Upstream Competition and Downstream Buyer Power

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Abstract

We present a model of supply-chain bargaining where sellers compete to supply a homogeneous product and competition implies they are uncertain about the total output they will win. Output uncertainty is motivated by case studies of private-label supermarket products with competitive supply. With output uncertainty and nonlinear costs, sellers base negotiations on the expected cost of supplying a buyer. We identify a new source of buyer power, which explains recent evidence of large buyer discounts with upstream competition. We show that large buyer size affects (i) small buyer terms and (ii) generates incentives for suppliers to adopt increasing returns to scale technology.

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

JEL numbers: L13, L42, L66

1 Introduction

In recent years many papers on vertically related markets have studied the implications of a bargaining interface as compared to a traditional market interface.[1] This literature seeks to understand how bargaining between two levels of a supply chain will be resolved and how it impacts on buyers, suppliers, and investment incentives. Understanding the bargaining interface is particularly important when exploring the possible causes of *buyer power*—i.e. the ability of large buyers to extract preferential terms from suppliers.

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[1] This terminology is drawn from Inderst and Sha®er (2006). The ¯rst papers to adopt a bargaining interface were Dobson and Waterson (1997) and von Ungern Sternberg (1996). See also MacDonald and Ryall (2004) and references therein.

Much of the interest in buyer power has been motivated by 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. The issue appears in many other settings including insurer negotiations with hospitals and hospital/drugstore negotiations with pharmaceutical companies. Policy concerns have focused on (i) the effect of downstream concentration on the profits and investment incentives of suppliers, and (ii) the consequences of large buyers for prices negotiated by small buyers; the latter are known as waterbed effects in the policy literature.[2]

Most of the buyer power literature with an explicitly modeled bargaining interface assumes a monopoly supplier. This assumption implies certainty for the supplier about the contracts she will win in equilibrium. Thus the seller knows where she will be on her cost curve with and without any given buyer, so she can compute incremental costs exactly. Many of the effects derive from the shape of the cost curve.

We develop a model of bargaining between competing upstream suppliers and downstream buyers seeking supply contracts, in which suppliers are uncertain which contracts they will win. We allow the suppliers' cost functions to be nonlinear so that, since the model generates output uncertainty, a supplier cannot now compute the incremental cost of supplying a given buyer exactly but must form an expectation of the incremental cost. To do this a supplier uses the probability distribution of her final output as implied by variables she can observe such as market structure (upstream and downstream). The model demonstrates that supplier certainty is a critical assumption and its relaxation reverses existing theoretical results and generates many new insights for market analysis.

We make three major contributions. First, we identify a new source of buyer power: the effect of the buyer's size on the seller's expected incremental costs of supplying the buyer. Second, we show that upstream and downstream market structure determines the probability distribution of a seller's output and hence negotiated prices for all buyers, which establishes a new source of waterbed effects. Third, we analyze the effect of supplier uncertainty on upstream investment incentives.

The idea that upstream competition introduces supplier uncertainty is both intuitively appealing and supported by evidence from two case studies we present in Section 2. For the first, the UK liquid milk supply chain, we conducted a number of interviews with executives representing supermarkets (buyers) and processors (suppliers). In the second, we draw on a study of the UK private-label Carbonated Soft Drinks business by the Competition Commission.[3] The

[2] See for example Competition Commission (2003), especially paragraph 2.218, and Competition Commission (2000b, 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 e®ects.

[3] Competition Commission (2006).

two cases share many similarities in the negotiation protocols and both highlight the importance of output uncertainty for suppliers. They suggest our model is likely to generate insights for an important class of applications: supermarket procurement of products where there are competing potential suppliers, e.g. fresh produce, secondary brands, and private-label products. We emphasize however that there are many potential applications outside the supermarket sector, including the supply of generic pharmaceuticals to retailers, hospital services to insurers, salt to trade buyers (from catering firms to pharmaceuticals), and standard mechanical components to automobile manufacturers.

With upstream monopoly the supplier knows with certainty that she will contract with all buyers, which leads the existing literature to the prediction that with upstream economies of scale large buyers will be disadvantaged and pay a price premium.[4] In our first main contribution we show that the introduction of upstream competition reverses this prediction: if the supplier is uncertain about which contracts she will win then when bargaining with a given buyer she discounts the volumes she might win from other buyers (and the greater the upstream competition the greater the extent of the discounting). Therefore the supplier is bargaining from a low expected volume point and the buyer she is bargaining with increases her expected output from this point by an amount that is increasing in the buyer's size. Economies of scale in this context lead naturally to lower expected incremental costs of supply to larger buyers. Thus we have identified a new mechanism linking upstream competition with buyer power.

This prediction is supported by a number of empirical studies which find buyer power in settings with upstream competition and where diseconomies of scale seem unlikely. A study in CC (2007) shows that negotiated prices are lower for larger supermarkets buying secondary brands and private label products. Ellison and Snyder (2001) find a similar result for drugstores buying generic drugs. No other bargaining-interface model is consistent with these findings.

In the second main contribution we analyze how market structure (upstream and downstream) affects the terms obtained by buyers. The analysis establishes a new source for waterbed effects (the effect of a large buyer on the prices paid by small buyers). Up to now there has been very little theoretical work that establishes a source of waterbed effects. Some recent work with an upstream monopoly has given support for a waterbed effect which derives from downstream competition effects.[5] Our paper is the first to show that waterbeds can derive from upstream competition and occur even in the absence of competition between downstream buyers (e.g. the important case of geographically separate retailers). The buyer power mechanism we propose

[4] The reason for this is that a large buyer bargains over relatively more of the monopoly supplier's ¯nal 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. This e®ect is discussed in Chipty and Snyder (1999) and Inderst and Wey (2007).

[5] See Inderst (2007) and Majumdar (2005).

also leads to a characterization of waterbed effects, both when they exist and the direction they operate (i.e. whether the presence of large buyers increase or reduce the prices paid by small buyers). In an important case, suppose a large downstream firm acquires some outlets from a small downstream firm, such that the total volume demanded by the downstream sector remains constant. For an individual supplier the acquisition causes a mean preserving spread of the quantities she wins—i.e. it has changed the variance but not the mean of her output. The supplier's uncertainty has increased. How does this affect another buyer? If the supplier's average incremental costs of supplying this buyer are convex in the supplier's output then by standard reasoning the extra variance raises the *expected* average incremental costs of the deal, so negotiated prices increase. Thus there is a waterbed effect: all the other downstream firms see their bargained prices rise. Further we show that convex declining marginal costs is sufficient to generate this effect—i.e. marginal costs which approach some lower bound in a gradual fashion. We discuss the plausibility of these alternative cost shapes.

The contributions so far depend on the shape of the cost function. The third main contribution of the paper is to analyze a supplier's incentive to change the cost function. We first show that, if a supplier faces a large downstream buyer, the incentive to reduce marginal cost at some local point along the cost curve is greater at her initial units of output (as opposed to the final units). Second, we allow the supplier to select her technology, i.e. we endogenize whether or not there are economies of scale. Here we find that if a sufficiently large buyer exists then each supplier would opt to move from a convex cost function to a concave cost function (increasing returns to scale), even though this implies that the transfer prices which can be extracted from large buyers fall while those from small buyers do not. Thus as large buyers emerge, investment incentives are created that further disadvantage smaller buyers.

The paper contributes to a recent literature exploring the effect of cost function shape—or more generally the surplus shape—on the bargained outcome.[6] We have already noted Chipty and Snyder (1999)[7] and Inderst and Wey's (2007) contributions with monopoly suppliers. Supplier competition has been studied in Inderst and Wey (2003) and de Fontenay and Gans (2005); however as uncertainty is absent from these models, its effects cannot be analyzed.[8] The paper is also related to the wider literature giving alternative explanations for buyer power, including Katz (1987), Inderst (2007), Inderst and Shaffer (2007), Snyder (1996), and De Graba (2003).[9]

[6] Surplus shape e®ects appeared earlier in Horn and Wolinsky (1988) and Stole and Zwiebel (1996).

[7] In the empirical part of their study, Chipty and Snyder estimate a surplus function for the cable TV industry and ¯nd strong evidence of substantial non-linearities in the upstream ¯rm's surplus function, a ¯nding which illustrates the relevance of surplus curvature e®ects in practice.

[8] More recently, Inderst (2006) considers the situation where a number of upstream ¯rms compete to supply a homogeneous product to a number of downstream ¯rms. The model is constructed such that there is a unique equilibrium allocation of demand amongst suppliers so that the e®ect of uncertainty in ¯nal volumes is again ruled out.

[9] A detailed overview can be found in Inderst and Sha®er (2006).

The rest of this paper is as follows. Two case studies are offered in Section 2. The formal model is introduced in Section 3. Sections 4 and 5 explore when buyer power will exist. Sections 6 and 7 analyze the effect of changes in market structure on bargained prices and social efficiency and contains the analysis of waterbed effects. Sections 8 and 9 analyze upstream investment incentives. Some discussion of model extensions is provided in Section 10, and Section 11 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 format is very similar and motivates the model developed in the paper.

2.1 Case 1: Bargaining in the UK Liquid Milk Supply Chain[10]

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[11] 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. The inequality in the size of the buyers allows scope for buyer power effects.[12]

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 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

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

[11] Organic milk is considered a di®erent market and is supplied by a di®erent supply chain.

[12] 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.

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. Starting from October 2001, these contract terminations occurred after the following gaps: 6 months; 10 months; 10 months; 11 months; 2 months; 9 months; 6 months; 6 months.[13] Supermarkets have relative ease in switching suppliers as the milk is supplied in their own supermarket colors. Thus milk is a private-label product and final consumers would be unaware of any change in the identity of milk supplier.

The industry participants we interviewed informed us that the volumes associated with a given contract are very accurately predictable. One supermarket reported offering her supplier 15 years of data on the volumes of milk sold in any given store on any given day.[14] However as contracts can be won and lost the total volumes actually supplied by a given supplier are volatile. Industry sources provided the data contained in Table 1 on volume volatility to supermarket buyers as a result of competition between the three main suppliers.

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 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

[13] One medium sized chain store buyer was explicitly mentioned as an exception to the uncertain renegotiation phases described above. This supermarket sought to coordinate with the large supermarket buyers by following the large buyers' renegotiation phase and sourcing from suppliers who had been successful in winning the biggest contracts. This was not typical buyer behaviour in this industry.

[14] 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.

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).

Failure of negotiations between buyer and supplier can be very visible and lead to unwillingness of key negotiators to work together. A well reported, if extreme, example of such a split occurred one level up in the supply chain between a given supermarket supplier, and their supplier: a farmers' cooperative. This split resulted in the parties being unable to agree to do business directly with each other for a period of time.

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.

4. If negotiations break down with a supplier the buyer is left with one less potential supplier in the current procurement exercise.

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".

Retail Price of Milk

As noted above the negotiations are over a per-unit price with no fixed fee element. However as the negotiations take as given the quantity to be supplied there are no obvious issues of double marginalization. The negotiated transfer price itself can thus be assumed to have no direct impact, independent of supplier marginal cost, on retail prices or retail quantities. This feature of negotiations is facilitated by the highly predictable nature of a supermarket's milk requirements, a consequence of the fact that (i) the elasticity of demand for milk at product-level is very low and (ii) the main supermarkets in practice never tolerate significant retail price differences to emerge between them.

Capacity Constraints and Supplier Investment

We were told that suppliers facing a demand peak 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.

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.[15]

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

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

to being the incumbent supplier. 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 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 were 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.

3.1 Industry Configuration

Suppose there are U upstream firms in competition to supply a homogeneous input to downstream 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.[16] For industries in which logistics and delivery play a part, Operations Research results show that economies of scale (concave total cost functions) are created by the delivery technology.[17]

Downstream there are D buyers labeled $i \in \{1, 2, \ldots, D\}$. 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

[16] The buyer power results we derive are robust to some capacity limitations as long as they are not too binding. We discuss further in Section 5.

[17] See, for example, Burns et al. (1985).

does not optimize against t_i the bargained linear price when setting the retail price. This is consistent with q_i being the efficient output when optimizing against expected marginal cost (i.e. avoiding double marginalization). It is also consistent with a setting where the input is a sufficiently small part of the final product put together by the downstream firms that it has little appreciable effect on the final product's price, such as the supply of e.g. an item in the consumer's bundle of purchases from a supermarket, salt to trade buyers, a standard component in the automotive supply chain, etc.

The fixed demand assumption makes the problem analytically tractable, allowing us to highlight the role that contract uncertainty plays in the bargaining stance of suppliers. However the framework can be extended to endogenize each downstream firm's demand. We discuss this further in Section 10.

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

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

Before detailing the bargaining assumptions 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.

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. 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. The buyers therefore randomize to determine the order to negotiate with the upstream firms. As the suppliers are identical the ordering will be irrelevant to the buyer. 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).[18] That is, the two

[18] 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.

parties make alternating offers and after each offer there exists a small exogenous probability ε that the bargaining 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.[19] 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. 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 which would be enjoyed if the buyer moves on and bargains with the second supplier, with one fewer supplier remaining.[20] 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. This bargaining game can be solved for the transfer price per unit explicitly. To develop intuition for the full model with supplier uncertainty we first solve it in subsection 3.2 for two simple cases: the case of a single buyer and the case where suppliers are assigned to specific buyers.

3.2 Two Simple Cases

3.2.1 Case of a Single Buyer

Consider the case of a single downstream buyer. We assume the buyer seeks q units and has a randomly-drawn ordering of the suppliers. 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:

[19] The 50-50 rule is not essential however. Had the probabilities of breakdown been ε_U when an upstream ¯rm 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.

[20] 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.

Lemma 1 *The price per unit agreed by the downstream ¯rm which seeks q units of input when it has u upstream ¯rms left to bargain with is given by*

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

The agreed price per unit exceeds average costs $C(q)/q$ 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 n^{th} supplier as opposed to the $(n-1)^{th}$ is $q[t(n-1) - t(n)]$. Next consider the upstream firm when there are n suppliers (including herself) left for this downstream firm to approach. Should agreement be reached at transfer price $t(n)$ then profits of the supplier are $qt(n) - C(q)$. 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 by the agreed transfer and so we have the difference equation

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

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

Lemma 1 shows how with a single buyer the transfer price agreed varies with the suppliers' average costs of supplying the buyer and the number of competing suppliers. It is immediate from this that, were there to be only one buyer, and the upstream firms had economies of scale, the larger the buyer the lower the price paid as the average costs decline at higher volumes.

3.2.2 Case of Supplier Certainty

This seemingly intuitive result is reversed in the case of many buyers and volume certainty for the suppliers. To impose volume certainty suppose that each buyer is assigned to a given supplier: if a deal can't be reached with this supplier the buyer must source at the outside option of κ. The seller then knows with certainty the total demand quantity Q of the buyers that are assigned to her. Then the price per unit agreed by a downstream firm which seeks q units of input from the supplier is given by

$$t(u) = \frac{1}{2}\kappa + \frac{1}{2} \cdot \frac{C(Q) - C(Q-q)}{q}$$

The expression is closely related to the case for a single buyer (with u set to 1) except that average costs of the buyer's units are now replaced with average incremental costs. To make things interesting suppose each supplier is assigned to at least two buyers (i.e. $Q > q$) so that these two cost concepts differ. Because the supplier knows Q she bargains with any buyer away from this volume level. Therefore with economies of scale large buyers receive worse prices as they pay more of the inframarginal costs. As the full bargaining model in the next subsection shows, this result is not robust to the introduction of supplier uncertainty over total output.

3.3 The Full Bargaining Model

The full bargaining model includes supplier uncertainty about total volumes, which was identified as key in our case studies. To capture this we now assume that the sellers do not know the D buyers' orderings of the sellers and that procurement exercises happen simultaneously, with no communication between the negotiations. Thus each supplier is uncertain of which contracts she will win and what her total volumes will be. By the assumption of symmetry between suppliers, each supplier views her probability of winning any other given contract as $\frac{1}{U}$. This symmetry assumption is not essential however; 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.

To aid understanding we can imagine the following narrative. Each buyer rents a hotel for the purposes of bargaining. Each of the U suppliers sends a sales representative to each buyer's hotel. The negotiations all occur at the same time and with no communication between hotels. Thus each supplier's sales representative is ignorant of how well her firm's negotiations are progressing with other buyers. This way the bargaining game is kept independent of the order in which buyers bargain, and a very simple tractable model is created which allows an analysis of the effects of uncertainty-creating upstream competition.

One can imagine more complicated bargaining dynamics such as random subsets of the buyers taking part in a renegotiation exercise with asymmetry between suppliers; and even a series of renegotiation exercises at random times. Such complications lead to order dependency in the bargaining outcomes, but the underlying buyer power results we find are robust. We explore this in more detail in Section 5.2. Our use of simultaneity is not new; other papers exploring buyer power have also crystalized the issues using this approach (e.g. Dobson and Waterson (1997), Inderst and Wey (2007)). Further both of our case studies (milk and carbonated soft drinks) are supportive, in our view, of the interpretation that suppliers are engaged in a static bargaining

game with suppliers; with uncertainty created over which contracts will be won; and incumbency contract effects being minimal. For example 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.

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

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

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

where

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

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 (1) as follows

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

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 and of the (uncertain) output q_{-i} the supplier wins from all other negotiations. Therefore, the seller's expectation of average incremental costs depends on the size of the buyer and, 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. Our buyer power analysis hinges on the effect of buyer size on this expectation, while the waterbed results are based on the implications of buyer size distribution for the mean and spread of the supplier's uncertain output. We now turn to these results in detail.

4 Motivating Example

Before considering buyer power in a general setting we first establish the main results in a simple motivating example. Suppose that there are two downstream firms: $D1$ wishes to buy 1 unit

of the input while $D2$ wants 2 units. Both of these firms can always buy the input at a price of κ per unit. There are two upstream firms. In the case of concave costs (increasing returns to scale) we suppose that both suppliers have costs of C for the first unit and c for each of the next two units, where $c < C < \kappa$. We denote this cost function as (C, c, c). The case of convex costs (decreasing returns to scale) is analyzed by upstream costs (c, C, C).

4.1 Increasing Returns to Scale

The suppliers have costs (C, c, c). When negotiating with retailer $D1$, each supplier sees its probability of winning business from $D2$ as $\frac{1}{2}$ as a result of the competition between them. Therefore we have expected incremental costs of

$$\Delta C_1 = \left[C + \frac{1}{2} \cdot 2c\right] - \left[\frac{1}{2}(C + c)\right] = \frac{1}{2}(C + c) \text{ and } \Delta C_2 = \frac{1}{2}(C + 3c).$$

The lower expected average incremental cost for $D2$ $\left(\frac{\Delta C_2}{2} < \frac{\Delta C_1}{1}\right)$ is a result of increasing returns to scale. That is, competition causes the seller to discount the volumes demanded by buyer j in her negotiations with buyer i. Thus only the economies of scale achievable with i dominate when negotiating with i. So the expected average incremental cost is smaller when dealing with the large buyer, who therefore bargains a lower transfer price t. In fact, using (3) we have

$$t_{D1} = \frac{\kappa}{4} + \frac{3}{8}(C + c) \qquad \text{and} \qquad t_{D2} = \frac{\kappa}{4} + \frac{3}{16}(C + 3c) \tag{4}$$

which give the prices per unit each buyer pays, confirming that the larger buyer ($D2$) enjoys buyer power as $t_{D2} < t_{D1} \Leftrightarrow c < C$.

4.2 Decreasing Returns to Scale

The suppliers now have costs (c, C, C). Thus the above analysis immediately implies that the final transfer prices are given by:

$$t_{D1} = \frac{\kappa}{4} + \frac{3}{8}(c + C) \qquad \text{and} \qquad t_{D2} = \frac{\kappa}{4} + \frac{3}{16}(c + 3C).$$

Now the situation is reversed and the smaller buyer now enjoys buyer power with the intuition paralleling that above.

5 How Large Buyers Wield 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 example in the previous section found the opposite: with increasing returns the large buyers have buyer power (and with decreasing returns the small buyers have buyer power). In this section we establish the result more generally.

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 transfer 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 transfer 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. 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 negotiating simultaneously 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

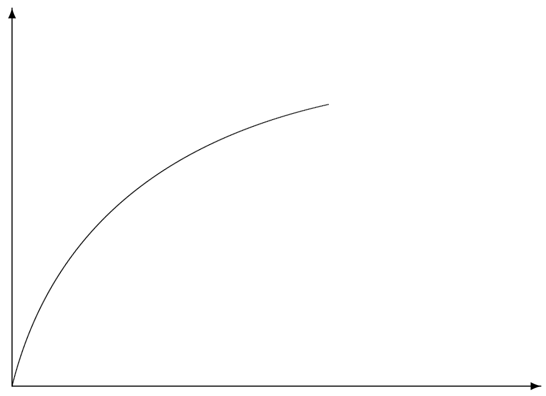
other contract. In this case the supplier puts more weight on the steeper of the two gradients. That is, a supplier sees losing a given contract as more likely than winning it and therefore is more concerned about average incremental costs taking volumes Q^j as its reference point. Thus the effect of competition is to introduce uncertainty which causes the supplier to discount the possibility of success in the other simultaneous negotiations. With this reference point and increasing returns to scale the larger buyer can be supplied at a lower expected average incremental cost. (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 transfer 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.

In summary, when suppliers have increasing returns to scale winning a large contract is better news as to average incremental cost than winning a small contract. Hence larger buyers wield buyer power when upstream suppliers have economies of scale.

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 indicating when large buyers wield buyer power.

If negotiating with the large buyer



5.2 Robustness To Relaxing The Simultaneous Bargaining Assumption

Suppose now that we alter the model so that the D suppliers bargain sequentially in a known order and maintain the assumption of complete homogeneity between upstream suppliers with increasing returns to scale technology. In this case the supplier who wins the first buyer contract will win all the buyer contracts as the assumption of increasing returns to scale will lead all subsequent buyers to coordinate on the successful supplier (i.e. these buyers would no longer be content to draw a random ordering). In addition, the first buyer would recognize that she was critical to securing the full industry profit and so she could extract most of this profit herself through a very low (possibly negative) per unit price. Thus it might seem that our results are not robust to this extension. However this is a knife edge result, with questionable insight for actual contracting. Firstly, as the first buyer secures all the rents, in this extended version of our model one would expect buyers to compete to be first. This would return us to the position of buyers contracting at the same time (and the competition to contract first would return the rents due to coordination back to the suppliers). Secondly the uncertainty in supplier volumes which we discovered in our case studies, and has motivated our model, have been removed: after the first contract is agreed supplier volumes are deterministic.

Supplier uncertainty can be reintroduced into this dynamic bargaining extension by allowing buyers to have private idiosyncratic taste shocks over suppliers. This approach is standard in the structural empirical literature and designed to capture unobserved preferences of buyers for supplier differentiation. A dynamic 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. Thus this is 'first buyer power' and not 'large buyer power'.[21]

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 of the competition she would therefore

[21] However if large buyers go ¯rst and are followed by small buyers then the result would be observationally equivalent to large buyer power. If the order of bargaining is not necessarily largest ¯rst in a procurement round then the buyer power e®ect created here is ambiguous. If a large buyer goes ¯rst and a small buyer second, then securing the large buyer means harnessing very big returns to scale and so makes the probability of securing the subsequent small buyer high. However as the second buyer is small this would translate into a small extra pro¯t. Therefore the large buyer going ¯rst would extract only a small extra rent with a high probability. By identical reasoning a small buyer going ¯rst would have a lower probability of creating a coordination rent as the economies of scale gained are modest and may be outweighed by the idiosyncratic taste shock. Hence a small ¯rst buyer extracts a large extra coordination rent but with only a low probability. Overall therefore the relationship between coordination rent and initial buyer size would be ambiguous: it would depend on the extent of di®erentiation, economies of scale and competition. The coordination rent lowers the prices paid by those contracting ¯rst.

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 the figure and large buyers would still wield buyer power if there were upstream economies of scale.

Therefore our results would survive in a dynamic context with idiosyncratic taste shocks preserving the suppliers' uncertainty about final demand. In this paper we present a static model of the competition as we believe both that it is actually a better fit to the case studies we report, and that it is the simplest model which allows us to analyze the effect of upstream volume uncertainty on bargaining power.

5.3 Supporting Evidence

Although conventional wisdom says that large buyers tend to get a better deal in many markets, studies of negotiated supplier-buyer prices are rare, because of data confidentiality. This section briefly reviews the most relevant studies that have been done; we find that these studies provide independent evidence in support of our predictions.

An empirical analysis of the bargained prices paid by supermarkets is conducted in Competition Commission (2007), using commercially sensitive data.[22] CC report a statistically significant negative relationship between buyer volume and the net price per unit, for non-primary branded goods (i.e. private label or secondary brand goods); these are the goods where upstream competition is present. The price reduction was estimated to be as large as 19% lower for the largest buyers as compared to the smallest buyers. Interestingly, there was no statistically significant buyer power effect for primary branded goods, where competition is absent.

Ellison and Snyder (2001) study a data set of prices negotiated by retailers in the generic antibiotics market and find that large retailers obtain a significantly lower price than small retailers; as these are off-patent drugs upstream competition is present. However for in-patent drugs, where competition is absent, they find no significant buyer power effects.

As the technology in these markets seems unlikely to be characterized by diseconomies of scale[23] the empirical buyer power findings when upstream competition is present are supportive of the model we propose in this paper. The finding that there is no effect of buyer size when competition is absent (i.e. primary branded goods and on-patent drugs), might appear to

[22] See Competition Commission (2007), Appendix 8.1. In particular paragraphs 44-45.

[23] Ellison and Snyder(2001) argree that diseconomies of scale is unlikely for pharmaceuticals

contradict the monopoly supplier model of Chipty and Snyder (1999), which suggests large buyers should actually pay a premium. However, this may be resolved by considering retailer-specific costs, which we have not modeled (but which the model can easily incorporate), and these are likely to be lower for large buyers, e.g. being able to order stock in full palette multiples, etc. The presence of such costs is likely to magnify the discounts to large buyers (in the competitive case) and diminish the large-buyer premium (in the monopoly case). After including these effects it is possible that there is both no large-buyer disadvantage (in the monopoly supplier situation), and a large-buyer advantage (in the competitive supplier case), as found in these studies.[24]

A further result emphasized in Ellison and Snyder (2001) is that the ability to substitute between alternative suppliers matters more than buyer size for the negotiated price. This is supported by Sorensen (2003), which studies negotiated insurer-hospital prices. These results are also consistent with our model: the effect of U is always present (see Lemma 2) regardless of cost curve shape, while the effect of buyer size depends on the presence of nonlinearities in supplier cost.[25]

Finally we turn to our two case studies. In the case of liquid milk KPMG(2003, page 30) show that the suppliers have economies of scale, while CC(2000a, §4.330 − 4.336) shows that larger retailers pay lower prices; this combination is as predicted by our model. In the CSD market, CC(2006) presents no evidence either way on economies of scale and find only slight evidence of large buyer advantages so this does not contradict our model; we view this case as supportive of the bargaining framework used in the model rather than being interesting for its evidence on buyer power.

6 Changes in Downstream Concentration: Effects on Prices and Welfare

Section 5 noted that if there are upstream economies of scale, then competition amongst suppliers implies that large buyers are in a position to wield buyer power. In this section we explore the effect of changes in the downstream market structure on the prices paid by buyers. We examine cases where the downstream buyers are of different size and the concentration increases the size inequality.

In particular, we focus on the question of whether an increase in the size of a large buyer affects the prices negotiated by the small buyers, i.e. whether there are *waterbed effects*. It has been suggested in public policy discussions that if a large buyer were to secure low transfer prices then in response transfer prices might be pushed up to other smaller buyers. This idea is

[24] Thus the findings in Ellison and Snyder(2001) are consistent with bargaining models.

[25] The cost function is not irrelevant however: see the discussion at the end of Section 7.

incomplete for two reasons. The first is that if a supplier could have increased prices to others why did it refrain initially? The second is that if upstream firms compete then how, short of collusion, would they be able to coordinate this price increase? In this section we provide the first analysis of waterbed effects amongst competing non-collusive upstream suppliers.

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

We divide our analysis into two cases (following Snyder's (1996) work on waterbed effects when the suppliers are collusive). In the first sub-section, we consider an increase in downstream concentration through growth by a downstream firm which leaves the size of all other downstream firms unaffected. (This might be interpreted as a retailer discovering an unserved clientele which it is able to service, or a retailer improving its marketing so that it increases the volume demanded by its existing customers). Here a waterbed effect exists and its direction (i.e. whether it is standard or inverse) depends on whether there are increasing or decreasing returns to scale upstream. In the second subsection we consider total downstream demand staying constant while the downstream buyers become more asymmetric: the smaller buyers shrink while the larger buyers grow. (This may be interpreted as a large retailer buying some stores off a smaller retailer). In this case we show that a waterbed effect exists and its direction depends upon the concavity or convexity in total supplier output of the average incremental cost function (1). In the final subsection we consider the welfare implications of increases in the downstream concentration: if there are upstream economies of scale then we find that increases in downstream concentration lead to an improvement in overall welfare.

6.1 Downstream Organic Growth

This sub-section notes the result that if a single buyer were to grow, while other buyers remain at their previous size, then with increasing returns to scale prices to the other buyers fall. That is, there is an inverse waterbed effect.

Theorem 2 *Suppose that downstream buyer 1 were to increase q_1 by organic growth, perhaps by serving a new group of consumers, without a®ecting 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 transfer 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 transfer price, for any number of suppliers, as a result of buyer $1's$ organic growth.*

The proof of this result is placed in the appendix. Note that the firm growth postulated here increases the total demand available to be served by the suppliers with implications for average incremental costs. Thus the expected volumes increase for all suppliers. This effect outweighs any risk enhancing effect of a change in concentration and so transfer prices move down if there are upstream economies of scale; transfer prices move up if there are upstream decreasing returns to scale.

6.2 Downstream Growth by Acquisition

We now consider the effect on bargained transfer prices of an increase in downstream concentration holding total downstream output constant (e.g. this might happen as a result of merger of some sales outlets). 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 transfer prices of the $D-2$ other retailers would be affected.

To answer this question we recall our definition of the average incremental cost function (1), $I_x(q)$, which gives the average cost of producing x more units from a base level of q units of production:

$$I_x(q) := \frac{C(q+x) - C(q)}{x} \text{ and } x \in \{q_1, q_2, \ldots, q_D\}$$

Our results depend on whether this is convex or concave in the supplier's total output q:

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

1. *If average incremental costs are convex* $(I''_x > 0)$ *then the increase in downstream asymmetry raises the transfer prices for all other downstream ¯rms (a standard waterbed e®ect), for any number of competing suppliers* $U \geq 2$.

2. *If average incremental costs are concave* $(I''_x < 0)$ *then the increase in downstream asymmetry lowers the transfer prices for all other downstream ¯rms (an inverse waterbed e®ect), 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).[26] Thus Theorem 3 applies more broadly than when marginal costs are convex or concave.

[26] $I''_x = \frac{1}{x}[C''(q+x) - C''(q)] = C'''(q+\boldsymbol{x})$ for some $\boldsymbol{x} \in [0,x]$ by a Taylor expansion. Therefore $C''' \gtrless 0 \Rightarrow I''_x \gtrless 0$.

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 $\frac{Q}{U}$ (each supplier believes they have as good a chance of winning contracts as any other supplier). This expected demand is unaffected by any changes in the downstream concentration that keep total volumes constant. However, an increase in downstream concentration makes things riskier for any supplier: it raises the variance of the supplier's volumes. Thus the increase in downstream concentration 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 negotiated price with all buyers not involved in the concentration increase. (For those involved in the concentration increase there are also the effects of Theorem 1). Thus there is a standard waterbed effect. By the same reasoning if average incremental costs are concave then the waterbed effect is inverted—i.e. an increase in downstream concentration lowers the input price for all buyers. This effect is depicted graphically in Figure 2.

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 una®ected, then:*

1. *If average incremental costs are convex then the downstream merger raises the transfer prices for all other downstream ¯rms (a standard waterbed e®ect), for any number of competing suppliers* $U \geq 2$*.*
2. *If average incremental costs are concave then the downstream merger lowers the transfer prices for all other downstream ¯rms (an inverse waterbed e®ect), 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. However it would seem that with increasing returns to scale the most natural assumption would be one of convex decreasing marginal costs which implies convex average incremental costs (see footnote 26): 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

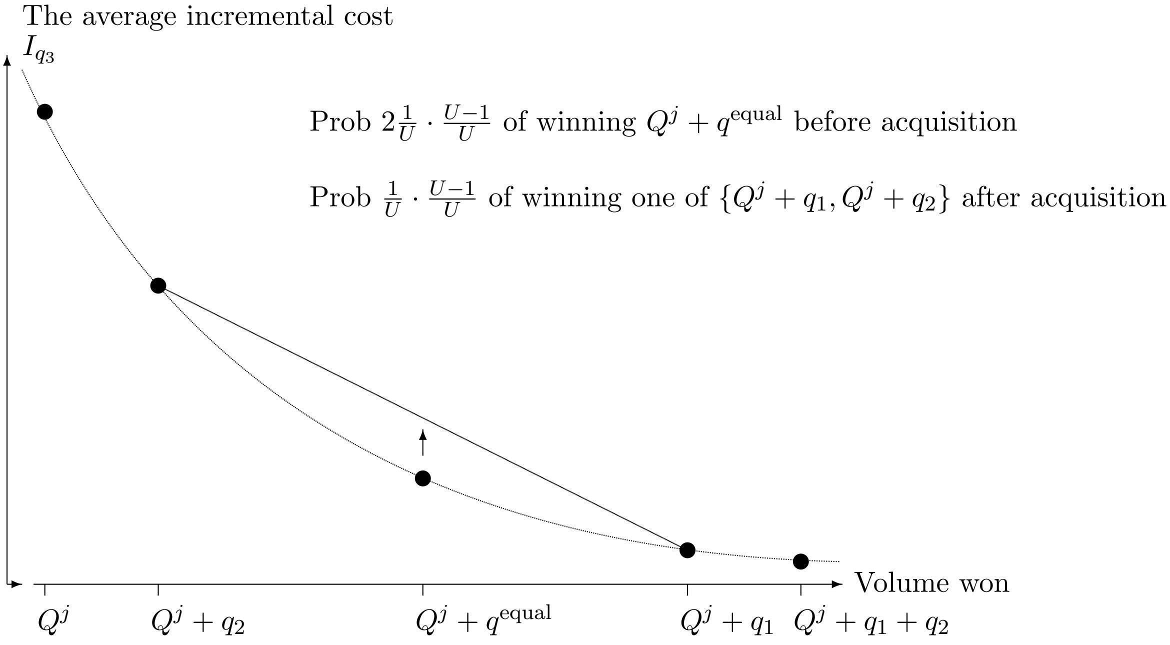


Figure 2: Suppose there are D downstream buyers and Q^j represents some realisation of volumes won by some supplier from buyers $\{4, \ldots, D\}$. Suppose initially buyers 1 and 2 require equal volumes of q^{equal}; subsequently buyer 1 acquires some of 2 so that $q_1 > q_2$. The graph depicts the average 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.

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.[27] Upstream increasing returns to scale is also the setting in which the merging firms will command buyer power. Thus the most natural form of waterbed effect from merger would be of a standard kind: any merger raising transfer costs for third parties while lowering them for the merging party. Note that this is a totally 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.

Theorems 2 and 3 identify the price effects of changes in concentration downstream. We now note that changes in downstream concentration have at least one direct welfare implication.

[27] The case of increasing returns to scale in upstream production appears, from industry interviews of the UK milk supply chain, to be the relevant one in this UK industry at least. The ability to optimize logistics and delivery is one feature which appears to contribute to these upstream increasing returns to scale.

6.3 The Welfare Effects of Increases in Downstream Concentration

In this subsection we consider the effect on welfare of changes in downstream concentration. Given our explanation for buyer power, a new welfare effect of downstream concentration in the context of buyer power becomes apparent. Note that this paper has made the assumption of a fixed output. Nevertheless, downstream concentration still has welfare effects arising from the cost of manufacture of the input:

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. In particular 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. That is 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 standard risk theory confirms that 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.

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

7 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 transfer price di®erential between large and small buyers grows if the upstream ¯rms have convex declining marginal costs (increasing returns to scale), and if* U *is su±ciently large.*

2. *The absolute transfer price di®erential between large and small buyers shrinks if the upstream ¯rms have concave increasing marginal costs (decreasing returns to scale), and if* U *is su±ciently 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 26). 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 is analogous.[28]

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 transfer prices. First, from Lemma 2 it reduces the chance of downstream buyers ultimately having to source at the expensive marginal cost of κ. Thus transfer 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 transfer 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 transfer prices. With decreasing returns to scale in upstream production smaller volumes reduce expected average

[28] We note the discussion on page 25 which suggests that, in the case of the UK liquid milk supply chain at least, part 1 seems more relevant | i.e. upstream mergers level the downstream playing ¯eld.

costs so the two effects work in the same direction, and transfer prices fall as supplier numbers rise.

8 Incentives to Invest: Marginal v Inframarginal

A concern often raised about downstream buyer power is that it may lower upstream incentives to invest in cost reducing technologies. Inderst and Wey (2007) make an important counter-argument. They consider the case of an upstream monopolist negotiating with certainty about its final output. Thus the negotiation is over the incremental surplus from the final q_i units of this output. In their setting, a small buyer can capture a high proportion of the gain from an investment to reduce cost at the *margin*, because the buyer's output approximates to the supplier's marginal output. But with large buyers the incremental cost is determined further from the margin, so the buyer captures proportionately less of a cost reduction at the margin. Consequently an increase in the proportion of large buyers *increases* the incentive of the supplier to lower marginal production costs (which can be welfare enhancing for consumers if it increases industry output).

In this section we show that this result is not robust when the supplier is uncertain of its final demand. This is because output uncertainty introduces two new factors at play that diminish the incentive to reduce cost at high output levels. First a buyer can extract more of the benefit of a supplier cost reduction at a given output level if her business is likely to be pivotal to reaching that output level: and large buyers will be important in reaching high output levels. Secondly, an investment at high output levels is more likely not to be reached at all reducing the expected benefit to the supplier. Therefore, an increase in the proportion of large buyers diminishes the incentive to invest at the margin.

Before we proceed, we must specify how the investing firm expects its upstream rivals to respond (a consideration absent in models with upstream monopoly). Note that with competing suppliers of a homogeneous product, a supplier with lower costs can expect to receive all of the demand. (Or, with decreasing returns to scale, more of the demand). Therefore, if one firm innovates others would wish to emulate. Thus if it was known a rival couldn't copy, e.g. because of a patent, incentives to innovate would be strong. However, in many markets the 'innovation' is not covered by patents, e.g. when cost reduction is due to well understood technology such as larger plants, so there is ample opportunity for any supplier to match the investment of a rival supplier. (This is the case in industries as diverse as milk and silicon chips). In such settings an appropriate standpoint from which to analyze investment decisions is the Wilson (1977) notion of *anticipatory equilibrium*: i.e. investing parties internalize the expectation that their rivals will also invest. In this section we will therefore assume 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 thus remains symmetric. These assumptions sit well with the UK Grocery Market. In their 2007 report into UK Groceries the Competition Commission note that 60% of suppliers to supermarkets responding to a CC survey claim that they conduct innovation to "keep up with the market."[29,30]

8.1 Motivating Example Continued

We aim to understand whether the firm has greater incentives to reduce marginal than to reduce inframarginal costs. To illustrate the main idea in this section we begin by exploring the investment incentives for the upstream firms in the motivating example introduced in Section 4. Using the anticipatory equilibrium notion described above, the upstream market remains symmetric before and after the innovation. If the upstream firms have costs per unit of (C, c, c) and so have increasing returns to scale then the expected industry costs are

$$\underbrace{\frac{1}{2}(C+2c)}_{\substack{\text{Pr both at same}\\ \text{supplier}}} + \underbrace{\frac{1}{2}(2C+c)}_{\substack{\text{Pr at different}\\ \text{suppliers}}} = \frac{3}{2}(C+c)$$

Hence from (4) the ex ante expected profit for each supplier is

$$E\left(\Pi^{\text{supplier}}\right) = \frac{1}{2}\left\{t_{D1} + 2t_{D2} - \frac{3}{2}(C+c)\right\} = \frac{3}{8}(\kappa - C)$$

It is immediate that such suppliers would wish to reduce the high initial cost per unit (C) but have no incentives to reduce the marginal cost c. Equally, if the upstream suppliers have decreasing returns to scale and so costs (c, C, C) then similar working implies that the ex ante expected profit per supplier is now $\frac{3}{8}(\kappa - c)$ so that suppliers would *again* seek to reduce the cost of the initial output, rather than the cost of the marginal unit. Thus, in both cases, the firm seeks to reduce the cost of the initial units rather than the cost of the marginal units.

8.2 An Analysis of Incremental Investment

The motivating example suggests that, conditional on running a plant, suppliers have an incentive to lower the variable costs of only the first units produced, *irrespective* of the shape of the total cost curve. That is, suppliers seek to lower the total cost of all units produced and not just the marginal ones at some high level of output. To generalize this result consider the case in

[29] See Competition Commission (2007), Appendix 8.2, paragraph 34.

[30] Similarly in the case of the UK milk market the processors have all chosen to build a number of large plants, characterized by greater economies of scale than the smaller dairies they replaced. The building of these large dairies was initiated by Wiseman but quickly copied by other ¯rms.

which the supplier's marginal cost at the x^{th} unit is lowered by some small amount δ. Formally we suppose a supplier can invest in an innovation parameterized by (x, δ) with δ small so that the total cost function is changed from $C(\cdot)$ to $C_{\text{new}}(\cdot)$ as follows

$$C_{\text{new}}(q) = \begin{cases} C(q) & q \in [0, x] \\ C(q) - \delta & q \in [x + \varepsilon, Q] \end{cases}$$

where $C_{\text{new}}(q)$ is made continuous and monotonic in the vanishingly small range $(x, x + \varepsilon)$.

To capture the insights we suppose that there are D_L large buyers who each demand volumes q_L, and $D_S > D_L$ small buyers who each demand volumes $q_S < q_L$. To simplify further we suppose that q_S is sufficiently small that the average cost per unit of supplying q_S extra units on top of volumes $\tilde{Q}$ is approximately equal to the marginal cost per unit at volumes $\tilde{Q}$. We now determine the profit maximizing point at which to place x. We ignore the vanishingly small region $(x, x + \varepsilon)$ as we are envisaging small innovations in which both ε and δ are arbitrarily small.

First note that the innovation has no consequence for prices negotiated with small buyers, since they are determined by expected marginal costs at any given realization of victories amongst other buyers, and the innovation leaves marginal cost unaffected for almost all units—i.e. $C'_{\text{new}} = C'$ almost everywhere. Only if expected output lies in $(x, x + \varepsilon)$ is this not the case, but the probability of this is vanishingly small as ε shrinks as a consequence of the uncertainty in our model.

Next we consider the prices paid by large firms. Here payments are determined by expected average incremental costs $\frac{\Delta C_{\text{new}_L}}{q_L}$ of supplying the q_L units a large buyer demands. There is a probability that the large buyer's output may push a supplier past the point x at which total costs come down, which reduces the payments received from large buyers. To be precise, the change in supplier costs at any given q is given by:

$$\frac{C_{\text{new}}(q + q_L) - C_{\text{new}}(q)}{q_L} = \begin{cases} \frac{C(q+q_L) - C(q)}{q_L} & x \notin [q, q + q_L] \\ \frac{C(q+q_L) - C(q)}{q_L} - \frac{\delta}{q_L} & x \in [q, q + q_L] \end{cases}$$

Let W_j be the set of buyers from $\{2, \ldots, D\}$ won by the supplier, and suppose that winning W_j occurs with probability $f(j)$ and results in volumes supplied to these firms of Q^j. In this case we have

$$\frac{\Delta C_{\text{new}_L}}{q_L} = \frac{\Delta C_L}{q_L} - \frac{\delta}{q_L} \Pr\left(x \in \left[Q^j, Q^j + q_L\right]\right). \tag{5}$$

Thus, payments from large buyers are maximized by minimizing the second term: the probability a large buyer's output pushes the supplier's expected output past point x.

It is intuitive that this is achieved either by setting a very high x, in which case it is never reached, or a very low x, in which case it is reached regardless of the large buyer's contract. The intuition here is that the supplier choosing x does not wish the large buyer to have a high probability of being pivotal in allowing the lower total costs to be achieved. If a large buyer has a high probability of being pivotal then much of the gains from the investment are lost to the large buyer in the price negotiations. This is true for both concave and convex costs.[31]

The suppliers choice of x is determined by the effect on profits, not just the effect on revenues. Turning to the cost side, therefore, we note that the expected overall cost for a supplier is given by

$$\underset{\substack{\text{total}\\ \text{volumes}}}{E} C_{\text{new}}(q) \approx \underset{\substack{\text{total}\\ \text{volumes}}}{E} (C(\cdot)) - \delta \Pr(\text{volumes won} > x + \varepsilon)$$

The right hand side is clearly minimized by reducing x as much as possible. This is intuitive: an innovation that only takes effect when high output is reached might never be realized.

Combining the revenue and cost considerations, it will both minimize costs and maximize transfer payments to choose the innovation (x, δ) with the smallest possible x, precisely as suggested by the motivating example above. Thus buyer power focuses the incentives to invest in incremental cost reduction exactly on those units which are unlikely to be dependent on securing a large contract to access the reduction.[32]

Note that the innovations favored by the suppliers—i.e. those that reduce marginal cost only at low output well away from the margin—are ones which do not lower the transfer prices paid by downstream firms and do not lower production costs at the margin; thus there is no effect here which might increase output and reduce deadweight losses if such effects were present in our model. (In our model they are in fact not present because we assume for convenience that downstream demands are fixed).

9 An Analysis of Endogenous Technology Choice

We have shown that if suppliers are given the option of reducing marginal costs for a small interval on the output range, they would prefer this reduction to be at a low output level, "away from the margin". As we showed, this result applies whether the cost function is concave or convex. In the paper so far we have derived results separately for the case of convex and concave cost functions, assuming the shape is exogenously given by the prevailing technology.

We now turn to the deeper question of which cost function shape suppliers prefer, given the bargaining interface in our model—i.e. we make the shape of the cost function endogenous. To

[31] A fuller exposition of this point is o®ered in Smith and Thanassoulis (2006, p31)

[32] In the interviews for the case study o®ered in Section 2, executives of suppliers claimed that they prioritized investment in core production facilities ahead of peak load facilities.

make the comparison fair we will consider changes in the shape that keep costs constant at the expected level of output.

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. In this section we show that this result continues to hold when we introduce upstream competition, and further find that as buyer concentration increases, competing suppliers would prefer to switch from linear costs to concave costs.

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 the 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 su±ciently large then under the anticipatory equilibrium (so investments are matched with upstream suppliers remaining symmetric):*

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 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. 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. A second point which is worth noting is that the large buyer's power grows as the cost function becomes concave and she is able to bargain to a lower price. Nevertheless, the suppliers would rather have technologies for which the average cost of servicing the small buyers is likely to be high ex post and for which they receive a lower transfer price from large buyers. The proof is provided in the appendix. Here we explain the intuition behind the result.

There are two main forces behind Theorem 6.

The first is that expected costs are minimized as 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 transfer prices of a switch to a linear and thence to a concave production technology shape.

The effect on transfer prices from the small buyers is ambiguous (and becomes arbitrarily small as the large buyer becomes a bigger and bigger part of the market). The transfer price for small buyers is a weighted average of the marginal cost at small volumes (high with concave cost), and the marginal cost at large volumes as the large buyer might be won (low with concave cost). These two effects offset each other—i.e. changing from convex to linear and then to concave costs makes little difference to the revenue from the small buyers.

The transfer prices from the large buyer, on the other hand, are unambiguously smaller under a concave cost function, for the reasons given before. 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 low the transfer prices can be forced. This reduces the effect of the technology on the bargained transfer 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 transfer prices.[33]

As one would expect, the dampening effect all but vanishes as U (the number of upstream competitors) tends to infinity. And indeed, it follows from (9) in the proof of Theorem 6 that the profit gain from changing technology vanishes as U tends to infinity, even if $q_L = 1$.

In sum, we find that if there is a large enough buyer then each supplier would opt for increasing returns to scale technology, even though this implies bargained prices from the large buyer fall while those from small buyers do not. Thus the emergence of large buyers creates investment incentives that are harmful to small buyers.

A note is in order explaining how this section relates to the previous section, both of which analyze incentives to reduce costs in the presence of large buyers. The previous section showed that the incentives to make a *local* reduction to marginal cost were greatest at a low level of output, to ensure that the cost benefit is realized ex post and to minimize consequences for bargained prices. In this section we analyze the choice of the *general* shape of the cost function. To make the comparison interesting we require that the costs at expected output $1/U$ remain

[33] The Case Study evidence for the UK milk supply chain noted that processors are increasingly building superdairies and shutting smaller regional dairies. These superdairies create a need for large volumes to achieve low marginal costs. We therefore interpret this outcome as strongly compatible with the result (and intuition) provided as Theorem 6.

constant, so that a move from concave to linear costs reduces marginal cost at low output but increases them at high outputs. The concave function dominates as the presence of large buyers implies a high variance of final demand and so lower expected costs (transfer prices are also lower but this effect is damped by the ultimate outside option of κ). In sum we conclude that while investments with local marginal cost effects will be focused on lower rather than higher output levels, investments that change the overall shape of costs may favor a concave shape, even if this implies higher marginal cost at low output.

10 Discussion of Model Extensions

The implications of relaxing a number of the assumptions of the model have already been discussed. In particular how the results are modified by capacity constraints, or by sequential contracting were considered in Sections 5.1 and 5.2. Here we consider two further extensions.

10.1 An Auction Model Instead of a Bargaining Model

A natural question to ask is why we have proposed a bargaining model instead of a procurement auction in which the buyers try to extract the product at the lowest possible price by having all U suppliers simultaneously bid for the business. A further question is whether the same results would be present in such a procurement auction.

On the first question we defend a bargaining framework because we observe bargaining being used commonly in practice. Investigations by competition authorities, as well as more anecdotal evidence, suggest that auctions are not often used by supermarkets for procurement.[34] In the case of milk it is notable that auctions are not used given that milk is close to being a homogeneous product. Part of the reason for this is that even with apparently homogeneous products such as milk there are still substantial logistic and packaging issues which have to be agreed. These negotiations take time and so in practice a supermarket finds itself conducting detailed negotiations with only one supplier (but failure to agree would mean taking negotiations to a new supplier); this is exactly the model we have provided.

Turning to the second question, the insights of our model are likely to carry over to a simultaneous auction setting (although such a model is not readily tractable). To see this note that if volumes are uncertain, then a supplier will consider its expected average incremental costs when determining what price to bid. Thus a firm with increasing returns to scale is likely

[34] One piece of evidence, from a non-supermarket buyer, comes from a large (see end of footnote) health beverage manufacturer. They told us that they did try a procurement auction for skimmed milk powder, but none of the processors agreed to take part as each instead held out for bilateral negotiations. Annual UK sales of the ¯nal product were over £30 million in 2005.

to bid more aggressively for a large contract, since a large contract is a good signal of what realized average incremental costs will be.

10.2 The Effect of Endogenous Downstream Demand

We have assumed for simplicity that the quantity demanded by each buyer is exogenous. This assumption has been relaxed by the authors to empirically estimate bargaining power in the liquid milk supply chain (Smith and Thanassoulis 2007). If there is efficient bilateral bargaining, and hence no double marginalization, then our buyer power results will apply as they stand. To see this note that if negotiations break down then the buyer will move on to the next supplier. The expected marginal cost faced by the supplier conditional on winning the contract is unchanged (as the suppliers are symmetric). Efficient bargaining would thus imply that the total surplus to be split between the buyer and supplier is unchanged by a break with one (or more) suppliers. The only question is how this surplus is split between the buyer and the supplier. Here the results in this paper apply directly: if there are economies of scale upstream then the larger the buyer the lower the supplier's expected average incremental cost and so the better the input price the buyer commands. The waterbed effects are even exacerbated. If one party grows by merger then that party will receive a lower input price and other buyers a higher input price for the reasons this paper describes. However these cost changes will be reflected by price changes and so the newly merged firm is likely to win more business and hence grow further at its rival's expense. This will lower its input price further by enhancing its buyer power.

In the UK liquid milk supply chain we noted that negotiations between suppliers and buyers were on a pence per liter basis and that these negotiations were conditional on a required volume. If the supermarkets choose the efficient volume then this maximizes the surplus available to be split between buyer and supplier. There was no evidence to suggest that the supermarkets allowed double marginalization inefficiencies to occur.

However in settings where double marginalization inefficiencies do occur, one new effect is clear. Suppose that supplier A is negotiating with downstream firm $D1$. A will reason that failure to agree leaves the buyer with only $U-1$ suppliers. This is a weaker position for the buyer who will therefore receive a higher input price and, in the presence of double marginalization, a loss of market share for $D1$. Thus supplier A will reason that any contracts with $\{D2, D3, \ldots\}$ will be more valuable. Thus the supplier's outside option is improved while the downstream firm's is weakened and so the supplier might expect to extract more rent. In general one might be sceptical of double marginalization because of the apparent simplicity of using two part tariffs to mitigate the problem. Of course in the setting studied here two part tariffs are made more difficult if there are economies of scale upstream and uncertainty as to final volumes.

11 Conclusions

This paper examines a bargaining interface 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 offered a formal analysis of this bargaining set up motivated by two case studies of different private-label supermarket procurement processes. The model allowed us to demonstrate the link between the uncertainty created for suppliers by competition and downstream buyer power and waterbed effects. For industries with economies of scale our results are consistent with the concerns competition authorities often voice, for instance, regarding the buyer power of the largest supermarkets.

We have interviewed industry executives and conducted case studies with a view to appropriately modeling the bargaining interface between upstream suppliers and downstream buyers. This 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 good in our homogeneous good model.[35] 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

[35] 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.[36] 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.[37] How bargaining in the supply chain adapts to the evolution of a consumer branded supplier is an extension of this paper 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

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

Combining we have

$$\Delta C_1 = \sum_{j=1}^{2^{D-2}} f(j)\left\{\frac{1}{U}\left[C\left(Q^j + q_1 + q_2\right) - C\left(Q^j + q_2\right)\right] + \frac{U-1}{U}\left[C\left(Q^j + q_1\right) - C\left(Q^j\right)\right]\right\} \quad (6)$$

[36] For further discussion see Duguid (2006).

[37] 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)

$$\begin{aligned} \frac{1}{U} & \quad \underbrace{\left[\frac{C\left(Q^j+q_1+q_2\right)-C\left(Q^j+q_2\right)}{q_1}\right]}_{(I)}+\frac{U-1}{U}\underbrace{\left[\frac{C\left(Q^j+q_1\right)-C\left(Q^j\right)}{q_1}\right]}_{(II)} \\ < & \quad \frac{1}{U}\underbrace{\left[\frac{C\left(Q^j+q_1+q_2\right)-C\left(Q^j+q_1\right)}{q_2}\right]}_{(III)}+\frac{U-1}{U}\underbrace{\left[\frac{C\left(Q^j+q_2\right)-C\left(Q^j\right)}{q_2}\right]}_{(IV)} \end{aligned} \tag{7}$$

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 transfer 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 (7) 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 (7) 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 transfer 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 (7) 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 (7) 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

$$\begin{array}{ccc} \frac{1}{U}\left\{-qC'\left(\tilde{Q}-q\right)+C\left(\tilde{Q}\right)-C\left(\tilde{Q}-q\right)\right\} & > & \frac{U-1}{U}\left\{qC'\left(Q^j+q\right)-C\left(Q^j+q\right)+C\left(Q^j\right)\right\} \\ \| & & \| \\ \frac{1}{U}\int_{z=\tilde{Q}-q}^{\tilde{Q}}\left(\tilde{Q}-z\right)C''(z)\,dz & & \frac{U-1}{U}\int_{z=Q^j}^{Q^j+q}\left(z-Q^j\right)C''(z)\,dz \\ \| & & \| \\ \frac{1}{U}\int_{w=0}^{q}wC''\left(\tilde{Q}-w\right)dw & & \frac{U-1}{U}\int_{w=0}^{q}wC''\left(w+Q^j\right)dw \end{array}$$

Hence (7) 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 (7) holds gives the required result. ■

Proof of Theorem 2. Using (3) we have $\frac{\partial}{\partial q_1}t_2zU$ 2sign]TJ/F15 7.97 Tf 21331 T.93 -D[(@)]TJ ET 0.44 w 214.63 -934.56 m

to a lower transfer 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 transfer 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 transfer 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

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

Hence we have

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

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

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

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 transfer 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 (6) and letting $z_U \sim \text{Bin}\left(D-2, \frac{1}{U}\right)$ we have

$$\begin{aligned} \frac{\Delta C_2}{q_2} - \frac{\Delta C_1}{q_1} &= \sum_{n=0}^{D-2} z_U(n) \left\{ \sum_{W_j : |W_j| = n} \Pr(\text{winning } W_j |\, \text{won } n \text{ buyers}) \cdot H\left(Q^j\right) \right\} \qquad (8) \\ \text{with } H\left(Q^j\right) &= \frac{1}{U}\left[\frac{C\left(Q^j + q_1 + q_2\right) - C\left(Q^j + q_1\right)}{q_2} - \frac{C\left(Q^j + q_1 + q_2\right) - C\left(Q^j + q_2\right)}{q_1}\right] \\ &\quad + \frac{U-1}{U}\left[\frac{C\left(Q^j + q_2\right) - C\left(Q^j\right)}{q_2} - \frac{C\left(Q^j + q_1\right) - C\left(Q^j\right)}{q_1}\right] \end{aligned}$$

Focus on $(\ddagger)$ and therefore on (8). 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 $H\left(Q^j\right)$ 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 (8) 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 $\{q_3, \ldots, q_D\}$. We aim to show that $G_{n+1}(\tilde{q}) \leq G_n(\tilde{q})$. This is true as:

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

We can rewrite (8) 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 $H\left(Q^j\right)$ were declining in volumes. Then as $G_{n+1} \leq G_n$ the expected value of $H\left(Q^j\right)$ 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 $H\left(Q^j\right)$ is declining in volumes. If U is sufficiently large then the requirement is to show that

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

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:

$$\begin{aligned}
\frac{\Delta G^r_L}{q_L} &= \frac{G^r\left(q_L + \frac{1-q_L}{U}\right) - G^r\left(\frac{1-q_L}{U}\right)}{q_L} = (1-r)\left[\frac{C\left(q_L + \frac{1-q_L}{U}\right) - C\left(\frac{1-q_L}{U}\right)}{q_L}\right] + rUC\left(\frac{1}{U}\right) \\
\frac{\Delta C_S}{q_S} &= \frac{U-1}{U}\frac{\partial G^r}{\partial q}\left(\frac{1-q_L}{U}\right) + \frac{1}{U}\frac{\partial G^r}{\partial q}\left(q_L + \frac{1-q_L}{U}\right) \\
&= (1-r)\left[\frac{U-1}{U}C'\left(\frac{1-q_L}{U}\right) + \frac{1}{U}C'\left(q_L + \frac{1-q_L}{U}\right)\right] + rUC\left(\frac{1}{U}\right)
\end{aligned}$$

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

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

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

$$\lim_{q_L\to 1}\frac{\partial}{\partial r}\left[E\left(\Pi^{\text{sup}}\right)\right]=\frac{1}{U}\frac{1}{2^{U}}\left[C(1)-UC\left(\frac{1}{U}\right)\right] \tag{9}$$

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 $\hat{C}(q)$.[38] 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

[38] 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

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

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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