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ABSTRACT

Upstream Competition and Downstream Buyer Power*

This paper considers buyer power in the presence of upstream competition to supply a homogeneous product. A likely consequence of upstream competition is that each supplier is uncertain of its final output, because it does not know how many downstream buyers will select it as a seller. We present a model where, for this reason, final volumes are uncertain for each seller. We find a new source of buyer power when the surplus function is nonlinear: the event of negotiation with a large buyer increases the seller's expected output, which changes the expected average net surplus from the deal; this increases buyer power when the seller's surplus function is concave (and diminishes it when convex). We explore consequences for welfare, industry productivity, and investment incentives.

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1 Introduction

In recent years many papers on vertically related markets have explored 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 the supply chain—upstream sellers and downstream buyers—will be resolved and how it impacts on final consumers, investment incentives, and so on. Understanding this bargaining interface is particularly important when exploring the possible causes of *buyer power*—i.e. the ability of large downstream buyers to extract preferential terms from upstream suppliers. One strand of this literature has explored how the bargained outcome is affected by the shape of the cost and demand curves, and therefore the shape of the surplus function: the core insight is that the loss of a small buyer is more 'at the margin' to a seller than the loss of a large buyer, so departures from linearity of the seller's surplus function open up differences between the average surplus effect of large and small buyers.

The recent advances in understanding buyer power from these 'surplus shape' effects have generally assumed a setting in which an upstream firm faces no competition and thus no uncertainty about the number of the downstream firms that will approach it for contract (as it is a monopoly, they all will). The introduction of upstream competition introduces this source of uncertainty, which implies uncertainty for each upstream firm about the point it will be on its surplus function. This paper is the first to allow upstream firms to face competition and uncertainty regarding final outputs. We show that this is not innocuous and alters many of the results on buyer power. We also explore the implications for welfare and investment incentives.

The literature on buyer power is largely motivated by the increasing dominance of a few strong supermarkets in retailing and the possible consequences for their suppliers; these concerns have risen in several economies.[2] To inform our analysis of the supplier-supermarket bargaining interface, with competitive upstream sellers, we conducted interviews with buying managers at a number of major UK supermarkets and sales directors at a number of UK milk suppliers. Milk is a good example of a competitive upstream market: the product is essentially homogeneous and there are three main competing suppliers (Arla/Express, Dairy Crest and Wiseman).

[1]This terminology is drawn from Inderst and Shaffer (2006). The first papers to adopt a bargaining interface were Dobson and Waterson (1997) and von Ungern Sternberg (1996).

[2]The Competition Commission (2000, paragraphs 11.113-11.117) has cited imbalances in buyer power that were disadvantageous to smaller supermarkets. Recently the Office of Fair Trading has called for the supermarket sector to be investigated again, citing buyer power as one of the main reasons OFT (2006, Chapter 6). For discussion of other countries, see also Dobson and Waterson (1999, Table 2).

There are four large supermarkets (ASDA/Wal-Mart, Morrison, Sainsbury, and Tesco), with an increasing share of the market, and a number of smaller supermarkets; the inequality in the size of the buyers allows scope for buyer power effects. The three main insights to emerge from the interviews were:

1. Supermarkets unilaterally start a new procurement round at unpredictable points in time.
2. Suppliers face uncertainty in future successful tenders. When bidding for new contracts, suppliers think strategically about their likely future tender successes and failures, and quote prices that are competitive against rival suppliers and that are expected to cover their medium term costs.
3. Supermarkets ask for and receive a per unit transfer price rather than a two-part tariff.

These points are consistent with recent published research on this market. For example in their report on the merger of Arla and Express Dairies, the Competition Commission (2003) noted the level of volume uncertainty faced by the suppliers (the procesors):

> "It is now the case that a high proportion of the sales of each processor to national multiples is concentrated in only three or four customers, such that the loss of any one of these is likely to have a serious consequence for the processor. The merger parties told us that the national multiples were fully aware of this fact and play off the major processors against each other. [The national multiples] .have the ability to switch volumes easily between suppliers [...]. In contrast a processor cannot readily find another avenue to market if it loses sales to a national multiple." CC (2003, paragraph 5.97)

The KPMG (2003) report into the dairy supply chain points out that supermarkets regularly initiate new negotiations, that volumes are buyer-led, and that the focus is on constant per-unit prices rather than fixed fees:

> "Negotiations...seem to follow guidelines which are relatively common across most supermarket/supplier relationships. The trigger is usually an invitation to tender by the supermarket or a periodic supplier review programme similar to the Sainsbury initiative in early 2002. The invitation to tender usually contains a demand profile using assumed quantities and container sizes. Bids are made on a per-gallon basis

regardless of actual product size and a supplier is selected" (KPMG paragraphs 178-179).

These insights have two main implications. The first is that suppliers are uncertain which buyers, out of the set of potential buyers downstream, will contract with them in the future. They are therefore uncertain of the total volumes they will supply. It is this uncertainty that existing models entirely ignore. The second implication is that, with linear prices, pricing is not fully efficient: production costs are typically not linear so fully efficient prices would require transfer prices to be renegotiated (or at least altered) once final volumes at each supplier had been decided. This is not a feature of the milk supply chain in the UK and we suspect it is not a feature of supply chain bargaining interfaces generally.

To capture these aspects of upstream competition, we present a model in which U upstream suppliers are in competition to supply a homogeneous input to D downstream buyers. Each downstream firm requires only one supplier and chooses this supplier randomly. Contracts are determined in simultaneous bilateral negotiations over a per-unit price. An upstream firm, when negotiating with a downstream firm, is uncertain how many other downstream firms it will ultimately supply in the simultaneous negotiations. At each point the bargaining outcome is affected by the number of rival suppliers a buyer can turn to. Should a buyer find herself having dismissed one supplier then the remaining suppliers are stronger (because they are fewer) and the agreed transfer price rises. This specification captures, in a static framework, the uncertainty in the contracting process noted above.

This setting for upstream competition leads to a new source of buyer power. Suppose the upstream firms have increasing returns to scale. Consider a supplier's bargaining position against a relatively large buyer. If a supplier wins a tender from a large buyer then this is a good signal as to her likely final volumes so her expected final output is relatively high. At high volumes the seller's average cost per unit is low. If the large tender is lost then the likely final volumes are low (as a large buyer is known to have got away). At low volumes the average cost per unit will be high. The large tender is therefore very valuable to the supplier who offers a low price. On the other hand, when negotiating with a small buyer then the winning or not of such a contract is not a very informative signal for likely final volumes. Thus when negotiating with a small buyer the expected average cost per unit is relatively high, and the supplier charges the small buyer a high price. The result is unambiguous and is reversed if suppliers have decreasing returns to scale.

In the case of milk, our interviews with industry executives suggests that technology is characterized by increasing returns to scale.[3] The CC (2003) report found evidence of buyer power in this sector (p 5.95–5.105). This finding is consistent with the predictions of our model—and inconsistent with previous 'surplus shape' models—in the presence of increasing returns.

The framework we establish also allows us to assess what effect increasing upstream concentration has on the relative transfer prices secured by large versus small buyers. We show that, for a large subset of increasing returns to scale cost functions, reducing the number of suppliers disproportionately hurts large buyers. This is because a supplier with fewer competitors has a greater chance of getting any given large contract. Thus each individual large buyer becomes a little less pivotal in allowing larger volumes to be attained, and a little less able to wield buyer power.

Having established a mechanism through which buyer power can operate in the presence of upstream competition we proceed to analyze its welfare implications. First we note that if upstream firms have increasing returns to scale then an increase in downstream concentration has a positive welfare effect which has not hitherto been noticed: it reduces the expected aggregate industry costs of production. The reason for this is that with upstream competition the final distribution of volumes amongst suppliers is random. With a more concentrated downstream sector the distribution of final volumes is adjusted by a mean preserving spread: the expected volume at any supplier is unchanged, but the variance increases so that suppliers are more likely to have extreme orders (sometimes high volumes, sometimes very low). If upstream production costs display increasing returns to scale then the cost functions are concave and so the mean preserving spread of volumes lowers expected industry costs.

We next consider the incentives suppliers have to introduce innovations that reduce marginal cost. We are interested in whether suppliers prefer to reduce marginal cost at low output levels away from the margin, or at high output levels close to the margin. As the upstream firms produce a homogeneous input, a supplier with lower costs can expect to receive all of the demand (more of the demand with decreasing returns to scale) and so 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, often cost reduction in a supply chain is a result of

[3] Average costs per unit are thought to be lower when large volumes are secured as plants can be more efficiently used and economies of scale in logistics can be exploited. Other authorities support this view. For example the Competition Commission reported evidence of increasing returns scale in milk processing (see CC (2003, paragraph 3.31)).

better practices or scale rather than a patentable innovation. To understand such settings we instead analyze the incentives to invest under anticipatory equilibrium (Wilson (1977)) in which upstream firms expect their rivals to copy a cost reducing innovation. We show that the incentives to reduce marginal cost incrementally in the presence of large downstream buyers are focused on the first units of output, as opposed to the marginal units, for two reasons. The first is that with uncertain output a supplier wishes to ensure that its cost reducing technology is reached; this is more likely if the reduction of unit costs occurs at small volumes rather than large. The second is that suppliers do not want the large buyers to be needed to reach the lower cost units, because the buyers can appropriate some of gain in the price negotiations. Both effects cause the suppliers to seek innovations such that, conditional on running a plant at all, the first units produced have a low avoidable cost. This result obtains regardless of whether technology gives convex or concave costs.

The results up to this point treat as exogenous the shape of the cost function; results are derived both for convex and concave costs. In the final section of the paper we relax this assumption to explore the firm's exogenous choice of technology. We find that the presence of large buyers influences the choice of upstream technology: if a sufficiently large buyer exists then the whole supplier industry would rather move from a linear cost function to one of increasing returns to scale, even though the transfer prices which can be extracted from large buyers falls. Such a change in technology in response to large buyers acts to create a disparity between the transfer prices given to large versus small buyers, the latter getting a worse deal. In moving to such an increasing returns to scale cost function, the expected total costs fall because of the mean preserving spread effect outlined above. On the other hand the transfer price to large buyers falls, but the effect is (slightly) damped by the ultimate threat of a buyer having to pay a high and unchanged price for the input from a different geographic market. There is no such dampening effect for the cost reduction. The transfer prices agreed with small buyers are not much affected. So overall, if a large enough buyer forms, the supplier industry would change to introduce technology which increased their profits but created a gap between the transfer prices secured by the large as compared to the small buyers.

The literature on the effect of surplus function curvature on buyer power took a large step forward with Chipty and Snyder (1999).[4] In the theoretical part of their study, they note that if there is a monopoly supplier then each buyer will take as given that the other buyers will

[4]Surplus shape effects appeared earlier in Horn and Wolinsky (1988) and Stole and Zwiebel (1996).

trade with this supplier and so considers itself to be the marginal buyer from a known point on the supplier's cost function (the whole industry volume less the buyer's output). In this case the bargaining outcome is dictated by the shape of the surplus function at the known marginal point. For example, if the supplier's cost function is convex (decreasing returns to scale) or revenues are concave, then a small buyer contributes little to revenue and has costly marginal units and so gets a higher transfer price. Under many revenue assumptions this boils down to predicting large buyers having buyer power only if there are decreasing returns to scale upstream. This result is perhaps at odds with casual empiricism, and is not robust to the introduction of upstream competition and uncertainty, as our model shows.

In the empirical part of their study, Chipty and Snyder estimate a surplus function for the cable TV industry and find strong evidence of substantial non-linearities in the upstream firm's surplus function, a finding which illustrates the relevance of surplus curvature effects in practice.

Inderst and Wey (forthcoming) extend the surplus curvature approach to examine investment incentives, again with an upstream monopolist. They note that bargaining for a large firm is determined further away from the margin than for a small firm, so if the structure of the downstream market shifts from small to large buyers, this reduces the proportion the buyers capture of a cost reduction at the margin. This increases the seller's incentive to invest in cost-reducing technology close to the margin, which brings positive welfare effects as total output increases.

Again this insight is not entirely robust with upstream competition: if a supplier's final volumes are uncertain due to competition then we find it wishes to invest on highly *infra*marginal units as (a) these are very likely to be delivered and (b) the probability of a large buyer being pivotal in attaining these cost reductions, conditional on market entry, is low. However, if large enough buyers exist then we also show that there can be a force towards technologies which disproportionately favour large buyers and which therefore have lower marginal costs at high levels of production.

Two papers in the existing surplus curvature literature drop the monopoly supplier assumption: Inderst and Wey (2003) and Inderst (2006).

Inderst and Wey (2003) consider two differentiated upstream firms with downstream firms optimally requiring both inputs in equilibrium. Their model is distinct from ours as it assumes away all uncertainty on the upstream parties: all suppliers supply all downstream firms in equilibrium with a uniquely determined optimal quantity. The solution concept is given by the

Shapley value. This approach cannot be extended to analyze the presence of downstream competition as subcoalitions would then have a negative externality on each other which the Shapley value rules out.[5] The model of the bargaining interface we propose here is readily extendable to downstream competition, which we explore in related work (see Smith and Thanassoulis (2006)).

More recently, Inderst (2006) considers the situation where a number of upstream firms compete to supply a homogeneous product to a number of downstream firms. As in our paper, each supplier's sales agents negotiate with different buyers simultaneously without communication, and form rational expectations regarding the point on the surplus function the firm will be at in the absence of a deal. However, Inderst assumes firms are not constrained to use per unit prices, which means that the equilibrium solution is characterized by the efficient allocation, which in turn implies a known positive output for each supplier and retailer (assuming convex costs for suppliers). Each of the supplier's sales agents can therefore be certain of the supplier's output in equilibrium; this contrasts with the uncertainty of the agents in our model. The presence of rival upstream firms provides an outside option for buyers, who can transfer demand to alternative sellers in the (out of equilibrium) event of a failure to agree a deal with any given seller. This outside option is less attractive for large than for small buyers because of the convexity of supplier cost functions; this disadvantages large buyers relative to small buyers and Inderst shows that this can reverse the result that large firms have more buyer power (where seller costs are convex).

In contrast to Inderst (2006), our paper permits upstream competition to introduce uncertainty for each seller in each negotiation with a buyer about the seller's ultimate output. A second difference is that firms bargain over per-unit prices rather than flexible tariffs. A third difference is the modeling of a buyer's outside option if a deal breaks down with a seller. Inderst assumes that the buyer redistributes the lost output evenly among all rival sellers. In our model the buyer only ever aims to source from a single seller and in the event of disagreement switches negotiations for all output to a single alternative seller; but the buyer is then placed in a weaker position as there are fewer suppliers remaining to turn to in the event of another disagreement. (This continues to a third supplier if negotiations also break down with the second, and so on, until there are no suppliers left). Rather than being merely a convenient out-of-equilibrium device, we believe that this is a good description of the scenario facing downstream firms should negotiations fail with a supplier. Each of these differences reflect important features of the

[5] See Jackson and Wolinsky (1996) for detailed discussions on this topic.

supplier-supermarket bargaining interface and the results of previous papers change when these features are introduced.

Not all possible explanations for buyer power stem from the curvature of the surplus function. A detailed overview of the current theories can be found in the survey chapter offered by Inderst and Shaffer (2006). These authors note that larger buyers can extract better transfer prices as (i) they can more credibly threaten to integrate upwards in the supply chain (Katz (1987)); (ii) they can reduce the varieties stocked and so cause hitherto differentiated suppliers to become competitors (Inderst and Shaffer (forthcoming)); (iii) if an upstream monopolist is risk averse then the larger a fraction of the market a downstream buyer controls the lower the transfer price the seller sets (De Graba (2003)); (iv) large buyers can limit how high a collusive transfer price can be sustained (Snyder (1996)).

The model is introduced in Section 2 with a motivating example describing the interplay of upstream competition, cost structure and bargaining power in Section 3. Section 4 explores when buyer power will exist, Section 5 assesses the impact on industry cost and Section 6 the investment incentives. Section 7 examines the endogenous choice of cost function by suppliers. Section 8 concludes.

2 The Model

Upstream competition creates uncertainty for the upstream suppliers as to the final volumes they will be supplying to downstream buyers. We seek to explore how this uncertainty interacts with the shape of the upstream cost function to create buyer power. We assume throughout that all sellers and buyers are risk neutral.

2.1 Industry Configuration

Suppose that there are U upstream firms in competition to supply a homogeneous input to the downstream firms. These upstream firms all have the same total cost function so that 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. This cost function is assumed twice differentiable, strictly increasing in quantity. We consider two classes of cost functions: concave and convex. Concave cost functions imply that average costs per unit 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.

To annotate the results, in addition to working with general cost functions, we also consider the class of quadratic cost functions. That is, through the paper we maintain a worked example with $C(q) = q(b - aq)$. Concave costs are explored with $a, b \geq 0$ and $\frac{b}{2a} \geq Q$ so that the cost function is increasing in the range $q \in [0, Q]$. Convex costs are explored with $a \leq 0$, $b \geq 0$ and so $\frac{b}{2a} \leq 0$ to again ensure that costs are positive and increasing for $q \in [0, Q]$.

To analyze the buyer power of large relative to small buyers we assume that there are D_L large downstream buying firms seeking q_L units of the input. In addition there are D_S small buyers seeking volumes $q_S < q_L$. This zero-elasticity assumption makes the problem analytically tractable and allows us to highlight the intuitions on the role uncertainty over final volumes plays in the bargaining stance of each size of upstream firm.

Thus the input price of the downstream firms does not change the downstream firms' revenues, nor the volume of input each buyer requires. This assumption holds well when the input provided by the upstream sector is just one part of the final product put together by the downstream firms. Thus we have in mind markets such as homogeneous goods supplied to supermarkets (e.g. milk) where the input forms one part of any given final customer's basket. A second example is the market for salt which forms one ingredient into many food recipes or chemicals manufacturers. The methodology we propose extends to the case when each downstream firm's demand is not zero-elastic, however this comes at a cost in tractability without altering the insights that the model generates.

2.2 The Bargaining Model

Each downstream firm seeks 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. Before defining the bargaining game we first define the ultimate disagreement outcome. If a downstream buyer should ultimately fail to agree with any of the U upstream suppliers then they 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 bargaining model itself has been designed to capture the salient features outlined to us by supermarket and supplier industry executives; in particular the role that uncertainty as to final volumes plays on the suppliers' bargaining strength. The game is depicted graphically in Figure 1, the full details follow:

- All U upstream firms are available for negotiation with the buyers.

- Negotiation is over a linear transfer price. (Fully efficient ex post marginal cost price agreement is not readily achievable here due to the non-linearity of the total cost function: a supplier would need to know exactly how much she was going to supply to know the exact marginal cost she will be incurring. We discuss this further at the end of the section.)

- The downstream buyers come simultaneously to the input market. Each buyer seeks to bargain for supply from a single supplier, and bargains sequentially with suppliers until an agreement is reached.

- As the U upstream firms are symmetric, a buyer randomizes as to which order to bargain with the upstream firms. The buyer then approaches the first supplier and bargains using the Binmore et al (1986) full information alternating offer bargaining game with no discounting. That is, after every offer there exists an ε (small) probability that the bargaining breaks down. In this case the upstream and downstream firms have argued and will not now reach a deal; the downstream firm moves to the next upstream firm in her ordering and begins bargaining again. However she is now in the weaker position of having one less potential supplier to threaten to move to. The upstream supplier has lost this downstream firm as a potential customer.

- If an upstream firm is picked by more than one buyer, the upstream firm makes a separate sales representative available to each of the buyers for the negotiations. The upstream firm's representatives negotiate simultaneously and independently with no communication between them. Thus each upstream firm's sales representative is entirely ignorant of how well, if at all, negotiations are progressing with other sellers. In this way the bargaining game is kept independent of the order in which buyers bargain and so the true effects of uncertainty can be analyzed; we elaborate on this below.

The implication of this bargaining game is that the parties split the gains from trade in excess of the value which would be enjoyed if the buyer found itself moving on and bargaining with the next supplier, with one fewer supplier remaining. Thus we capture the idea that a downstream firm is able to point out that should negotiations with U_1 break down it will be able to go to U_2 and derive a known surplus, thus if U_1 is to win the business she must offer a price lower than U_2 will. The bargaining game supposes that the extra pie available from dealing with U_1 is split equally.[6]

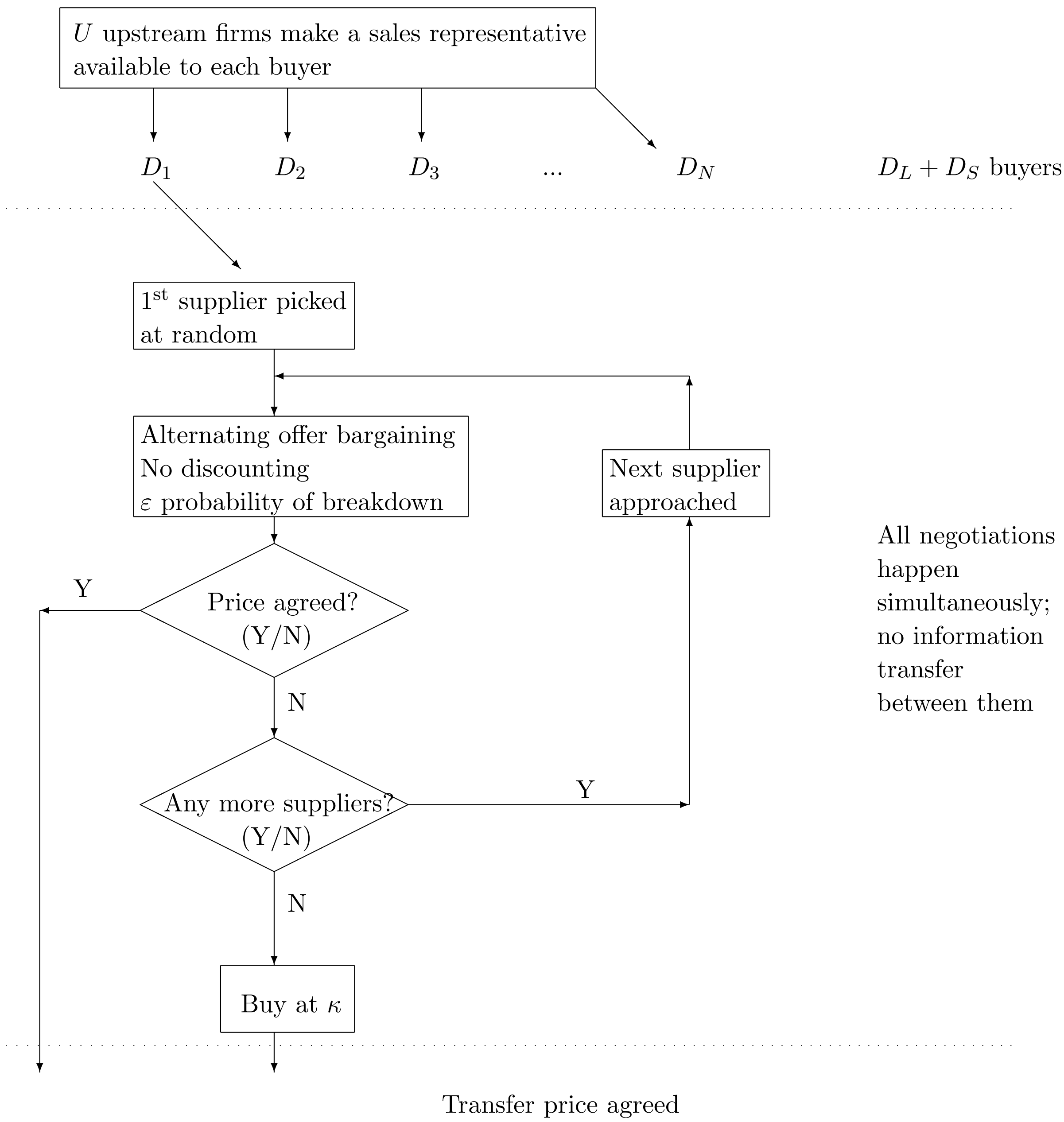

Figure 1: Flowchart of the Negotiation Process.

Assumption of Simultaneous and Independent Bargaining

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

The assumption of simultaneous bargaining between buyers and the seller(s) has been used widely in the literature (e.g. Dobson and Waterson (1997), Inderst and Wey (forthcoming)). However these models have a single upstream firm. In our model with more than one upstream firm, an upstream firm bargaining with a downstream firm must resolve the bargaining without knowing how many negotiations it is conducting with other potential downstream buyers. Thus final volumes are uncertain and this uncertainty will be reflected in the agreed price between buyers and sellers in a manner which depends upon the number of suppliers U, the number and size of possible buyers $\{D_L, D_S\}$, and the shape of the cost function. This assumption of simultaneous and uninformed bargaining is designed to capture the essence of a dynamic bargaining game in which buyers who are currently contracted may decide to re-tender for the business at some unknown future point. For example, industry interviews have revealed that such sudden re-tendering is very much a feature of bargaining between supermarkets and the suppliers in the UK milk industry.

Assumption of Linear Transfer Pricing

We finally turn to the assumption that bargaining is over a linear price per unit. This assumption is a direct consequence of the industry interviews we conducted. In the context of non-linear upstream costs coupled with uncertainty as to final volumes, two part tariffs cannot be used to give fully efficient pricing as the final volumes and so the final marginal cost at each supplier is unknown. Inderst and Wey (forthcoming) suppose that a monopoly supplier could unilaterally alter the volumes downstream buyers take and so arrive at efficient input prices; but the assumption of ex post quantity forcing does not fit well in the bargaining game described to us by supermarket or supplier executives in the UK milk industry. Rather these executives described the bargaining as being over a constant price per unit. Further, the volumes were buyer led (rather than supplier driven) and the prices did not adjust to supplier volumes. Our model seeks to capture these features.[7]

2.3 Initial Results

Recall that D_L large and D_S small downstream firms approach U upstream firms simultaneously. If a downstream firm of type $i \in \{L, S\}$ is left having to negotiate with one of u possible suppliers

[7]Some executives also described a second agreed price point representing a modest per unit price reduction if unexpectedly large volumes are sold thus creating an incentive for the supermarket to market the product well - but this was typically not triggered. We do not recreate the (modest) buyer incentive here as the focus of this paper is on the role of upstream volume uncertainty.

where $u \in \{0, 1, 2, \ldots U\}$ then the bargaining game would result in a transfer price for the input of $t : \{L, S\} \times \{0, 1, 2, \ldots U\} \rightarrow \mathbb{R}_+$ denoted $t_i(u)$.

Lemma 1 *The price per unit a downstream firm of type D_i, $i \in \{L, S\}$ pays when she has u upstream firms left to bargain with is given by*

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

where

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

Thus the agreed price per unit exceeds the expected average cost per unit $\Delta C_i/q_i$ by an amount which depends upon the ultimate outside option facing the downstream firm: to supply from a different geographic market at price κ once negotiations have broken down with all the remaining u upstream 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.[8] Thus consider a downstream firm of type $i \in \{L, S\}$ who 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 $q_i[t_i(n-1) - t_i(n)]$. 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 $t_i(n)$ then the expected profits of the supplier are

$$q_i t_i(n) + E(\text{payments from other negotiations}) - E\left(\text{total cost}\,\middle|\,\begin{matrix}\text{win contract}\\ \text{with type } i\end{matrix}\right)$$

The expected profits in the event of this bargain breaking down can similarly be derived and so the benefit to the supplier of agreeing transfer price $t_i(n)$ is $q_i t_i(n) - \Delta C_i$. The Binmore et al

[8] The total pie to be divided (buyer revenue - supplier expected costs) is independent of the agreed transfer price as downstream demand is inelastic. The Nash bargaining solution therefore splits the pie in excess of outside options equally. With elastic downstream demand the Nash bargaining solution would in part depend on the shapes of the agents' profit functions.

(1986) bargaining game requires the gains from trade to be equal and so we have the difference equation

$$q_i \left[t_i \left(n-1 \right) - t_i \left(n \right) \right] = q_i t_i \left(n \right) - \Delta C_i$$

whose solution is given in the lemma. ■

Equation (1) shows how the transfer price agreed varies with the suppliers' average costs per unit and the number of supplier competitors. Before exploring the effect of the cost function's shape on buyer power we first describe a motivating example. It is immediate from equation (1) that the average cost (as opposed to simply marginal cost) will play an important role in the bargaining and price setting process.

3 Motivating Example

Suppose that there are two downstream firms: $D1$ wishes to buy 1 unit while $D2$ wants 2 units of the input. 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).

3.1 Increasing Returns to Scale

The suppliers have costs (C, c, c). Further, when negotiating with retailer $D1$, each supplier sees its probability of winning business from $D2$ as $\frac{1}{2}$. Therefore we have

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

The lower cost per unit for $D2$ $\left(\frac{\Delta C_2}{2} < \frac{\Delta C_1}{1} \right)$ is a result of increasing returns to scale. That is, if negotiating with the smaller buyer $D1$, there is a 50% probability of not winning the other contract which would cause the cost of the unit to be C, whereas if the other contract is won then the cost will be c: so the average cost is $\frac{1}{2} (C + c)$. When dealing with the larger buyer $D2$ signing up the contract at all lowers the average per unit cost below C whether or not the other contract is won. So the expected average cost per unit is smaller when dealing with the large buyer who therefore bargains a lower transfer price t. In fact, using (1) we have

$$t_{D1} = \frac{\kappa}{4} + \frac{3}{8} \left(C + c \right) \qquad \text{and} \qquad t_{D2} = \frac{\kappa}{4} + \frac{3}{16} \left(C + 3c \right) \tag{2}$$

which give the prices per unit each buyer pays. The larger buyer ($D2$) enjoys buyer power as $t_{D2} < t_{D1} \Leftrightarrow c < C$. This result follows as with increasing returns to scale sellers desire large as opposed to small volumes. Landing the large contract carries better news as concerns final volumes and final average per unit costs; large buyers therefore receive a better price.

3.2 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: with decreasing returns to scale small volumes are sought after and so securing the large contract is bad news as to final average costs per unit and so large buyers receive a worse price.

The following section will establish the results and intuition more fully.

4 Conditions for Buyer Power

We have noted that previous literature investigating the effect of a monopoly supplier's cost on bargained transfer prices has suggested that increasing returns to scale hands power to small buyers who should receive a lower price than the large buyers (e.g. Chipty and Snyder (1999)); a result which sits at odds with policy discussion in many industries. In this section we explore the question in the context of supplier competition and supplier uncertainty.

4.1 Upstream Technology and Buyer Power

With a competitive upstream supply sector we find that increasing returns to scale upstream does lead to large downstream buyers wielding buyer power. The simple intuition for the difference between our result and that of the previous literature is given in Figure 2. Suppose there is a single large buyer and a single small buyer. The suppliers are depicted with increasing returns to scale (concave total cost functions). The gradients drawn on the total cost function give the anticipated average cost per unit conditional on the outcome of possible negotiations with the other buyer. If $U > 2$ then there is a greater chance of losing as opposed to winning the other contract. In this case more weight is put on the steeper of the two gradients. The graph therefore shows that when bargaining with the large buyer, lower average costs per unit are anticipated than when bargaining with the small buyer. So the large buyer negotiates a preferential deal: that is 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. Thus all the probability weight is attached to the flatter of the two gradients and in that case (as the diagram shows) higher average costs are anticipated when bargaining with the large buyer.

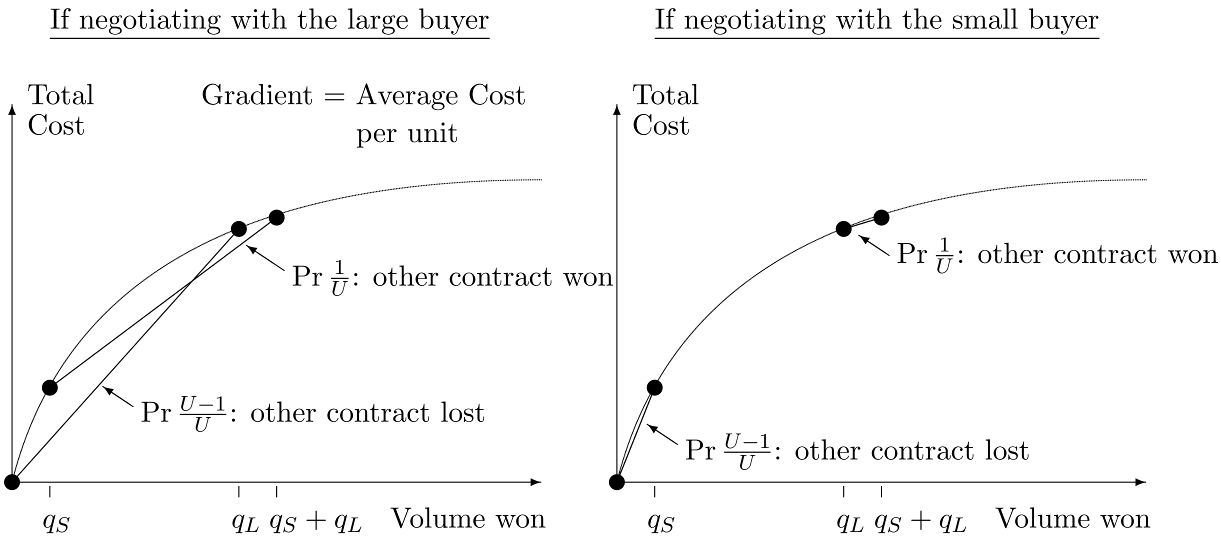

Figure 2: U upstream suppliers compete to supply one large buyer (requiring volume q_L) and one small buyer (volume q_S). The suppliers are depicted with increasing returns to scale (concave total cost functions). The gradients drawn on the total cost function give the anticipated average cost per unit conditional on the outcome of possible negotiations with the other buyer. If $U > 2$ then there is a greater chance of losing as opposed to winning the other contract. In this case more weight is put on the steeper of the two gradients (Pr $\frac{U-1}{U}$). The graph therefore shows that when bargaining with the large buyer, lower average costs per unit are anticipated than when bargaining with the small buyer. So the large buyer negotiates a preferential deal.

To establish our results more generally it will be helpful to define two probability density functions: $z_i \sim Bin\left(D_i - 1, \frac{1}{U}\right)$ with density function $f_i(z_i)$ and $w_i \sim Bin\left(D_i, \frac{1}{U}\right)$ with density function $g_i(w_i)$. The $Bin(\cdot,\cdot)$ is shorthand for the Binomial density function. The first density function gives the probability of securing z_i other contracts from the other $D_i - 1$ downstream firms. The second density function considers the ex ante probability of securing w_i contracts out of the total number of D_i available. As before $i \in \{L, S\}$.

Proposition 2 *If D_S is large ($D_S >> D_L$) and q_S ($q_S << q_L$) is small then:*

1. *With concave total costs (increasing returns to scale), large downstream firms receive a lower transfer price if U is sufficiently large.*
2. *With convex total costs (decreasing returns to scale), small downstream firms receive a lower transfer price if U is sufficiently large.*

In both of the above cases, for the family of quadratic costs, $U > 2$ is required to give the buyer power result.

Proof. From Lemma 1 small downstream firms pay a higher price per unit than large downstream firms if and only if $\frac{\Delta C_S}{q_S} > \frac{\Delta C_L}{q_L}$. Now note that if negotiating with a large buyer, the expected total cost conditional on success is given by

$$E\left(\text{total cost} \left| \begin{array}{c} \text{win contract} \\ \text{with type } L \end{array} \right.\right) = \sum_{w_S=0}^{D_S} g_S(w_S) \sum_{z_L=0}^{D_L-1} f_L(z_L) \cdot C(w_S q_S + z_L q_L + q_L).$$

Repeating for the total costs conditional on losing this contract we have

$$\frac{\Delta C_L}{q_L} = \sum_{w_S=0}^{D_S} g_S(w_S) \sum_{z_L=0}^{D_L-1} f_L(z_L) \left[\frac{C(w_S q_S + z_L q_L + q_L) - C(w_S q_S + z_L q_L)}{q_L}\right].$$

Similarly if negotiating with a small downstream buyer we have

$$\frac{\Delta C_S}{q_S} = \sum_{z_S=0}^{D_S-1} f_S(z_S) \sum_{w_L=0}^{D_L} g_L(w_L) C'(z_S q_S + w_L q_L)$$

where we have used the fact that $\frac{C(z_S q_S + w_L q_L + q_S) - C(z_S q_S + w_L q_L)}{q_S} \approx C'(z_S q_S + w_L q_L)$ as q_S is assumed small.

We now note that $f_S \approx g_S$ as the assumption that D_S is large implies that the probability of winning every single small downstream firm is approximately zero $(g_S(D_S) \approx 0)$. Further note that $g_L(w_L)$ is the probability of w_L success from D_L trials while $f_L(z_L)$ is the probability of z_L successes from $D_L - 1$ trials so that the following probability decomposition is possible:

$$g_L(z) = \binom{D_L}{z} \left(\frac{1}{U}\right)^z \left(\frac{U-1}{U}\right)^{D_L - z} = f_L(z) \frac{U-1}{U} + f_L(z-1) \frac{1}{U}.$$

Hence we establish that

$$\frac{\Delta C_S}{q_S} - \frac{\Delta C_L}{q_L} = \sum_{j=0}^{D_S-1} f_S(j) \sum_{z=0}^{D_L-1} f_L(z) \left\{ \begin{array}{l} \frac{U-1}{U} C'(jq_S + zq_L) + \frac{1}{U} C'(jq_S + zq_L + q_L) \\ - \left[C(jq_S + zq_L + q_L) - C(jq_S + zq_L) \right] / q_L \end{array} \right\} \quad (3)$$

Increasing Returns to Scale (Concave Costs)

If the total cost function is concave then we have

$$C'(jq_S + zq_L) > \frac{C(jq_S + zq_L + q_L) - C(jq_S + zq_L)}{q_L} > C'(jq_S + zq_L + q_L)$$

Therefore we have $\frac{\Delta C_S}{q_S} - \frac{\Delta C_L}{q_L} > 0$ if U is sufficiently large. This implies that larger buyers get lower transfer prices as required.

With the quadratic costs $C(x) = x(b - ax)$ we have $\frac{U-1}{U} C'(x) + \frac{1}{U} C'(x + q_L) = b - \frac{1}{U} 2aq_L - 2ax$ and $\frac{C(x+q_L)-C(x)}{q_L} = b - aq_L - 2ax$ so that (3) can be rewritten

$$\frac{\Delta C_S}{q_S} - \frac{\Delta C_L}{q_L} = E_{z_S}\left[E_{z_L} \left[aq_L \left(1 - \frac{2}{U} \right) \right] \right] > 0 \Leftrightarrow U > 2$$

Decreasing Returns to Scale (Convex Costs)

If the total cost function is convex then by identical reasoning we have $\frac{\Delta C_S}{q_S} - \frac{\Delta C_L}{q_L} < 0$ so that small buyers get better input prices if U is sufficiently large. With the quadratic costs with $a \leq 0$ we again require $U > 2$ for $\frac{\Delta C_S}{q_S} - \frac{\Delta C_L}{q_L} < 0$. ■

To understand this result, consider a supplier's optimal response to downstream buyers conditional on getting z_L large contracts and z_S small ones from the other $D_L - 1$ and $D_S - 1$ large and small buyers respectively. When negotiating with the large buyer, agreement will see volumes rise from $z_S q_S + z_L q_L$ by q_L and so the average cost per unit is given by the gradient of the chord of the cost function $\frac{C(z_S q_S + z_L q_L + q_L) - C(z_S q_S + z_L q_L)}{q_L}$, and the possible extra business from the small buyer has a negligible effect on volumes. If negotiating with a small buyer then with probability $\frac{U-1}{U}$ the last large contract won't be won, volumes supplied will be at $z_S q_S + z_L q_L$ and so the average cost per unit of supplying this small buyer is approximately the marginal cost at that volume, i.e. $C'(z_S q_S + z_L q_L)$. However, the large contract might be won with probability $\frac{1}{U}$ in which case average costs for the small buyer would fall to $C'(z_S q_S + z_L q_L + q_L)$. In a competitive setting losing a contract is more likely than winning it if $U > 2$ and so the supplier puts more weight on the costs if the final large buyer is not won. Thus the small buyer receives a less good rate if costs are concave, and a better rate if costs are convex. This is exactly the situation depicted in Figure 2.

4.2 The Effect of a Change in Upstream Concentration

We now examine the effect on buyer power of an change in upstream concentration.

Consider an increase in supplier numbers. For any buyer of given size, this has two effects on the actual level of the transfer prices. First, from Lemma 1 it reduces the chance of downstream buyers ultimately having to source at the expensive marginal cost of κ. Thus transfer prices fall towards the average cost per unit ($\frac{\Delta C_i}{q_i}$ in equation (1)). This effect is always negative. Second, as the number of suppliers rises, each supplier expects to serve smaller total volumes, which either increases or decreases expected average cost per unit, depending on the direction of returns to scale.

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 smaller volumes reduce expected average costs so the two effects work in the same direction, and transfer prices fall.

We now consider whether an increase in the number of suppliers benefits large buyers more than small buyers. We show that this is the case for a large subset of cost functions with increasing returns to scale:

Proposition 3 *As the number of upstream suppliers* (U) *increases:*

1. *The absolute transfer price differential between large and small buyers grows if the upstream firms have concave costs (increasing returns to scale) with marginal costs which decline at a decreasing rate, and if* U *is sufficiently large.*

2. *For the family of quadratic costs,* $U > 2$ *is required for the result to hold.*

3. *If costs are convex (decreasing returns to scale) the results are ambiguous and depend on the actual technology of the upstream suppliers.*

Before proving the result we unpack the proposition and note that a total cost function ($C(q)$) which satisfies part 1 has positive marginal costs $(C' > 0)$, is concave implying that $C'' < 0$ and finally if marginal costs decline at a declining rate then the marginal cost curve is itself downward sloping and convex so that $C''' > 0$. This requirement is satisfied by many cost functions as it essentially just requires marginal cost to tend in a 'well-behaved' way to some lower bound. Thus the proposition applies to the quadratic total cost functions; those with a log form (e.g. $C(q) = \ln(1+q)$); those with a square root form (e.g. $C(q) = \sqrt{q}$); and those with a quotient form (e.g. $C(q) = 1 - \frac{1}{1+x}$).

Proof. Using (1) note that the difference in transfer prices agreed by large versus small buyers is given by

$$t_S(U) - t_L(U) = \underbrace{\left[1 - \frac{1}{2^U}\right]}_{(\dagger)} \underbrace{\left[\frac{\Delta C_S}{q_S} - \frac{\Delta C_L}{q_L}\right]}_{(\ddagger)}$$

It is immediate that (†) is increasing in U. We therefore turn to (‡) which is written explicitly in (3) and which we rewrite as

$$\frac{\Delta C_S}{q_S} - \frac{\Delta C_L}{q_L} = E_{z_S} E_{z_L} \left[\begin{array}{c} \frac{U-1}{U} C'(z_S q_S + z_L q_L) + \frac{1}{U} C'(z_S q_S + z_L q_L + q_L) \\ -\left[C(z_S q_S + z_L q_L + q_L) - C(z_S q_S + z_L q_L)\right]/q_L \end{array} \right] \tag{4}$$

Consider first the case of concave costs (increasing returns to scale). Note that as U increases the square bracketed term rises as more weight is put on the higher marginal cost at volumes $z_S q_S + z_L q_L$ as opposed to the lower marginal cost at $z_S q_S + z_L q_L + q_L$. However, altering the number of suppliers also alters the probability of winning a contract and so alters the random variables $\{z_i\}$. Now recall that $z_i \sim Bin\left(D_i - 1, \frac{1}{U}\right)$. To capture the dependence on U denote this during the proof as $z_i(U)$. As U increases the probability of success falls and so the random variable $z_i(U)$ puts increasing weight on low numbers of successes. That is $z_i(\underline{U})$ first order stochastically dominates $z_i(\overline{U})$ if $\underline{U} < \overline{U}$. Overall therefore we can only unambiguously conclude that (‡) is increasing in U if the square bracketed term in (4) is weakly decreasing in volumes. That is if

$$\frac{U-1}{U} C''(q) + \frac{1}{U} C''(q + q_L) - \frac{\left[C'(q + q_L) - C'(q)\right]}{q_L} \leq 0 \text{ for all } q \in [0, Q - q_L] \tag{5}$$

If marginal costs decline at a declining rate then C' is convex decreasing so that $C''(q) \leq \frac{[C'(q+q_L) - C'(q)]}{q_L} \leq C''(q + q_L) \leq 0$. Hence if U is sufficiently large then the inequality in (5) holds, hence (4) takes the expectation of a weakly decreasing function. And as increasing U alters the probability of successes in a first order stochastically dominated way then we have that (‡) is increasing in U. Combining therefore $t_S(U) - t_L(U)$ is increasing in U giving part 1 of the Proposition.

For part 2 recall from the proof of Proposition 2 that (4) can be rewritten

$$\frac{\Delta C_S}{q_S} - \frac{\Delta C_L}{q_L} = E_{z_S} E_{z_L} \left[a q_L \left(1 - \frac{2}{U}\right)\right]$$

The square bracketed term is independent of the volume of supplies won (that is independent of the z variables) and so is constant (and hence weakly decreasing). As costs are concave $a > 0$ the square bracketed term is positive if $U > 2$ as stated.

We finally turn to the case of convex total costs, so that $C'' > 0$. Increasing U causes the square bracketed term in (4) to shrink, while we noted that (†) is increasing in U. These are conflicting forces and so no unambiguous results are available - the actual effect of altering U on the relative transfer prices will depend upon the actual upstream technology. ■

There is therefore a clear result available regarding the difference between the transfer prices secured by large versus small buyers under conditions of upstream economies of scale with marginal costs which decline at a decreasing rate. To see the intuition for this result 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 rapidly as the number of competing suppliers increases. The supplier therefore puts much more weight on low volumes and so the transfer price agreed is high, as expected average costs are high. If negotiating with a large buyer then this contract will on its own raise the expected volumes of production and so allow expected costs per unit to decline; a lower transfer price is therefore agreed. Thus increasing the numbers of suppliers reduces transfer prices more for large buyers than small buyers.

If the upstream firms have decreasing returns to scale, on the other hand, then increasing the number of upstream competitors shrinks the likelihood of winning any given large contract and so signing a deal with a large buyer is less of a bad signal as to the likely size of final average costs per unit. This acts to bring the transfer prices for large and small buyers together. However, with a large number of upstream suppliers the transfer price is based increasingly on the expected average costs per unit and less on the final disagreement input cost of κ, and so the final transfer price becomes more sensitive to changes in the expected average costs per unit. With convex costs upstream these two effects work in opposite directions so that the effect of increasing supplier on the transfer price for large relative to small buyers depends on the specific details of the upstream technology.

4.3 The Robustness of the Buyer Power Result

Note that in the previous discussion of buyer power (Section 4.1), the number of large and small buyers was not key, rather their relative size was important. Thus signing up a large buyer is a better signal as to final volumes than signing up a small buyer. Under increasing returns to scale this causes large buyers to receive a discount. However, in Proposition 2 it was convenient to assume that small buyers are more numerous than large buyers as this fact was used to imply that $g_S \approx f_S$. To show that it is the size and not the number effect that is key we have the following result.

Proposition 4 *Suppose that there is only one small buyer ($D_S = 1$) and q_S ($q_S << q_L$) is small then:*

1. *With concave total costs (increasing returns to scale), the large downstream firms receive a lower transfer price if U is sufficiently large.*
2. *With convex total costs (decreasing returns to scale), the large downstream firms receive a higher transfer price if U is sufficiently large.*

Further, for the family of quadratic costs, $U > 2$ is required to give these buyer power results.

Proof. Following the proof of Proposition 2 and using the fact that $D_S = 1$ we have $\frac{\Delta C_S}{q_S} = \sum_{z=0}^{D_L} g_L(z) C'(zq_L)$. Further, as q_S is small we have $\frac{1}{U} C(zq_L + q_S) + \frac{U-1}{U} C(zq_L) \approx C(zq_L)$ and so

$$\frac{\Delta C_L}{q_L} = \sum_{z=0}^{D_L - 1} f_L(z) \left[\frac{C(zq_L + q_L) - C(zq_L)}{q_L} \right]$$

Hence

$$\frac{\Delta C_S}{q_S} - \frac{\Delta C_L}{q_L} = \sum_{z=0}^{D_L - 1} f_L(z) \left\{ \frac{U-1}{U} C'(zq_L) + \frac{1}{U} C'(zq_L + q_L) - \frac{C(zq_L + q_L) - C(zq_L)}{q_L} \right\}$$

and so the result follows by the same proof as that following equation (3).

For the family of quadratic costs, recalling that there is only one small buyer by assumption, we have,

$$\frac{\Delta C_S}{q_S} - \frac{\Delta C_L}{q_L} = E_{z_L} \left[a q_L \left(1 - \frac{2}{U} \right) \right]$$

so that for concave costs ($a > 0$), the result holds if $U > 2$. If costs are convex then $a < 0$ and so again $U > 2$ is required for the buyer power result. ■

5 Price and Welfare Effects of Downstream Concentration

In the above we have assumed two sizes of downstream firms, and defined buyer power as the preferential transfer price enjoyed by large firms. A number of existing papers on buyer power take the alternative approach of assuming that the downstream industry is symmetric with all firms having the same size; in these papers 'buyer power' is modeled by reducing the number of downstream firms, while holding industry demand constant, and exploring the consequences for transfer prices (e.g. Dobson and Waterson (1997) and von Ungern-Sternberg (1996)). This can be interpreted, for example, as the effect of a downstream merger, or an increase in downstream concentration. These are questions of considerable policy interest given that the concentration of the retail sector has been trending upwards in recent years. The previous papers that have taken this approach have assumed upstream monopoly. In this section we use a downstream symmetric version of our model of upstream competition and explore the effect of an increase in downstream concentration on transfer prices, industry costs, and social welfare.

Our model is symmetric if we set $D_S = 0$ and allow total downstream demand Q to be divided equally between the D_L large firms; $\frac{Q}{D_L}$ for each firm. Hereafter in this section we drop the L subscript and use D for the number of downstream firms. Once again we find that fewer and larger downstream firms, holding the overall industry volumes constant, leads to lower transfer prices being agreed in equilibrium when suppliers have increasing returns to scale.

Proposition 5 *Suppose that $D_S = 0$ so that there are no small buyers. The D large buyers each require $\frac{Q}{D}$ units of supply.*

1. *With increasing returns to scale (concave costs) the transfer price per unit declines as D does if U is sufficiently large.*

2. *With decreasing returns to scale (convex costs) the transfer price per unit grows as D declines if U is sufficiently large.*

Further, for the family of quadratic costs, $U > 2$ is required for these results to hold.

Proof. Using Lemma 1 with the notation that the average cost per unit for q more units from a base of x is $\frac{C(x+q)-C(x)}{q} := A(x; q)$ then the transfer price agreed is increasing in

$$\frac{\Delta C_L}{q_L} = \sum_{z=0}^{D-1} \left(\frac{1}{U}\right)^z \left(\frac{U-1}{U}\right)^{D_L-1-z} \begin{pmatrix} D-1 \\ z \end{pmatrix} A\left(z\frac{Q}{D}; \frac{Q}{D}\right).$$

We prove the result by induction. Suppose that the number of downstream buyers grows by one from D to $D+1$ then

$$\left.\frac{\Delta C_L}{q_L}\right|_{D+1} - \left.\frac{\Delta C_L}{q_L}\right|_{D}$$
$$= \sum_{z=0}^{D-1} \left(\frac{1}{U}\right)^z \left(\frac{U-1}{U}\right)^{D-1-z} \begin{pmatrix} D-1 \\ z \end{pmatrix} \left\{ \begin{array}{c} \frac{U-1}{U} A\left(z\frac{Q}{D+1}; \frac{Q}{D+1}\right) + \frac{1}{U} A\left((z+1)\frac{Q}{D+1}; \frac{Q}{D+1}\right) \\ -A\left(z\frac{Q}{D}; \frac{Q}{D}\right) \end{array} \right\}$$

Now suppose that total costs are concave (increasing returns to scale). In this case $A(zq;q)$ is decreasing in q due to the economies of scale in production. To see this note that

$$\frac{\partial}{\partial q} A(zq;q) =_{\text{sign}} \left[C(zq) - zqC'(zq)\right] - \left[C(zq+q) - (zq+q)C'(zq+q)\right]$$

By the concavity of the cost function C' is decreasing so that $C'(zq+q) < C'(zq)$. Therefore

$$C(zq) - zqC'(zq) < C(zq) - (zq)C'(zq+q)$$

But $C'(x) > C'(zq+q)$ for $x < zq+q$ so that increasing quantities from zq to $zq+q$ causes total costs to grow at a faster rate than $C'(zq+q)$ and hence

$$C(zq) - (zq)C'(zq+q) < C(zq+q) - (zq+q)C'(zq+q)$$

which confirms that with concave costs $\frac{\partial}{\partial q}A(zq;q) < 0$. But then $A\left(z\frac{Q}{D+1}; \frac{Q}{D+1}\right) > A\left(z\frac{Q}{D}; \frac{Q}{D}\right)$ and so $\left.\frac{\Delta C_L}{q_L}\right|_{D+1} > \left.\frac{\Delta C_L}{q_L}\right|_{D}$ if U is sufficiently large. Thus smaller numbers of larger firms wield buyer power.

An identical approach confirms that if costs are convex then average costs per unit rise and so smaller firms wield buyer power.

In the case of quadratic costs we have $A(zq;q) = b - aq - 2aqz$ so that

$$\begin{aligned} \frac{\Delta C_L}{q_L} &= E_{z_L}\left(b - a\frac{Q}{D} - 2a\frac{Q}{D}z_L\right) \\ &= b - a\frac{Q}{D} - 2a\frac{Q}{U}\frac{D-1}{D} \end{aligned}$$

which is increasing in D if and only if $a\left(1 - \frac{2}{U}\right) > 0$ as required. ■

The increase in concentration brings down the agreed transfer price paid by the buyers. However, given our assumption of a fixed downstream retail price, there is no beneficial effect of reduced dead weight loss from more efficient downstream pricing. Nevertheless, upstream concentration still has welfare effects arising from the cost of manufacture of the input, as described in the next proposition:

Proposition 6 *Suppose D symmetric downstream buyers source their input from U competing upstream suppliers with some economies of scale so that the total cost function is concave. In this case fewer buyers raises welfare. The converse holds if upstream costs are convex (decreasing returns to scale).*

This welfare result follows for the same reason that transfer prices fall. When suppliers negotiate with large buyers, landing a deal is a very good signal as to the likely final volumes which a supplier will be supplying. Under the economies of scale assumption, this lowers the expected average cost per unit and so allows larger buyers to receive lower transfer prices (buyer power). In addition however, industry production is likely to be concentrated in a few suppliers resulting in economies of scale being released so that average costs per unit across the whole industry are also lower. This latter effect is welfare enhancing in expectation, as the same volume of inputs are made for a lower expected cost.

Proof. With D buyers we denote the expected costs per supplier as EC_D where

$$EC_D = \sum_{i=0}^{D} \binom{D}{i} \left(\frac{1}{U}\right)^i \left(\frac{U-1}{U}\right)^{D-i} C\left(\frac{iQ}{D}\right)$$

We next show that

$$\begin{aligned} & EC_D - EC_{D-1} \qquad (6) \\ = & \sum_{i=1}^{D-1} \left(\frac{1}{U}\right)^i \left(\frac{U-1}{U}\right)^{D-i} \left\{ \begin{array}{c} \binom{D}{i} C\left(\frac{iQ}{D}\right) - \underbrace{\binom{D-1}{i-1} C\left(\frac{(i-1)Q}{D-1}\right)}_{(A)} \\ \\ -\underbrace{\binom{D-1}{i} C\left(\frac{iQ}{D-1}\right)}_{(B)} \end{array} \right\} \end{aligned}$$

to see this note that

$$\sum_{i=1}^{D-1} \left(\frac{1}{U}\right)^i \left(\frac{U-1}{U}\right)^{D-i} \binom{D}{i} C\left(\frac{iQ}{D}\right) = EC_D - \left(\frac{U-1}{U}\right)^D C(0) - \left(\frac{1}{U}\right)^D C(Q) \qquad (7)$$

and

$$\begin{aligned} (A) &= \sum_{i=1}^{D-1} \left(\frac{1}{U}\right)^i \left(\frac{U-1}{U}\right)^{D-i} \binom{D-1}{i-1} C\left(\frac{(i-1)Q}{D-1}\right) \\ &= \sum_{i=0}^{D-2} \left(\frac{1}{U}\right)^{i+1} \left(\frac{U-1}{U}\right)^{D-1-i} \binom{D-1}{i} C\left(\frac{iQ}{D-1}\right) \end{aligned}$$

and therefore

$$\begin{aligned}(A)+(B) &= \frac{1}{U}\left(\frac{U-1}{U}\right)^{D-1}C(0)+\left(\frac{U-1}{U}\right)\left(\frac{1}{U}\right)^{D-1}C(Q) \\ &\quad +\sum_{i=1}^{D-2}\left(\frac{1}{U}\right)^{i}\left(\frac{U-1}{U}\right)^{D-1-i}\begin{pmatrix} D-1 \\ i \end{pmatrix}C\left(\frac{iQ}{D-1}\right) \\ &= EC_{D-1}-\left(\frac{U-1}{U}\right)^{D}C(0)-\left(\frac{1}{U}\right)^{D}C(Q) \end{aligned} \tag{8}$$

And so (7) and (8) imply (6) as required.

The proof now follows by the concavity of C. Recall that C concave implies that $C(\alpha x+(1-\alpha)y)\geq \alpha C(x)+(1-\alpha)C(y)$ and now note that

$$\begin{pmatrix} D-1 \\ i-1 \end{pmatrix}\frac{(i-1)Q}{D-1}+\begin{pmatrix} D-1 \\ i \end{pmatrix}\frac{iQ}{D-1}=\begin{pmatrix} D \\ i \end{pmatrix}\frac{iQ}{D}$$

while

$$\begin{pmatrix} D-1 \\ i-1 \end{pmatrix}+\begin{pmatrix} D-1 \\ i \end{pmatrix}=\begin{pmatrix} D \\ i \end{pmatrix}$$

and hence we must have $EC_D \geq EC_{D-1}$ and so as expected industry costs with D buyers are given by $U \cdot EC_D$ expected costs are lower with fewer buyers and so welfare is higher.

The exactly opposite result is reached if total costs are convex (decreasing returns to scale).

■

Some further intuition into this result is available. Suppose that there are a lot of downstream buyers. The number of contracts any upstream supplier wins is given by the random variable $w \sim Bin\left(D,\frac{1}{U}\right)$. Recall that for large D the binomial distribution closely approximates the normal distribution and so $w \sim N\left(\frac{D}{U}, D\cdot\frac{U-1}{U^2}\right)$. The actual demand supplied is a random variable which we denote η_D where $\eta_D=\frac{Q}{D}w$ as each contract won is worth $\frac{Q}{D}$ in volume. Therefore ex ante each supplier sees their volumes as distributed according to $\eta_D \sim N\left(\frac{Q}{U},\frac{Q^2}{D}\cdot\frac{U-1}{U^2}\right)$. Note that the expected volume is always $\frac{Q}{U}$ while the variance of volume declines as the downstream firms become more numerous and smaller. In particular, as the number of buyers falls, the distribution of volumes takes a mean preserving spread: 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 costs are increasing and concave standard risk theory confirms that if $D_1 > D_2$ so that η_{D_2} is a mean preserving spread of η_{D_1} then $E_{\eta_{D_1}}\left(C\left(\eta_{D_1}\right)\right)\geq E_{\eta_{D_2}}\left(C\left(\eta_{D_2}\right)\right)$. Hence expected industry costs are lower with fewer buyers.

Note that from the upstream firm's point of view the market with large buyers is characterized by the high probability of extreme events: very big volumes but also very small volumes. In a repeated context the expected volumes supplied remain constant at $\frac{Q}{U}$. But this masks wide variation.[9]

Note also that in this model industry volumes are constant. One concern might be that a downstream merger may lead to retail price increases and output reduction. This is ruled out in our model by the assumption of zero-elastic demand. However, even if such an increase occurs it is not sufficient to guarantee that welfare has declined as expected costs of production will also have declined.

6 Incentives to Invest

A concern often raised about downstream buyer power is that it may lower upstream incentives to invest in cost reducing technologies. Inderst and Wey (forthcoming) make an important contribution to this question. They consider the case of an upstream monopolist, so the negotiation between the supplier and any buyer takes as given that the supplier will be the only firm supplying the downstream industry, and negotiation is over the surplus from the incremental output demanded by the buyer. In this setting, small buyers can can capture a high proportion of the gain from a cost reduction at the *margin*, because the buyer's incremental output approximates to the seller's marginal output. But with large buyers incremental effect is further from the margin, so the buyer captures proportionately less of the gain from a cost reduction at the margin. Consequently a greater proportion of large buyers increases the inventive of the supplier to lower marginal—as opposed to the inframarginal—production costs; this can be welfare enhancing if it increases industry output. This is a welfare argument in favour of for downstream concentration.

In this section we consider whether this logic is robust to the introduction of upstream competition. The effect of upstream competition, in our model, is to create uncertainty about the supplier's ultimate demand. Therefore the bargaining is now over expected costs. Consequently, the whole shape of the cost function affects the bargaining, not just the incremental effect of the last q_i units (for $i \in \{S, L\}$).

[9] Some have proposed that managers may be risk averse. This changes the nature of the bargaining outcome , see de Graba (2003) for a discussion. Risk averse upstream managers may very well dislike downstream concentration, because it increases the uncertainty.

As the upstream firms produce a homogeneous input, a supplier with lower costs can expect to receive all of the demand. (Or, with decreasing returns to scale, more of the demand). And so, 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.

In many markets the 'innovation' is not covered by patents, e.g. if cost reduction is due to better practices or larger plants which enjoy economies of scale, using well understood technology. Further, such investments are visible to all substantially before they become ready commercially. Thus 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*: that is investing parties internalize the reaction of their rivals to invest also. The upstream firms therefore invest so as to maximize their individual profits in the expectation that profitable investments will be undertaken by all so that the upstream market remains symmetric.

6.1 Motivating Example Continued

We therefore begin by exploring the investment incentives for the upstream firms in our motivating example in Section 3. 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 (2) 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. On the other hand, 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 $\frac{3}{8}(\kappa - c)$ so that suppliers would again seek to reduce the cost of the initial (inframarginal unit) while having no incentives to reduce the costs of the marginal price per unit.

6.2 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 overall shape of the total cost curve. That is, suppliers seek to lower the average costs per unit of all units produced and not just the marginal ones at some high level of output. To generalize this result consider the case in 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 parametrized 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 $(x, x + \varepsilon)$.

We now determine profit maximizing x allowing implications for negotiated prices. We ignore the vanishingly small region $(x, x + \varepsilon)$ as we are envisaging small innovations in which both ε and δ are arbitrarily small. We consider the baseline model of Proposition 2 in which there are D_L large buyers and D_S small buyers.

First note that the innovation has no consequence for prices negotiated with small buyers, since they are determined by expected marginal costs 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 given D_S is large the probability of this is vanishingly small as ε shrinks.

Next we consider the prices paid by large firms. Here payments are determined by expected average 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:

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

so that expected average costs are

$$\frac{\Delta C_{\text{new}_L}}{q_L} = \frac{\Delta C_L}{q_L} - \frac{\delta}{q_L} \Pr\left(x \in [w_S q_S + z_L q_L, w_S q_S + z_L q_L + q_L]\right). \tag{9}$$

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. To see this we examine the probability distribution of the supplier's output absent the deal with a given large buyer. Recall that as D_S is large, the distribution of the number w_S of contracts the supplier obtains with small buyers, is Normal: $w_S \sim N\left(\frac{D_S}{U}, D_S\frac{U-1}{U^2}\right)$. The distribution of the number z_L of contracts with *other* large buyers is Binomial: $z_L \sim Bin\left(D_L - 1, \frac{1}{U}\right)$. Both of these distributions are unimodal and they are independent: the sum of the total volumes secured is therefore typically also unimodal with most weight lying in an output region containing the expected total volume from all deals absent the possible one with the given large buyer, $\frac{D_S q_S}{U} + \frac{(D_L-1)q_L}{U}$. Thus the final subtracted term can be made smallest by having x very small or very large, avoiding the interval $\left[\frac{D_S q_S}{U} + \frac{(D_L-1)q_L}{U}, \frac{D_S q_S}{U} + \frac{(D_L-1)q_L}{U} + q_L\right]$ where the probability in (9) is greatest, and moving as far from this region as possible.

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 large buyers have 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.

The sellers 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

$$\begin{aligned} & \sum_{w_S=0}^{D_S} g_S(w_S) \sum_{w_L=0}^{D_L} g_L(w_L)\, C_{\text{new}}(w_S q_S + w_L q_L) \\ \approx \; & E(\text{total cost with } C(\cdot)) - \delta \Pr(w_S q_S + w_L q_L > x + \varepsilon) \end{aligned}$$

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. That is, the suppliers would like to invest in innovations which lower the average cost per unit of all units which are made rather than just a few, conditional on being active in the market anyway. 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.[10]

[10] Arguably this is the case with extra large plants prevalent in industries such as milk and silicon chips:

Note that the innovations favoured 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 not present because we assume for convenience that downstream demands are zero elastic). This result is in contrast to the result in Inderst and Wey (forthcoming), mentioned at the start of this section, where suppliers favour investments that reduce marginal costs "at the margin".

7 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.

In the previous literature the shape of the cost function is often treated as exogenous. An exception to this is in Inderst and Wey (forthcoming) who show that as downstream concentration increases, the firms would prefer to switch from convex costs to linear costs. In this section we find that as downstream concentration increases, the suppliers would prefer to switch from linear costs to concave costs.

We take as our benchmark a linear total cost function: under such costs there are no buyer power effects and small and large buyers alike receive the same transfer price per unit. Normalizing the total industry volume to 1, the ex ante expected volumes each supplier expects to serve is $\frac{1}{U}$. We consider an alternative technology which has concave costs (increasing returns to scale) but for which the cost of manufacturing volumes $\frac{1}{U}$ is unchanged and costs are 0 if nothing is produced. With such a technology marginal costs are higher if a supplier supplies volumes below $\frac{1}{U}$ and lower if larger volumes are supplied as compared to the linear cost benchmark. Further, as there are increasing returns to scale, a disparity is created between the transfer prices secured

conditional on running the plant at all, the avoidable cost is low for all the units which are produced. Other costs are sunk once the decision is made to run the plant and so do not affect the bargaining stage.

by large versus small buyers: large buyers see their transfer prices fall whilst small buyers do not. This section will show that if a large enough buyer is present then there exists such a concave total cost function which suppliers would prefer to the linear production technology; even though the large buyer will pay less. Formally the result we show is:

Proposition 7 *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 small buyers where D_S is large. Take any linear cost function. If q_L is sufficiently large then there exists a concave cost function which is preferred to this linear cost function for any number of competing suppliers and such that under both cost functions:*

1. *Costs are* 0 *if nothing is produced.*

2. *The cost of producing volumes $\frac{1}{U}$ (the ex ante expected volume) is unchanged under both technologies.*

Note that under conditions 1 and 2 the total cost of producing volumes in the range $\left(0, \frac{1}{U}\right)$ is lower with the linear cost function. Further if U is large then the probability of winning the large buyer is small. 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. We discuss why after the proof.

Proof. Take any linear cost function and renormalise cost units so that the marginal cost is 1 and maximum industry volumes are 1. Now consider the family of total cost functions given by $C(q) = q\left(1+\frac{a}{U}\right) - aq^2$. If $a = 0$ then this technology is one of linear costs. If $a \in \left(0, \frac{1}{2-1/U}\right)$ then the cost function is concave and increasing on $[0,1)$. Further $C\left(\frac{1}{U}\right) = \frac{1}{U}$ which is independent of the parameter a.

Next consider the demand from the D_S small firms, each supplying output $q_S = \left(\frac{1-q_L}{D_S}\right)$. The total volume these buyers demand is a random variable given by $v_S = \left(\frac{1-q_L}{D_S}\right) w_S$ where $w_S \sim Bin\left(D_S, \frac{1}{U}\right) \approx N\left(\frac{D_S}{U}, D_S\frac{U-1}{U^2}\right)$ where 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.

Now using the quadratic cost function and the fact that we have one large buyer, one can show that

$$\begin{aligned}
\frac{\Delta C_L}{q_L} &= \frac{C\left(q_L + \frac{1-q_L}{U}\right) - C\left(\frac{1-q_L}{U}\right)}{q_L} = 1 - \frac{a}{U} - aq_L\left(1 - \frac{2}{U}\right) \\
\frac{\Delta C_S}{q_S} &= \frac{U-1}{U}C'\left(\frac{1-q_L}{U}\right) + \frac{1}{U}C'\left(q_L + \frac{1-q_L}{U}\right) = 1 - \frac{a}{U} \\
E\left(\text{costs}\right) &= \frac{U-1}{U}C\left(\frac{1-q_L}{U}\right) + \frac{1}{U}C\left(q_L + \frac{1-q_L}{U}\right) \\
&= \frac{1}{U} - \frac{aq_L^2}{U}\left(\frac{U-1}{U}\right)
\end{aligned}$$

We next note that each supplier's expected profits are given by

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

and so we have

$$\begin{aligned}
\frac{\partial}{\partial a}\left[E\left(\Pi^{\text{sup}}\right)\right] &= \frac{1}{U}\left(1 - \frac{1}{2^U}\right)\left\{q_L\frac{\partial}{\partial a}\frac{\Delta C_L}{q_L} + \left(1-q_L\right)\frac{\partial}{\partial a}\frac{\Delta C_S}{q_S}\right\} - \frac{\partial}{\partial a}E\left(\text{costs}\right) \\
&= \frac{1}{U^2}\left\{q_L^2\left[1 + \frac{U-2}{2^U}\right] - 1 + \frac{1}{2^U}\right\} \qquad (10)
\end{aligned}$$

and so we note that $\frac{\partial}{\partial a}\left[E\left(\Pi^{\text{sup}}\right)\right]\Big|_{q_L=1} > 0$ for all feasible positive U (i.e. for $U > 1$) implying that if q_L is large then the suppliers' profits are maximized with the concave (increasing returns to scale) technology as opposed to the linear one. ■

There are two main forces behind this result. The first is that expected costs are minimized using the concave production technology. This follows as increasing buyer power (larger q_L) corresponds to a mean preserving spread of likely business. Ex ante each supplier, as they are symmetric, expects to supply $\frac{1}{U}$ units, and the cost for this is independent of the technology by assumption. 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 so the greater the mean preserving spread, then the lower are the costs.

Against this we must consider the effect on bargained transfer prices of a switch to a concave shape.

The effect on transfer prices from the small buyers is ambiguous, and vanishes in the quadratic cost case analyzed. The transfer price for small buyers is a weighted average of the marginal cost at small volumes which is high with concave cost functions, and the marginal cost at large volumes as the large buyer might be won, and this marginal cost is very low with concave cost functions. These two effects cancel each other out—i.e. changing from linear to concave costs makes no 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 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 by a factor of $\left(1 - \frac{1}{2^U}\right)$; 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.

(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 (10) that the profit gain from changing technology vanishes as U tends to infinity, even if $q_L = 1$).

This model assumed downstream demand at each firm was inelastic. The consumer surplus effect of moving to an upstream concave cost function is therefore not addressed in this paper. Clearly though, small buyers would come off worse in any downstream competition once their input costs were less favourable than that secured by larger buyers. This would create a reinforcing effect which would strengthen the result we have described.

8 Conclusions

This paper examines a bargaining interface between upstream sellers competing to supply a homogeneous product to downstream buyers. The previous literature concentrated on the monopoly case where the upstream firm is assumed to be certain of the number of firms—and the total output—it will supply in equilibrium.

However, in many industries the upstream firms are uncertain of the final contracts they will win and hence of the volumes they will finally be supplying. If there is competition upstream, and downstream firms can unilaterally invite upstream firms to enter negotiations at unpredictable points in time, uncertainty about final output is likely to be a fact of life of an upstream supplier.

We introduce a model of the supplier-buyer bargaining interface incorporating supplier uncertainty and supplier competition. We explore the consequences for buyer power, efficiency, and supplier incentives. We find that supplier competition and supplier uncertainty change the results of the previous literature.

If the supplier's technology has increasing returns to scale, we find that the buyer power advantage is now with large, rather than small, downstream firms; this is the reverse of previous 'surplus shape' literature, derived under conditions of certainty. Our result is consistent with the concerns of competition authorities, who have expressed concern about the buyer power of large supermarkets in situations where there are thought to be increasing returns to scale among upstream firms.

Turning to welfare effects of downstream concentration, we find that an increase in downstream concentration reduces both the transfer prices to the downstream buyers and expected industry costs. Thus the consolidation in the supermarket sector, which has been a driver of policy concern in several economies, is found to result in a more efficient upstream sector.

Our paper also explores the incentives for upstream firms to invest in innovations that reduce the marginal costs of some units of output. In contrast to results in the absence of supplier uncertainty, the most desired investments are those that affect the first units of output—i.e. innovation is not focused on marginal costs "at the margin". This result applies whether upstream costs are convex or concave.

Up to this point our results have been derived taking as given the direction of upstream returns to scale, i.e. we derived the results separately for the cases of convex and concave upstream cost functions. In the final section of the paper we examine whether downstream concentration gives sellers an incentive to choose one shape over the other. We find that the presence of large buyers creates an endogenous force towards increasing returns to scale, and so engenders a disparity between the transfer prices of large and small buyers.

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