hence $\hat{C}(1/U) = C(1/U)$, and $\hat{C}(0) = 0$ by assumption.

$\frac{1}{U}$ remains constant. We proceed exactly analogously to the above working to deduce that

$$\lim_{q_L \to 1} \frac{\partial}{\partial r} \left[E \left(\Pi^{\text{sup}} \right) \right] = \frac{1}{U} \frac{1}{2^U} \left[U \hat{C} \left(\frac{1}{U} \right) - \hat{C} \left(1 \right) \right]$$

and as $\hat{C}$ is concave with $\hat{C}(0) = 0$ this is positive 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 concave production technology which preserved the cost of producing the ex ante expected volume of $\frac{1}{U}$ as claimed. ∎

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