The Milk Supply Chain Project

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The authors would like to thank the Milk Development Council (MDC) and DEFRA for financial support. In addition we are grateful to all the industry executives who kindly made themselves available for us to interview. The views in this report are solely ours and cannot be attributed to the MDC, Oxford University, DEFRA or any other industry participant.
Executive Summary

This report presents the results of an Oxford University research project into the UK liquid milk supply chain. Financial sponsorship was kindly provided by the Milk Development Council (MDC) and by DEFRA. The research reported here is independent academic research which is not designed to further any group’s particular agenda. We have striven to be as objective as possible.

The project’s aim is to investigate the competitive forces which influence the buyer-seller relationships between supermarkets, processors and farmers; to measure and understand the level of market power that exists at each stage in the supply chain; and to understand the effects of this market power on the main players in the supply chain.

In conducting the research we have interviewed industry executives at all stages in the supply chain for liquid milk: from the supermarket right up the supply chain to farmers’ representatives. We have constructed a theoretical model of the bargaining and price setting which occurs at all levels in the industry. Finally we have conducted an empirical estimation of the model using publicly available financial data and further data provided by the Milk Development Council.

This report is split into four sections:

0. Initially we offer a Layman’s Introduction to all the research undertaken and the findings generated.
1. Chapter 1 presents “Estimating Bargaining Power In The Supply Chain”. The theoretical model of the bargaining in the supply chain above the supermarket is developed and then estimated empirically. The chapter offers a quantiative analysis of where bargaining power lies. The chapter allows counterfactual industry scenarios to be modelled.
2. Chapter 2 presents “Milk Prices in Retail Competition”. A theoretical model of consumers’ dual choice of first supermarket, then volume of milk to buy, is offered. The model is estimated providing demand elasticities for milk and non-milk. Hence mark-ups compatible with non-collusive price competition between supermarkets are generated.
3. Chapter 3 presents “Upstream Competition and Downstream Buyer Power”. The bargaining relationship between supermarkets and their suppliers of own-label products (such as milk) is analysed further. The implications of the bargaining form on the creation of buyer power are discussed. Further the chapter explores how waterbed effects are propagated (the creation of a large buyer alters supply terms for other buyers). Finally the investment incentives of upstream firms in the context of large buyers are studied.

The keynote results of our study are as follows:

- Suppliers negotiate with supermarkets over only a subset of the profits of the supply chain. The highest price suppliers can secure is constrained by the buyers’ ability to source from the next closest market. In the case of milk this would mean sourcing abroad. This limits the supply chain to bargaining over quite a small ‘pie’. For example, in the case of milk, bargaining is over only about 5ppl of surplus. Only a fraction of this is secured by the supply chain.
Much of the supermarkets’ retail margins are therefore out of reach to the suppliers. (Supermarket margins for milk are estimated by the MDC as over 15 ppl.)

- Supermarket bargaining strength comes from the competition between suppliers, not any innate better quality of bargaining. In one to one negotiations over milk we estimate that processors have greater bargaining power than supermarkets. However the competition between processors yields the greater share of gains to the supermarket.

- The data we analyse provides a consistent estimate of the bargaining power of the processors versus the supermarkets as our theoretical model predicts. However the estimate exhibits a blip in 2002, shrinking in 2003, when processors appeared to enjoy a surge in their bargaining power. This is very compatible with the current OFT allegations, which have been accepted by most of the parties, of collusion in the milk industry during these years.

- In the bargaining between milk processors and cooperatives, the processors hold the stronger bargaining position. Our estimates suggest that the processor secures over two thirds of the margin per litre supplied, for every third secured by farmers. This estimate bares the standard caveat that longer data series would allow refinement of the estimate.

- At the retail end of the supply chain, our model of consumer demand quantifies how inelastic the demand for milk is. The product elasticities estimated imply that mark-ups of around a third remain compatible with standard price competition. Such large mark-ups are similar in scale to those actually levied in UK supermarkets for milk.

- Analysis of the model we have developed of the bargaining between supermarkets and their suppliers of own label products illustrates buyer power effects. If the upstream technology is characterised by economies of scale then the largest buyers will be able to secure better input prices than smaller buyers. This is because large buyers are key in ensuring that the benefits of the economies of scale are realised.

- Under standard supplier cost shape assumptions, waterbed effects will exist between supermarkets and their suppliers. That is downstream acquisitions which make some downstream buyers more asymmetric will worsen the terms of trade for other downstream buyers.

- The presence of large buyers will create an incentive for suppliers to develop technologies yielding greater economies of scale. Such technologies further improve input prices for the largest buyers and damage them for the smallest buyers.

We are grateful to all those executives who spared their time to discuss with us our modelling assumptions. We are also grateful to the MDC and DEFRA for their support. Chapters 1 through 3 of this report present independent academic work. These pieces of
work are objective and represent research output for us. They are being presented in academic venues and will be submitted to academic journals for publication.
Layman's Version

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Layman's Introduction

Overview

This introduction gives a layman's overview of the findings of the three research papers which were developed in the Dairy Supply Chain research project, undertaken at Oxford University with financial assistance from the Milk Development Council. The papers themselves follow in Chapters 1-3 respectively.

The project's aim is to investigate the competitive forces which influence the buyer-seller relationships between supermarkets, processors and farmers; to measure and understand the level of market power that exists at each stage in the supply chain; and to understand the effects of this market power on the main players in the supply chain. The research methods include (i) interviews with industry executives at all stages in the supply chain; (ii) the theoretical modelling of price setting at all levels in the industry and (iii) the empirical estimation of the model using data provided by the Milk Development Council.

Chapter 1 Estimating Bargaining Power In The Supply Chain explores the relationship between supermarkets, processors, and suppliers. A theoretical model is presented, based on assumptions that come from the interviews undertaken in the project.

In the model of processor-supermarket bargaining the processors are in competition to supply milk to supermarkets who are themselves in competition. The competition between processors creates uncertainty for any individual processor as to its final output. The negotiated price lies naturally between an upper and a lower bound. The upper bound is the price that the supermarket could obtain by going abroad for its milk; the lower bound is the marginal production cost of the milk.

The exact point between these bounds that the two sides will negotiate depends on the number of processors and the bargaining power of the supermarkets. The more processors there are the more options the supermarkets have and lower the price the processors negotiate. We fit this model of bargaining to data on prices and costs from the milk industry.

A model of negotiation between farmer cooperatives and processors is also developed. Following discussions with the industry we consider this best modelled using a bilateral monopoly in which cooperatives and processors split the gains from trade according to their bargaining power. The farmers are assumed to have an inside option given by the commodity market prices that are available. (This captures the cost and opportunity cost to the farmers of supplying milk for drinking). We use price data to estimate the bargaining power of the processors in the processor-cooperative negotiations. The prices obtained by direct farmers are determined as a mark-up to the prices obtained by the farmer cooperatives.

Overall the model explains: (i) the prices negotiated between processors and supermarkets; and (ii) the prices obtained by coops and direct farmers. The model
provides a method for calculating how profit splits would alter if parties were to merge or if costs were to change. We explore some of these counterfactuals.

Chapter 2 *Milk Prices in Retail Competition* explores retail pricing behaviour by supermarkets. Unlike previous studies of milk demand we are able to estimate elasticites of demand for milk at the level of the retailer rather than at the level of the product. This allows us to analyze the pricing incentives of supermarkets. We develop a model of consumer choice in which consumers choose their supermarket based on the retail prices of a basket of products. Milk is an important component of most shoppers' baskets. Supermarkets are assumed to set their retail prices to maximize profits over marginal costs. Alternative models of supermarket pricing include cooperative and non-cooperative pricing. The retail mark-up that is obtained depends on (i) the price sensitivity of consumers and (ii) whether or not supermarkets cooperate with each other in their setting of milk prices. To estimate the model we use consumer data from the TNS survey as provided by the MDC. We find that the estimated price elasticites of consumers imply non-cooperative mark-ups that are close to the actual mark-ups. Thus, the model suggests that the market power enjoyed by supermarkets (i.e. their ability to increase prices above marginal cost) derives from the price sensitivity of consumers rather than from any attempt by supermarkets to coordinate prices.

Chapter 3 *Upstream Competition and Downstream Buyer Power* This paper extends the theory model in Chapter 3 to explore the circumstances in which (i) a large supermarket buyer has more buyer power than small supermarkets (ii) the presence of a large buyer causes prices negotiated by small buyers to increase (a phenomenon known as a waterbed effect). As in Chapter 1 competition between processors creates uncertainty for any individual processor as to its final output; i.e. the model incorporates the uncertainty experienced by a supplier at the point of negotiation with any given buyer over how successful the supplier it will be with the other buyers. In this setting we find a new source of buyer power when supplier cost functions are nonlinear: the event of negotiation with a large buyer increases the seller’s expected output, which changes the expected average costs of supplying the buyer. This increases the power of a large buyer when the seller’s cost function has increasing returns to scale. We use this framework to analyze the pricing and welfare consequences of changes to market structure upstream and downstream. We also analyze investment consequences of buyer power. We show that upstream suppliers respond to buyer power by selecting technologies with increasing returns to scale, which disadvantage smaller buyers and benefit larger buyers.
Chapter 1 Estimating Bargaining Power In The Supply Chain

Introduction

In this chapter we aim to explain why profits accrue where they do in the milk supply chain. A schematic depiction of the supply chain is presented above in Figure 1. The analysis is both theoretical and econometric.

In the theoretical part of the paper we present a theory model of bargaining between competing suppliers and downstream retailers to capture Stage A. This is followed by a theoretical model for stage B which captures the relationship between farmers and processors. This analysis incorporates both coop and direct formers.

In the empirical part of the paper we introduce the data and estimate the bargaining power at each stage of the supply chain.

Finally, we perform some policy counterfactuals and draw conclusions.

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A model of bargaining between competing suppliers and downstream retailers

This model captures the bargaining in part A of the chain.

Evidence Gathering: Executive interviews

Interviews were conducted at all stages of the supply chain. This included supermarkets, processors, co-operatives, farmers via the National Farmer's Union (NFU), and the Milk Development Council (MDC). The aim of the interviews was to identify key aspects of the bargaining processes at all stages in the chain. In the course of these interviews the following insights emerged regarding the supplier-retailer interface, i.e. stage A in the diagram above.

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

2. Suppliers face uncertainty regarding successful tenders. When bidding for new contracts, suppliers think strategically about likely tender successes with other retailers and quote prices that are competitive and expected to cover overall costs.

3. Supermarkets receive a per unit transfer price.

4. The suppliers’ costs are well known to the supermarkets through their contact across many different input suppliers.

5. The volumes of product demanded are highly predictable.

Model Key Features

We assume there are U upstream suppliers in competition to supply D downstream buyers – who themselves compete. The U suppliers have access to the same technology; variable cost per unit of \( c \).

We first determine natural lower and upper bounds to the negotiated price.

We assume that the lower bound to any agreed price is determined as follows:

The U suppliers will never agree to an overall price per unit of less than marginal cost \( c \) as this would be loss making. Thus marginal cost \( c \) acts as the lower bound for any bargaining agreement.

We assume the upper bound is determined by the supermarkets' ultimate outside option. If a supermarket argues with all U suppliers then (we assume) she can source the milk from abroad. Thus the retailer will not have to go without product. But sourcing from abroad is expensive: a cost of \( \kappa \) per unit. Thus we have an upper bound to the agreed price is as follows:
A buyer will never agree to an overall price per unit of more than $\kappa$ as sourcing abroad would then be preferable. $\kappa$ acts as an upper bound for any bargaining agreement.

We make a number of further assumptions that fit the setting of liquid milk.

First, we assume that there is one winner per contract: each of the $D$ buyers desires one input supplier on any contract. This may be because of the costs of contracting for example. Thus there will be losing suppliers for any given contract. In the liquid milk market some supermarkets have more than one supplier but our assumption is justified by the observation that these supermarkets subdivide milk contracts geographically, e.g. a southern England & Wales contract and a Scotland & N. England contract, but for each of these subdivided contracts one supplier is sought and contracted with.

Second, we assume that on the contract that is up for tender the buyer proceeds as follows. The buyer initially selects a first supplier to bargain with from the $U$ suppliers that exist in the market. If negotiations with this supplier should break down then the buyer can approach the next supplier on her list. However, as there are now fewer competing suppliers the buyer is a little disadvantaged at this point. This bargaining form thus captures the following implicit buyer threat:

“You are only one of $U$ suppliers. If we fail to strike a deal then I will still have $U-1$ suppliers I can source product from. Thus to get the business you must make it worth my while.”

The buyer must therefore be able to get at least the profit she secures if only $U-1$ suppliers are left. But note that if there are only $U-1$ suppliers left the retailer's threat is weakened, because there are now even fewer suppliers left to threaten to move to. This means that there is an advantage (to both the $U^{th}$ supplier and the retailer) of striking a deal (rather than moving to the next supplier). The monetary size of this advantage is the incremental pie. Thus the bargaining problem between $U^{th}$ supplier and retailer is how to split the incremental pie. The exact way this is split is determined by the bargaining power of the processor. We use the parameter $\lambda$ to refer to the processor's bargaining power; this is defined such that the incremental pie is split $\lambda$ parts to the retailer and $1-\lambda$ parts to the supplier. $\lambda$ is a bargaining power parameter between 0 and 1. A value of $\lambda$ below $\frac{1}{2}$ means that suppliers can more than hold their own in bilateral discussions.

The extent to which the supermarkets can negotiate price down towards the lower bound—the processors’ marginal cost $c$—is determined by two factors:

(i) The number of processors $U$: the more processors there are the more options the supermarket has to turn to before the ultimate outside option of sourcing abroad.

(ii) The supermarket bargaining power parameter $\lambda$: the greater the bargaining power of supermarkets the greater their ability to bargain in any one-to-one negotiation with an individual processor.

Capturing Supplier Uncertainty As To Contracts Won

Our interviews indicated that retailers can and do switch milk supplier at relatively short notice. This is possible as the contracts typical in this industry are usually rolling with

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notice periods of only three months. Thus at any point supermarkets may be about to open up negotiations with suppliers as to the price for input going forward. To capture this aspect of the market we assume that all buyers go to the suppliers simultaneously, and a supplier in any given negotiation does not know how she will she will do in negotiations with other potential retailers. This is a way of capturing the uncertainty the supplier faces regarding how many contracts she will win (a feature of the market that came through in our interviews with executives).

**Bargaining Over A Two-Part Tariff**
The model assumes that the parties bargain over a two part tariff: a fixed fee and a per unit price. In interviews the parties reported that negotiations were actually over *prices per unit* but this is easily reconciled with our two-part tariff assumption because volumes are highly predictable so that a per unit price translates into a very predictable total payment from a two-part tariff. (The parties also in practice agree volume discounts and spot prices if unusual volumes were subsequently required so a retailer forced to respond to a significant unexpected demand change optimises over an input price per unit that is not the same as the agreed per unit price.)

**Efficient Bargaining Result**
With the two part tariff assumption we have the following result: parties agree to a two part tariff in which the marginal price in the event of unexpected demand realizations is at a marginal cost of $c$. This is efficient because it means that the price setter (the retailer) faces the correct incentives (marginal cost, $c$) from the whole chain's point of view.

**An Intuition for Efficient Bargaining Result**
One aspect of the supplier’s and retailer’s interests are aligned: to grow the incremental pie as much as possible. The two part tariff allows this by letting the retailer optimise against marginal costs when setting retail prices (and hence volumes). The profits made are then maximized and can be divided between the supplier and retailer using the fixed fee. The implication that final retail price is then optimised against the *actual* variable costs of production is true no matter how many suppliers compete upstream so that upstream mergers would not alter the downstream retail prices in this model.

Efficient bargaining appears to be a plausible feature of the model. In negotiations parties profess to be keen to avoid losses that occur if volumes differ from the efficient level given marginal cost (i.e. they are keen to avoid double marginalization losses).

**Deducing The Total Retailer Payment**
The total payment per unit by the retailer will depend on four industry parameters: $\kappa$ (cost of sourcing abroad), $c$ (variable cost of domestic production), $\lambda$ (supermarket bargaining power) and $U$ (number of upstream competitors). This is depicted in Figure 2. $\kappa$ and $c$ give the upper and lower bound to the agreed per unit payment. The position of the agreed price between these limits is determined by the supermarkets’ bargaining power $\lambda$ and the number of competing processors $U$. An increase in either $\lambda$ or $U$ has a downward effect on the price negotiated with the processor. All of these parameters are observable with the exception of $\lambda$ (which we will estimate).
Figure 2: The Four Parameters Determining the Supermarket-Processor Split

$k$ and $c$ give the upper and lower bound to the agreed per unit payment. The position between these limits is determined by the supermarket's bargaining power $\lambda$ and the number of competing processors. An increase in either $\lambda$ or $U$ has a downward effect on the price negotiated with the processor.
The Bargained Split

We derive an expression for the actual per unit price paid by the supermarkets to the processors. This is done by working backwards through the U potential suppliers, i.e. we first compute the price that would be agreed with the last remaining supplier using $\kappa$ as the outside option, this price then is in turn the outside option used when negotiating with the U-1'th supplier, and so on. As shown formally in the paper the agreed per unit price which results is given as follows:

\[
\text{Overall per unit payment by retailers} = c + (1 - \lambda)^U(\kappa - c)
\]

This equation gives the price (i.e. payment per unit) paid by supermarkets to suppliers. This price is decreasing in both $\lambda$ and U--i.e. decreasing in the number of processors and (for any given number of processors U) decreasing in supermarkets bargaining power, $\lambda$.

The term $(1 - \lambda)^U$ is of key importance. It may take values in the range zero to one. It represents the bargaining position of the processor. Thus the price paid by the retailer to the processor is pushed to its lower bound $c$ as $(1 - \lambda)^U$ goes to zero and is pushed in the other direction to its upper bound $\kappa$ as $(1 - \lambda)^U$ increases to one.

$(1 - \lambda)^U$ is the share of the available surplus $(\kappa-c)$ that the processor captures in the negotiations.

The effect of a merger of processors can be computed by reducing U by one integer, e.g. from 4 to 3. We will discuss some counterfactuals of this type later in the chapter.

Profits remaining to be split between processors and farmers

The value of the profit accruing to the parts of the supply chain upwards from the retailer (i.e. to be split between processors and farmers) is thus given by the following:

\[
\text{Profit to be split between processors and farmers per unit supplied} = (1 - \lambda)^U(\kappa - c)
\]

The irrelevance of retailers' margins above $\kappa$.

Our model highlights the important insight that there is an upper bound on the price the milk supply chain (i.e. the farmers and processors) can extract in negotiations with supermarkets. This upper bound is determined by the cost $\kappa$ to the supermarkets of going to the next closest market to secure the desired input. As depicted in Figure 3, the bargained over surplus per litre is therefore just $(\kappa - c)$. It is of this that we have calculated processors are in a position to receive a share of $(1 - \lambda)^U$. Even though the supermarkets may be able to raise retail prices above $\kappa$ and enjoy some additional surplus (depending on competitive retail market conditions) this additional surplus is beyond the reach of the farmers and processors via negotiations, as it is still available to the retailers if they dropped local farmers and sourced from abroad.
Figure 3: What the Processors Can and Can't Bargain Over
Figure 4 sets out the key relationships in the model of bargaining between processors, cooperatives (coops) and farmers. We begin with a discussion of the processor-direct farmer contracts.

**Processor to Direct Farmer Contract**

Suppose that a processor has agreed to buy q litres from its cooperative at a price of $P+$(farmer marginal costs). In other words suppose the price that the coop obtains in pence per litre is given by $P/q + $farmer marginal cost$.

We assume that the negotiations between processors and direct farmers take as a reference point this price agreed between coops and processors, with a risk premium as follows:

\[
\text{Direct Farmer ppl payments} = \text{[costs]} + \frac{P}{q} + \left[ \text{risk premium} \right]
\]

In the interviews we were told that the risk premium is for a range of factors including: (i) the processor’s sales are more volatile than coop’s; (ii) the coop can make it
unattractive for a farmer to return; and (iii) coops serve farmers while processors serve shareholders.

**Cooperative To Processor Bargaining**

We model this as a standard bilateral bargaining situation. The reason for this is that the relationships between coops and processors are more stable through time than those between processors and supermarkets, perhaps due to geographic proximity between coop and processor facilities. Currently First Milk is the only cooperative providing substantial milk volumes to the main processors (Wiseman and Dairy Crest in this case). Arla, the other leading UK processor of milk, is almost all direct farmer supplied, but does a little load balancing with Milk Link.

The processor and cooperative bargain over the payment $P$ *above costs* for $q$ litres supplied. The deal is therefore worth $P$ to coop. But because $P/q$ is used as a benchmark for the payments to direct farmers, to the processor the deal is worth:

$$\text{Profit to be split between processors and farmers} - P - \frac{P}{q} \times \text{Volume direct farmers supply}$$

That is we are assuming that the coop accepts that the payment $P$ provides a reference point for direct farmers. The risk premium payable to direct farmers is not however part of the bargaining between cooperative and processor. The risk premium is therefore a cost the processor voluntarily elects to bear in return for having direct farmers whose milk supply is 100% secured.

Note that the coop farmers ultimately get less than $P/q$ for milk. This is because the cooperative also sells to commodity markets, and profits on these markets are lower than profits on liquid milk. This reduces the average profit to coop farmers from a unit of milk.

The final split between processors and the coop is determined by the processor’s bargaining power in this bilateral relationship. We denote this $\alpha$. This parameter lies between 0 (coop gets all the rents) and 1 (processor gets all the rents). The actual payment is found using the Nash Bargaining Solution which is a standard approach.

The payment to direct farmers follows:

$$\text{Total pl payment to direct farmers} = \text{Production costs} + (1 - \alpha) \cdot \text{Processor plus cooperative profit per litre supplied} + \text{risk premium}$$

As the equation shows, as the bargaining power of the processors decreases towards 0 so the payments to direct farmers increases to capture all of the surplus from the supply chain captured by processors in their negotiations with supermarkets.
Data on Costs and Payments in UK Liquid Milk

We now take the model we have developed to the data to estimate bargaining power in the supply chain. This allows us to understand and explain where profits accrue as well as to perform counterfactual analysis. To do this we need to construct estimates of the variable cost of GB milk production (the variable $c$); the minimum cost to supermarkets of sourcing milk abroad (variable $\kappa$); and the risk premium paid to direct farmers.

Before constructing these estimates we detail five data series that are available and used in our analysis.

Five Data Series

1. Commodity Price of Milk: reasons to choose MCVE

Milk commodity markets are primarily those for cheese, butter, or Skimmed Milk Powder (SMP). The monthly margin available from these uses at the coop gate is calculated by the MDC. DEFRA notes that in 2005/6, 49% of milk made in Great Britain is used for things other than liquid milk. Of this 28% (the majority) went to cheese, 2% for butter, and 12% for powders and condensed milk. We conclude that the cheese margin will be the best measure of milk’s opportunity cost. This conclusion is supported by the observation that in recent years the wholesale price of milk (as paid by the supermarkets) tracks MCVE better than any other measure, as shown in Figure 5.

Figure 5: MCVE tracks the wholesale price of milk better than other measures
2. Supermarket Payments for Milk

Annual financial accounts include volume data and can be used to obtain a figure for the price per litre paid by supermarkets for milk. The MDC have computed this. Details of the computations are given in the full paper.

3. Farmgate Price For Milk outside GB

Should a retailer fail to source milk in GB it can in principle go outside GB. The nearest neighbour markets are Ireland, Northern Ireland, France, Belgium, and the Netherlands. The European Union's DG Agri provide farmgate milk prices in Euros per 100kgs for the four Eurozone countries, while the Department of Agriculture and Rural Development (DARD) produces figures for Northern Ireland. The MDC has supplied exchange rate figures which we use to convert to sterling. To compute a single figure for the farmgate price of milk outside GB we take an average monthly figure. Summary statistics for this are given in Table 1

<table>
<thead>
<tr>
<th>Observations</th>
<th>Mean (ppl)</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>European farm gate average price (ppl)</td>
<td>96</td>
<td>18.35</td>
<td>1.59</td>
<td>15.53</td>
</tr>
</tbody>
</table>

Table 1: European Farmgate Average Price

4. Direct Farmer Payments

We obtain information on monthly direct payments to farmers using figures from mandatory filings with DEFRA. This data is made available monthly from April 2002 through to March 2005. We take a weighted average of payments to direct farmers by Wiseman, Arla, Dairy Crest (weights are by volumes).

<table>
<thead>
<tr>
<th>Observations</th>
<th>Mean (ppl)</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct farmer payments in Great Britain (ppl)</td>
<td>36</td>
<td>19.02</td>
<td>1.01</td>
<td>16.95</td>
</tr>
</tbody>
</table>

Table 2: Direct Farmer Payments in Great Britain
5. Inflation

Shortly we will establish base-year estimates for transport, processing, and bottling costs. To allow for the effects of inflation on these costs over time we use the Office of National Statistics inflation index for plastics and rubber. This is the most appropriate index given the importance of plastic and oil in the bottling and distribution process. This index is shown in Figure 6.

Construction of Key Variables

Using the data series presented above the papers details how one can construct estimates of the three main variables required. These were the variable cost of GB milk production (the variable c); the minimum cost to supermarkets of sourcing milk abroad (variable κ); and the risk premium paid to direct farmers.

Complete Variable Costs of Production, c

To supply into the liquid milk supply chain, a farmer must give incur the costs of production and forgo the opportunity to supply the commodity markets. We estimate this opportunity cost (which includes the cost of production) as MCVE. To obtain the complete variable cost of production to the supermarket gate we add MCVE to the costs of production from farmgate to supermarket. We obtained costs of production from farmgate to supermarket using estimates from published sources. This includes costs of processing, bottling and distribution.

These cost estimates are detailed in Table 3 along with the published source for the estimate. Nothing in our empirical work replies upon the breakdown of the overall
figure into individual components. The only figure that is of relevance is the *overall* figure. We presented the figures to experts on the milk processing industry. They told us that the overall figure of 16.7 ppl at 2007 prices was a reasonable estimate.

<table>
<thead>
<tr>
<th>Item</th>
<th>Variable Cost</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottling</td>
<td>4.5ppl</td>
<td>West LB Panmure</td>
</tr>
<tr>
<td>Distribution from processor to supermarkets</td>
<td>4.5ppl</td>
<td>West LB give average of 4.5 ppl for industry: much higher for smaller stores but focus here on supermarkets.</td>
</tr>
<tr>
<td>Distribution from farm to cooperative</td>
<td>1.35ppl</td>
<td>MDC use 1.5ppl for average cost from farm to cooperative in 2007. Deflate to a 2000 figure</td>
</tr>
<tr>
<td>Distribution from cooperative to processor</td>
<td>1.35ppl</td>
<td>As same volume of milk must be sent on by cooperative as is received we have assumed the same cost as above</td>
</tr>
<tr>
<td>Wastage/Inefficiency</td>
<td>2.5% loss assumed</td>
<td>Guesstimate.</td>
</tr>
<tr>
<td><strong>Total production cost in 2000 prices</strong></td>
<td><strong>15.1 ppl</strong></td>
<td><strong>1.025 * (3+4.5 + 4.5 + 1.35 + 1.35)</strong></td>
</tr>
<tr>
<td>Inflated to 2007</td>
<td>10.6% price rise</td>
<td>Plastics and rubber index (correlated with fuel and bottling costs)</td>
</tr>
<tr>
<td><strong>Total Production Costs: farmgate to supermarket</strong></td>
<td><strong>16.7 ppl</strong> (2007 prices)</td>
<td><strong>1.106 * 15.1</strong></td>
</tr>
</tbody>
</table>

**Table 3: Complete Variable Costs of Production**

The overall variable costs of liquid milk production are therefore given by the equation below. They equate to the sum of the production cost from farmgate to supermarket and the farmers’ opportunity cost of supplying milk. We compute this figure for each month in the period of the study (using inflation figures to compute the production costs).

\[
\text{Marginal cost of liquid milk production} = \text{production cost from farmgate} + \text{farmer's cost including opportunity cost} \\
= \left[ \frac{15.1 \text{ ppl in } 2000}{1.025} \right] + [\text{MCVE} - 1.35 \text{ ppl in } 2000] \\
= \text{MCVE} + 13.7 \text{ ppl in } 2000
\]

It is perhaps worthy of note that the costs of the farmers are taken into account by this procedure: they are subsumed into MCVE. In other words we have identified MCVE as

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an estimate for the combined sum of the farmers’ unavoidable costs of production and their opportunity cost of selling milk into other uses.

**Minimum cost to supermarket of sourcing milk abroad $\kappa$**

The minimum cost to the supermarket of sourcing milk abroad, $\kappa$, is computed as follows. We assume that production costs are as computed above in Table 3. To these we add the EU farmgate price for milk and the estimates of the transportation costs as given in DEFRA’s document *The Potential for GB-European Trade in Liquid Milk* (September 2007). The details of this calculation are shown in Table 4.

### Minimum Cost to Supermarket of Sourcing Milk Overseas

<table>
<thead>
<tr>
<th>Item</th>
<th>Variable Cost</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw milk costs</td>
<td>EU farm gate price</td>
<td>Average of Ireland, Northern Ireland, France, Belgium, Netherlands as nearest countries and so cheapest sources of imported milk.</td>
</tr>
<tr>
<td>Production Costs</td>
<td>16.7ppl</td>
<td>Assumed same technology as in GB (2007 prices).</td>
</tr>
<tr>
<td>Transportation Across Sea</td>
<td>5.2ppl</td>
<td>DEFRA(^1) give transport costs if trucks bring raw milk over the sea and return empty. These costs are Belgium at 5.9ppl, Netherlands 6.0ppl, Ireland at 5.2ppl, Northern Ireland 5.7ppl and France 3.0ppl. The mean of these prices is 5.2ppl.</td>
</tr>
<tr>
<td>Minimum cost to supermarket of importing Milk from outside GB</td>
<td>EU farm gate price + 21.9 ppl</td>
<td>EU farmgate + 16.7 + 5.2 ppl 2007 prices</td>
</tr>
</tbody>
</table>

Table 4: Cost to Supermarket of Sourcing Milk Overseas

**Direct Farmer Risk Premium**

The figure used for the direct farmer risk premium is derived as follows. During executive interviews we were given the following figures for the risk premium: Dairy Crest pays 1ppl more than First Milk, Arla pays 0.3ppl more than DC, and Wiseman pays 0.2ppl more than Arla. Thus we assume the average risk premium is 1.3 ppl and constant over time.

**Number of Processors**

The number of processors $U$ is assumed to be 3 from 2004/5 onwards and 4 before this. The change is due to the merger of Arla with Express.

---

\(^1\) DEFRA (September 2007) *The Potential for GB-European Trade in Liquid Milk*, Table 4.3
Explaining The Profit Split Between Supermarkets and the rest of the Supply Chain

We do not seek to impose any seasonality and so take the ppl price paid to the processors over the year as the appropriate one in each month. We can therefore calculate a value for the supermarkets’ bilateral bargaining power (\( \lambda \)) every month from April 1999. We plot these values in Figure 7. Over any year these \( \lambda \) estimates will show some seasonality inherited from MCVE and these are shown in the plots. Therefore to average these out we also present in the figure the annualized \( \lambda \)s, i.e. the average value of \( \lambda \) for each calendar year in the data. Outside of 2002 and 2003 the bargaining power of the supermarkets \( \lambda \) is consistently estimated at between 0.3 and 0.4.

Note that \( \lambda \) is lower in 2002 and 2003. The processors appear to become stronger bargainers in 2002 and (to a lesser extent) 2003. Collusive actions which acted to increase the money in the supply chain are one (but only one) explanation for such a result. Since the calculations were conducted, the UK Office of Fair Trading has issued an accusation of price collusion on liquid milk by supermarkets and processors for the years 2002 and 2003. The majority of the accused parties have in turn admitted to the alleged anticompetitive practices. The spike in processor bargaining power is very consistent with this development.

**Annual Estimation of Supermarket Bargaining Power**

![Figure 7: Plot of Monthly Lambda Parameters and Annualized Averages](image)

Descriptive statistics for \( \lambda \) over the 74 months in the entire period of the bargaining power data set are presented in Table 5. The mean value of \( \lambda \) over this period is 0.294:
<table>
<thead>
<tr>
<th>Observations</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>95% Conf Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \lambda )</td>
<td>74</td>
<td>0.294</td>
<td>0.015</td>
</tr>
</tbody>
</table>

**Table 5: Descriptive Statistics for the \( \lambda \) parameter**

**Interpretation of the Supermarkets' Bargaining Power Parameter \( \lambda \)**

We have determined a supermarket bargaining power parameter (\( \lambda \)) of 0.294. If the unusual years 2002/3 are omitted then \( \lambda \) rises to take values in the range 0.3-0.4. How do we interpret this? A parameter of \( \frac{1}{2} \) would represent equality of bargaining power in one-on-one negotiations between supermarkets and processors. The estimated parameter is slightly less than this which suggests that in one-on-one situations processors can more than hold their own against supermarkets.

Recall that \( \lambda \) is only one of two factors determining how close negotiated prices are pushed to marginal cost \( c \), the other factor being the number of processors \( U \). The fact that \( \lambda = 0.294 \) suggests that the extent to which supermarkets can push prices down towards marginal costs comes from upstream competition (\( U \)) rather than superior bargaining power in one-to-one negotiations with processors. In layman's terms, the supermarket may be said to have advantageous outside options rather than inherently superior negotiating skills.

Recall that:

\[
(1 - \lambda)^U \text{ is the share of the surplus (} \kappa - c \text{) that the processor is able to capture in the negotiations.}
\]

**Interpretation:** As the number of processors \( U=3 \) and we have estimated that \( \lambda=0.294 \) the processor is able to capture a proportion \( (1 - 0.294)^3 = 36\% \) of the surplus \( (\kappa - c) \) that is being bargained over.

**The irrelevance of retailers' margins above \( \kappa \).** As we noted earlier there is an upper bound on the price the milk supply chain (i.e. the farmers and processors) can extract in negotiations with supermarkets, which is determined by the cost \( \kappa \) to the supermarkets of going to the next closest market to secure the desired input. The bargained over surplus \( (\kappa - c) \) is approximately 5ppl; predominantly driven by the cost of transport of milk between Northern Europe and the UK. The above calculations show that the processors are in a position to receive 36\% of this, with the remaining going to supermarkets. Thus although supermarkets do in practice raise retail prices above \( \kappa \) and enjoy additional profit, this additional profit is not available to the farmers and processors through negotiations. This is because this additional profit is still available to the retailers if they dropped local farmers sourced from abroad.
We now use the estimate \( \lambda = 0.29 \) (which includes the contentious data for 2002 and 2003) to calculate the wholesale prices that the model predicts that supermarkets and processors negotiate. We plot the financial year means for these predictions in Figure 8. Also on the table we plot the actual price data as used to estimate the model. The figure is intended to give a visual representation of the fit of the model, i.e. a visual representation of how well the model predicts the wholesale price.

The model fits well in most financial years. There are two unusual years. In 2000/1 the actual wholesale price is significantly below the predicted value. In 2002/3 the actual wholesale price is significantly above the predicted value. One possible explanation for this is that during 2000 Wiseman were investigated by the Competition Commission in the UK for aggressive price reductions which were alleged predatory towards the expansion of a rival (Express) in the Scotland. The Commission did find Wiseman guilty, though with a split panel. Such a conclusion is compatible with Wiseman agreeing to supply at lower prices than their bargaining position would entail. The situation in 2002/3 has already been discussed.
Explaining The Profit Split Between Farmers and Processors

Turning to the split between farmers and processors we estimate the processors bargaining power $\alpha$ according to the following equation implied by our theoretical bargaining model:

$$ [\text{Total PPL payment to direct farmers from DEFRA survey} ] $$  
$$ = [MCVE] - [1.5ppl transport cost (in 2007)] $$  
$$ + (1-\alpha) \left\{ [\frac{ppl paid to processors}{MCVE + 13.7ppl (in 2000)}] + [1.3ppl risk premium] \right\} $$

The inflation series is used to inflate the costs appropriately. A value of 1 for the parameter $\alpha$ would indicate a maximal possible level of bargaining power for processors while a value of 0 would represent the minimal possible level of bargaining power.

**Model Predictions**

We run a regression model based exactly on the above theoretical model.

Our data delivers:  
$$ \alpha = 0.73 \quad 95\% \text{ conf interval } [0.57,0.89] $$

Thus processors have upper hand against cooperatives

**Regression results for 1-\(\alpha\)**

The regression output is reported in the table below.

<table>
<thead>
<tr>
<th>Direct</th>
<th>(1-(\alpha)) estimate</th>
<th>Std error</th>
<th>T</th>
<th>P</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.271</td>
<td>0.077</td>
<td>3.50</td>
<td>0.001</td>
<td>[0.114,0.428]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R$^2$=0.259</td>
<td>Obs=36</td>
</tr>
</tbody>
</table>

The fit of the model is shown visually in Figure 9, where the model tracks the data well, with the exception of some seasonal variation which our model does not aim to track.
Predicting Direct Farmer Payments

Interpretation of alpha

The cooperatives bargain on behalf of their farmers. The prices they secure from processors form the benchmark against which direct farmer contracts are set. Thus cooperatives represent all farmers either directly or by proxy. Thus in our calculation of the bargaining power of the processors versus the cooperatives, we have found that farmers in general are able to secure 27% of the total processor-cooperative surplus (in excess of costs). In other words 27% of the surplus secured by the chain from the supermarkets will flow to farmers, the remainder to the processor.

The interviews we conducted suggest that the processor bargaining strength derives in part from its ability to approach individual coop farmers. This (a) allows the processor to secure some supply in the event of impasse with the cooperative. (b) signing farmers to direct supply weakens the cooperative in further negotiations. As evidence that signing up large proportion of the required volume by direct supply is the outside option for processors, one might point to Arla which is currently almost 100% direct supply.
A Counterfactual Analysis

Our research into the bargaining power in the UK Milk Supply Chain allows us to explore a number of counterfactual analyses as to the implications of changes to costs and changes to market structure (e.g. via merger). Here we provide a summary of some potentially interesting counterfactuals and the movements of profits they imply.

As our research highlights, supermarkets and processors bargain over only a subset of the available profits: the upper bound on input prices is provided by the cost $\kappa$ of sourcing abroad, while the lower bound is the variable cost of production $c$. As a benchmark figure this bargained-over surplus ($\kappa - c$) is approximately 5ppl which is predominantly driven by the cost of transport between Northern Europe and Great Britain.

In the structural model the supermarket payments per unit are given by the following relationship,

\[
\text{Overall payment by supermarkets per unit supplied} = c + (1 - \lambda)^U (\kappa - c)
\]

This gives a per unit profit obtained by processors as follows:

\[
\text{Profit to be split between processors and farmers per unit supplied} = (1 - \lambda)^U (\kappa - c)
\]

Our empirical research estimates $\lambda = 0.29$. As the number of processors $U$ is 3, this implies that the proportion of the bargained-over surplus extracted by processors in the negotiations is given by $(1 - \lambda)^3 = 0.36$.

This profit, obtained by processors, is split with the farmers. Our model of processor-cooperative bargaining suggests that the cooperatives' bargaining power is $\alpha = 0.27$, i.e. that the per unit margin bargained by the processors is split 27% to the farmer (direct or coop) and 73% to the processor. So at current market structure farmers obtain 27% of 36% (=10%) of the bargained over surplus $(\kappa - c)$ per litre supplied. The direct farmers in addition receive the direct-farmer risk premium which comes from the processors’ share of the pie.

Note on retail prices: recall the efficient bargaining solution discussed earlier: supermarkets always set their prices in reference to the marginal cost $c$ rather than the negotiated wholesale price. Therefore in the below counterfactuals retail prices only change if $c$ changes.

Using the above equations and the estimated parameters we can analyze the effect of a number of interesting counterfactual scenarios on processors and farmers.

Effect of Cost Changes on Negotiations between Processors and Supermarkets

Scenario 1 a 1ppl increase in marginal production costs $c$ (of farmers or processors)
Implications: If the marginal production costs \( c \) rose by 1ppl, e.g. because commodity prices rise, then this increases the lower bound \( c \) to the negotiated price but shrinks the size of the surplus \( (\kappa - c) \) to be bargained over. The overall effect on the negotiated price is positive. The above equation predicts that the price to suppliers would rise by \( 1 - (1 - \lambda)^3 = 1 - 0.36 = 0.64 \)ppl. Thus there is support for the claim that cost increases can be passed through to supermarkets.

Note on retail prices: Given the efficient bargaining result retailers set prices with respect to actual marginal costs \( c \). Thus we expect retail prices to increase in this scenario.

Scenario 2 a 1ppl increase in the cost \( \kappa \) of sourcing milk abroad.

Implications: If the cost \( \kappa \) of going abroad for milk rose by 1ppl then the bargained-over surplus \( \kappa - c \) increases by 1ppl. The suppliers can capture a proportion \( (1 - \lambda)^3 \) of this extra surplus. Thus the price they receive increases by \( (1 - \lambda)^3 = 0.36 \)ppl. As the processors are bargaining over the benefit they offer to supermarkets above going abroad for milk. So the processors can extract more surplus if the cost of going abroad increases.

Note on retail prices: Given the efficient bargaining result retailers set prices with respect to actual marginal costs \( c \). Thus we do not expect retail prices to increase in this scenario.

Effect of Changes to Market Structure on Prices and Profits

Scenario 3: A processor withdraws, or is acquired by the other two processors, so that we move from 3 to 2 competing processors, with no effect on marginal cost \( c \).

Implications: Prior to any merger, with 3 competing processors we calculated that the supply chain was able to secure 36% of the bargained-over surplus \( (\kappa - c) \); roughly 1.8ppl (=0.36x5ppl). The 36% figure is deduced by the equation

\[
(1 - \lambda)^U = 0.36 \text{ when } \lambda = 0.29 \text{ and } U = 3
\]

We have calculated the supermarket bargaining power parameter \( \lambda \) at 0.29. The fact that this is less than \( \frac{1}{2} \) implies that we have found that in one to one negotiations processors can more than hold their own against supermarkets. Supermarkets get the deal they do because of upstream competition between the \( U \) suppliers. After the postulated processor merger, the number of competing processors \( U \) falls by 1. Now there is less competition between processors so they get a greater share of the bargained-over surplus \( (\kappa - c) \). Our analysis would imply that the supply chain would then be able to secure 50% of the available surplus, as derived from the following equation:

\[
(1 - \lambda)^U = 0.5 \text{ when } \lambda = 0.29 \text{ and } U = 2
\]

Thus the processor can extract half the bargained over surplus, i.e. approximately 2.5 ppl. This is up from the 1.8ppl prior to the merger.
We have estimated that the cooperatives' bargaining power is $\alpha = 0.27$. Therefore our model predicts the enlarged surplus of $2.5 - 1.8 = 0.7ppl$ negotiated by the processors will be split 73% to the processor and 27% to the farmers (cooperative and direct). Thus processors would expect to see their margins rise by a further 0.5ppl, while farmers would expect to see an extra 0.2ppl. The farmers who work for a cooperative would of course see a smaller rise as a consequence of profits being shared with farmers whose milk is used for uses other than liquid milk.

Note on retail prices: In this scenario we assume the change in the number of processors does not impact on $c$. Therefore final retail prices are unchanged due to the efficient bargaining result (i.e. retailers set prices with respect to actual marginal costs $c$).

Scenario 4: A new processor enters, or an existing processor is split into two, changing the number of processors from 3 to 4 (e.g. undoing the Arla/Express merger), with no effect on marginal cost $c$.

Implications: This scenario involves the same calculations as in scenario 3 except that we now increase $U$ to 4 rather than reduce it to 2. Again, the processors are bargaining over the benefit $(\kappa - c)$ that they offer to supermarkets above going abroad for milk.

Our model implies the processors can secure $(1 - 0.29)^3 = 36\%$ of this surplus at the current market structure. Moving to a structure with four processors (e.g. undoing the Arla/Express merger) would decrease this to a figure of $(1 - 0.29)^4 = 25\%$.

Thus moving to four processors would have a significant negative effect on the surplus negotiated by processors. As 27% of this surplus is shared with farmers, farmers are negatively impacted too (because $\alpha = 0.27$).

Note on retail prices: As with the previous scenario we assume the change in the number of processors does not impact on $c$. Therefore final retail prices are unchanged due to the efficient bargaining result (i.e. the result that retailers set prices with respect to actual marginal costs $c$).

Scenario 5: Suppose retailers required processors, as a condition of business, to ensure farmers are rewarded on a cost-plus contract. So that all farmers must receive a certain margin for all of the units they supply.

Implications: Such contracts strengthen the hand of the farmers when negotiating with the processors they supply. They reduce the allowable set of agreements which can be struck in the farmers’ favour. If the margin guaranteed is below that which would be received anyway through bargaining then they would have no effect. However, suppose that the cost plus contracts were more generous. In this case the cooperative and farmers’ share secured from processors will grow to ensure that farmers get the margin specified. However the processor, when negotiating with the supermarket, now faces a larger per unit cost of supply mandated by the buying supermarket. Hence (a) the processor will secure higher prices as the increase in the variable costs of production are passed through the chain via efficient bargaining, and (b) retail prices will also rise as the supermarkets respond to the new higher production costs of every unit of milk.
Scenario 6  Suppose that direct farmer contracts became uncommon or are phased out. How would the processors’ bargaining power change?

Implications: The relationship between cooperatives and the processors they supply is relatively stable through time as compared to other levels of the supply chain. Nevertheless we calculate that processors have the upper hand in bargaining with cooperatives and are able to secure roughly 73% of supply chain profits as compared to farmers securing 27%. Industry interviews suggest to us that the reason for this econometric result lies in the fact that, in the event of disagreement between coop and processor, the processor can approach coop farmers directly and sign them up. This allows milk to be sourced regardless of the coop and, importantly, weakens the coop in further bargaining rounds. As evidence that this can and does happen one might point to Arla which has now become almost totally supplied by farmers with direct contracts. If such direct contracts were not possible then one would expect the bargaining power of cooperatives to grow versus the processors. Thus farmers would receive more of the supply chain profits. This would not be expected to feed into retail prices however. This is because the actual variable costs of production in the supply chain will not have been affected. Unlike scenario 5 there is no external restraint on the processor raising the per unit variable cost of milk production. Thus is it in no party’s interest to introduce double marginalization losses into the supply chain. All that has happened is that the balance of power in sharing the surplus between processor and cooperative has been altered. That is the total profit to the supply chain would not be altered, whereas the profit splits between farmers and processors would be, in favour of farmers.
Conclusions

This paper develops a model of bargaining in the supply chain when upstream suppliers compete. We apply this model to the UK milk industry using both publicly available data and further data provided by the MDC and DEFRA. Our main results are:

- Suppliers negotiate with supermarkets over only a subset of the profits of the supply chain. The highest price suppliers can secure is constrained by the buyers’ ability to source from the next closest market. In the case of milk this would mean sourcing abroad. This limits the supply chain to bargaining over quite a small ‘pie’. For example, in the case of milk, bargaining is over only about 5ppl of surplus. Only a fraction of this is secured by the supply chain. Much of the supermarkets’ retail margins are therefore out of reach to the suppliers. (Supermarket margins for milk are estimated by the MDC as over 15 ppl.)

- Supermarket bargaining strength comes from the competition between suppliers, not any innate better quality of bargaining. In one to one negotiations over milk we estimate that processors have greater bargaining power than supermarkets. However the competition between processors yields the greater share of gains to the supermarket.

- The data we analyse provides a consistent estimate of the bargaining power of the processors versus the suppliers as our theoretical model predicts. However the estimate exhibits a blip in 2002, shrinking in 2003, when processors appeared to enjoy a surge in their bargaining power. This is not incompatible with the current Office of Fair Trading allegations against the milk industry of collusion during these years. Other explanations are also possible.

- In the bargaining between milk processors and cooperatives, the processors hold the stronger bargaining position. Our estimates suggest that the processor secures over two thirds of the margin per litre supplied, for every third secured by farmers. This estimate bares the standard caveat that longer data series would allow refinement of the estimate.

Finally note that the bargaining splits we have calculated have included no analysis of the fixed costs of setting up plants and factories, nor of the accounting costs of depreciation against those assets. This is because in economic terms these costs are sunk. That is they have already been spent or committed to, and current price negotiations will not affect that. It is true that any business which cannot make back its cost of capital is liable to close. However, conditional on staying open, the accounting costs of depreciation are not economic variable costs of production and so do not form part of the profit maximisation calculations which the parties undertake in deciding what prices they can agree to.
Chapter 2  *Milk Prices in Retail Competition*

**Overview**

The aim of this paper is to understand retail milk pricing. Specifically we are interested in understanding what determines the size of the margins between retail prices set by supermarkets and the marginal cost of milk. This mark-up depends primarily on two factors: the sensitivity when making their supermarket choice of consumers to changes in milk prices and whether the retailers are cooperating when setting prices.

To investigate empirically the determinants of the observed margins we estimate a model of consumer demand using TNS data and use this to compute the elasticity of demand for a supermarket firm with respect to a change in the price it sets for milk. We use the estimated demand model to compute the milk margins that these demand elasticities imply in the absence of any agreement or coordination between supermarkets. We then compare these margins to those observed in the data. The model is estimated for the years (2002-2005).

We begin by presenting some facts about milk prices and milk shopping. We then present the model of consumer shopping and discuss the consumer data used to estimate the model. Finally we present the econometric results and derive the price elasticities and hence the implied non-cooperative milk profit margins. We compare these with the actual retail profit margins and conclude with a discussion of the results and some caveats.

**Some Facts: Milk Prices and Milk Shopping**

<table>
<thead>
<tr>
<th>Year</th>
<th>Farm to Retailer</th>
<th>MCVE</th>
<th>Total MC</th>
<th>Retail Price ppl</th>
<th>Margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>13.7</td>
<td>21.81</td>
<td>35.6</td>
<td>42.7</td>
<td>17%</td>
</tr>
<tr>
<td>2002</td>
<td>13.8</td>
<td>16.81</td>
<td>30.6</td>
<td>44.3</td>
<td>31%</td>
</tr>
<tr>
<td>2003</td>
<td>13.8</td>
<td>18.74</td>
<td>32.5</td>
<td>46.6</td>
<td>30%</td>
</tr>
<tr>
<td>2004</td>
<td>13.9</td>
<td>20.15</td>
<td>34.1</td>
<td>47.5</td>
<td>28%</td>
</tr>
<tr>
<td>2005</td>
<td>14.6</td>
<td>20.42</td>
<td>35.0</td>
<td>50.9</td>
<td>31%</td>
</tr>
</tbody>
</table>

Table 1: Milk Margins (using Marginal Costs Derived in Paper 1)

Table 1 presents retail milk margins for the years 2001-2005. Note that the retail margins are based on industry marginal cost rather than the wholesale price. Our concept of industry marginal cost is built up using MCVE as the opportunity cost of the farmer in the same way as described in Chapter 1. Thus the total MC (marginal cost) figure in the table is the same as the c variable in Paper 1. We can see that the margins have risen over time from 2001 to a figure of 31% in 2005.

The next series of tables give a description of milk shopping:
Table 2: Sales Volumes by Type of Milk 2005 [Source MDC]
Table 2 shows that regular milk (as opposed to filtered or organic milk) constitutes 90% of retail milk.

<table>
<thead>
<tr>
<th>Milk Type</th>
<th>Million Litres</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular Milk</td>
<td>2.93</td>
<td>90.7</td>
</tr>
<tr>
<td>Filtered Milk</td>
<td>0.2</td>
<td>6.2</td>
</tr>
<tr>
<td>Organic Milk</td>
<td>0.1</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Table 3: Comparison of Retail and Doorstep Source MDC
Table 3 shows that the retail market is 90% of liquid milk (i.e. that doorstep delivery is now a small part of the market).

<table>
<thead>
<tr>
<th>Year</th>
<th>% Volume Retail</th>
<th>Doorstep Price</th>
<th>Retail Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>83.3%</td>
<td>75.5ppl</td>
<td>46.2ppl</td>
</tr>
<tr>
<td>2004</td>
<td>86.5%</td>
<td>77.5ppl</td>
<td>48.6ppl</td>
</tr>
<tr>
<td>2005</td>
<td>88.6%</td>
<td>79.6ppl</td>
<td>48.7ppl</td>
</tr>
<tr>
<td>2006</td>
<td>90.2%</td>
<td>82.2ppl</td>
<td>52.2ppl</td>
</tr>
</tbody>
</table>

Table 4: Market Shares of GB Supermarkets 2002-2005
Table 4 shows that the market is quite concentrated: the largest four supermarkets account for 70% of milk sales.

<table>
<thead>
<tr>
<th>Firm</th>
<th>All Goods</th>
<th>Milk</th>
<th>Firm</th>
<th>All Goods</th>
<th>Milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tesco</td>
<td>0.27</td>
<td>0.25</td>
<td>Coop</td>
<td>0.03</td>
<td>0.04</td>
</tr>
<tr>
<td>ASDA</td>
<td>0.20</td>
<td>0.18</td>
<td>Somerfield</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>Sainsbury</td>
<td>0.16</td>
<td>0.12</td>
<td>Kwik-Save</td>
<td>0.02</td>
<td>0.03</td>
</tr>
<tr>
<td>Morrison</td>
<td>0.10</td>
<td>0.08</td>
<td>Waitrose</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Subtotal</td>
<td>0.80</td>
<td>0.69</td>
<td>M&amp;S</td>
<td>0.02</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Subtotal</td>
<td>0.80</td>
<td>0.69</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Iceland</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lidl/Aldi/Netto</td>
<td>0.04</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Table 5: Primary Shopping Dominates Source TNS
(Primary Shopping is expenditure in top store in shopping period)

<table>
<thead>
<tr>
<th>Expenditure Shares</th>
<th>Primary Shopping</th>
<th>Secondary Shopping</th>
</tr>
</thead>
<tbody>
<tr>
<td>75%</td>
<td>87%</td>
<td>54%</td>
</tr>
</tbody>
</table>

Table 6: % of biweeks where household includes milk in basket Source TNS
Table 6 shows that milk is present in most shopping baskets. Primary shopping is the main shopping trip in any given two-week period.

<table>
<thead>
<tr>
<th>Median Household</th>
<th>Primary Shopping</th>
<th>Secondary Shopping</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>87%</td>
<td>54%</td>
</tr>
</tbody>
</table>

Table 7: Milk Share of Shopping Budget: Household Averages
Table 7 shows that milk only makes a relatively small share of the baskets.

<table>
<thead>
<tr>
<th>Mean Household</th>
<th>Primary Shopping</th>
<th>Secondary Shopping</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4.2%</td>
<td>4.3%</td>
</tr>
</tbody>
</table>
Table 8: Proportion of biweek periods household visits its top store

<table>
<thead>
<tr>
<th>Percentile</th>
<th>% periods visit &quot;top&quot; store</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>.25</td>
</tr>
<tr>
<td>20</td>
<td>.53</td>
</tr>
<tr>
<td>30</td>
<td>.70</td>
</tr>
<tr>
<td>40</td>
<td>.83</td>
</tr>
<tr>
<td>50[median]</td>
<td>.91</td>
</tr>
<tr>
<td>60</td>
<td>.96</td>
</tr>
<tr>
<td>70</td>
<td>.98</td>
</tr>
<tr>
<td>80</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 8 shows that people switch stores infrequently.

A Model of Retail Pricing

Retailers' Milk Pricing Incentives

We assume that consumers consider the price of a basket of groceries when deciding which store to shop at. Thus for any supermarket the basket price determines number of customers. For this reason the milk price affects demand not just for milk products but also for products other than milk.

Where firms sell a single product, theory tells us that non-cooperative margins depend inversely on the price elasticity of demand for the product offered by the firm. For multiproduct firms such as supermarkets the same principle applies although the price also depends on the cross-elasticities. In particular the equilibrium prices tend to be lower because of the complementarily of the products: when a supermarket cuts the price of milk it increases the number of people coming to the store and hence the demand for the other products.

Consumer Model Assumptions

We assume that consumers choose a primary store for each shopping period and may also choose a secondary store. We assume that for each consumer store choice is based on a basket price, as well as on other variables such as distance to the store and size of the store. We also model the consumers demand for milk and for other goods conditional on the choice of store. We assume that the effect of a change in the milk price on the consumer's utility is proportional to its weight in the consumer's basket.

Data on Consumers and Stores

Consumer Data (Source TNS)

We randomly select a subsample of 3977 households from TNS Worldpanel survey. This is a self-scanning survey of households that tracks purchases and store choices over the three years Oct 2002-Oct 2005. The survey includes household information including the number of adults and children, car ownership, and location. Information obtained for each household each period includes store chosen, quantities, and prices for all items bought.

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January 2008
Store Data (Source IGD)

We also obtained a dataset of stores. This comprises all (9617) stores in GB operated by the main 15 supermarket firms. For each store we know the location of store by postcode, the size of the store, and the firm operating the store. We match the consumer and store datasets to identify the 30 stores in a consumer’s area by distance from that consumer.

Model of Consumer Choice

All consumers are assumed to visit at least one store per shopping period for their primary shopping. Primary shopping is the main shopping trip in any shopping period. We define a shopping periods as a two-week period.

We assume that in any shopping period the consumer's primary shopping decision can be broken down into two stages as follows:

1. **Stage 1**: the consumer makes a choice of store from the stores in his locality and decides how much of his budget to allocate to grocery shopping. The consumer makes this store choice decision based on the price of a basket of products at each alternative store. Once the store has been chosen the consumer decides how much budget to allocate to grocery expenditure: this depends on the price of a basket of groceries.
2. **Stage 2**: the consumer visits the store he selected at stage 1 and allocates the budget between milk and other shopping, depending on milk prices.

The consumer is allowed also to make secondary shopping trips and follows a similar two-stage decision process for these trips.

Econometric Model

The consumer model is estimated using TNS consumer choice data. The data is informative about consumers’ preferences because it is possible to relate variation in prices to variation in consumer responses. Consumers in each unique location face a unique choice set of stores. To estimate the consumer model we compare the choices of consumers across locations and find the demand model that best explains the data.

The econometric model is estimated in two stages as is conventional practice in demand analysis. We start with the second stage demand model which conditions on store choice and budget allocation. Then we estimate the first stage demand model.

Consumer's Stage Two (Allocation of Budget to Milk)

We aggregate all products other than milk into the catch-all category other. In stage two the consumer divides budget g between milk and other goods (i.e. other). The details of the model are given in paper 2, including the estimated parameters. The estimated model allows us to compute the elasticity of demand for milk conditional on store choice. This is given below.
**Data:**

1. $w_m$ and $g$: household-level budget share data from TNS
2. $p_m$: quantity-weighted milk price index (at chosen store)
3. $p_n$: Tornqvist sales-weighted non-milk price index (a sales weighted index is used here as we cannot use quantity weights to aggregate diverse products).

<table>
<thead>
<tr>
<th>Primary Shopping</th>
<th>Secondary Shopping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations=156340</td>
<td>Observations=40735</td>
</tr>
<tr>
<td>$w_m=0.054$</td>
<td>$w_m=0.054$</td>
</tr>
</tbody>
</table>

**Table 10: Summary Statistics for Consumer Stage Two Model**

<table>
<thead>
<tr>
<th></th>
<th>Primary</th>
<th>Secondary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Milk</td>
<td>Other</td>
</tr>
<tr>
<td>Own-price elasticity</td>
<td>-0.60</td>
<td>-0.99</td>
</tr>
</tbody>
</table>

**Table 11: Elasticities Conditional on Store Choice and Grocery Budget**

Table 10 presents summary statistics for the budget share of milk and we see that it occupies a budget share of about 5% of a typical basket.

Table 11 presents the elasticities from the model of the consumer's second choice stage. We see that the own-price elasticity of milk is -0.6. This is interpreted as meaning that a 1% increase in the price of milk results in a 0.6% fall in the demand for milk. This level of elasticity is similar to other studies of the elasticity of demand for milk, showing that the demand for milk is inelastic. The demand for other goods is relatively more elastic, with an elasticity of about 1.

As with conventional studies of milk demand this elasticity is conditional on the consumer's choice of store and budget; i.e. it gives the change in demand for milk if we hold constant the consumer’s grocery budget and choice of store.

If we are interested in the pricing incentives of the supermarkets, however, we need to know the elasticity of demand for products at the *firm* level; e.g. the effect on demand for supermarket X of a change in the price of milk at supermarket X. To compute firm level elasticities we need estimates from stage one of the consumer's demand.

**Consumer's Stage One (Choice of Store and Budget)**

In stage one the consumer makes a choice of store and chooses the amount of his income to allocate to the grocery budget. These decisions are based on a number of variables such as the closeness of the store, its size, and the price of a basket of goods at that store. Note that we make the natural assumption that the effect of the milk price on the consumer’s choice of store is proportional to its expenditure share in the consumers basket. The estimated parameters are presented in Paper 2. Here we present the
implications of the parameters in terms of firm level elasticities and implied milk mark-ups.

**Firm-Level Elasticities and Non-cooperative Margins**

We now compute the elasticity of demand for milk (and other groceries) at the level of the supermarket firm. That is, what is the percentage change in the demand for milk at a given firm that results from a 1% change in the price of milk. Note that this is the overall elasticity, allowing for the following effects of a price change: a change in budget spent on groceries and a change in the choice of store.

Table 12 presents the overall elasticities at firm level. Note that Table 12 reports price elasticities averaged across supermarkets.

There are four elasticities of interest:

- the own price elasticity of milk
- the own price elasticity of other products
- the cross elasticity of demand for milk with respect to the price of other products
- the cross elasticity of demand for other products with respect to the price of milk

*The table should be read as follows: the numbers are the elasticities of demand for the product in the column with respect to the price of the product in the row.*

We break down the results into several components. There are four 2-by-2 matrices.

The first two columns present results considering primary shoppers alone. The next two columns present results for all shoppers including secondary shoppers. As firms cannot set prices separately for primary and secondary shoppers, it is the elasticities in the last two columns that are relevant for pricing. The figures do not change greatly when secondary shopping is included showing that it is essentially primary shoppers that determine the pricing incentives of firms.

The first two rows present results holding store choice constant while the second two rows allow consumers to switch. It can be seen that the figures change considerably when consumers are allowed to switch stores, suggesting that the pricing incentives of stores are strongly influenced by the effect of price on store choice.

<table>
<thead>
<tr>
<th></th>
<th>Primary</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Other</td>
<td>Milk</td>
</tr>
<tr>
<td><strong>Hold store choice constant</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>-0.779</td>
<td>-0.068</td>
</tr>
<tr>
<td>Milk</td>
<td>-0.004</td>
<td>-0.675</td>
</tr>
<tr>
<td><strong>Let store choice change</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>-2.822</td>
<td>-2.068</td>
</tr>
<tr>
<td>Milk</td>
<td>-0.095</td>
<td>-0.789</td>
</tr>
</tbody>
</table>

*Table 12: Elasticities of Column Quantity with respect to Row Price*

*These are firm-level elasticities averaged across firms*
Thus the bottom right 2-by-2 matrix in Table 12 presents the overall elasticities of demand implied by the estimated choice model (putting consumer stages one and two together). The table shows that the overall own-price elasticity of demand for milk is given by -0.754, i.e. a 1% increase in milk has a -0.754% reduction in demand for milk. A 1% increase in milk price also causes a reduction of quantity demanded for other groceries of 0.087%.

Turning to the elasticity of demand for other goods we see an own-price elasticity of other products of about -2.76%. This is interpreted as a 1% increase in the price index of non-milk products leads to a 2.76% drop in the quantity demanded of non-milk goods. Note that this also leads to a 2% drop in the demand for milk (i.e. the cross elasticity of demand for milk with respect to the price of other goods is 2%).

We now compute the profit maximizing profit margins that firms set in response to these price elasticities. We assume that the firms do not cooperate when setting prices. We compute prices that are a non-cooperative Nash equilibrium, i.e. the set of prices that ensure that for each firm prices maximize profit conditional on the prices set by the other firms.

For single product firms it is well known that Nash equilibrium mark-ups generally have a negative relationship to the absolute size of the price elasticity of demand: i.e. the greater the price elasticity of demand the lower the optimal mark-ups the firm should set. Moreover, if the elasticity of demand is smaller than 1 then a single-product firm can always make more profit by increasing the price. That is, inelastic demands (demand elasticities less than 1) are incompatible with profit maximization.

For multi-product firms however, such as supermarkets, inelastic demands are possible. This is why milk can have an inelastic demand. When setting the price of milk the supermarket internalizes the effect of the milk price on the demand for other products. The negative effect of an increase in the milk price on the demand for other products reduces the profit gain from an increase in the milk price.

<table>
<thead>
<tr>
<th>Primary Shoppers</th>
<th>All Shoppers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common</td>
<td>Milk</td>
</tr>
<tr>
<td>All</td>
<td>33</td>
</tr>
<tr>
<td>Tesco</td>
<td>36</td>
</tr>
<tr>
<td>ASDA</td>
<td>31</td>
</tr>
<tr>
<td>Morr</td>
<td>31</td>
</tr>
<tr>
<td>Sain</td>
<td>42</td>
</tr>
</tbody>
</table>

Table 13: Implied Non-Cooperative Profit Margins (%)

These margins are supported without coordination

Table 13 presents the non-cooperative profit margins implied by the demand elasticities in Table 12. The profit margin is defined with respect to marginal costs rather than the wholesale input cost secured from the supplier.

The first three columns compute profit margins assuming that the firm only faced primary shoppers. The second three columns report the profit margins considering all shoppers. The margins are similar in each case suggesting that primary shoppers have the main influence on prices.
The first column (in each set of three) computes the profit maximizing profit margin if the firm had a policy of uniform margins across all products (i.e. sets the same margin for milk as for other products). We see that the model predicts a margin of about 33% on average with a modest amount of variation across firms.

The remaining two columns present the implied markups that obtain when the firm allows margins to vary by product. The margins predicted for milk are slightly higher than the margins on other products. The supermarket is predicted to set non-cooperative margins of about 36% on milk.

Comparison with Observed Retail Margins

The non-cooperative milk retail margin figure of 36% is similar to the retail price margins of about 31% that we currently actually observe on milk as presented in Table 1. It may be concluded that the actual milk prices that are observed are not far off (and slightly below) the margins and prices that we predict using the estimated elasticities and a non-cooperative model of price setting. Thus if the estimated demand model is correct the firms appear to be setting prices consistent with non-cooperative pricing. The supermarkets are able to enjoy non-cooperative margins at this level because consumers are not in general more sensitive to price differences between supermarkets.

Conclusions to Chapter 2

In this paper we estimate a demand system for milk using TNS data. Unlike previous demand studies we specified the demand model at the level of the firm, which allows us to understand the pricing incentives faced by firms. We use the demand model to compute the own-price demand elasticities at the level of the supermarket firm. We divide the consumers' purchases into two categories: milk and everything else ("other"). The price elasticity estimates imply equilibrium margins on milk of about 36% without coordination between retailers. This is similar to the price margins over marginal cost that are currently observed. Thus if the estimated demand model is correct the firms appear to be setting prices consistent with non-cooperative pricing.
Chapter 3: Upstream Competition and Downstream Buyer Power

In the work of paper 1 (“Estimating bargaining power in the supply chain”) we developed a methodology for analysing the bargaining between supermarkets and their competing suppliers. This subsequent piece of theoretical research explores the implication of the bargaining interface between buyers and their competing suppliers on buyer power, waterbed effects and investment incentives. Buyer power is the contention that larger buyers (either in absolute or relative size) should receive lower prices. Waterbed effects arise if the growth of one buyer results in a worsening (or improvement) in the input prices other buyers are able to secure. These issues have all, for example, come under some intense scrutiny by the UK competition commission in the analysis of the UK grocery market.2

This analysis applies to much more than the liquid milk supply chain. It is a model of the bargaining interface between competing suppliers of a homogeneous good to downstream buyers. The specific bargaining form chosen is best suited to the study of own-label procurement. However it would also apply to, for example, the purchase of salt by trade buyers and other homogeneous inputs in which prices can be determined in advance and the technology and cost functions are well understood.

We build on the work of chapter 1 by allowing for upstream economies of scale. The paper analyses what the effect of any such economies (or diseconomies) would be on buyer power, waterbed effects and innovation. It has been noted in the operations research literature that delivery and logistics naturally gives rise to economies of scale as more customers often means denser customers; and with greater customer density more efficient routing algorithms are possible.3

A Recap of Industry Interviews

We develop the bargaining model in the supply chain by relying on the evidence collected through the interviewing of key executives in the UK liquid milk supply chain. We reported on the insights these interviews generated in the introduction to the first chapter above. Here we build, in particular, on the evidence provided by supermarket buyers and their suppliers. These interviews highlighted the following features:

- Supermarkets unilaterally start a new procurement round at unpredictable points in time. Thus the length of contracts that a supplier (or its rivals) holds is uncertain.
  - Further, we were told, contracts could be cancelled with 3 months notice. Thus any and all supermarkets could be reconsidering their suppliers every 3 months.

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3 Burns et al (1985); “Distribution Strategies that Minimize Transportation and Inventory Costs”, Operations Research.
The effect of competition was that suppliers face uncertainty in which tenders will be successful: Thus suppliers priced strategically aiming to be competitive and cover expected costs.

- The costs are only expected (not certain) because of the interaction between economies of scale and uncertain volumes won.

These twin findings of supermarket led procurement and supplier volume uncertainty tally with other published research. For example:

"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, § 5.97)

"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 §178-179)

As further evidence that volumes won by suppliers are uncertain, consider the following volumes sold to the largest 4 UK supermarkets by the main competing UK milk processors:

<table>
<thead>
<tr>
<th>Date</th>
<th>Processor 1 mlpa</th>
<th>Processor 2 mlpa</th>
<th>Processor 3 mlpa</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/03</td>
<td>585</td>
<td>690</td>
<td>870</td>
<td>2145</td>
</tr>
<tr>
<td>11/04</td>
<td>575</td>
<td>555</td>
<td>1020</td>
<td>2150</td>
</tr>
<tr>
<td>1/05</td>
<td>350</td>
<td>835</td>
<td>940</td>
<td>2125</td>
</tr>
<tr>
<td>10/05</td>
<td>430</td>
<td>760</td>
<td>920</td>
<td>2110</td>
</tr>
</tbody>
</table>

Data from industry sources

These show considerable volume variation for all processors. It is further the case that in the two months between November 2004 and January 2005 the 3 largest supermarkets (accounting for around half of all UK grocery sales) all changed their suppliers essentially simultaneously.

We will shortly use these findings to extend our model of competing suppliers bargaining with downstream buyers. However before doing so it is reasonable to ask whether buyer power insights are available from a simpler model of upstream

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4 “Arla Foods amba and Express Dairies plc: A report on the proposed merger”.
5 “Prices and Profitability in the British Dairy Chain”
monopoly, or certainty in upstream volumes. We would argue that such models do not yield the buyer power insights generated by upstream competition.

**Why Not A Simpler Monopoly Supplier/Volume Certainty Model?**

Much of the academic literature has considered buyer power in the context of an upstream monopolist. This is arguably a good model for a primary branded good supplier. However for the suppliers of own-label, or of secondary branded products, then this assumption of monopoly status is less appealing. In addition an assumption of upstream monopoly, or of upstream volume certainty, leads to the prediction that if upstream technology exhibits economies of scale, then large buyers should be weak. That is they should get a higher price than smaller buyers.

The intuition as to why is offered in the diagram below.⁶

If a supplier knows the volumes that they will supply then they will always bargain with a buyer for volume supplied at the margin. That is every negotiation is conducted as if all the other negotiations go according to plan. Perusal of the diagram above then confirms that the average cost per unit for small buyers is less than that for large buyers. Hence small buyers get a better price. We will see that this seemingly paradoxical insight will not hold when one allows for upstream competition and the resultant upstream volume uncertainty.

**The Model**

The paper develops the model in detail. Here we solely outline its main assumptions. We seek to capture what we consider to be the salient features of the bargaining process illuminated by our industry interviews through the following key assumptions:

- We consider upstream firms with access to the same production technology seeking to supply a homogeneous good to the downstream buyers. These suppliers may have economies (or diseconomies) of scale.

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• The downstream buyers in this theory paper are assumed to have known constant demand which depend only upon the buyer’s identity. Thus we are assuming that the buyers’ demands are inelastic. This is arguably a good model for the supply chain of an input which is one part of a larger whole ultimately sold to consumers. An example is milk that fits into an overall shopping basket with other items.

• Each downstream buyer seeks only one supplier. In the case of milk the largest supermarkets subdivide their purchases into two geographic regions (broadly North and South), but currently in each region one supplier is sought.

• The buyer and supplier bargain bilaterally. If negotiations should break down then a buyer can commence bargaining with another supplier. Ultimately, if the buyer fails to agree terms with all the suppliers then the input can be sourced from some other market at higher cost.

• To preserve the uncertainty as to how other negotiations might be going, we assume that all bargaining with buyers happens simultaneously with no information transfer between them. This is plausibly the case as frequently as every 3 months in the UK milk supply chain when buyers are able to consider changing suppliers/renegotiating price (all 3 main supermarkets did change their suppliers of milk at the end of 2004 for example).

This modelling interpretation of the bargaining between buyers and suppliers preserves the uncertainty in realised volumes that the suppliers experience. In combination with the returns to scale in production we will show that securing a large supplier has a different effect on the expected average incremental cost versus securing a small supplier. In short, securing a large contract is suggestive that realised volumes will be high and so marginal costs will be low with economies of scale.\textsuperscript{7}

This bargaining game can be solved inductively by working backwards from the worst case scenario for a buyer of having failed to agree terms with all suppliers. The resultant input price is a weighted average between the expected costs per unit of serving the buyer and the ultimate outside option of sourcing from a different geographic market. The expected cost depends upon the distribution of volumes there are to be won. The split between these two bounds depends on the bargaining skill of the parties (assumed equal here) and the number of competing suppliers.

\textbf{How Large Buyers Wield Buyer Power}

Our first result is that if there are upstream economies of scale, and if there is sufficient upstream competition, then large buyers wield buyer power. Note that this stands in contrast to the case with a monopolist upstream. Thus we have an immediate implication of carefully considering the upstream competition.

The result is generated by considering what the expected cost of serving a large versus small contract is in the context of volume uncertainty. So for any realization of supplier

\textsuperscript{7} We do not allow the buyers to coordinate their purchases on one supplier in the case of economies of scale. This would not be optimal in a repeated setting as the victorious supplier would then wield monopoly power. Further any differentiation between suppliers over unobserved characteristics would preserve uncertainty in volumes and so the model as described would apply. We note that such coordination on one supplier does not happen in any case in the UK milk supply chain.
volumes from all but 2 possible buyers, consider the expected costs underlying the bargaining between the supplier and these 2 buyers; one large and one small.

We suppose that the number of suppliers, \( U \) is larger than 2. In this case each supplier is more likely to lose rather than win any other given contract. Thus more weight is put on the steeper of the two gradients. The gradients of the chords drawn equal the average incremental cost of delivering the required volumes. So large buyers get a better deal than small buyers. In short securing a large buyer is better news as to final volumes and so is most likely to help steer the supplier into profit. Therefore the supplier is willing to negotiate a lower price to such a buyer.

The analysis next goes on to consider waterbed effects arising from changes in concentration, down and upstream.

**Downstream Organic Growth and Waterbeds**

Our analysis goes on to confirm that if a downstream buyer were to increase their volumes by organic growth without affecting the volumes demanded by other buyers then:

1. With concave total costs upstream (increasing returns to scale), all other buyers receive a lower transfer price.
2. The opposite is true with decreasing returns to scale upstream.

This result follows as the expected volumes served by any supplier grow and so the economies of scale upstream generate the link across input prices.

**Downstream Growth By Acquisition**

The research reported in this section indicates how downstream consolidation results in waterbed effects which alter the input prices for other buyers. To explain the result, suppose that two buyers become more asymmetric while holding their combined purchase volumes constant. Suppose also that all other purchase volumes are unaffected. Then:
1. If average incremental costs are convex then the increase in downstream asymmetry raises the transfer prices for all other downstream firms (a *standard* waterbed effect).

2. If average incremental costs are concave then the increase in downstream asymmetry lowers the transfer prices for all other downstream firms (an *inverse* waterbed effect).

The average incremental cost is the incremental cost per unit of serving a given client plotted as a function of the volumes already being supplied to others. With economies of scale this incremental cost per unit will be declining in volumes already won. If these incremental costs decline at a declining rate (and so costs per unit decline slowly to some lower bound at full efficiency) then we are in case 1 above.

The result is perhaps most neatly explained by the following diagram:

The diagram considers the partial merger of downstream firms 1 and 2 so that they move from being an equal size to firm 1 being the larger, and plots the average incremental cost of serving some other buyer (numbered 3). In this case the volumes upstream suppliers can hope to win have undergone a mean-preserving spread. That is they are more risky as now winning buyer 2 yields little volume. Standard results from risk theory then guarantee that in this case the expected cost per unit of serving buyer 3 has risen. Thus buyer 3 receives a worse input price.

Hence our research identifies a mechanism by which downstream mergers or partial acquisitions can have adverse consequences for the input terms of other buyers. Further we argue that the case of convex average incremental costs is the most relevant. Thus one would typically expect a standard waterbed effect to exist.

In the current investigation into the UK Grocery Market the Competition Commission considered whether waterbed effects might operate in the UK. The model they considered assumed an upstream monopolist and they noted that it was unclear how
relaxing this assumption to upstream competition could generate waterbed effects. Our model here highlights one mechanism implied by the salient features of bargaining in the UK liquid milk supply chain we have identified.

Welfare Effect of Increases in Downstream Concentration

Changes in downstream concentration have the effect of altering the risk profile of volumes won by the suppliers. This alters the expected industry costs and so has a welfare effect. Our analysis highlights the direction of this welfare effect. The results here should be caveated however by the fact that this model assumes downstream volumes are fixed. Thus any changes in retail prices generated by alterations in downstream concentration are not included in the analysis.

Our model shows us that if two downstream buyers become, by partial acquisition, more asymmetric, and if there are increasing returns to scale upstream, then welfare is raised as expected industry costs fall.

Effect of a Change in Upstream Concentration

The paper presented in Chapter 3 then goes on to consider the relative gain of large versus small buyers as the number of suppliers increases. Here we find a link to the shape of the marginal cost curve. In particular, as the number of suppliers increases; and if there are convex declining marginal costs upstream, then the absolute transfer price differential between large and small buyers grows. That is large buyers become relatively better off and smaller buyers are at a relative disadvantage.

The intuition for this is highlighted in the diagram below. Consider a convex declining marginal cost curve. Thus marginal costs decline slowly to some lower bound. More suppliers means lower volumes are expected to be won. Due to the curvature of the marginal cost curve, incremental costs rise more for small reductions at low volume levels than at high volume levels. Winning a large buyer results in a supplier expecting to finish up with large volume levels. Therefore a rise in supplier numbers helps large buyers more than small ones.

This result concludes our analysis of the waterbed effects which concentration changes create. We next move on to the investment incentives created by the bargaining interface between suppliers and buyers.

Investment Incentives and Buyer Power

In this research we seek to understand how the presence of large buyers wielding buyer power alters the incentives suppliers have to invest in their production technology. Thus we seek to endogenise the industry technology and understand whether innovation will act to curb, or promote further buyer power effects.

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In many homogeneous good industries, such as liquid milk supply, any production innovation is unlikely to be covered by patents. For example, if cost reduction is due to better practice or larger plants using well understood technology then this is easily replicable. We therefore make use of the concept of *anticipatory equilibrium*: Does a supplier wish to invest after internalising that her rivals will react by investing also to maintain their competitiveness? In support of our contention that this reciprocal investment is the relevant case note that in the current Competition Commission report into the UK Grocery Industry\footnote{Op cit, App 8.2, para 34.}, 60% of suppliers responding to the CC’s survey claim that they conduct innovation to “keep up with the market”

**Deploying a Small Cost Reducing Innovation**

In this first result we consider at what level of production a supplier would choose to deploy a small cost reducing innovation which lowered the cost of producing one unit by some small amount. Thus the thought experiment here is whether incentives to invest are strongest ‘at the margin’ – that is at high levels of production; or perhaps incentives are strongest at low levels of production. This question is of interest as were downstream demand to be slightly elastic, innovations at the margin could be expected to filter down into lower retail prices.

We find that suppliers facing the bargaining interface described would rather lower costs will inside their expected production levels. The reason is two fold:

Firstly when bargaining with buyers the supplier will be at pains to share as little of the cost reduction with the buyer as possible. A buyer can claim a fraction of the cost saving if her volume turns out to be pivotal in getting the supplier to access the lower cost unit. A cost reduction at high levels of production is more likely to be dependent on signing up any given buyer and so the buyers extract more of the rents.

Secondly, after the input prices are agreed, the cost reduction is only triggered if volumes are sufficiently large. Thus a cost reduction at high volume levels is just less likely to be achieved.

Combining therefore, if the cost reduction is deployed for a unit produced when volumes are low then costs are more certainly lowered but transfer prices stay high.

**Analysis of Endogenous Technology Choice**

Our final analysis seeks to endogenise the entire upstream technology rather than focus on incremental cost reductions. The question this section seeks to answer is whether the mere presence of large buyers pushes technology towards one exhibiting economies of scale in which, as we have shown, buyer power is strengthened. We show that indeed this is the case.

To achieve this insight suppose that the suppliers begin with an industry technology exhibiting no returns to scale or decreasing returns to scale. Thus larger buyers either
wield no buyer power or are actually made weaker. Next suppose that downstream we have many small buyers and one large buyer. This large buyer can be thought of as growing by acquisition through acquiring the smaller buyers. In this case we show that if technology is made endogenous then a large enough buyer creates the incentives for the upstream industry to change to increasing returns to scale.

At first sight this is a surprising result. There are a number of competing suppliers only one of whom can win the large buyer. Thus a move to upstream economies of scale will raise the costs of serving the smaller buyers which the non successful suppliers will be left with. Further economies of scale result in the large buyer wielding buyer power and paying less. Thus given the anticipatory equilibrium – suppliers know if they build in economies of scale their rivals will match – why would the suppliers walk down this road?

The answer lies in the changes to the expected costs. By moving to a technology exhibiting economies of scale the expected costs fall as volumes won have undergone a mean preserving spread. On the other hand the price reduction to the large buyer cannot be too great as the cost of souring abroad remains high and constrains the bargaining agreement. Thus on balance the suppliers are happy to take their chances in competition with economies of scale as the expected cost reductions outweigh the lower input prices secured.

Of course a move to a technology exhibiting economies of scale disadvantages the smaller buyers as we have already established. A manifestation of this move to technology exhibiting economies of scale in the UK liquid milk industry is the continued move to ever larger dairies (superdairies) at which substantial economies of scale can be realised.10

Conclusions to Chapter 3

This final chapter develops a framework applicable to supply chains where consumers see goods as homogeneous. Examples include own-label procurement generally and milk in particular. We have shown that if the upstream technology exhibits economies of scale then large buyers wield buyer power. This power is generated by the uncertainty upstream competition creates. The analysis also highlights one mechanism by which downstream mergers can harm the supply deals of downstream rivals. That is waterbed effects can exist when suppliers compete. Finally the presence of large buyers pushes the upstream technology towards one with economies of scale in which larger buyers become increasingly advantaged as compared to their smaller downstream rivals.

As in all of the three chapters presented here, we are indebted to our sponsors, MDC and DEFRA, and also to all those who provided time for interviews and discussions. Our work is very much improved by their generosity.

10 Superdairies are classed as dairies capable of processing over 300 million litres of milk per annum. At the time of writing the three main processors have, between them, over 7 such dairies. (Industry sources).
Chapter 1: Estimating Bargaining Power in the Supply Chain

Howard Smith and John Thanassoulis
Estimating Bargaining Power In The Supply Chain

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Abstract

We analyse the bargaining power and profit splits in supply chains for homogeneous inputs. Upstream suppliers are in competition to supply product to downstream buyers who are themselves in competition: (supermarket private label procurement, milk, car parts for example). We first set out a bargaining framework for modelling this bargaining interface. The model seeks to capture the core features of bargaining identified in a series of interviews we conducted with key executives in a supermarket supply chain. The model provides a method for calculating how profit splits would alter if parties were to merge or if costs were to change. We source data on costs and payments from the UK liquid milk supply chain. We then estimate the bargaining power of supermarkets, their milk suppliers and the farmers in Great Britain. We explain the division of profits in the chain and discuss its dependence on key market characteristics.

1 Introduction

How profits are shared in the supply chain is a matter of keen interest to most firms and producers. This paper seeks to provide a methodology for explaining the bargaining power and calculating the profit splits in supply chains for homogeneous inputs. The model we develop and estimate is grounded in interviews with executives at all levels of the UK liquid milk supply chain into the largest supermarkets. However the model is applicable to all supply chains in which upstream suppliers are in competition to supply a homogeneous product to downstream buyers who are themselves in competition (supermarket private label procurement, milk, car parts for example).

The liquid milk market is of itself of substantial current policy interest in the UK. At the time of writing the Competition Commission is investigating the entire Groceries Market as it is feared that supermarkets are not operating in the interests of customers or fairly towards suppliers. The Office of Fair Trading has, in the last weeks, accused the supermarkets and some of their suppliers of colluding to raise the price of milk to consumers. And finally two of the largest farmers’ cooperatives in the UK (First Milk and Milk Link) have announced their intention to merge to the Office of Fair Trading. Thus understanding how bargaining power would be altered by market changes, and exploring the historic record of that bargaining power, is of both academic and policy interest.

*We would like to thank Yuwi Manachotphong for invaluable research assistantship. We are very grateful to the Milk Development Council and the Department for the Environment, Food and Rural Affairs in the UK for both financial support and the provision of data. This research is conducted entirely independently and consequently any of the views expressed in this paper belong to the authors and not to the MDC or to DEFRA.
We make two contributions in this work. The first contribution is that we offer a theoretical model of bargaining between competing upstream suppliers and competing downstream buyers. The model provides a framework in which the bargaining power in a vertical supply chain can be empirically estimated and so the profit splits between up and downstream firms explained. This model is an extension of Smith and Thanassoulis (2007) to allow for downstream competition (or indeed collusion if this is found to be relevant in a given market). The second main contribution is that we extend the analysis to a full structural model of the UK liquid milk supply chain: from farmer down to the supermarket. We then source data on the costs of producing milk in the UK and abroad and on the actual payments made by supermarkets for their milk. We estimate the model using this data and so illustrate how the bargaining power parameters and profit splits in this supply chain can be explained.

The bargaining framework we offer has been informed through a process of interviews and case study investigation of the UK liquid milk supply chain. In this way we seek to identify what is core in the bargaining process. The key features we have identified and included in our modelling are that the buyers are in a position to play the suppliers off against each other by threatening to go to another firm not offer a sufficiently attractive deal. Buyers seek one supplier for a contract and so suppliers face uncertainty as to which contracts they will actually win. Ultimately, if a buyer did find negotiations had broken down with all domestic suppliers, then the buyer has an outside option to purchase the input from some other geographic area at a high cost per unit: the buyer will not be left without the product on its shelves.

These core features have the implication that the overall bargained transfer per unit of input will lie between two bounds. The lower bound is the marginal cost of production to the upstream firm. No matter how much bargaining power a downstream firm wields no supplier would supply at a rate which lost money per unit supplied. At the other extreme the bargained price must lie below the cost to a downstream buyer of sourcing the input from the expensive alternative geographic region. Where, between these bounds, the agreed transfer price falls will depend on the number of competing suppliers coupled with the bargaining power of the parties in a bilateral meeting in a manner which our model will make explicit.

The second part of the paper extends the model to a full structural model of the liquid milk supply chain in Great Britain. That is we aim to determine the bargaining power of all players from farmers down to the largest supermarkets and understand how this depends on market structure. We are grateful to the Milk Development Council and DEFRA for providing data on commodity milk prices in the UK, farmgate prices in Europe, and for confidential data concerning payments made direct to farmers by UK processors. Further analysis of financial reports allows us to extract all the data necessary to complete our empirical analysis. We determine the split of the surplus between cost and sourcing abroad which supermarkets are able to secure (64%) and show its vulnerability to the extent of upstream competition. We similarly identify the bargaining power of the farmers as compared to the processors. Overall we hope to show how our methodology can be used to determine bargaining powers in a manner which has not been previously attempted.

Recently a number of researchers have begun to explore the structure of supply chains empirically and theoretically. Our model builds on the work of Smith and Thanassoulis (2007) by including downstream competition and bargaining over two part tariffs. The main other approach to modelling bargaining in the supply chain when there is no upstream monopolist generate Shapley Value results (Inderst and Wey...
In these approaches all suppliers agree a deal with all buyers so that no one is a loser and all receive payments. For homogeneous supply chains (such as supermarket private label goods) these approaches have the implication that these payments are so that no supplier will announce that they would not be willing to supply 'off the equilibrium path'. Our approach is instead informed by interviews of supermarket buyers and supplier sales directors, from which we have sought to extract the key determinants of the bargaining framework.

On the empirical side our work is innovative in actively seeking to estimate bargaining power and its dependence on industry characteristics. The most related empirical analyses of the supply chain do not explore supply chain bargaining. Rather they assume that suppliers set prices which the buyers (e.g. supermarkets) must take or leave. These analyses then explore whether suppliers set two part tariffs or linear prices. In the case of two part prices per unit prices are at cost so that final retail prices are efficient. With linear prices, double marginalization losses are created as retailers optimise their prices against too high a cost. Thus the two models (accepting no upstream bargaining) predict different retail price responses to cost shocks. By this route the question of double marginalization or not can be addressed. Two recent contributions to this area are Villas Boas (2007) and Bonnet et al. (2006). Both of these find evidence for two part tariffs (efficient retail pricing) in the studied supermarket supply agreement; the first in yoghurt and the second in bottled water. We offer an analysis of the bargaining interface itself. In addition we are fortunate in having detailed cost data allowing our us to avoid inferring costs from the movement of commodities such as oil.

There is a second, older, strand of empirical literature in which profit margins are analysed if one assumes that double marginalization does exist. Papers in this stream include Bresnahan and Reiss (1985), and more recently Hellerstein (2004) and Kadiyali, Chintagunta and Vilcassim (2000). However again bargaining is not considered; and the assumption of double marginalization has itself been brought into question by the cited work above.

Our theoretical model of bargaining in the supply chain is offered in Part I. The model is presented in Section 2. That efficient retail prices result is proved in Section 3, and Section 4 solves for the explicit link between bargaining power, cost parameters and upstream competition. Proofs from these sections are contained in the appendix. The empirical analysis is offered in Part II. This begins in Section 5 where the full structural model of the UK liquid milk supply chain is developed. The data is discussed in Section 6. Section 7 offers the full analysis and discussion for the bargaining between supermarkets and processors (their suppliers of milk). Section 8 analyses the bargaining between the processors, the cooperatives and the farmers. Section 9 concludes the entire paper.
Part I

Modelling Bargaining Power in the Supply Chain

2 The Model

This section develops the model of upstream-downstream bargaining offered in Smith and Thanassoulis (2007) to allow both upstream suppliers and downstream buyers to compete with each other; and for the bargaining to be over a two part tariff. Although the model is motivated by private label procurement for supermarkets, it applies to other supplier-buyer situations with upstream competition where the effect of upstream competition is that any supplier can readily be discarded in favour of a competing supplier.

Smith and Thanassoulis (2007) show that if the upstream technology exhibits increasing returns to scale then larger buyers wield buyer power. We here will stick to upstream firms having constant returns to scale as this is the most simple to estimate with real data. The extension to upstream economies of scale is theoretically straightforward. However estimating such a model is more onerous on data requirements. We assume throughout that all sellers and buyers are risk neutral.

2.1 Industry Configuration

Suppose there are \( U \) upstream firms in competition to supply a homogeneous input to the downstream firms. These upstream firms all have the same constant returns technology so that a firm supplying \( q \) units incurs total cost \( cq \).

Downstream there are \( D \) buyers labeled \( i \in \{1, 2, \ldots, D\} \). The \( D \) downstream buyers are themselves retailers who are differentiated from each other and compete in prices to sell their products to final consumers. Each retailer requires only one upstream supplier to source the input. This might be because of increased coordination and contracting costs with multiple suppliers for example. Retailer \( R \in \{1, \ldots, D\} \) itself has idiosyncratic constant marginal costs of \( \gamma_R \). Each retailer is assumed to negotiate a two part tariff \( (t_R, T_R) \) with a supplier. Thus retailer \( R \) will ultimately have a per unit transfer price of \( t_R \) and in addition pay a fixed fee of \( T_R \). The downstream price competition takes place with full cost information. Thus given a vector of transfer prices \( \underline{t} \) the retailers will come to an equilibrium of an appropriate model of competition resulting in retailer \( R \) serving demand \( Q_R(\underline{t}) \) as a consequence of posting optimal price \( p_R(\underline{t}) \). Downstream Bertrand price competition would be one way to generate such a link between costs and retail prices; but other models of collusion or competition can also be accommodated. Thus retailer \( R \)'s profit is a function of the set of agreed transfer prices between all retailers and their suppliers:

\[
\pi_R(t_{R, \underline{t}-R}) = Q_R(t_R, \underline{t}_{-R}) \cdot [p_R(t_R, \underline{t}_{-R}) - t_R - \gamma_R] - T_R
\]

Assumption of Bargaining Over a Two Part Tariff

Interviews with executives in the UK liquid milk industry highlighted that contracts were remarkably simple and consisted mostly of a price per unit and a detailed understanding of planned volumes. Volumes in this industry are highly predictable in advance. Further retailers went to great lengths to give the
suppliers accurate volume predictions: sometimes using 15 years of sales data for given days in particular stores. A casual interpretation of these facts would suggest that bargaining was over linear contracts and so double marginalization problems should be prevalent. However, our interviews also noted that the parties did agree some volume discounts for above expected sales and were in a position to agree ‘spot’ prices if unexpected volumes were required. Further the executives highlighted the aim of optimizing the retail proposition against the actual costs of production: that is minimizing double marginalization. Thus, and in keeping with current economic research (e.g. Villas-Boas (2007), Bonnet et al (2006)) we interpret the joint agreement of an expected volume plus price per unit as forming a fixed fee with the price per unit for volume deviations being agreed separately. We therefore propose that this is most cleanly modelled as supposing bargaining is over a two part tariff as described.

2.2 The Bargaining Model

Before discussing 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 \( \kappa \) per unit. (High means \( \kappa >> c \)). This could be through importing from a different geographical market for example.

Each downstream firm ultimately seeks only one upstream supplier for the input under discussion. Thus the buyer will only make payments to the winning supplier, i.e. we rule out side payments to other potential suppliers. As suppliers have access to the same production technology, each buyer is assumed to randomize when determining the order to negotiate with the upstream firms. A 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 based on Binmore et al (1986).

As Binmore et al (1986) show the solution to this bargaining session is that the parties split, according to their bilateral bargaining strength, the joint surplus from the relationship relative to their respective alternatives when bargaining breaks down. 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.

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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) \( \kappa \).

---

1This assumption is violated by other current approaches to studying the bargaining interface which extend Shapley value type results. See, for example, Inderst and Wey (2003) or de Fontenay and Gans (2005). In these approaches side payments are made to ensure that a supplier who was unsuccessful would be willing to remain available should the other supplier try to renegotiate terms.

2As Binmore et al (1986) note their model is a way of providing a micro-foundation for the Nash bargaining solution. The results of our model are therefore consistent with any model generating the Nash bargaining solution.
The overall solution to the game is built up by iteration through the $U$ upstream firms in the buyer’s ordering and the buyer’s ultimate outside option of $\kappa$ per unit.\(^3\)

This overall solution is given by a split $\lambda$ parts to the buyer and $1 - \lambda$ parts to the seller, 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. 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, thus 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.

The $D$ negotiations between the downstream buyers and their suppliers happen simultaneously and with no communication between a seller’s different sales representatives. 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 simultaneously with no communication between hotels. Thus each upstream firm’s sales representative is ignorant of how well his firm’s negotiations are progressing with other buyers. This way the bargaining game is kept independent of the order in which buyers bargain, which models the uncertainty in final contracts won created by the upstream competition.

**Assumption of Simultaneous and Independent Bargaining**

The assumption of simultaneous bargaining between buyers and the seller(s) has been used widely in the literature with a single upstream firm (e.g. Dobson and Waterson (1997), Inderst and Wey (forthcoming)). In our model there is more than one upstream firm and each upstream firm bargains with each downstream buyer without knowing the outcome of bargaining with the other downstream buyers. Thus the buyer and seller are uncertain of the agreements between other supplier-buyer pairs and so cannot condition their agreements on them. Instead they seek to make themselves as competitive as possible given the likely agreements that others will strike. This assumption of simultaneous bargaining therefore captures in a static framework the essence of a dynamic bargaining game in which buyers may decide to re-tender for the business at some unpredictable points in time.

### 3 Efficient Bargaining Equilibrium

When negotiating, the supplier and buyer have two aims. The first is to maximise the size of the pie they are bargaining over. This equates to avoiding double marginalization, and so allowing the buyer to herself price optimally in response to her rivals. Both of the parties’ interests are aligned here. The second aim is to maximise how much of this pie is secured. The two parties have diametrically opposed interests here. The two part tariff allows these two objectives to be separated. The pie can be maximized by setting the per unit transfer price to reflect the technology thus minimizing double marginalization losses. The fixed fee is then used to divide the subsequent pie. This section proves that the parties will avoid double marginalization losses in this framework.\(^4\)

\(^3\)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.

\(^4\)Villas-Boas (2007) and Bonnet et al (2006) both find econometric evidence that double marginalization losses are avoided in supermarket supply chains.
The model builds on two further assumptions which we explain and seek to justify below:

**Assumption 1: Bargaining In Good Faith** We assume that a supplier would never strictly prefer not to supply a retailer and to precipitate a breakdown at any stage in the bargaining: thus suppliers always bargain in good faith.

This assumption is common to the multiparty bargaining literature\(^5\) where it is referred to as "feasibility". Here this assumption rules out the case that other contracts which *might* be won with rival retailers become so much more valuable if retailer \(R\) has to bargain with fewer suppliers, that refusing to deal with \(R\) becomes optimal for the supplier. Instead we are assuming that there exists a set of mutually advantageous contracts between each retailer and any given supplier: the bargaining game allows us to determine which one is selected.

Assumption 1 will be sufficient to guarantee no double marginalization losses. Thus the per unit transfer \(t\) will equal marginal cost of \(c\) (Theorem 1 to come). However the fixed fee agreed depends ion the number of competing suppliers as this is a key determinant of a given supplier’s bargaining power. We here make an assumption which simplifies the calculation of the fixed fee between suppliers and retailers.

**Assumption 2: Ultimate Off Equilibrium Market Share Preservation** Ultimately off the equilibrium path it is possible that a retailer will argue and so break off negotiations with all \(U\) upstream suppliers and so will find herself sourcing the input at the high marginal cost of \(\kappa\). In this extreme off equilibrium path event we assume that the retailer will elect to post the equilibrium retail price as if she were sourcing her good at the per unit price of \(c\) regardless. Thus the retailer chooses to maintain rather than sacrifice market share in this ultimate off equilibrium path event.

This equilibrium price assumption is perhaps particularly defensible in a dynamic context in which recontracting occurs frequently with agents acting to maximize their (myopic) profits each period. If consumers have any hysteresis in their shopping choices then it might be hard for a retailer to recover from a sharp increase in her retail prices as compared to her rivals. Further, empirical evidence from the UK retail market suggests that only very small price differentials are acceptable to firms (Chakraborty et al (2007)). Thus this assumption may be quite a close to practice in any case.\(^6\)

**Theorem 1** Under assumption 1 (Bargaining In Good Faith) bargaining is efficient: An equilibrium exists in which the per unit transfer prices agreed between the retailers and their upstream suppliers equals the upstream marginal cost \(c\). This equilibrium is unique if upstream competition is sufficiently strong.

Efficient bargaining allows the surplus generated by the supply chain to be maximized which is in the interests of supplier and retailer. To understand why this is an equilibrium note that in the bargaining game all parties will offer just enough to get the rival to agree as opposed to wait for their turn to make a counter-offer. When proposing therefore a retailer can seek to win agreement by offering just enough

\(^5\)See for example, Stole and Zweibel (1996) and de Fontenay and Gans (2005).

\(^6\)Without assumption 2, in the ultimate off equilibrium event of a retailer failing to agree a deal with all \(U\) suppliers, the retailer could increase her profits by responding optimally to the higher input price and raising her retail prices. This would mean that the retailer should agree a slightly lower fee to the last supplier as the incremental benefit of the link is reduced. This small reduction in the fixed fee will be premultiplied by \((1 - \lambda)^U\) as it is inducted up the list of upstream suppliers. This is small unless upstream suppliers have almost all of the bargaining power (\(\lambda\) near to 0).

7
concession on the fixed fee. Any increase in supply chain profits above this level accrues to the retailer and so the retailer proposes the most efficient agreement: marginal cost transfer pricing. Likewise when a supplier offers she wants a very large fixed fee. To get the retailer to agree she wishes to facilitate the retailer making as much money as possible and so again offers marginal cost per unit pricing.

However, though the firms may agree on how to maximise the pie, they disagree completely on how this pie should be split up. The next section discusses how upstream competition leads to a specific split of the pie between retailer and supplier.

4 Total Supplier Profits From The Bargaining Interface

In equilibrium the previous section has established that the bargained per unit transfer prices between retailers and their suppliers will be given by marginal cost so as to maximise joint surplus. Thus the demands each retailer serves in equilibrium can be found from whatever the mode of downstream competition is. We denote these demands \( q_R := Q_R(t^*) \) for retailer \( R \). As the total pie available to be split is independent of the fixed fee, the alternating offer bargaining formulation yields Nash bargaining over the fixed fee. That is the fixed fee is found by splitting the incremental pie created by the supplier-retailer pair according to the bargaining power \( \lambda \) (Binmore et al 1986). To determine the incremental surplus of a link one needs to determine the surplus available if the link were to break down and negotiations moved on to the next supplier. Doing this inductively for all the \( U \) suppliers a retailer could approach we have:

**Theorem 2** Under both assumptions 1 and 2 (Bargaining in Good Faith and Ultimate Off Equilibrium Market Share Preservation) suppliers receive an overall payment per unit supplied (from fixed fee plus per unit transfer prices) of

\[
\left( \frac{\text{overall payment by downstream firms per unit supplied}}{\text{per unit supplied}} \right) = (1 - \lambda)^U \kappa + \left[ 1 - (1 - \lambda)^U \right] \epsilon
\]

where \( U \) is the number of competing upstream firms.

Theorem 2 states that the agreed overall payment will be given by the weighted average of two boundary prices where the weights depend upon the number of competing suppliers retailers have to negotiate with \( (U) \) and the bilateral bargaining power of the retailer versus the supplier \( (\lambda) \). The lower bound on the agreed transfer per unit is the marginal cost of production for the upstream firm. No matter how much bargaining power a downstream firm wields no supplier would supply at a rate which lost money per unit supplied. At the other extreme the bargained price must lie below the cost to a downstream buyer of sourcing the input from the expensive alternative geographic region. Here this price is given by \( \kappa \). Note that the transfer does not depend upon the actual retail profits made by the downstream retailer. This is because of the existence of the ultimate outside option of sourcing input from abroad. If the ultimate outside option was to not stock the product at all then a final upstream supplier would extract a share of the retailer’s profits and so the level of profits would affect the agreed transfer price in this model setup.

Theorem 2 exactly corresponds to Smith and Thanassoulis (2007, Lemma 1) even though we here explicitly allow for downstream competition. As a result Smith and Thanassoulis (2007, Theorem 1) applies to our setting. Larger buyers wield buyer power if the upstream production technology exhibits
increasing returns to scale. The smaller buyers are not disadvantaged in terms of their per unit transfer price - this is set efficiently to maximise joint surplus. Rather the smaller buyers are obliged to pay relatively higher fixed fees. The intuition behind this result is discussed fully in Smith and Thanassoulis (2007).

In part II we acquire data from the UK liquid milk supply chain allowing us to estimate the bargaining power at different levels of the chain and to quantify to what extent this depends on the number of credible upstream rivals.

Part II

Estimating Bargaining Power in the UK Liquid Milk Supply Chain

In this part of the paper we offer a structural model of the liquid milk supply chain in the UK which utilises the theoretical bargaining framework from part I. We then bring the model to data from 1999-2006 and seek to explain the split of profits between the parties over that time.

5 A Structural Model of the UK Liquid Milk Supply Chain

The UK liquid milk supply chain is organised in four distinct stages as captured by the figure below:

\[
\text{Farmers} \rightarrow \text{Cooperatives} \rightarrow \text{Processors} \rightarrow \text{Retailers}
\]

Production begins with the farmer who sells his milk either to a cooperative or direct to a processor. The cooperative is a wholesaler who either sells the milk on to processors for the liquid milk market, or alternatively sells the milk into commodity uses (cheese, butter, skimmed milk powder). The cooperative incurs some transport costs. The processor pasteurizes and bottles the milk into the retailer’s colours. Then the processor delivers to the retailer store. The processor thus incurs processor, bottling and distribution costs.

In the UK there are currently 3 national processors of milk: Wiseman, Arla and Dairy Crest. These are the only suppliers to the main supermarkets in the UK. These processors source their milk either from farmers with whom they have a direct contract, or through one cooperative: First Milk.

5.1 Bargaining Between Processors and Supermarkets

For this bargaining interface the work of part I applies directly. Let us denote the incremental cost per litre of production of milk from the farm through to delivery to the supermarket as \( c \) pence. If a retailer should break off negotiations with all \( U = 3 \) possible suppliers in the market then the retailer could source the milk from abroad. In the case of the UK this is likely to mean buying milk on spot markets in Ireland, Northern Ireland, France, Belgium and the Netherlands as these countries are closest geographically. Let us denote the pence per litre (ppl) price which must be paid in this case as \( \kappa \) pence.
Thus $\kappa$ is the incremental cost per litre from the spot market in mainland Europe through to ultimate delivery of processed milk at the supermarket. Theorems 1 and 2 would apply directly. That is:

1. The retailers would agree to an overall pence per litre payment to their suppliers (milk processors in this case) given by:

$$\text{ppl payment to processor} = c + (1 - \lambda)U (\kappa - c)$$

(1)

Thus the supply chain lying above the supermarket would make a total pence per litre profit of:

$$\text{ppl profit of supply chain} = (1 - \lambda)U (\kappa - c)$$

(2)

The bargained price depends upon the price of sourcing milk as an outside option from abroad ($\kappa$), the cost of domestic production ($c$), the number of competing upstream suppliers ($U$), and the bilateral bargaining power of the supermarkets ($\lambda$). The profits of the supermarket are not important as the ultimate threat point for the supermarkets is not that they will not have milk on their shelves - rather that they must source from more distant areas.

2. The retailers and their suppliers make this total payment through a two part tariff in which the marginal price per unit paid by the supermarket to the supplier would be at production cost $c$.\(^7\)

Thus downstream competition is efficient.

The profit gained by the upstream supply chain (industry volume $\times$ (expression 2)) must be split between the processor, cooperative and farmers.

### 5.2 Bargaining Between Processors, Cooperatives and Farmers

In the UK liquid milk supply chain the processor pasteurizes, bottles and delivers milk to the supermarket buyers. This milk is sourced through two channels. The first channel is that the processors have some direct farmers. These are farmers who are contractually bound to the processor and whose milk the processor guarantees to buy. The second channel is that the milk is sourced from a cooperative of farmers. In mainland UK only one cooperative supplies substantial quantities of milk to the processors: First Milk. First Milk is owned and seeks to bargain on behalf of its members: the farmers.\(^8\) The cooperative uses the milk of its farmers not only for liquid milk; but for commodities such as cheese, butter and skimmed milk powder (SMP) also.

The main interfaces in this supply chain work as follows. The cooperative and the processor engage in bargaining as to the price per litre which will be paid to the cooperative for the milk that they supply. The cooperative in turn pools the profits it makes here with profits from elsewhere and pays these out to farmers. The direct farmers are offered a contract by the processor. The direct farmers can hope to return to the cooperative if their interests are not looked after. Thus the price agreement bargained between the processor and the cooperative forms a reference point for the price the direct farmers receive.

\(^7\)It is worth reiterating that when volumes are predictable a per unit price and a fixed fee are equivalent. The marginal price $c$ is the price the processor is able to make product available to the supermarket to deal with an unprecedented volume requirement.

\(^8\)Milk Link is a second cooperative providing some load balancing to the processor Arla. However Arla is almost entirely supplied by their direct farmers.
Consider a milk processor who has won contracts with retail supermarkets totalling a volume of $Q$ in return for a total payment of $\Pi + cQ$. Thus $\Pi$ is the surplus available to be split between the processor, cooperative and farmers once all the variable costs have been paid. Suppose that the processor has direct farmers able to produce $F$ units when working at their efficient scale. These farmers are assumed to be base load for the processor and so if $Q \geq F$ (which is so for all processors in the UK) then they are utilised in full. We will now construct a model as to how the supply chain profit $\Pi$ is shared out amongst the stakeholders.

Farmer Payments

Suppose that the processor and cooperative were to agree to a transfer of $P + [\text{costs}]$ in return for the cooperative supplying $Q - F$ units of milk. This will be seen by direct farmers as an additional (to costs) payment of $\frac{P}{Q-F}$ per unit of milk supplied by the cooperative. Direct farmers will expect to receive at least $\frac{P}{Q-F}$ per litre of milk supplied in excess of their costs. Further, for historical reasons farmers receive a premium to tie themselves to a processor as selling direct is seen by farmers as more risky. Thus we assume that processors pay a premium of $\delta$ ppl for their direct farmers in addition to the perceived fee earned by cooperative farmers. Thus direct farmers receive a share of the surplus of the supply chain equal to $\delta + \frac{P}{Q-F}$ per litre supplied.

Cooperative Processor Bargaining

Case study evidence from the UK liquid milk supply chain suggests that the relationships between processors and their cooperatives are quite stable over time; it appears predominantly due to geographic complementarities between the location of farms and the pasteurization facilities. The bargaining interface between the cooperative and the processor is therefore modelled using Nash bargaining (NBS) with the disagreement point set to be zero. One interpretation of this is that production would be halted for the duration of a prolonged bargaining impasse. An alternative explanation is that with no cooperative a processor would have to use all her rents from retailer agreements in sourcing milk from less geographically convenient locations.

A bargained transfer of $P + [\text{costs}]$ to the cooperative in exchange for the $Q - F$ units of milk therefore translates into a utility of $P$ for the cooperative. The processor for her part secures a utility, gross of the premium $\delta$ to attract the farmers of:

$$\Pi - P - \frac{P}{Q-F}F = \Pi - P \left[ \frac{Q}{Q-F} \right]$$

We assume that the premium price ($\delta$) to attract farmers away from cooperatives and to the processor direct is not part of the negotiation and is a payment coming out of the processor’s ex post profits. This is because the premium is not an unavoidable feature of the supply chain - thus it is not clear why the cooperative should contribute to its payment by allowing the processor to in effect remove $\delta F$ from...

---

9 This risk is, we were told during executive interviews, due to the following causes: (1) processors have more volatile sales than the main cooperatives which aggregate across a larger fraction of the market; (2) cooperatives can make it unattractive for a farmer to return if the processor doesn’t need them; (3) whereas cooperatives exist to serve farmers, processors serve their shareholders.
the surplus to be bargained over. However, the \( \frac{P}{Q-F} \) ppl payment for the direct farmers is included in the negotiation as whether the farmers work for the cooperative or the processor they will still be due payment for their milk.

We suppose that the processor has bargaining power of \( \alpha \in (0, 1) \) as compared to their paired cooperative. The larger is \( \alpha \) the stronger the bargaining position of the processor. The bargaining is assumed to occur after values of surplus \( \Pi \) and quantity \( Q \) have been realised by the downstream bargaining with the retailers. The NBS then requires that the payment solves

\[
\max_P \, P^{1-\alpha} \cdot \left[ \Pi - P \left( \frac{Q}{Q-F} \right) \right]^\alpha
\]

This has first order condition

\[
\frac{1-\alpha}{P} = \frac{\alpha}{\Pi - P \left( \frac{Q}{Q-F} \right)} \frac{Q}{Q-F} \Rightarrow P = (1-\alpha) \frac{\Pi Q}{Q-F} \tag{3}
\]

Recall that \( P \) is the transfer net of costs to the cooperative. Thus as the processor’s bargaining power grows (\( \alpha \) tends to 1) the payment to the cooperative is forced down to only the unavoidable cost of milk. In addition, the cooperative has the side effect of protecting the direct farmers due to our assumption that the processor will treat her direct farmers on a par with the cooperative ones and in addition offer a risk premium of \( \delta \) ppl.

Combining therefore, the total ppl price received by the direct farmers is given by

\[
\text{total ppl payment to direct farmers} = \left[ \text{production costs} \right] + (1-\alpha) \frac{\Pi Q}{Q-F} + \delta \tag{4}
\]

6 Data On Costs and Payments In UK Liquid Milk

The previous section constructed a structural model of the UK liquid milk supply chain in which the bargained prices at different stages in the supply chain could be expressed as functions of the costs and structural features of the market. These relationships were captured in equations (1) and (4). We will estimate these equations, hence deduce the bargaining powers of the parties and so seek to explain where the profits accrue in the supply chain. To achieve this we must capture the variable costs of production \( (c) \), the minimum cost a supermarket would incur if forced to source abroad \( (\kappa) \) and the risk premium \( (\delta) \) direct farmers require over working for a cooperative. In this section we outline the data we have sourced to allow us to estimate these parameters:

Commodity Price of Milk: MCVE The liquid milk commodity markets are those for cheese or butter or SMP (Skimmed Milk Powder). Such a sale to commodity uses can be conducted by groups of farmers or by the cooperative. The margin for these uses is calculated on a monthly basis by the Milk Development Council (MDC) as a series of publicly quoted prices. These prices are calculated by a combination of telephone surveys of farmers in the UK combined with European data on spot prices for the cost of other components of manufacture. DEFRA (2007 p3) notes that in 2005/06 49% of milk made in Great Britain was used for uses other than fresh liquid milk for drinking. Of this 49%, 28% (the majority) went to cheese while only 2% was used for butter and 12% for
powders and condensed milk. Thus we consider the cheese margin to be the best measure of the farmers’ opportunity cost. This is captured in a monthly price series called the Milk for Cheese Value Equivalent (MCVE). We have used this series every month from January 1999 through to the present. The MCVE is the pence per litre (ppl) margin the cooperative would receive if it used its milk for cheese production. Thus MCVE is gross of the costs of transport from the farmgate to the cooperative.

<table>
<thead>
<tr>
<th></th>
<th>No. observations</th>
<th>Mean (ppl)</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCVE</td>
<td>101</td>
<td>19.65</td>
<td>1.61</td>
<td>15.47</td>
<td>23.10</td>
</tr>
</tbody>
</table>

**Supermarket Payments For Milk: Wiseman Accounts** Wiseman plc is one of three main processors of milk in the UK. Unlike their two main rivals, Wiseman’s business is almost entirely devoted to selling liquid milk and some cream. The cream is a by-product of the preference of the UK consumer for semi-skimmed milk. Wiseman releases annual financial accounts. These accounts give the total turnover and number of litres sold. The MDC have kindly analysed these to extract the likely contribution from cream to Wiseman’s turnover and so deduce an annual estimate of the ppl payment for liquid milk. This ppl payment received by Wiseman will aggregate milk sold to all buyers including supermarkets. However, this is likely to closely track the price the largest supermarkets pay as the volumes they buy are so substantial. Industry participants estimate that the 5 largest supermarkets account for an average of 70% of the milk Wiseman sells.

To deduce the contribution of cream to Wiseman’s turnover the MDC have constructed an average bulk cream price per tonne for the UK. Further the MDC estimate that one tonne of cream is approximately 40% butterfat so that 400kg of butterfat are needed to produce a tonne of cream (the rest is water). Each litre of milk processed by Wiseman is approximately 3.9% butterfat by volume. Of this 1.98% butterfat should stay in the milk to form semi-skimmed leaving 1.92% by volume of butter fat for each litre processed. As a litre of milk weighs 1.03kg, each litre of milk processed produces approximately \(\frac{1.92}{3.9}\) x 1.03 kgs of butter fat. Hence division of 400kg by this figure gives the number of litres which Wiseman would need to process to generate a tonne of cream: 20,200 litres (to 3 s.f.). Division of the total number of litres processed by Wiseman by this figure and then multiplication of this by the bulk cream index gives the contribution to turnover from cream and hence leaves the ppl contribution to turnover from liquid milk for each financial year.

We have this series from financial year 1993/94 onwards.

<table>
<thead>
<tr>
<th>Price paid by retailers to Wiseman for liquid milk (ppl)</th>
<th>No. observations</th>
<th>Mean (ppl)</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price paid by retailers to Wiseman for liquid milk (ppl)</td>
<td>13</td>
<td>36.93</td>
<td>3.24</td>
<td>32.36</td>
<td>41.95</td>
</tr>
</tbody>
</table>

**Farmgate Price for Milk in Europe** Should a retailer fail to source milk in Great Britain they would have to source from overseas. This is likely to mean sourcing from some of Ireland, Northern Ireland, France, Belgium or the Netherlands as these are the nearest countries. The European union in the form of DG Agri provides estimates of the price farmers are receiving for their milk in Euros per 100kg for all these countries every month (except Northern Ireland). This yields 4 monthly data series running from January 1995 to the present:

\(^{10}\)The rest is evenly split between cream and yoghurt.
<table>
<thead>
<tr>
<th>Farmgate price in Euros per 100kg in</th>
<th>No. observations</th>
<th>Mean (Euro per 100kg)</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>149</td>
<td>29.19</td>
<td>3.02</td>
<td>23.23</td>
<td>36.42</td>
</tr>
<tr>
<td>France</td>
<td>149</td>
<td>30.07</td>
<td>2.40</td>
<td>25.10</td>
<td>34.37</td>
</tr>
<tr>
<td>Ireland</td>
<td>149</td>
<td>28.00</td>
<td>1.75</td>
<td>25.01</td>
<td>31.92</td>
</tr>
<tr>
<td>Netherlands</td>
<td>149</td>
<td>31.18</td>
<td>3.01</td>
<td>25.29</td>
<td>38.86</td>
</tr>
</tbody>
</table>

These data series are converted to pence per litre by using the density conversion of a litre of milk weighing 1.03kg. The conversion of Euros into sterling is accomplished using a series of daily exchange rates kept by the MDC and stretching back to January 1999. Each month the monthly mean exchange rate is used for conversion.

In addition the Department for Agriculture and Rural Development (DARD) in Northern Ireland provide monthly farmgate prices for milk in Northern Ireland in pence per litre. This data series is available from January 2000 onwards:

<table>
<thead>
<tr>
<th>Farmgate price in Northern Ireland in ppl</th>
<th>No. observations</th>
<th>Mean (ppl)</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>84</td>
<td>17.79</td>
<td>1.73</td>
<td>14.20</td>
<td>21.20</td>
</tr>
</tbody>
</table>

We combine these data series to establish an average monthly pence per litre price which would need to be paid to European farmers at the farmgate to source milk overseas. This data series runs from January 1999 and has the following summary table:

<table>
<thead>
<tr>
<th>European farmgate average price in ppl</th>
<th>No. observations</th>
<th>Mean (ppl)</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>96</td>
<td>18.35</td>
<td>1.59</td>
<td>15.53</td>
<td>22.01</td>
</tr>
</tbody>
</table>

**Direct Farmer Payments** A number of farmers in mainland UK have supply contracts directly with one of the three major processors. The monthly payments in pence per litre made to these farmers, excluding any transport and administrative costs are captured in mandatory filings with the Department for the Environment, Food and Rural Affairs in the UK. DEFRA have kindly made this data available to us for every month of the three financial year period April 2002 through to March 2005. We combine the data for the three main processors (Wiseman, Arla and Dairy Crest) together to calculate a weighted average direct farmer payment. The weights are given by the volumes of milk bought by each of the processors from their direct farmers. The aggregate direct farmer monthly price has the following descriptive statistics:

<table>
<thead>
<tr>
<th>Direct Farmer Payments in Great Britain in ppl</th>
<th>No. observations</th>
<th>Mean (ppl)</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>36</td>
<td>19.02</td>
<td>1.01</td>
<td>16.95</td>
<td>20.64</td>
</tr>
</tbody>
</table>

**Inflation** We will establish estimates of the transport, processing and bottling costs. To inflate these over the period from 1999 through to the present we use the Office of National Statistics inflation index for plastics and rubber. The milk bottles are all made from plastic. Further, as oil is the input for plastic production, this inflation index will respond to the price of oil and so be correlated
with fuel and hence transport cost inflation. The inflation index is available monthly and rises from a base of 100 in 2000 to 111 in July 2007.

We now combine these data series with published reports on the milk industry to construct estimates of the key parameters of our bargaining model.

6.1 Variable Production Costs For Liquid Milk (c)

For milk taken from the farmgate, the following costs must be incurred before the milk can be delivered, pasteurized and bottled, to the retailer. In each case we give our best estimate of the costs and explain the evidence behind the figure:

<table>
<thead>
<tr>
<th>Item</th>
<th>Variable Cost</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processing</td>
<td>3 ppl</td>
<td>West LB Panmure (2000) broker’s report: best practice is given as 3ppl with worst at 4ppl.</td>
</tr>
<tr>
<td>Bottling</td>
<td>4.5 ppl</td>
<td>West LB Panmure (2000)</td>
</tr>
<tr>
<td>Distribution from processor to supermarkets</td>
<td>4.5 ppl</td>
<td>West LB give an average of 4.5 ppl for the industry: much higher for smaller stores. We use the average as our focus here is on supermarkets.</td>
</tr>
<tr>
<td>Distribution from farm to cooperative</td>
<td>1.35 ppl</td>
<td>The Milk Development Council (MDC) use 1.5ppl for the average cost from farm to cooperative in 2007. We deflate this to a 2000 figure to be in keeping with the other cost entries using the ONS plastics and rubber inflation index.</td>
</tr>
<tr>
<td>Distribution from cooperative to processor</td>
<td>1.35 ppl</td>
<td>As the same volume of milk must be sent on by cooperative as is received we have assumed the same cost figure as above</td>
</tr>
<tr>
<td>Wastage/Inefficiency</td>
<td>2.5% loss assumed</td>
<td>Guesstimate</td>
</tr>
<tr>
<td><strong>Total production cost in 2000 prices</strong></td>
<td><strong>15.1 ppl</strong></td>
<td><strong>1.025 \times (3 + 4.5 + 4.5 + 1.35 + 1.35)</strong></td>
</tr>
</tbody>
</table>

We suppose that to supply into the liquid milk supply chain the farmer must receive reimbursement for the opportunity cost of not supplying milk into commodity markets. The margin available at the cooperative for such a use is given by the MCVE price series. Cooperatives share their profits with the farmers, and so this is equivalent to a farmers’ margin gross of the costs of transportation from farmgate to cooperative. We remain consistent to the above table and so assume this cost to be 1.35 ppl in 2000. We therefore assume that farmers must receive at least MCVE - 1.35 ppl and will receive more than this according to (4).

---

11 See http://www.mdcdatum.org.uk/MilkPrices/ampeguide.html This is the basis upon which UK milk producer prices are calculated from IMPE (EU Farmer Intervention Milk Price Equivalent).
In conclusion therefore we have:

\[
\begin{align*}
\text{marginal cost of} & \quad \text{liquid milk production} \\
= & \quad \left[ \text{production cost from} \right. \\
& \quad \text{the farmgate} \left. + \text{farmer’s cost including} \right] \\
& \quad \text{opportunity cost} \\
= & \left[ 15.1 \text{ ppl in 2000} \right] + \left[ \text{MCVE} - 1.35 \text{ ppl in 2000} \right] \\
= & \text{MCVE } + 13.7 \text{ ppl in 2000}
\end{align*}
\]

This is the marginal cost \( c \) used in (1). We have monthly data for this cost from April 1999 onwards.

### 6.2 Costs To Retailer Of Sourcing Milk Abroad (\( \kappa \))

In the (off-equilibrium) event of negotiations breaking down with all the processors, a supermarket would be forced to source milk from abroad. This is therefore the maximum price that a supermarket could ever feasibly be driven to in the negotiations with a supplying processor. The theory part of this paper captured this as \( \kappa \). This outside option price is found as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Variable Cost</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw milk costs</td>
<td>EU farm gate price</td>
<td>Data series compiling the average of Ireland, France, Belgium, Netherlands and Northern Ireland farmgate prices.</td>
</tr>
<tr>
<td>Production Costs</td>
<td>16.7 ppl</td>
<td>Assumed same technology as in GB: 15.1 ppl in 2000. Inflated up to a 2007 figure by inflation of 10.6%.</td>
</tr>
<tr>
<td>Transportation Across the Sea</td>
<td>5.2 ppl</td>
<td>DEFRA (2007 Table 4.3) gives transport costs for trucking raw milk over the sea and returning empty. These costs are Belgium at 5.9ppl, Netherlands 6.0ppl and Ireland at 5.2ppl, Northern Ireland at 5.7ppl, while that to France at only 3.0ppl. The mean of these prices is 5.2ppl.</td>
</tr>
</tbody>
</table>

\[
\begin{align*}
\text{Minimum cost to supermarket of importing milk from outside GB} & \equiv \kappa \\
= & \left[ \text{EU farmgate price} \right] + \left[ \text{Transport across sea} \right] + \left[ \text{Production costs from farmgate to supermarket} \right] \\
= & \left[ \text{EU farmgate price} \right] + 21.9 \text{ ppl in 2007}
\end{align*}
\]

In conclusion we have

We have monthly data for \( \kappa \) for all dates from April 1999.

### 6.3 Supermarket Payments To Their Suppliers

We take the data series of prices paid to Wiseman for their processed and bottled milk as our price series of the prices supermarkets pay to the processors. This is firstly making the implicit assumption that the
technology the competing processors use is the same so that one processor cannot charge systematically
more or less than another. Secondly this is an upper bound on the amount received from the largest
supermarkets if these largest supermarkets wield any buyer power. Smith and Thanassoulis (2007) show,
in this bargaining framework, how buyer power is generated if there are economies of scale in upstream
production. The payment to processor data set is annual. We do not manufacture any seasonality and
so assume the same ppl figure for each month within the year.

6.4 Direct Farmer Payments and the Direct Risk Premium ($\delta$)
The direct farmer payments are available in the confidential data kindly supplied by DEFRA. The causes
of the risk premium ($\delta$) direct farmers enjoy which were highlighted in industry interviews are recounted
in footnote 9. Industry executives placed the following estimates on the premium required: Dairy Crest
must pay 1ppl more than the main cooperative First Milk. Arla pays 0.3ppl more than Dairy Crest and
Wiseman pays 0.2 ppl more than Arla. Taking the average of these suggested risk premia gives a figure of
1.3 ppl. We therefore set $\delta = 1.3$ ppl in the estimation of the processor-cooperative bargaining power as
given in equation (4). These risk premia are not likely to be correlated with plastics inflation. Further,
industry interviews suggest that these risk premia have been stable in nominal terms over time. Thus we
don’t deflate the figure of 1.3ppl over time.

7 Explaining The Profit Split Between Supermarkets and the
Supply Chain

The relationship between the total ppl payments by supermarkets to their suppliers and the structural
features of the market is given by the theory we develop leading to equation (1). Substituting the specific
cost estimates we have established in Section 6 we have:

\[
\begin{align*}
ppl & \text{ payment to processors} \\
& \text{(from Wiseman accounts)} \\
& \left[ (1 - \lambda) U \right] \cdot \begin{bmatrix}
EU \text{ farmgate +} \\
21.9 \text{ ppl deflated from 2007} \\
+ 13.7 \text{ ppl inflated from 2000}
\end{bmatrix} \\
& \text{MCVE}
\end{align*}
\]

We noted above that there are currently three main processors in the UK who compete for supermarket
business: Arla, Dairy Crest and Wiseman. In March 2003 a fourth main processor, Express, announced its
intention to merge with Arla. This merger only received regulatory clearance from the UK Competition
Commission in October 2003. We therefore consider that from financial year 04/05 onwards there have
been three processors competing ($U = 3$) while prior to this date there were four competing processors
($U = 4$). Our model assumes that $\lambda$, the bilateral bargaining power of the supermarket versus the
processor, is constant through time. The theory seeks to capture how the degree of upstream competition
will affect the bargaining split through the term $(1 - \lambda)^U$. Our model assumes that each buyer requires
one supplier. In the UK the two largest supermarkets subdivide their requirements into two contracts:
supply to their South England and Wales stores and a supply to their North England and Scotland stores.
However for each of these contracts one supplier is sought and contracted with.

With the exception of the ppl payments to the processors for milk, all the data in equation (5) is
available in monthly data series. The price paid to the processors is available only in financial years.
We do not seek to reimpose any seasonality and so take the ppl price paid to the processors over the year as the appropriate one in each month. We can therefore calculate a value for the supermarkets’ bilateral bargaining power ($\lambda$) every month from April 1999. Over any year these $\lambda$ estimates will show some seasonality inherited from MCVE. The descriptive statistics of the bargaining power data set ($\lambda$) constructed are:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Observations</th>
<th>Mean</th>
<th>Std. Err.</th>
<th>[95% Conf. Interval]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\lambda$</td>
<td>74</td>
<td>0.294</td>
<td>0.015</td>
<td>[0.264, 0.324]</td>
</tr>
</tbody>
</table>

This data set, and the annual averages for $\lambda$ it generates are plotted in Figure 1:

![Figure 1: The bargaining power of the supermarkets ($\lambda$) over the sample period.](image)

The overall sample generates an estimate of $\lambda = 0.29$. With the exception of 2002, and to a lesser extent 2003, the $\lambda$ estimates, averaged over the year to remove seasonality, appear to be remarkably constant. These results give rise to the following insights:

### 7.1 Pass Through Analysis

Since the start of 2004 there have been 3 main suppliers in competition for supermarket business. The effect of this competition on the agreed input prices between the supermarkets and their suppliers is the
subject of this paper. The theory of part I contends that if the cost to a supermarket of going abroad to source the input were to rise by 1ppl, then the transfer price to the supply chain would rise by \((1 - \lambda)^3\) ppl as there are 3 competing upstream suppliers. We have estimated \(\lambda = 0.29\). Thus a 1ppl deterioration in the supermarkets’ outside option would translate into an increase of 0.36 ppl in the price which would have to be paid to the supply chain. Similarly, if the marginal costs of production in the supply chain were to rise by 1ppl, \(1 - 0.36 = 0.64\) ppl of this could be passed on to the supermarkets. An increase in commodity prices (that is MCVE) is one way for production costs to rise; increases in fuel and so distribution costs is another way. This analysis therefore provides some support for the assertion by the CEO of Dairy Crest that increases in costs can be substantially passed on to the supermarkets.\(^{12}\)

Note that the effect of mergers amongst upstream processors is easily handled in this framework. The suppliers and retailers are bargaining over the available surplus from trade. This is the gap between production cost at home versus importing from abroad. Before the merger of Arla and Express our analysis predicts that the supply chain above the supermarkets would be able to secure \((1 - \lambda)^4 = 25\%\) of this surplus. This increases to \((1 - \lambda)^3 = 36\%\) post merger. Our model does not predict that this should have influenced final consumer prices however as the parties strike efficient contracts (avoiding double marginalization). The upstream merger, our model suggests, purely increases the supply chain’s ability to capture more of the rents generated by the industry.

Note that the profits generated for the supply chain by these agreements will have to be shared with the cooperatives and farmers in a manner to be explored below.

### 7.2 Strong Processors

The \(\lambda\) parameter gives the estimate of the bargaining power of the supermarket as compared to the processor in individual bilateral negotiations. The effect of upstream competition is captured by the theory through the raising of \((1 - \lambda)\) to a power equal to the number of upstream competitors. Had \(\lambda\) been greater than \(\frac{1}{2}\) then independently of any supplier competition, supermarkets would be in a position to extract more of any surplus generated. However \(\lambda\) is estimated as 0.29 which is smaller than \(\frac{1}{2}\). Thus we are finding that on a one to one level processors are more than able to hold their own as compared to the supermarkets. Supermarket power comes from the effect of upstream competition - not more skilled negotiators. The better performance of the processors as compared to the supermarkets may be because buyers from a supermarket typically buy many different products and so have to spread their focus across multiple areas. Suppliers on the other hand, when dealing with a large supermarket, will be totally focused on the few (often single) products they are hoping to supply.

### 7.3 Market Turmoil in 2002 and 2003

The bargaining power of the supermarkets is depicted in Figure 1. The annual \(\lambda\) estimates are clearly visible in this figure. These annual figures average over the yearly seasonality in farming costs (as captured here by MCVE). Outside of 2002 and 2003 the bargaining power of the supermarkets (\(\lambda\)) is quite consistently estimated at between 0.3 and 0.4. However the processors appear to become much stronger bargainers in 2002 and similarly to a lesser extent in 2003. It is unclear why this might be. At the time of writing the UK Office of Fair Trading has just issued an accusation of price collusion\(^{12}\)

\(^{12}\)Financial Times, 14 August 2007, “Dairy Crest points to higher price for a pint”.
on liquid milk by the supermarkets and the processors for the years 2002 and 2003.\textsuperscript{13} The spike in processor bargaining power is consistent with, but not necessarily evidence of, foul play in the industry. If supermarkets were colluding on price and so focused less on bargaining a good deal with the suppliers then one would see $\lambda$ drop. Likewise if suppliers required a larger payment in exchange for not whistle blowing then the same observation on $\lambda$ would be made. However there may have been other relevant market events which caused supermarkets to not seek to push their advantage in 2002 of which we are currently unaware.

7.4 Assessing Model Predictions of Supermarket Input Prices

Our analysis has generated a bargaining power estimate of $\lambda = 0.29$ over the entire data period of 1999 through to 2006. Taking this estimate we can calculate predicted prices at which the supermarkets and the processors should agree to trade given the number of upstream rivals and other cost indices. These predicted prices can be compared against the actual recorded prices. This is done in Figure 2.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2.png}
\caption{Actual and model predicted prices for milk supplied to supermarkets in pence per litre.}
\end{figure}

With the exception of the financial years 2000/01, and again 2002/03 the predictions have been quite accurate. During 2000 Wiseman were investigated by the Competition Commission in the UK for aggressive price reductions which were alleged predatory towards the expansion of a rival (Express) in the Scotland. The Commission did find Wiseman guilty, though with a split panel. Such a conclusion is compatible with Wiseman agreeing to supply at lower prices than their bargaining position would

\textsuperscript{13}See UK Office of Fair Trading press release 134/07 issued on 20th September 2007.
ordinarily require for a period into the financial year 2000/1. The situation in 2002/3 has already been discussed.

8 Explaining the Profit Split Between Farmers and Processors

Recall that there are two types of farmer in the liquid milk supply chain: direct farmers who have contracts directly with a processor; and farmers belonging to a cooperative which bargains on their behalf. The bargaining between the cooperatives and the processors is modelled above. The transfer agreed here acts as a reference point for the payment to the direct farmers in a manner which we have modelled. This predicted payment is given explicitly in equation (4).

The model of section 5.2 broke the direct farmer payments into the farmers’ production cost; a risk premium for being direct; and a share of the profits per litre of the supply chain reflecting the bargaining power of the cooperative. This is the content of equation (4). Note that the profit per litre of the supply chain is equal to the price paid to the processors less the unavoidable costs of production. Thus, substituting in from the data we have:

\[
\text{total ppl payment to direct farmers from DEFRA survey} = [\text{MCVE}] - [1.5 \text{ ppl (in 2007) transport farmer to coop}] + (1 - \alpha) \left( \text{ppl price paid to the processors (from Wiseman accounts)} - \text{MCVE} + 13.7 \text{ ppl inflated from 2000} \right) + [1.3 \text{ ppl risk premium for being direct}] \]

In the equation above, line (6) captures the opportunity cost to the farmer of supplying milk for liquid use at all. If the farmer fails to receive this they would be better off selling direct into the commodity markets. Thus this line captures the farmers’ unavoidable cost (including opportunity cost). The transport cost is deducted from MCVE as the MCVE price series is a margin available at the cooperative (and not farm) gate. The second line, labelled (7) gives the share of the supply chain profits which the cooperative is able to secure for itself. The \( \alpha \) parameter captures the bargaining power of the processor as compared to the cooperative. Thus a value for \( \alpha \) near to 1 would imply that the processor is able to wield more bargaining power than the cooperative.

As the direct farmer payments come from the DEFRA provided survey we are restricted in our estimation of \( \alpha \) to a 3 year period encompassing the financial years between 2002 and 2005. Conducting the above regression to generate \( \alpha \) yields an estimate of \( \alpha = 0.73 \) with a 95% confidence interval of \([0.57, 0.89]\). The formal results are:

---

14 See case 32/00, "The Supply Of Milk In Scotland", a Competition Commission report issued in December 2000.
<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>Number of obs</th>
<th>36</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>0.00139</td>
<td>1</td>
<td>0.00139</td>
<td>F (1, 35)</td>
<td>12.25</td>
</tr>
<tr>
<td>Residual</td>
<td>0.00398</td>
<td>35</td>
<td>0.00011</td>
<td>Prob &gt; F</td>
<td>0.0013</td>
</tr>
<tr>
<td>Total</td>
<td>0.00537</td>
<td>36</td>
<td>0.00015</td>
<td>R-squared</td>
<td>0.259</td>
</tr>
</tbody>
</table>

| Direct farmers’ return above commodity price and risk (ppl) | (1 – α) estimate | Std. Err | t | P>|t| | [95%Conf. Interval] |
|-----------------------------------------------------------|-------------------|-----------|---|------|------------------|
| Supply chain profit per litre                             | 0.271             | 0.077     | 3.50 | 0.001 | [0.114, 0.428] |

Thus we estimate that processors are in a stronger position bargaining than the cooperatives and every extra penny of surplus is split 0.73p to the processor and only 0.27p to the cooperative. This enhanced bargaining power was anecdotally referred to in the executive interviews we conducted. The cooperatives were seen to be in a weaker position as a processor can always threaten to approach individual farmers and sign them up directly in the event of disagreement. This not only allows the processor to source milk, it also weakens the cooperative in subsequent negotiations.

To visually see the quality of the fit we can recalculate a predicted direct farmer payment and compare to the actual direct farmer payments. This is equivalent to inserting α = 0.73 in equation (6) above. The result of this exercise is offered in Figure 3.

The trend of the predicted prices and their level appear to be reasonably accurate. However substantial seasonality in the payments is missed: especially in May 2003 and May 2004. This may reflect processors using the payments to direct farmers to provide explicit incentives to maintain year round production by dropping the payment price in summer when milk supply is plentiful as cows can graze on fresh grass outdoors.

9 Conclusion

This analysis offers a method for estimating and explaining where profits will accrue in a supply chain, and how those profits will change as the industrial structure itself changes. Further we have shown how this method can be applied to actual data. In this way we have offered an analysis of the bargaining powers which exist in the UK liquid milk supply chain.

The theoretical model of the bargaining interface is informed by interviews of key executives in the liquid milk supply chain. The parties stressed that they were keen to retail price efficiently and so subdivide the largest possible pie between themselves. Our analysis built on this by allowing bargaining over a two part tariff. Such a contract is implementable by per unit prices for a known volume coupled with spot prices for unexpected volume changes; as in fact exists. The overall agreed price per unit, we find, must lie between two bounds. The lower bound is the cost of production. The upper bound is not the full supply chain profit, but rather the price of the ultimate outside option of having to source the good from a different geographic area. Thus supermarkets and their suppliers are only bargaining over a subset of the pie. How much of this possible pie the supplier secures depends on the number of
competitors and on the bilateral bargaining power: only the former would be expected to alter in the face of mergers.

The empirical section of the paper demonstrated what data one would need to estimate and explain the profit splits in a given supply chain. Thus one can determine how much cost pass through one would expect if costs were to change, or if the industrial structure was to change. This can be done at all levels of the supply chain so that ultimately producers can understand why the profit split that is left to them is the size it is. Specifically we find that supermarkets secure the majority of the pie - but this strength is due to the upstream competition. In bilateral bargaining situations the suppliers actually have the greater bargaining power. The threat to be able to use a competitor is what forces prices in favour of the supermarkets’ interests. This greater supplier bargaining skill perhaps derives from the fact that a supplier’s negotiation with a major national supermarket is one of the biggest deals they do and so the focus of all their attention. A supermarket buyer on the other hand is responsible for many negotiations and so is perhaps less focused. The supermarket suppliers (processors in milk) also wield the bargaining power as compared to their suppliers: the farmers. Here geographic proximity prevents the ability to chop and change so that the processors do secure most of the rents leaving a small share to farmers.

Our analysis has assumed that there are no economies of scale in the upstream technology. The
This bargaining round. If the retailer does reject the offer or for a breakdown in this bargaining round. By the assumption of good faith bargaining (assumption 1) the disagreement payoff is not so large that agreement is precluded. $V^*_R$ and $\Phi_R$ are defined similarly for the downstream retailer. When the supplier makes the offer, to be serious and get agreement she must give the retailer as much as the retailer can get by disagreeing and hanging on for her own chance to offer or for a breakdown in this bargaining round. If the retailer does reject the offer there is an $\varepsilon (1 - \lambda)$ probability of breakdown. Suppose that in equilibrium the other retailers will agree transfer prices of $\ell^*-R$. Therefore we must have

$$-T^*_5 + Q_R \left( t^*_5, \ell^*-R \right) \cdot [pr \left( t^*_5, \ell^*-R \right) - t^*_5 - \gamma_R] = (1 - \varepsilon (1 - \lambda)) V^*_R + \varepsilon (1 - \lambda) \Phi_R$$

This therefore determines the fixed fee in terms of the transfer price. As the supplier, by assumption, is bargaining in good faith she will seek to maximise her payoff from a deal. This payoff is

$$T^*_5 + (t^*_5 - c) Q_R \left( t^*_5, \ell^*-R \right) + \sum_{j=1}^{2^{D-1}} \Pr(W_j) \left\{ \sum_{i \in W_j} \left[ T^*_i + (t^*_i - c) Q_i \left( t^*_i, \ell^*-R \right) \right] \right\}$$

Using (9) to substitute for $T^*_5$ and then maximising over the possible $t^*_5$’s yields the desired formula: (8).

A Proofs of Technical Results

Proof of Theorem 1. The proof is in two parts. The first part is to show that the equilibrium per unit transfer prices agreed to by downstream retailer $R$ must satisfy:

$$t^*_R = \arg \max_{t^*_R} \left[ pr \left( t_R, t^*_R \right) - \gamma_R - c \right] Q_R \left( t_R, t^*_R \right) + \sum_{j=1}^{2^{D-1}} \Pr(W_j) \left[ \sum_{i \in W_j} (t^*_i - c) Q_i \left( t_R, t^*_R \right) \right]$$

where $W_j$ is the set of other retailer contracts won by the supplier with index $j \in \{1, \ldots, 2^{D-1}\}$. There are $2^{D-1}$ possible such combinations. The second part of the proof is to confirm that pricing at marginal cost of $c$ solves the set of equations (8).

Part 1: Proof that (8) holds

Suppose that when it is the upstream supplier’s turn to offer she proposes $(T^*_S, t^*_S)$ and would have valuation in equilibrium of $V^*_S$. Should the supplier and retailer argue and the bargaining break down then the supplier will receive a payoff of $\Phi_S$ which is independent of any of the offers made in this bargaining round. By the assumption of good faith bargaining (assumption 1) the disagreement payoff is not so large that agreement is precluded. $V^*_R$ and $\Phi_R$ are defined similarly for the downstream retailer. When the supplier makes the offer, to be serious and get agreement she must give the retailer as much as the retailer can get by disagreeing and hanging on for her own chance to offer or for a breakdown in this bargaining round. If the retailer does reject the offer there is an $\varepsilon (1 - \lambda)$ probability of breakdown. Suppose that in equilibrium the other retailers will agree transfer prices of $\ell^*-R$. Therefore we must have

$$-T^*_5 + Q_R \left( t^*_5, \ell^*-R \right) \cdot [pr \left( t^*_5, \ell^*-R \right) - t^*_5 - \gamma_R] = (1 - \varepsilon (1 - \lambda)) V^*_R + \varepsilon (1 - \lambda) \Phi_R$$

Using (9) to substitute for $T^*_5$ and then maximising over the possible $t^*_5$’s yields the desired formula: (8).

Theoretical implications of economies of scale have been explored in Smith and Thanassoulis (2007). Such economies generate buyer power for the largest buyers. Further the profits per unit of suppliers would depend on exactly which contracts are won. And finally retail prices would respond to upstream changes in concentration. We do not explore this here for two reasons. Firstly the model is most cleanly illustrated with the (standard) assumption of constant returns to scale technology. However the work here and in Smith and Thanassoulis (2007) can be combined to extend to this case. Secondly estimating the shape of the cost function puts substantial strain on the available data, which, we judged to be too great.

Finally a caveat is in order. Our analysis has identified a spike in bargaining power which coincides (2002 and 2003) with the current accusations made by the competition authorities of foul play by supermarkets and their suppliers in the milk industry. Though our findings would be consistent with such an accusation, the analysis cannot by itself be taken as proof. There may be other reasons, not included in this analysis, why market participants behaved differently over this time period.
Identical reasoning for when the retailer makes the offers again yields that the per unit transfer price is used to maximise the pie and so (8) is again generated. Thus we have that (8) holds.

Part 2: Transfer prices at marginal cost $c$

That transfer prices at marginal cost is a local maximum of (8) follows directly as the profits within a supply chain are maximized by removing double marginalization. To check when marginal cost transfer pricing is the unique equilibrium consider differentiating the objective function in (8) with respect to $t_R$.

This gives:

$$\frac{\partial}{\partial t_R} \left[ \text{objective function in (8)} \right] = \frac{\partial}{\partial t_R} \left[ (p_R - \gamma_R - c) Q_R \right] + \sum_{j=1}^{D-1} \Pr(W_j) \left[ \sum_{i \in W_j} (t_i^* - c) \frac{\partial Q_i}{\partial t_R} \right]$$

As the transfer price $t_R$ is increased the profits made in the supply chain with retailer $R$ fall. The increased transfer price to retailer $R$ causes $R$ to be less competitive and so allows rival downstream retailers to raise their prices a little. Whether this leads to rival retailers serving more or less demand depends upon the demand curve. If rival retailers contract then the expression above is negative and marginal cost per unit pricing is the unique equilibrium of the bargaining game. Otherwise the second term above is positive. However if competition between suppliers is strong then a given supplier will have a low enough probability of winning a given contract that the left hand term will dominate again giving that marginal cost transfer pricing is the unique equilibrium.

**Proof of Theorem 2.** Suppose that there are $S > 1$ suppliers left for the downstream retailer to approach. By Theorem 1 retailer $R$ and the supplier bargain over the fixed fee of $T_R(S)$ in return for supply of the $q_R$ units at a per unit transfer price of $c$. The surplus bargained over is independent of the agreed fixed fee and so Binmore et al (1986) note that in this setting the Nash bargain will result with disagreement point equal to the utilities the parties would enjoy in the event of the bargain collapsing.

For the retailer the value of the agreement is simply $T_R(S-1) - T_R(S)$ as the per unit transfer price is unchanged in the event of disagreement. For the supplier the value of agreement is $T_R(S)$. Thus Nash bargaining with bargaining power $\lambda$ implies that

$$(1 - \lambda) \left[ T_R(S-1) - T_R(S) \right] = \lambda T_R(S)$$

This yields a difference equation for $T_R(S)$. Iteration implies that

$$T_R(S) = (1 - \lambda)^{S-1} T_R(1)$$

Now consider the bargain with the last remaining supplier. Again the pie to be split in the event of agreement is independent of the agreed fixed fee and so Nash bargaining applies. The benefit to the supplier of agreement is as before. The volume $R$ sells remains at $q_R$ whether or not there is a disagreement with the final supplier by the ultimate off equilibrium market share preservation assumption (assumption 2). Hence the value of agreement to the retailer is simply given by $-T_R(1) + (\kappa - c) q_R$. As a result:

$$(1 - \lambda) \left[ -T_R(1) + (\kappa - c) q_R \right] = \lambda T_R(1)$$

$$\Rightarrow T_R(1) = (1 - \lambda) (\kappa - c) q_R$$

25
Substituting $T_R(1)$ into the expression for $T_R(S)$ yields

$$T_R(S) = (1 - \lambda)^S (\kappa - c) q_R$$

Hence the average overall payment is

$$\frac{1}{q_R}(T_R(S) + cq_R) = c + (1 - \lambda)^S (\kappa - c)$$

(10)

In equilibrium the retailer will agree with the first supplier she approaches. Hence setting $S = U$ in (10) gives an expression which is equivalent to the weighted average given in the Theorem. ■

References


[9] Inderst and Wey (forthcoming), "Buyer Power and Supplier Incentives", *European Economic Review*


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Chapter 2: Milk Prices in Retail Competition

Howard Smith and John Thanassoulis
Milk Prices in Retail Competition*

Howard Smith, John Thanassoulis, Yuwi Manachotphong
Economics Department, Oxford
October 9, 2007

Abstract

This paper measures the market power of supermarkets in the market for liquid milk. As consumers have costs of shopping choice of store for milk is not determined by milk price alone but also by other prices. We specify a model in which consumers make a choice of store and a choice of basket at the store based on an indirect utility function. The choice model is estimated at the level of the individual consumer using a panel of consumer shopping decisions. We aggregate all non-milk purchases into a single commodity. Using the profit functions implied by the demand model for these two products we compute the implied Nash prices for each product, allowing for internalization of shopping-induced complimentarities between them. Our estimates suggest that consumer price elasticities are low enough to give considerable market power on firms when acting noncooperatively. We compare the markups implied by the model assuming noncooperative pricing with actual markups and find that they are a similar size.

*Department of Economics, Oxford University, Manor Road, Oxford, United Kingdom, OX1 3UQ. We are grateful to the Milk Development Council (MDC) and to the Department for the Environment, Food and Rural Affairs (DEFRA) for financial support. We are also very grateful to a number of executives in the UK milk supply chain for their insights into the bargaining process. Any errors are ours and the views contained are ours and not necessarily shared by the MDC or any other entity involved in the UK milk supply chain. We are grateful for comments from conference participants at the Centre for Applied Microeconometrics, Copenhagen University (July 2007 Microeconometrics Conference).
1 Introduction

In this paper we measure the market power of UK supermarket retailers when setting the price of a particular product: milk. The UK retail market for milk is dominated by a relatively small number of supermarkets. Milk is important to supermarkets as it is bought by most of their shoppers. As well as setting the retail price the supermarkets negotiate their purchase price with processors. Supermarket milk pricing and supermarket markups have been the focus of intense scrutiny from groups ranging from competition authorities (see OFT (2007)) to the dairy industry (see KPMG (2003)) including farmers. The latter took direct action against supermarkets on a number of occasions in protest at prices they believed were too low.

A number of recent papers have studied consumer products sold from supermarkets e.g. Nevo (2001) studied RTE breakfast cereals and Villas Boas (2007) studied yoghurt. These papers evaluate the market power in two stages. First they estimate a demand system using data on prices and quantities. Then, with the estimates in hand, they compute the markups implied by the demand system under noncooperative profit maximizing behaviour. In this literature it is conventional to assume that the manufacturer determines prices so that pricing incentives can be studied using demand systems estimated at the level of the brand (e.g. Nevo (2001)). However for many products—milk included—the retailer is likely to have market power. Consequently, some recent papers have estimated demand for each brand at the level of the retailer, permitting analysis of retail incentives (e.g. Villas Boas (2007)).

As pointed out by Bliss (1988), retail pricing incentives are complicated by the fact that shopping costs make it optimal for a shopper to buy a basket of products in the same store, even though individually that store may not be optimal for all the products. This changes the pricing incentives for the retailer, because a reduction in the price of one product will increase the demand for other products through increased store traffic. These considerations are likely to be especially important for a staple product that is widely purchased, such as milk.

To allow for these effects we specify a model in which consumers choose store based on a basket of shopping. The consumer solves a discrete-continuous choice problem in which an indirect utility function is used to determine (i) the optimal (discrete) choice of store, (ii) the optimal (continuous) amount to budget on shopping in the store, and (iii) the optimal division of that
budget between milk and other products. We assume that the consumer can take the problem in two budgeting stages: in the first stage of budgeting the consumer chooses the store and the budget, in the second stage the consumer divides this budget optimally among the products.

To estimate the demand system we use two data sources: a survey of consumer choices and a dataset of store characteristics. The location of the consumers and of the stores is known, so that choice sets can be constructed for the locality of each consumer. The consumer survey records all grocery purchases made in each store for each consumer, including the prices paid and volumes purchased at the level of each pack size. We do not therefore directly observe the prices in stores that were not visited by the consumer. However we can exploit the fact that UK supermarkets adopted a national-pricing practice during the period of the study (2002-2005), which indirectly provides the prices in the stores not chosen. The data is very disaggregated and to simplify the analysis we aggregate shopping purchases into two commodities: milk and other groceries. We compute a price index for each commodity for each firm in each period using the survey data. We also observe consumer attributes and store characteristics.

The model is estimated in two steps following the two stages of budgeting noted above. In the first step we estimate the model of consumer’s choice preferences between milk and other products conditional on choice of store and budget allocated to groceries. We then construct price indices for each store and estimate a model of choice of store and grocery budget. A common issue in this literature is the fact that prices are endogenous and may be correlated with unobserved quality of the products in the store. Given the national pricing practices of the firms the price will however be correlated only with firm-level rather than store-level quality. We therefore deal with this problem by adding firm dummies which control for firm-level quality.

The estimated demand system is used to compute price elasticities for the main retailers. The elasticities are used to compute Nash equilibrium price-cost markups for each of the main supermarket firms. We find that the Nash markups for milk derived from these elasticities are similar to the empirically known markups that have been observed in the industry. This suggests that the actual markups in the industry are consistent with noncooperative pricing and their magnitude reflects market power from product differentiation between retailers.

The rest of the paper is as follows. In section 2 we present some relevant information about the retail milk market in the UK. In section 3 we review the
incentives of retailers with multi-stop shopping. In section 4 we discuss the consumer model we take to the data. In section 5 we discuss the data, with particular emphasis on the construction of price indices. Section 6 discusses some details that arise in the estimation of the model. Section 7 outlines the estimates, and analyses of market power of the retailers. Section 8 concludes by discussing interpretation of the results and some caveats associated with the analysis.

2 The Retail Milk Market

In this section we summarise developments in the retail milk market in the period Oct 2002-Oct 2005. During this time retail prices were under close scrutiny from farmers and competition authorities. We focus our attention on the market for regular fresh milk and ignore variants such as organic milk and filtered milk; even at the end of this period the combined market share of the latter was still less than 10% (see Table 1).

<table>
<thead>
<tr>
<th>Table 1: Sales Volumes by Type of Milk 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Million Litres</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Regular Milk</td>
</tr>
<tr>
<td>Filtered Milk</td>
</tr>
<tr>
<td>Organic Milk</td>
</tr>
<tr>
<td>Source Milk Development Council</td>
</tr>
</tbody>
</table>

The retailers represent the main channel through which milk is distributed to households. Table 2 shows that only 10%—of the approximately 4700m annual litres of milk consumed by households—was supplied to the doorstep (at a much higher price to the customer). Thus we do not analyze the doorstep market for milk, and confine our attention to the retail market.

<table>
<thead>
<tr>
<th>Table 2: Comparison of Retail and Doorstep (Source MDC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>2003</td>
</tr>
<tr>
<td>2004</td>
</tr>
<tr>
<td>2005</td>
</tr>
<tr>
<td>2006</td>
</tr>
</tbody>
</table>
As the Competition Commission (2000) report *Supermarkets* points out, consumers shopping can be categorised into *primary shopping*—the main shopping in any shopping period—and other shopping. We use two-week period shopping periods (for reasons we explain in section 5) and define primary shopping in a given period as the shopping in the consumer’s main store for that period. Primary shopping accounts for about 76% of consumer grocery expenditure and secondary shopping (analogously defined) for another 15%.

**Table 3: Market Shares of the GB Supermarkets 2002-2005**

(Source TNS)

<table>
<thead>
<tr>
<th>Firm</th>
<th>Market Share by Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All Groceries</td>
</tr>
<tr>
<td>Tesco</td>
<td>0.27</td>
</tr>
<tr>
<td>Asda</td>
<td>0.20</td>
</tr>
<tr>
<td>Sainsbury</td>
<td>0.16</td>
</tr>
<tr>
<td>Morrisons</td>
<td>0.10</td>
</tr>
<tr>
<td>Safeway</td>
<td>0.07</td>
</tr>
<tr>
<td><em>Subtotal</em></td>
<td>0.80</td>
</tr>
<tr>
<td>Co-op</td>
<td>0.03</td>
</tr>
<tr>
<td>Somerfield</td>
<td>0.03</td>
</tr>
<tr>
<td>Kwik</td>
<td>0.02</td>
</tr>
<tr>
<td>Waitrose</td>
<td>0.02</td>
</tr>
<tr>
<td>Marks</td>
<td>0.02</td>
</tr>
<tr>
<td>Other</td>
<td>0.02</td>
</tr>
<tr>
<td>Iceland</td>
<td>0.02</td>
</tr>
<tr>
<td>Lidl</td>
<td>0.02</td>
</tr>
<tr>
<td>Aldi</td>
<td>0.01</td>
</tr>
<tr>
<td>Netto</td>
<td>0.01</td>
</tr>
<tr>
<td>Budgen</td>
<td>0.00</td>
</tr>
</tbody>
</table>

The retail market for milk is dominated by a few firms (see Table 3). The largest four (Tesco, ASDA, Sainsbury, and Morrison/Safeway\(^1\)) have a collective market share of about 70% (by sales using TNS data) of retail liquid

\(^1\)Morrison and Safeway merged in 2004.
milk. These four retailers also dominate the market for groceries generally with a combined sales share of 80%.\(^2\)

**Table 4: Proportion of Shopping Periods where Household Includes Milk in Shopping (Source TNS)**

<table>
<thead>
<tr>
<th></th>
<th>Primary Shopping</th>
<th>Secondary Shopping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median Household</td>
<td>0.87</td>
<td>0.54</td>
</tr>
<tr>
<td>5th percentile</td>
<td>0.14</td>
<td>0</td>
</tr>
<tr>
<td>10th percentile</td>
<td>0.32</td>
<td>0.06</td>
</tr>
<tr>
<td>25th percentile</td>
<td>0.65</td>
<td>0.29</td>
</tr>
<tr>
<td>75th percentile</td>
<td>0.97</td>
<td>0.75</td>
</tr>
<tr>
<td>90th percentile</td>
<td>1</td>
<td>0.92</td>
</tr>
</tbody>
</table>

Milk is a very important product for supermarkets in the sense that it is a component in a very large proportion of shopping baskets. Table 4 presents some TNS data showing how important it is. It shows that in 87% of consumer shopping periods the median consumer includes milk in their primary shopping. In fact, as the Table shows there are very few consumers who never buy milk: ranking households by how often they include milk the bottom 5th percentile still buys milk on 14% of occasions, while the lower 25th percentile includes milk on 65% of occasions. Table 4 presents equivalent figures for secondary shopping. Milk is purchased in a somewhat smaller proportion of secondary trips.

**Table 5: Milk Share of Shopping Budget: Household Averages (Source TNS)**

<table>
<thead>
<tr>
<th></th>
<th>Primary Shopping</th>
<th>Secondary Shopping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Household</td>
<td>0.042</td>
<td>0.043</td>
</tr>
<tr>
<td>25th percentile</td>
<td>0.01</td>
<td>0.00</td>
</tr>
<tr>
<td>75th percentile</td>
<td>0.03</td>
<td>0.02</td>
</tr>
<tr>
<td>90th percentile</td>
<td>0.06</td>
<td>0.07</td>
</tr>
</tbody>
</table>

\(^2\)The market shares in Table 3 are constructed using sales data for primary and secondary shopping computed from TNS data using figures for each consumer’s largest two stores visited each two-week period from October 2002–October 2005.
Milk, however, is rarely the only product bought on a main shopping trip, given that consumers want to minimize shopping costs and therefore purchase products in bundles. Milk in fact occupies a rather small fraction of the budget spent on primary shopping trip of about 4.2% on average (4.3% for secondary), as seen in Table 5.

A very striking feature of retail milk pricing is that the major firms do not tolerate price differences conditional on package size and fat content. Figure 1 shows the price of a 4-pint bottle of semi-skimmed milk, by far the most common pack size/fat content combination. The four retailers typically matched prices (the only deviation, for part of the time, was Safeway which was merged into Morrison during the period of the study). These retailers—as noted above—have 70% of the liquid milk market. Figure 2 adds the remaining retailers. Here we see some firms prepared to price a few pence higher and lower. Some of these are small-format stores belonging to the larger firms (Tesco Metro etc.). A few firms are willing to price a few pence higher, e.g. M&S. A few others price below the big four, namely Aldi, Lidl, and Netto. Together, these 5 deviating firms have a market share of retail
milk of about 5%.

Note also that the retailers overwhelmingly adopted a policy of national pricing during the period 2002-2005, not just for milk but for all prices. For a firm that operates its stores under more than one branding format, such as Tesco, different national prices are used for each format.

The two figures illustrate another striking feature of the retail pricing market. During this period there were two important retail price hikes, the first about July 2003 and the second about March 2005, which can be seen in most clearly Figure 1 for the four main retailers, although the other retailers price largely in parallel. These were two instances in a longer series of price increases associated with ‘farmer direct action’ against the supermarkets, which comprised picketing of shoppers and the blockading of various distribution centres. The farmers argued that the price they received at the farmgate was not enough to cover their long run costs and that increases in prices were required along the supply chain. The main retailers responded with price increases called retail price initiatives and the intention of the retail price initiatives was that these price increases would be passed on up-
stream to the ultimate advantage of the milk farmer.

**Table 6: Prices and Margins in the Supply Chain (Source MDC)**

<table>
<thead>
<tr>
<th></th>
<th>Farmgate</th>
<th>Wholesale</th>
<th>Retail</th>
<th>Farmgate</th>
<th>Wholesale</th>
<th>Retail</th>
<th>Farmgate</th>
<th>Wholesale</th>
<th>Retail</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Price</td>
<td>Price</td>
<td>Margin</td>
<td>Price</td>
<td>Margin</td>
<td>Margin</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000/1</td>
<td>19.17</td>
<td>33.93</td>
<td>14.75</td>
<td>42.70</td>
<td>8.78</td>
<td>0.21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001/2</td>
<td>17.11</td>
<td>33.00</td>
<td>15.89</td>
<td>44.30</td>
<td>11.30</td>
<td>0.26</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002/3</td>
<td>18.08</td>
<td>33.68</td>
<td>15.60</td>
<td>46.60</td>
<td>12.93</td>
<td>0.28</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003/4</td>
<td>18.50</td>
<td>34.40</td>
<td>15.91</td>
<td>47.50</td>
<td>13.10</td>
<td>0.28</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004/5</td>
<td>18.51</td>
<td>35.33</td>
<td>16.82</td>
<td>50.90</td>
<td>15.58</td>
<td>0.31</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The farmers (also known as producers), the processors, and the supermarkets make up the three main links in the liquid milk supply chain. The 20,000 milk farmers either sell the milk direct to a processor, or supply it to a processor via a co-op intermediary and receives a ‘farmgate’ price in pence per litre. The processor then pasteurises and packages the milk. There are three main processors (falling from four as a result of a merger in 2003) who negotiate with supermarkets for large supply contracts. The processors receive a ‘wholesale’ price in pence per litre. The prices at each stage in the supply chain are given in Table 6 using the figures gathered by the MDC. The table shows the rising retail prices arising from the retail price initiatives. The percentile margin in the final column is the difference between the retail and wholesale milk price expressed as a percentage of retail price. While retail prices are public information, the wholesale price is backed out by MDC from the Annual Report of one of the processors (Wiseman). Assuming that the retailers incur negligible direct marginal costs per litre of milk, the margin figures provide a useful measure of the price-cost markups of the supermarkets. However, the markups over the industry marginal cost is likely to exceed this because the manufacturer is likely to obtain a markup on marginal cost.

We will return to these retail margin figures later to see how they compare with the markups implied by the demand model estimated in the paper using the TNS consumer data. The estimated demand model will provide us with figures for the price sensitivity of consumers. Before turning to the details of the model, however, we note that Table 7 gives an interesting insight from the TNS data into how willing consumers are to shop around. For each
consumer we identify their top store and then compute the proportion of two-week shopping periods in which the consumer uses that store for the three year period of the data. The median shopper uses that store in 91% of two-week periods. This does not tell us whether the consumers are shopping around for lower prices or for better quality but either way the figures do not suggest a high level of responsiveness of shoppers to changes in price.

<table>
<thead>
<tr>
<th>Percentile</th>
<th>% periods visit “top” store</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>.25</td>
</tr>
<tr>
<td>20</td>
<td>.53</td>
</tr>
<tr>
<td>30</td>
<td>.70</td>
</tr>
<tr>
<td>40</td>
<td>.83</td>
</tr>
<tr>
<td>50 [median]</td>
<td>.91</td>
</tr>
<tr>
<td>60</td>
<td>.96</td>
</tr>
<tr>
<td>70</td>
<td>.98</td>
</tr>
<tr>
<td>80</td>
<td>1</td>
</tr>
</tbody>
</table>

3 The Firm’s Pricing Incentives

In this section we briefly review the retailer’s price setting problem in the presence of one-stop shopping (see Bliss(1988) for a more extensive treatment). For simplicity assume a retailer \( j \) sells two products: milk \( m \) at price \( p_{jm} \) and another commodity \( n \)—representing all other grocery purchases—at price \( p_{jn} \). Each consumer \( i \) evaluates the utility they would obtain from the store, given by the indirect utility function

\[
u_{ij} = u(p_j, y_i)
\]

where \( p_j = (p_{jm}, p_{jn}) \) and \( y_i \) is the consumer’s income. We assume

\[
i \text{ chooses } j \iff (u_{ij} \geq u_{ik} \ \forall k \in J).
\]

The number of shoppers choosing store \( j \) is given by the function \( S_j (p_j; p_{-j}) \)

\[
S_j (p_j; p_{-j}) = \sum_{i=1}^{M} 1 [u_{ij} \geq u_{ik} \forall k \in J_j]
\]
where $\mathbf{p}_{-j}$ is a vector of prices in all other stores, $1[]$ is a function taking the value 1 if the inequality inside $[]$ is true and zero otherwise, $J_j$ is the set of stores the consumer considers and $M$ is the total number of shoppers.

Suppose for simplicity—we relax this in the empirical analysis—that all shoppers have identical demands conditional on choice of any store $j$. Then the total gross profit $\Pi_j$ of store $j$ is given by

$$\Pi_j (\mathbf{p}_j; \mathbf{p}_{-j}) = S_j (\mathbf{p}_j; \mathbf{p}_{-j}) \pi_j (\mathbf{p}_j)$$

(1)

where $\pi (\mathbf{p}_j)$ is the gross profit the retailer makes per shopper given prices $\mathbf{p}_j$. We assume prices and marginal costs are linear so that $\pi (\mathbf{p}_j)$ is as follows

$$\pi_j (\mathbf{p}_j) = q_{jm}(p_{jm}, p_{jn}) \times (p_{jm} - c_{jm}) + q_{jn}(p_{jn}, p_{jm}) \times (p_{jn} - c_{jn})$$

where $q_{jm}(p_{jm}, p_{jn})$ is milk demand per shopper, $q_{jn}(p_{jn}, p_{jm})$ is ‘other’ demand per shopper, and $(c_m, c_n)$ are the marginal costs for milk and ‘other’ respectively.

Even if the per-shopper demands $q_{jm}, q_{jn}$ are characterized by substitutability so a shopper substitutes towards $q_{jn}$ if $p_{jm}$ increases, the presence of shopping costs can result in complementarity at the level of store demands. That is, the increase in $p_{jm}$ drives enough consumers away from the store to reduce the store’s total demand for ‘other’. Each store $j$ sets prices to internalize this complementarity:

$$\max_{p_j} \Pi_j (\mathbf{p}_j; \mathbf{p}_{-j}) \forall j$$

which implies the set of Nash equilibrium markups. The following first order condition applies for the marginal effect of the price of milk on store $j$’s profit:

$$\frac{\partial \Pi_j}{\partial p_{jm}} = \frac{\partial S_j}{\partial p_{jm}} \pi_j + S_j \frac{\partial \pi_j}{\partial p_{jm}} = 0$$

where the first term is the effect of $p_{jm}$ on profits via the number of shoppers (who then purchase both products) and the second term is the effect via profits per shopper. Thus the internalization of complementarities generated by shopping costs creates a downward incentive on prices.

More fully—now allowing for individual heterogeneity in per-shopper demand—the profit for supermarket store $j$ is given by

$$\Pi_j = \sum_i s_{ij} [q_{ijm}(p_{jm} - c_{jm}) + q_{ijn}(p_{jn} - c_{jn})]$$

11
so the first order condition with respect to milk price is:

$$\frac{\partial \Pi_j}{\partial p_{jm}} = (p_{jm} - c_{jm}) \sum_i \left[ \frac{\partial s_{ij}}{\partial p_{jm}} q_{ijm} + s_{ij} \frac{\partial q_{ijm}}{\partial p_{jm}} \right]$$

$$+ (p_{jn} - c_{jn}) \sum_i \left[ \frac{\partial s_{ij}}{\partial p_{jn}} q_{ijn} + s_{ij} \frac{\partial q_{ijn}}{\partial p_{jn}} \right] + \sum_i s_{ij} q_{ijm}$$

$$= 0$$

The firm also solves for $p_{jn}$:

$$\frac{\partial \Pi_j}{\partial p_{jn}} = (p_{jm} - c_{jm}) \sum_i \left[ \frac{\partial s_{ij}}{\partial p_{jn}} q_{ijm} + s_{ij} \frac{\partial q_{ijm}}{\partial p_{jn}} \right]$$

$$+ (p_{jn} - c_{jn}) \sum_i \left[ \frac{\partial s_{ij}}{\partial p_{jn}} q_{ijn} + s_{ij} \frac{\partial q_{ijn}}{\partial p_{jn}} \right] + \sum_i s_{ij} q_{ijn}$$

$$= 0$$

To solve for the firm’s profit maximizing markups we define the matrices $A_j$, $B_j$, and $\delta_j$ as follows:

$$A_j = \begin{bmatrix}
\sum_i \frac{\partial s_{ij}}{\partial p_{jm}} q_{ijm} + s_{ij} \frac{\partial q_{ijm}}{\partial p_{jm}} \\
\sum_i \frac{\partial s_{ij}}{\partial p_{jn}} q_{ijm} + s_{ij} \frac{\partial q_{ijm}}{\partial p_{jn}}
\end{bmatrix}
\begin{bmatrix}
\sum_i \frac{\partial s_{ij}}{\partial p_{jm}} q_{ijm} + s_{ij} \frac{\partial q_{ijm}}{\partial p_{jm}} \\
\sum_i \frac{\partial s_{ij}}{\partial p_{jn}} q_{ijm} + s_{ij} \frac{\partial q_{ijm}}{\partial p_{jn}}
\end{bmatrix}
$$

$$B_j = \begin{bmatrix}
\sum_i s_{ij} q_{mn} \\
\sum_i s_{ij} q_{jn}
\end{bmatrix}
$$

$$\delta_j = \begin{bmatrix}
p_{jm} - c_{jm} \\
p_{jn} - c_{jn}
\end{bmatrix}.$$  

Thus the first order conditions for firm $j$ in matrix form are

$$A_j \delta_j + B_j = 0$$

giving the firm’s pair of optimal markups as follows:

$$\delta_j = A^{-1}(-B).$$
Similar expressions can be computed for each $j$.

In practice the firms have adopted national pricing so we will have first order conditions at the level of the firm rather than store. To implement this we derive the above matrices at the level of the firm $f$ rather than the individual store $j$. This requires that the expressions in $A$ and $B$ are aggregated to firm level, e.g. for the top left element $a_{11}$ in $A$

$$a_{11} = \sum_{j \in J_f} \sum_i \left[ \frac{\partial s_{ij}}{\partial p_{jm}} q_{ijm} + s_{ij} \frac{\partial q_{ijm}}{\partial p_{jm}} \right]$$

where $J_f$ is the set of stores operated by firm $f$.

4 The Consumer Model

4.1 Overview

We assume that each consumer goes shopping at least once per shopping period. We consider a two week shopping period and assume a static consumer model in which the consumer consumes all purchases within each period. We focus on the choice of store—and choice of purchases at the chosen store—in each period. For simplicity we abstract from the frequency with which the consumer visits the chosen store. We initially present the model for primary shopping. In section 6 we discuss how we accommodate secondary shopping.

We assume the consumer’s store choice problem is one of evaluating the utility offered from each alternative store conditional on the consumer’s income. We assume that the consumer computes the maximum utility available from each store conditional on his income and the set of prices available in the store. As stores offer many products and different stores offer different prices this involves a mapping from prices and consumer income to utility, for each store; i.e. in effect the consumer uses an indirect utility function evaluated using the prices at the alternative stores.

For any store we distinguish between two types of utility: the utility from the experience of shopping at a given store and the utility from consumption of the purchased groceries. Suppose in any shopping period $t$ consumer $i$ selects store $j$ and a vector of quantities $q$. (In this section we will suppress consumer $i$’s type subscripts as well as period $t$ subscripts).
The consumer’s direct utility $w$ from consumption conditional on store $j$ is:

$$w = w(q, r)$$

where $r$ is a scalar quantity representing all other consumption. The direct utility from the experience of shopping at store $j$ is:

$$\sigma(x_j, \xi_j) + \varepsilon_j$$

where $(x_j, \xi_j)$ are observable and unobservable characteristics of store $j$ and $\varepsilon_j$ is the consumer’s idiosyncratic random utility term for store $j$. We assume these two components of utility are separable. Given a bi-weekly budget $y$ the consumer has a budget constraint

$$y = p_j' q + p_r r$$

where $p_j$ is a vector of prices at store $j$, and $p_r$ is the price of a unit of $r$ (which is independent of store choice).

We assume the consumer’s problem can be modelled in two budgeting stages: in stage one he determines which store $j$ to visit and the amount $\{g : 0 \leq g \leq y\}$ to spend on groceries. In stage two he determines the vector $q$ conditional on $g$. We assume utility from consumption (2) is weakly separable in the utility from groceries $q$ and the utility from other consumption $r$ respectively, i.e.

$$w(q, r) = w [w_1(q), w_2(r)] .$$

The consumer’s stage-two subproblem is therefore to allocate $g$ optimally between the products in $q$:

$$v_1(p_j, g) = \max \mathbb{Q} \ w_1(q) \ \text{subject to} \ p_j q = g$$

where $v_1(p_j, g)$ is the indirect subutility function conditional on choice of store $j$.

The consumer’s stage-one problem is simultaneously to choose store $j$ and grocery budget $g$. The consumer (i) computes for each $j$ the maximum attainable utility from consumption

$$v(p_j, y) = \max \mathbb{G} [v_1(p_j, g), w_2(r)] \ \text{subject to} \ g + p_r r = y$$

and (ii) computes the utility from the shopping experience at each store

$$\sigma(x_j, \xi_j) + \varepsilon_j$$
and selects the store that maximizes overall utility, which is assumed to take the following additive form:

$$\max_{j \in J} [v(p_j, y) + \sigma(x_j, \xi_j) + \varepsilon_j]$$  \hspace{1cm} (5)$$

where $J$ is the choice set of stores given consumer $i$’s location. In the specification to follow we allow for consumer heterogeneity such that different consumers can weigh differently the two components of utility.

### 4.2 Stage-Two Budgeting Problem: Specification

This section specifies consumer $i$’s sub-utility function in equation (3). As we are interested in milk we aggregate to just two products: milk $m$ and an aggregate ‘other’ $n$ comprising everything else purchased in store $j$. The consumer faces a price vector $p_{jt} = \{p_{mjt}, p_{njt}\}$ in store $j$ at time $t$. We assume that the indirect utility function (3) is given by the standard AI form:\[^3\]

$$v_{i1}(p_{jt}, g_{it}) = \ln \left[ \frac{g_{it}}{a_i(p_{jt})} \right]/b(p_{jt})$$

where

$$\ln a_i(p_{jt}) = a'_i p_{jt} + \frac{1}{2} \ln p_{jt} C \ln p_{jt}$$  \hspace{1cm} (6)$$

where $a_i$ is a consumer-specific $2 \times 1$ parameter vector and $C$ is a symmetric $2 \times 2$ parameter matrix (with elements $c_{mm}$ etc.) and\(^4\)

$$b(p_{jt}) = p_{mjt}^b n_{njt}^b.$$  \hspace{1cm} (7)$$

By Roy’s identity the budget share $w_{imt}$ on $m$ is given by the AI expression:

$$w_{imt} = a_{im} + c_{mm} \ln p_{mjt} + c_{mn} \ln p_{njt} + b_m \ln \left( \frac{g_i}{a_i(p_{jt})} \right).$$  \hspace{1cm} (8)$$

\[^3\]See Deaton and Muellbauer (1980). The log of this utility function is a Generalised Gorman Polar Form (see Lewbel (1987)), one of the necessary conditions for the upper stage of two stage budgeting to be represented in terms of a single price index.

\[^4\]By inverting indirect utility we obtain the (“piglog”) cost function:

$$c_i(p, v_{i1}) = \exp [a_i(p) + v_{i1} b(p)].$$
Consumer taste heterogeneity for milk enters through $a_i$. For consistency with utility theory we assume the following conditions hold. The following are required for the cost function to be linear homogeneous in prices:
\[ a_{im} + a_{in} = 1 \text{ and } c_{mn} + c_{mm} = c_{mm} + c_{nm} = b_m + b_n = 0 \]
and Slutsky symmetry requires $c_{mn} = c_{nm}$. The own- and cross- elasticities derived from this sub-utility model hold constant the consumer's choice of $(g, j)$.

### 4.3 Choice of Store and Grocery Budget: Specification

This section specifies the first stage indirect utility function (5) which the maximizes by choice of $(g, j)$ based on the prices at all alternative stores $j \in J$ and other relevant store characteristics. We assume that the consumer summarises price information for any store $j$ in a price index $P_{jt}$ constructed from prices $p_{jt}$ using individual-specific weights from the stage-two choice model.

The first component of (5) is the utility from consumption conditional on store $j$, as defined in the indirect utility function (4). We assume the following functional form for (4):
\[
  v_i(P_{jt}, y_i) = \left( \frac{\alpha_1}{\gamma} + \alpha_i + \alpha_1 \ln P_{jt} + \alpha_2 Q_t + \gamma y_i \right) \exp \left( -\gamma \ln P_{jt} + \lambda_i \right) \quad (9)
\]
where $Q_t$ is a quarterly dummy for the period around Christmas, the $\alpha_i$ is an individual effect, reflecting taste for groceries, and the parameter $\gamma$ is common in its three appearances. The parameter $\lambda_i$ is an effect that varies across consumers that allows heterogeneity in consumer price sensitivity at the level of store choice. By Roy’s identity this yields the following linear expression for the consumer’s utility maximizing choice of budget $g_{jt}$
\[
  g_{ijt} = \alpha_i + \alpha_1 \ln P_{jt} + \alpha_2 Q_t + \gamma y_i. \quad (10)
\]
We assume utility from consumption enters the overall utility function (5) as follows
\[
  u_{ijt} = v_i(P_{jt}, y_i) + \sigma_i(x_j, \xi_j) + \varepsilon_{ijt} \quad (11)
\]
\[
  = v_i(P_{jt}, y_i) + x_j \beta_i + \xi_j + \varepsilon_{iji} \quad (12)
\]
where the vector $x_j$ consists of two observable store attributes: size and distance from consumer’s home; taste $\beta_i$ for these varies across consumers (we specify shortly exactly how). $\xi_j$ is the unobserved mean utility associated with the experience of shopping at store $j$ and $\varepsilon_{ijt}$ is consumer $i$’s unobserved deviation from this mean in period $t$.

We now specify how $\lambda_i$ varies across consumers. The term $\lambda_i$ varies across $i$ to allow different consumers to weigh differently the effect of a given price difference. It is established practice to assume to assume this varies with the consumer’s income level so we assume that

$$\lambda_i = \lambda \ln y_i$$

where $y_i$ is the household’s income. We expect higher income households to be less price-sensitive ($\lambda < 0$).

As we noted above the observable store attributes $x_j$ consist of store distance from household and store size. Taste for distance $\beta_1$ depends on car use as follows

$$\beta_1 = \beta_{11} + \beta_{12} \text{car}_i$$

where the variable $\text{car}_i$ is the number of cars owned by the household. We expect this to reduce transport costs. Taste for store size $\beta_2$ is assumed to depend on household size;

$$\beta_2 = \beta_{21} + \beta_{22} \text{hz}_i$$

where $\text{hz}_i$ is a count of the number of people in the household. We expect larger households may have more diverse requirements that are better met in larger stores.

The error term $\varepsilon_{ijt}$ is assumed iid and is distributed according to the double exponential (Type–1 Extreme Value) distribution function, i.e. $F(\varepsilon) = \exp(-\exp(-\varepsilon))$. This is the only source of random utility in the choice model. Consequently the probability of consumer $i$ choosing store $j$ in period $t$ from choice set $J$ is given by the Multinomial Logit choice probability:

$$s_{ijt} = \Pr (u_{ijt} \geq u_{ikt, \forall k \in J}) = \frac{\exp (v_i(P_{j,t}, y_i) + \sigma_i(x_j, \xi_j))}{\sum_{k \in J} \exp (v_i(P_{kt, y_i}) + \sigma_i(x_k, \xi_k))}. \quad (13)$$

where $J$ is the set of stores nearest to consumer $i$. 
5 Data and Construction of Price Indices

5.1 TNS Consumer Data and IGD Store Data

The consumer choice data are taken from TNS’s Worldpanel survey comprising 26,133 households. Each household scans in their shopping purchases, recording items bought, price paid, and outlet of purchase, during a 156-week (3 year) time span starting from 41st week of year 2002 to the 40th week of year 2005. We also have information on each household’s characteristics, including location, car use, and household size (but not household income). We select the more committed households from the sample to remove participants that do not take the survey seriously. Households are classified as “committed” if they participated in the survey for longer than 50 consecutive weeks and had a participation rate—number of participating weeks divided by the number of active weeks—of over 40%. This results in 15044 households who are committed to the survey. We assume that this selection rule is exogenous and in support of this we find (in unreported analysis) that the committed households’ demographic characteristics are similar to the characteristics of the entire sample. We draw a random sub-sample of 3977 of these households for estimation purposes, because estimation on the full set of committed households is computationally demanding. To avoid analyzing very small purchases we drop observations in which primary shoppers spend less than £20/biweek period and in which secondary shoppers spend less than £10/biweek period.

<table>
<thead>
<tr>
<th>Table 8a: Shopping Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shopping Frequency</td>
</tr>
<tr>
<td>&gt;3 times per week</td>
</tr>
<tr>
<td>1-2 times per week</td>
</tr>
<tr>
<td>&lt;1/week, &gt;1/month</td>
</tr>
<tr>
<td>&lt;1 time per month</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 8b: Store Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Store Data (Source IGD)—Observations: 9617 UK stores</td>
</tr>
<tr>
<td>--------------------</td>
</tr>
<tr>
<td>Size (square feet)</td>
</tr>
<tr>
<td>Firm Identifier (F)</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
Table 8a illustrates the frequency with which households engage in shopping trips. The most common is once or twice per week. We set our shopping period somewhat higher than this at two weeks to ensure that we pick up main shopping trips in each period and to avoid major divergence between purchasing and consumption (these will be minimized using two week periods given the rate at which food is perishable). Thus we treat the shopping and the consumption decision periods as coterminous. Using the 78 biweek periods from October 2002 to September 2005 gives 156,340 household-period observations. This is less than $78 \times 3977 (=310206)$ because some of the households do not participate in all biweek periods; at any point in time some households join the survey panel while others leave.

Store characteristics data, from the *Institute of Grocery Distribution* (IGD, London, UK) are obtained for all stores in the UK. For each store we use data on location, size, and firm name. Table 8b gives some summary statistics. Just over a quarter of stores are run by the big four firms, namely ASDA/Wal-Mart, Morrison, Sainsbury and Tesco, but because their stores are larger than average their share of floorspace is much higher than their share of stores. We define the choice set $J$ for each consumer as the nearest 30 stores: Figure 3 shows that this covers almost all consumer choices. To
construct choice sets the locations of the stores are identified to the nearest 10 meters, using the grid reference associated with the full postcode (which is given in the IGD data). The households are located up to the first four digits of the UK postcode, which gives a more approximate location. See Smith (2004) for a detailed discussion. We compute the distance from consumer $i$ to each store $j$ using the pythagoras formula not taking account of the curvature of the earth, and select the nearest 30 to each consumer.

5.2 Construction of Price Variables

The practice of national pricing is convenient as it allows us to compute price indices at the level of each firm—using observed purchase data in chosen stores—and then assume these apply within each store of that firm including those that were not chosen. Our model assumes two commodities: milk $m$ and ‘other’ $n$ (representing everything else) and thus we require two prices \{p_{fmt}, p_{fnt}\} for each firm $f$ and biweek period $t$. This subsection explains how these prices are constructed.

We begin by classifying the tens of thousands of products sold by each retailer into a much smaller number of elementary categories $k = 1, \ldots, K$ (these are at the level of “milk”, “bread”, etc. and there are only a few dozen such categories in a supermarket). For each firm $f$ we construct for each category $k$ a category price index made up of the prices of the individual items $a$ that fall within the category. We use quantity weights and an arithmetic mean as follows:

\[
p_{fkt} = \sum_{a \in k} w_{aft} p_{aft} \quad \text{where} \quad w_{aft} = \frac{\text{quantity}_{aft}}{\sum_{a \in k} \text{quantity}_{aft}}
\]

where the quantity is measured in some common unit that applies to the category (e.g. litres for milk, kilograms for bread etc.). We are able to use quantity weights because these commodities are typically sufficiently homogeneous that they are measured in common units. Note that these weights are intertemporally-variable, i.e. the weight changes from period to period. The use of weights that are time-variable allows for substitution effects within firms when the firm’s prices change. It is generally considered appropriate do do this as there will be considerable substitution for such narrowly defined commodities.

We now aggregate the category indices up to the level used in the study. In the case of milk we need proceed no further. Our final price index for milk
$p_{fmt}$ is in the following relative form:

$$p_{fmt} = \frac{p_{fmt}}{p_{1m1}}$$

where $p_{1m1}$ is the price of milk in the reference period ($t = 1$) and the reference firm ($f = 1$, i.e. Tesco). The price index $p_{jnt}$ for the ‘other’ commodity requires aggregation over the analogous price relatives

$$p_{fkt} = \frac{p_{jkt}}{p_{1k1}}$$

for all remaining non-milk categories (i.e. all $k \neq 1$). We use the standard Tornqvist form price index which is constructed as follows using sales information from both base and comparison firm and period:

$$p_{jnt} = \exp \left( \sum_{k \neq 1} \hat{w}_{k1}^{f} \log \left( \frac{p_{jkt}}{p_{1k1}} \right) \right)$$  \hspace{1cm} \text{(14)}$$

where

$$\hat{w}_{k1}^{f} = \frac{1}{2} \left( w_{1k}^{1} + w_{tk}^{f} \right);$$

and

$$w_{tk}^{f} = \frac{\text{spending}_{k}^{f}}{\sum_{k} \text{spending}_{k}^{f}}.$$

The price index should reflect the relative prices faced by consumer $i$ at alternative stores in period $t$. Fixed-weight indices tend to overstate differences between stores because it ignores consumer substitution. This is true whether the index is at individual level or averaged across individuals. The Tornqvist index is generally thought to represent a good way of minimizing substitution bias (see Deaton and Muellbauer (1980) for further discussion).

6 Estimation

Secondary shopping. Some shoppers visit more than one store per shopping period, which accounts for a small but significant share of spending. We find (in unreported analysis) that the decision to engage in secondary shopping is largely determined by exogenous unobserved household-specific effects that are not observed in the data. We therefore do not model consumer’s choice...
between one-store shopping and two-store shopping and treat it as exogenous each period. In those periods when households practice secondary shopping we estimate a model of secondary shopping that mirrors the above model for primary shopping; i.e. we have the same two-stage budgeting set up and the same functional forms for utility. Implicitly we treat secondary shopping as independent of primary shopping, e.g. reflecting top-up shopping for unexpected needs. This is likely to account for much of secondary shopping. We comment further on this issue in the final section.

National Pricing, National Quality and Endogenous Prices. We have noted the practice of national-pricing by the main firms in the UK supermarket industry. The firms also operate national quality standards, with standard store formatting, checkout practices and product quality for any given item. Thus we also assume that unobserved quality $\xi_j$ is common for all stores of the same firm, so we hereafter replace $\xi_j$ with $\xi_f$ where $f = f(j)$.

A traditional concern in demand estimation is that the price is endogenous as it is set by firms and may be positively correlated with unobserved quality, resulting in a positive bias to the price parameter. In our model the profit maximizing value of $P_f$ is likely in principle to be positively related to unobserved quality $\xi_f$. To avoid a positive bias on the price parameter we control for $\xi_f$ by estimating a constant term for each firm; i.e. $\xi_f$ will be an parameter estimated using firm dummies. As firms set price nationally, this eliminates any potential for positive bias on the price parameter.

Second stage of budgeting. The second stage budgeting model is a two-good system, so we only need to estimate one budget share equation to obtain all the relevant parameters. The budget share for milk (8) is specified as follows:

$$w_{int} = a_m + \Delta a_{im} + \Delta a_f + c_{mm} (\ln p_{fmt} - \ln p_{fnt}) + b_k \ln \left( \frac{g_i}{P_{if}} \right) + e_{int} (15)$$

where $m$ indicates milk, $\Delta a_{im}$ is a fixed individual-specific disturbance to $a_{im}$ reflecting heterogeneity in taste for milk, and $e_{int}$ is an error term. We allow a disturbance $\Delta a_f$ determined by the firm which reflects prominence given to milk etc. We estimate using within-groups. As the shopping budget $g_i$ may be correlated with disturbances to milk demand we instrument $g_i$ using the following household attributes: number of adults, number of children, social class, car ownership, and Christmas. (If the analysis is for primary shopping we add the proportion of the shopping periods in which the household is a two-stop shopper). In some periods some consumers do not buy
any milk: these observations are simply dropped from the regression. (We also ran alternative specifications based on the Tobit model but this made a negligible difference to estimates). Following the practice in the literature we use the Stone Price index $P_{if} = w_m \ln p_{fm} + (1 - w_m) \ln p_{fn}$ for the term $P_{if}$ in (15) using non-time-varying household-specific expenditure-share weights computed using the entire period’s primary shopping for the household.

**First Stage of Budgeting.** We estimate the parameters of the first stage utility function (9) in two states. First, we estimate the equation (10) as follows:

$$g_{ijt} = \alpha + \Delta \alpha_i + \alpha_1 \ln P_{ift} + \alpha X + \alpha_2 Q_{xt} + \gamma y_i + \eta_{it}$$  \hspace{1cm} (16)

where $\Delta \alpha_i$ is a fixed effect representing the individual’s taste for groceries, $Q_{xt}$ is a season dummy (for the final quarter of the year, to allow for Christmas), and $\eta_{it}$ is a disturbance for individual $i$ in period $t$. $\eta_{it}$ is a mean-zero time-specific unobservable disturbance that is assumed not to influence the choice of store (hence its absence from (9)); e.g. $\eta_{it}$ may represent something specific to the shopping period not known to or considered by consumer when he chooses $j$. We estimate using within-groups. $P_{ft} = w_m \ln p_{fm} + (1 - w_m) \ln p_{fn}$ is a Stone price index for firm $f$ at time $t$ constructed in the same way as described for equation (15). We do not observe $y_i$ so we cannot estimate $\gamma$ at this stage and simply include this in the fixed effect.

**First Stage Choice Probability** We now estimate the remaining parameters in the utility function (12). Plugging the fitted value $\hat{g}_{ijt}$ and the estimated $\hat{\alpha}_1$ from the estimation of equation (16) into (12) we obtain:

$$u_{ijt} = \left( \frac{\hat{\alpha}_1}{\gamma} + \hat{g}_{ijt} \right) \exp \left( -\gamma \ln P_{jt} + \lambda y_i \right) + x_j \beta_i + \xi_f + \varepsilon_{ijt}.$$  \hspace{1cm} (17)

Thus the remaining parameters to estimate are $\gamma$, $\lambda$, $\xi_f$. We do not observe income $y_i$ so to estimate $\lambda$ we use as proxy the household’s mean weekly grocery expenditure divided by the number of people in the household (which we expect has a positive monotonic relationship with $y_i$). The choice set $J$ is assumed to be the nearest 30 stores but a small number of stores are chosen outside the nearest 30; as the number is negligible we remove these observations from the sample. Estimation is by maximum likelihood.\(^5\)

---

\(^5\)To speed up estimation time we estimate the MNL choice probability (13) on a random subset of 8 of the 30 alternatives as proposed by McFadden (1978).
7 Results and Analysis of Market Power

In this section we present the estimated parameters and compute the markups over marginal costs implied by non-cooperative price setting behaviour among the firms in the industry.

<table>
<thead>
<tr>
<th>Table 9a: Summary statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary Shopping</strong></td>
</tr>
<tr>
<td>( w_{milk} ) &amp; Mean 0.054 &amp; S.Dev. 0.042 &amp; Max 0.693 &amp; Min 0.001</td>
</tr>
<tr>
<td>( \log(p_{milk}/p_{oth}) ) &amp; Mean 0.059 &amp; S.Dev. 0.093 &amp; Max 0.502 &amp; Min -0.524</td>
</tr>
<tr>
<td>( \log(g_i/P) ) &amp; Mean 3.896 &amp; S.Dev. 0.343 &amp; Max 5.209 &amp; Min 2.568</td>
</tr>
<tr>
<td><strong>Secondary Shopping</strong></td>
</tr>
<tr>
<td>( w_{milk} ) &amp; Mean 0.082 &amp; S.Dev. 0.071 &amp; Max 1.000 &amp; Min 0.003</td>
</tr>
<tr>
<td>( \log(p_{milk}/p_{oth}) ) &amp; Mean 0.060 &amp; S.Dev. 0.110 &amp; Max 0.502 &amp; Min -0.524</td>
</tr>
<tr>
<td>( \log(g_i/P) ) &amp; Mean 3.426 &amp; S.Dev. 0.340 &amp; Max 4.937 &amp; Min 2.187</td>
</tr>
</tbody>
</table>

Table 9a gives summary statistics for the second stage budgeting model where the consumer chooses between milk and ‘other’ conditional on the store and budget allocated in the first stage. As this is a two-good model we need only estimate one budget share equation—namely equation (15)—and the parameters of the whole subutility function are available by the standard adding-up and symmetry restrictions implied by consumer theory. As budget \( g_i \) is chosen by the consumer it is endogenous and may be correlated with unobserved error, so we instrument for \( g_i \) using exogenous observable consumer attributes including social class, household size, and car ownership. We run the model first for primary shopping then for secondary shopping, dropping those observations where the shoppers do not buy a positive amount of milk. The estimated parameters are in Table 9b for two specifications: (i) “TSLS” a simple Two Stage Least Squares instrumental Variables specification and (ii) “Panel TSLS” where in addition there are fixed effects for firms and households to allow for unobservable differences that may be correlated with relative price. The primary and secondary parameters are similar for each specification. The inclusion of fixed effects and firm dummies reduces the magnitude of the price and income parameters. The smaller number of ob-

24
servations for secondary shopping is because there are many shoppers who
do not make a significant secondary shopping trip in any shopping period.

Table 9b: Estimates from Second-Stage Budgeting

<table>
<thead>
<tr>
<th></th>
<th>TSLS</th>
<th>Panel TSLS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate</td>
<td>Std. Error</td>
</tr>
<tr>
<td>Primary Shopping</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \log(p_{mlk}/p_{oth}) )</td>
<td>0.055</td>
<td>0.001</td>
</tr>
<tr>
<td>( \log(g_i/P) )</td>
<td>-0.017</td>
<td>0.001</td>
</tr>
<tr>
<td>Constant</td>
<td>0.118</td>
<td>0.002</td>
</tr>
<tr>
<td>firm dummies</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>fixed effects</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations=156340 Time periods=78</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

|                         |          |            |          |            |
| Secondary Shopping      |          |            |          |            |
| \( \log(p_{mlk}/p_{oth}) \) | 0.0818  | 0.003      | 0.020    | 0.005      |
| \( \log(g_i/P) \)       | -0.026  | 0.001      | 0.015    | 0.009      |
| Constant                | 0.166   | 0.004      | 0.022    | 0.031      |
| firm dummies            | No      | Yes        |
| fixed effects           | No      | Yes        |
| Observations=40735 Time periods=78 |

The implications of the estimated parameters for second-stage price elas-
ticities are given in Table 10. These are \textit{uncompensated} elasticities in
the sense that the grocery budget \( g_i \) is held constant. The uncompensated price
elasticity for milk is approximately \(-0.6\) and for other is approximately \(-1\).
These results are unsurprising as we know from other studies that milk de-
mand is relatively price-inelastic. As these elasticities condition on total
budget \( g_i \) and store choice \( j \)—as determined in the first stage choice model—
-they cannot be used on their own to analyze the firm’s pricing incentives.
To analyze these incentives we require to combine these with estimates from
the first stage in the consumer’s problem.
Table 10: Second Stage Choice Elasticities

(Conditional on Total Budget and Store)

<table>
<thead>
<tr>
<th></th>
<th>Primary</th>
<th>Secondary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>-0.60</td>
<td>-0.55</td>
</tr>
<tr>
<td>Other</td>
<td>-0.99</td>
<td>-0.98.</td>
</tr>
</tbody>
</table>

The first-stage choice model is estimated in two steps: (i) the expenditure equation (16) is estimated using linear regression and (ii) the remaining parameters in (17) are estimated by maximum likelihood using the choice probability expression (13).

Summary statistics for step (i) are given in Table 11a, showing that the mean total biweek expenditure in the primary shopping store is £54.34 (with considerable variation across observations). Average household size is 2.17 adults and 0.668 children. Secondary shopping expenditures are smaller—which follows by definition—and the household characteristics differ slightly from primary shoppers because secondary shoppers are a subset of primary shoppers. The parameters from the expenditure equation are presented in Table 11b for primary and secondary shopping.

Table 11a: Summary statistics

<table>
<thead>
<tr>
<th>Grocery Expenditure</th>
<th>Mean</th>
<th>S.Dev.</th>
<th>Max</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Shopping</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$g_{it}$</td>
<td>54.34</td>
<td>28.290</td>
<td>488.40</td>
<td>20.01</td>
</tr>
<tr>
<td>$lnP$</td>
<td>0.008</td>
<td>0.130</td>
<td>0.679</td>
<td>-0.516</td>
</tr>
<tr>
<td>#adults</td>
<td>2.179</td>
<td>0.843</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>#children</td>
<td>0.668</td>
<td>1.001</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>#cars</td>
<td>1.330</td>
<td>0.812</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Secondary Shopping</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$g_{it}$</td>
<td>23.689</td>
<td>11.706</td>
<td>168.32</td>
<td>10</td>
</tr>
<tr>
<td>$lnP$</td>
<td>0.010</td>
<td>0.192</td>
<td>0.679</td>
<td>-0.516</td>
</tr>
<tr>
<td>#adults</td>
<td>2.272</td>
<td>0.863</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>#children</td>
<td>0.678</td>
<td>1.018</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>#cars</td>
<td>1.36</td>
<td>0.807</td>
<td>7</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 11b: First Stage Expenditure Equation

<table>
<thead>
<tr>
<th></th>
<th>Primary Spending</th>
<th>Secondary Spending</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>35.758</td>
<td>4.263</td>
</tr>
<tr>
<td>$\ln P_f$</td>
<td>10.866</td>
<td>0.558</td>
</tr>
<tr>
<td>$Q_4$</td>
<td>3.392</td>
<td>0.143</td>
</tr>
<tr>
<td>#Adults</td>
<td>6.105</td>
<td>0.372</td>
</tr>
<tr>
<td>#Children</td>
<td>3.788</td>
<td>0.285</td>
</tr>
<tr>
<td>#Cars</td>
<td>2.966</td>
<td>0.387</td>
</tr>
<tr>
<td># Obs=200630</td>
<td>#Obs=77156</td>
<td></td>
</tr>
<tr>
<td>Between R$^2$</td>
<td>0.170</td>
<td>0.135</td>
</tr>
<tr>
<td>Overall R$^2$</td>
<td>0.085</td>
<td>0.044</td>
</tr>
</tbody>
</table>

Implied Price Elasticity at Mean Expenditure and Price

<table>
<thead>
<tr>
<th></th>
<th>Primary Shopping</th>
<th>Secondary Shopping</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.798</td>
<td>0.988</td>
</tr>
</tbody>
</table>

The parameter on the price variable $\ln P_f$ determines the elasticity of demand for groceries with respect to basket price $P_f$, holding constant the consumer’s choice of store. To get a feel for the implications of the estimates, the bottom row of the table reports the mean implied consumer-level demand elasticities. These are $-0.80$ for primary shopping demand and $-0.99$ for secondary demand. (These elasticities are computed to give the effect of price on quantity rather than expenditure). These magnitudes correspond approximately to the elasticity of demand for food estimated in existing demand studies such as Blundell et al (1993).

The above elasticities measure the effect of a change in price holding store choice constant. As noted in section 3, to measure pricing incentives we must also have the elasticity of store choice with respect to the basket price $P_f$. To obtain this we require the remaining parameters in the store choice model; i.e. we require the parameters in (17). These are estimated maximum likelihood using the choice probability expression in (13). The estimated parameters are reported in Table 12 for primary shopping and Table 13 for secondary shopping.

For primary shopping store size is a positive characteristic, store distance is negative, but car ownership reduces transport costs, while firm dummies are all significant. The signs of these parameters make sense intuitively. For
secondary shopping store size is less important, distance is less important, and car ownership is insignificant—possibly because households are less likely to undertake a trip for the sole purpose of secondary shopping (i.e. because households are more likely to undertake secondary shopping while on other business).

<table>
<thead>
<tr>
<th>Table 12: First Stage Choice Model (Primary Shopping)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimates: Taste Parameters</td>
</tr>
<tr>
<td>Units</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>$\gamma$</td>
</tr>
<tr>
<td>$\lambda$</td>
</tr>
<tr>
<td>Store size</td>
</tr>
<tr>
<td>Distance from $i$</td>
</tr>
<tr>
<td>Distance$\times$car</td>
</tr>
<tr>
<td>Firm dummies</td>
</tr>
<tr>
<td>Time periods</td>
</tr>
<tr>
<td>Households</td>
</tr>
<tr>
<td>#Observations</td>
</tr>
<tr>
<td>LLF</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 13: First Stage Choice Model (Secondary Shopping)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimates: Taste Parameters</td>
</tr>
<tr>
<td>Units</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>$\mu_1$</td>
</tr>
<tr>
<td>$\mu_2$</td>
</tr>
<tr>
<td>Store size</td>
</tr>
<tr>
<td>Distance from $i$</td>
</tr>
<tr>
<td>Distance$\times$car</td>
</tr>
<tr>
<td>Firm dummies</td>
</tr>
<tr>
<td>Time periods</td>
</tr>
<tr>
<td>Households</td>
</tr>
<tr>
<td>#Observations</td>
</tr>
<tr>
<td>LLF</td>
</tr>
</tbody>
</table>
At this stage all the parameters are estimated and we can now analyse their implications for the market power of the supermarkets when setting the price of milk. We do this first by looking at the implied price elasticities, and then by using the demand system to compute the markups that they imply firms would set over marginal cost if pricing noncooperatively.

In Table 14 we present the implied elasticities. Importantly these elasticities are at the level of the individual *firm* and *product*, i.e. they give the effect of a firm’s price of a product on the firm’s total quantity of a product, where there are two products, milk and ‘other’. Rather than presenting these firm-by-firm we present an average across all firms listed in Table 3 in Section 2. Thus they are interpreted as the price elasticity faced by an average supermarket firm. The first two columns present the figures considering primary shopper demand functions only; i.e. these are the elasticities if secondary shoppers were ignored. The remaining two columns give average elasticities for the full set of shoppers, primary and secondary. As there are two products, the elasticities are presented in $2 \times 2$ matrices.

<table>
<thead>
<tr>
<th>Table 14: Elasticity Estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Implied Demand Elasticities:</strong></td>
</tr>
<tr>
<td>Elasticity of column Q w.r.t. row P</td>
</tr>
<tr>
<td>Primary Customers</td>
</tr>
<tr>
<td><strong>Other</strong></td>
</tr>
<tr>
<td>A: Holding Store Choices Constant</td>
</tr>
<tr>
<td><em>Other</em></td>
</tr>
<tr>
<td><em>Milk</em></td>
</tr>
<tr>
<td>B: Letting Store Choices Change</td>
</tr>
<tr>
<td><em>Other</em></td>
</tr>
<tr>
<td><em>Milk</em></td>
</tr>
</tbody>
</table>

In Panel A we present price elasticities *holding store choices constant*: this elasticity allows the consumer to adjust $g_i$ in response to the price change or substitute from milk to ‘other’ but not to choose a new store. The own price elasticities of the two products are about -0.8 for ‘other’ and -0.7 for milk (and adding secondary shoppers has only a small effect).

Panel B shows the elasticities allowing consumers to respond by changing stores. These as expected are much higher. An increase in the price of all
non-milk products—i.e. an increase in the price of ‘other’—has a significant
effect on demand for both commodities: the own price elasticity of ‘other’ is
-2.8 and the cross price effect on milk is about -2. That is unsurprising given
that ‘other’ typically represents more than 90% of the value of a consumer’s
purchases. The cross elasticity between the two products is very large and
shows the effect of overall basket price on the demand for all products at the
store. The two demand elasticities with respect to milk—in the bottom row
of panel B—are much lower because of the small share that milk takes of a
consumer’s basket. Again, the addition of the secondary shoppers has little
effect to these elasticities.

The own-price elasticity of demand for milk is given in the bottom-right
box, the figure is -0.78 for primary shoppers and -0.75 when all shoppers are
considered. This is an inelastic demand (i.e. it has magnitude less than -1).
In conventional analysis with a firm selling a single product, a price elasticity
smaller than -1 would be considered inconsistent with profit-maximization,
because both an increase in revenue and a fall in total cost can be achieved
by raising the price. However the firm here is a supermarket selling other
products (the other products than milk summarised in the ‘other’ commod-
ity) and consumers combine their purchases of milk with purchases of these
other products. Table 14 shows that milk and ‘other’ have substantial nega-
tive cross-price elasticities (see the off diagonal terms). Thus an increase in
the price of milk reduces demand for other goods at the same store, making
the own-price elasticity consistent with profit maximization.

We now turn to the implications of these elasticities for the market power
of the largest four supermarket firms. We use the price setting model in
section 3 to compute the price-cost margins, i.e. the value \((p - mc) / p\) for
both milk and the ‘other’ commodity, where \(mc\) is the marginal cost faced by
the supermarket firm. Recall that the model set out in that section assumes
non-cooperative Nash equilibrium. We do not know whether this model of
price setting is correct; for example the firms may engage in cooperative
pricing (which would result in higher markups). Thus the markups should
be seen as a measure of the market power that is available even in the absence
of coordination. Positive markups are possible in that setting provided the
elasticity is not too high; the higher the elasticity the lower is the equilibrium
non-cooperative markup. In the supermarket industry elasticities may not
be very high for a number of reasons including the fact that a consumer in a
given area often has a limited number of stores to choose between and these
stores are imperfect substitutes.
Table 15 reports the markups that our elasticities imply. We present a number of alternative ways of computing the markups. As before we compute the equilibrium markups that would be obtained if the firms considered only their primary shoppers. These are given in columns 1-3. We then compute the markups obtained assuming that the firm considers all its shoppers; these are given in columns 4-6. We decompose the results in this way mainly as a check that secondary shoppers are not having an unreasonable effect on the markups. As the table indicates, the secondary shoppers have at most only a small effect.

For primary shoppers (and for all shoppers) we present three columns: (i) Common is the markup obtained assuming that the firm opts to constrain itself by setting common markups for both products; (ii) Milk is the optimal markup for Milk assuming that the firm is not setting common markups; and (iii) Other is the optimal markup on the ‘other commodity. The reason for including (i) is to allow an alternative model of price setting and also because it does not require use of the elasticity parameters estimated for the second stage of budgeting and is therefore robust to changes in these parameters.

We present five rows. The first, ‘All Firms’ gives the average markup across all firms (not just the big four) and the remaining rows present firm-specific results.

We see a markup of about 36% for milk across the industry. The remaining four rows show markups by firm. There are small variations between firms. The markups on milk for Tesco and Sainsbury (about 37%) are a little higher than average; in the case of Tesco this is because of its greater market share and in the case of Sainsbury this is because of the higher income (and lower price sensitivity) of its customers. The markups for ASDA and Morrison are slightly lower than average (at about 33%), mainly because these firms tend to have lower income shoppers, who tend to be more price sensitive. (Recall that our demand model allows price sensitivity to vary across consumers depending on an income proxy).
We now compare these figures with the figures in section 2. In table 6 of that section it is reported that the retail markup over wholesale price is 31%. Thus our estimates provide a similar level of markup to this. Thus, if the elasticities estimated in this paper are correct, the markups over wholesale price are roughly consistent with noncooperative price setting.

It is important to note that the theoretical markups derived above may not relate to markups over *wholesale* price (as presented in Table 6 of 2). The cost concept in the above markups are the marginal cost against which the retail price is optimised. This may in fact be lower than the wholesale price of milk if the retailers and manufacturers were negotiating to an optimal joint profit outcome; in this case the relevant marginal cost concept is *industry* marginal cost.

Summarising, we have estimated elasticities that imply markups on milk that approximate to the markups observed in the industry, whether these markups are defined relative to industry marginal cost or to wholesale price. The estimates suggest that this market can support are relatively high non-cooperative markups; i.e. firms with markups of about 30% do not have unilateral incentives to cut prices.

### 8 Conclusion

*Interpretation of the Results* This paper estimates a demand system for milk which is specified at the level of the retail firm and the level of the individual product, allowing retail incentives to be analyzed. The responsiveness of consumers to price differences between stores is estimated using a panel survey of consumer choices. The consumer’s choice of store is assumed to depend
on the price of the consumer’s overall basket, as well as other variables such as distance to store and store size.

The markup between retail price and wholesale price in 2005 was computed to be around 30% by the Milk Development Council. The demand system that we have estimated predicts non-cooperative (one-period Nash equilibrium) markups for milk that are close to this figure. If the estimates are correct this implies the firms have no unilateral incentive to deviate from the markups that are observed; i.e. they are a static equilibrium.

In principle it is possible to attempt to use the estimates and the assumption of single-shot Nash prices to determine which concept of marginal cost the retailers are optimising against: the wholesale price versus the industry marginal cost. We do not attempt to do this for two main reasons: (i) the marginal cost concepts are within a few pence of each other and (ii) the assumption of Nash pricing is only one of a number of possible assumptions with alternatives including dynamic pricing.

A note is in order on the long term upward trend in retail milk markups observed in Table 6 of 2. One possible explanation for this is that consumers have become less price elastic over time, resulting in higher equilibrium markups on price. Another possibility is that firms have been slow to raise prices towards the equilibrium because of marketing advantages of setting identical prices on a given pack-size of milk. A further possibility is that equilibrium prices were lower in earlier years because of the presence of the milkman as a significant presence in the milk market; as the milkman diminished in importance so the optimal price for supermarkets may have increased.

Caveats A caveat that must be kept in mind is the that demand estimation required a number of simplifying assumptions to be made. One of these is that consumers are one-stop shoppers and never contemplate splitting their purchases across different sellers to minimize expenditure; e.g. we rule out a consumer buying all their non-milk groceries from one store and then all their milk separately from another store in an attempt to achieve a saving on milk. While this kind of behaviour may happen to a small extent, the data suggests it is relatively unimportant. A second and related point is that we have treated primary and secondary shopping as independent, when it may in fact be the case that a two-stop shopper allocates expenditure between the two stores depending on the prices in the two stores. Given the relatively small share that secondary shopping makes of overall shopping, we believe this is unlikely to have a major effect. A third caveat is that there
are alternative ways to construct the price indices. Some methods result in greater price differences between firms than others, which has implications for the price elasticities estimated in the model.

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Chapter 3: Upstream Competition and Downstream Buyer Power

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Upstream Competition and Downstream Buyer Power

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Abstract

This paper presents a model of buyer power where sellers compete to supply a homogenous product. The model is motivated by a case study that highlights an important consequence of upstream competition: when negotiating with any buyer the supplier is uncertain how successful it will be with other buyers. In this setting we find a new source of buyer power when supplier cost functions are nonlinear: the event of negotiation with a large buyer increases the seller’s expected output, which changes the expected average costs of supplying the buyer. This increases the power of a large buyer when the seller’s cost function has increasing returns to scale. We use this framework to analyze the pricing and welfare consequences of changes to market structure upstream and downstream. If the average incremental costs are convex then we find that an increase in the relative size of the largest upstream firms can cause the input prices to all other downstream buyers to rise (i.e. there is a waterbed effect). We also analyze investment consequences of buyer power. We show that upstream suppliers respond to buyer power by selecting technologies with increasing returns to scale, which disadvantage smaller buyers and benefit larger buyers.

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

JEL numbers: L13, L42, L66

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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’.\footnote{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).} This literature seeks to understand how bargaining between two levels of the supply chain will be resolved and how it impacts on final consumers and investment incentives. Understanding this 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. Much of the interest in buyer power has been motivated by increases in retail concentration and the possible consequences for suppliers and investment incentives. These concerns have risen in several economies, with the emergence of large retail firms such as Wal-Mart, Carrefour, and Tesco.

Most of the buyer power literature with a bargaining interface assumes a monopoly supplier. However in practice it is very common for buyers to have a choice of alternative suppliers. This can make it difficult for any given supplier to predict how many contracts it will win. We present case study evidence showing that competition between suppliers generates uncertainty of exactly this type. This paper allows for these realities. We present a model of buyer-seller bargaining where upstream competition implies that each supplier is uncertain, at the time of negotiation with any buyer, how successful it will be with other buyers. We make three contributions in this setting. First, we identify a new source of buyer power. Second, we show how changes to upstream and downstream concentration influence the prices paid by large and small buyers. In particular, we show that an increase in the size and buyer power of the largest buyer can influence the prices negotiated by smaller buyers. Third, we analyze the effect of buyer power on upstream investment incentives. In each of these contributions our results differ from the existing literature, developed in the absence of supplier uncertainty.

We consider buyers that bargain with symmetric suppliers for a homogenous input good. Each buyer wants to be supplied by just a single supplier and picks one at random. If negotiations fail with this supplier the buyer switches negotiations for all output to an alternative seller. The buyer is then placed in a weaker position as there are fewer suppliers remaining in the event of further disagreement. This continues to a third supplier if negotiations break down with the second, and so on, until there are no suppliers left and the buyer must source from a high price outside option, e.g. a different geographical region. This approach allows us to capture in a tractable static model the uncertainty facing suppliers. We believe it is a good description of the scenario facing buyers should negotiations fail with any supplier; a scenario which hands the
supplier at least some bargaining power.

In the absence of upstream competition the supplier knows with certainty that all buyers will have to source from it, which leads to the prediction that, with upstream economies of scale, large buyers will be disadvantaged and pay a price premium. The introduction of upstream competition in our paper reverses this prediction: with upstream economies of scale large buyers now receive a lower transfer price. The reason is that upstream competition introduces uncertainty, at the time of negotiation with any buyer, about the number of other contracts the supplier will ultimately win, and therefore the total output it will supply. Agreeing a deal with a large buyer is a stronger signal that final volumes will be high than agreeing a deal with a small buyer. Therefore, if there are economies of scale, the expected average incremental cost of supplying the buyer is lower if the buyer is large, so large buyers receive better terms. Identifying this mechanism is the first contribution of this paper.

The specification of the model is motivated by a number of interviews with executives in the UK liquid milk supply chain, representing supermarkets (buyers) and processors (sellers). A short case study of this supply chain is offered in Section 2. The interviews highlight the importance of output uncertainty facing suppliers, who cannot estimate precisely how many contracts they will win.

We emphasize however that the model we offer is not specific to liquid milk but instead is likely to find a wide range of applications. One important class of applications is supermarket procurement of any product where there are competing potential suppliers, such as fresh produce such as fruit and vegetables, and private label products. For example, a recent investigation by the Competition Commission noted that the market to supply private label Carbonated Soft Drinks to supermarkets was characterized by competition between suppliers, supplier dependency on retailers for output, and frequent retendering by retailers. They highlight the output uncertainty for the supplier: “The loss of an individual supply agreement with a retailer can have a significant impact on the supplier’s overall financial performance. For example, in 2005 Macaw’s CSD volumes decreased by just over 10 per cent as a result of losing a major supply agreement” (paragraph 5.30).

Other examples outside the supermarket sector include the supply of salt to trade buyers (from catering firms to pharmaceuticals), the supply of a standard mechanical component in the automotive supply chain, and the supply of business services.

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2 The reason for this is that a large buyer bargains over relatively more of the monopoly supplier’s final units. Thus, if there are economies of scale the average cost of supplying the buyer is relatively larger (as the supplier’s total cost function is concave) than that for a small buyer. This effect can be seen in Chipty and Snyder (1999) and Inderst and Wey (forthcoming).


4 In the business services example, a recent report on systems integration services noted that buyers such as
Having identified the source of buyer power we turn to the second main contribution of our paper: an analysis of how changes in concentration affect the terms obtained by downstream buyers. We consider both upstream and downstream concentration.

The consequences of downstream concentration have been considered by many competition authorities, including the UK’s Competition Commission. One of the main issues is the effect of a large buyer on the prices negotiated by small buyers. Most of the attention has been given to the case where the effect is upward, an outcome commonly known as a waterbed effect. However we show that a downward effect is possible. To distinguish these two alternatives we call the first outcome a standard waterbed effect and the second an inverse waterbed effect. There has been relatively little theoretical work explaining why the presence of large buyers should affect the prices negotiated by small buyers. Some recent work with an upstream monopoly has given support for a standard waterbed effect, which derives from downstream competition effects. Our paper is the first to show that waterbeds can (i) derive from upstream competition and (ii) 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 leads to a characterization of waterbed effects, both when they exist and the direction they operate. 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 overall. For an individual seller, the acquisition causes a mean preserving spread of the quantities the supplier wins—i.e. it has changed the variance but not the mean of the seller’s output. The seller’s uncertainty has increased. How does this affect another buyer? If the seller’s average incremental costs of supplying that buyer are convex in the sellers output then the extra variance raises the expected average incremental costs of the deal, so the negotiated prices increase. Thus there is a standard waterbed effect: all the other downstream firms see their bargained prices rise. By exactly the same reasoning if average incremental costs of supplying the buyer are concave in the seller’s output there is an inverse waterbed effect. We discuss the plausibility of these alternative shapes.

The results so far depend on the shape of the cost function. The third contribution of the paper is to analyze the effect of buyer power on 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 costs decreases.
cost at some local point along the cost curve is greater at the supplier’s initial units of output (as opposed to the final units). Uncertainty penalizes cost reduction at the margin because it reduces the probability that marginal units are realized. Second, we allow the supplier to select its 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 falls 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.\(^8\) In an early contribution, Chipty and Snyder (1999) show that upstream economies of scale, coupled with a monopoly upstream supplier, results in large buyers bargaining to higher transfer prices than small buyers, a result often at odds with casual empiricism and (as our model shows) not robust to the introduction of upstream competition and uncertainty.\(^9\)\(^-\)\(^10\)

Inderst and Wey (forthcoming) were the first to extend the surplus shape approach to examine investment incentives, again with an upstream monopolist. They show that buyer power can increase investment incentives at the margin of production, because bargaining for a large buyer is determined further away from the margin than for a small buyer (so large buyers appropriate a lower proportion of a cost reduction at the margin). As we have just noted competition diminishes this effect because it reduces the probability that marginal units are realized.

Supplier competition where uncertainty is absent has been studied in Inderst and Wey (2003) and de Fontenay and Gans (2005). In both these models (as in ours) suppliers bargain with downstream firms in a manner that splits the gains from the relationship. However, the agreed payments are based on Shapley values, which implies that no supplier is a loser. This implication may be realistic in cases where the upstream firms are all highly differentiated, so that all downstream firms would like to source input separately from each of the upstream firms. However, it is unrealistic if upstream firms are substitutable, because it requires payments to the firms that fail to supply any product.\(^11\) In our model each buyer sources from a single seller and

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\(^8\)Surplus shape effects appeared earlier in Horn and Wolinsky (1988) and Stole and Zwiebel (1996).

\(^9\)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.

\(^10\)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; however, the model is constructed such that there is a unique equilibrium allocation of demand amongst suppliers so that the effect of uncertainty in final volumes is ruled out.

\(^11\)These payments would be required to ensure that a supplier who was unsuccessful would be willing to remain
the other suppliers receive no payment. The consequence is unique in the literature: upstream
competition is combined with output uncertainty, a feature that emerged as important in our
case study.

The paper is also related to the wider literature giving alternative explanations for buyer
power, including the following:12 (i) large buyers can more credibly threaten to integrate upwards
in the supply chain (Katz (1987), Inderst (2007)); (ii) larger buyers have greater opportunity
to reduce varieties stocked and so cause hitherto differentiated suppliers to become competitors
(Inderst and Shaffer (2007)); (iii) large buyers can limit the maximum collusive transfer price
that can be sustained (Snyder (1996)); and (iv) if a seller is risk averse and cannot observe buyer
valuations but can observe buyer demand then a large buyer (being riskier than several small
buyers with iid valuations) is set a lower price by the seller (De Graba (2003)).

The rest of this paper is as follows. A case study of the liquid milk supply chain is 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—
upstream and downstream—on bargained prices and social efficiency. Sections 8 and 9 analyze
upstream investment incentives. Some discussion of model extensions is provided in Section 10,
and Section 11 concludes.

2 Case Study: Bargaining in the UK Liquid Milk Supply Chain13

To inform our analysis of the supplier-supermarket bargaining interface, with competitive up-
stream sellers, we conducted interviews with a number of buying managers at major UK super-
markets and a number of sales directors at UK milk suppliers. This section reports the findings,
which motivate the modeling choices which follow. Readers may skip straight to the model in
the next section without affecting their understanding of the rest of this paper.

The UK milk supply chain provides a good example of upstream competition. The product is
homogeneous to consumers14 and there are three main competing suppliers (processors), Arla,
Dairy Crest and Wiseman.15 The buyers are the four dominant supermarkets—ASDA/Wal-
Mart, Morrison, Sainsbury, and Tesco—and some other much smaller supermarkets. The in-

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12 A detailed overview of the current theories can be found in Inderst and Shaffer (2006).
13 We would like to thank all the industry executives who allowed us to interview them and released the facts
which we report below.
14 Supermarkets receive their liquid milk prepackaged with the supermarket’s own branding so that consumers
do not differentiate between suppliers. Organic milk is considered a different market and is supplied by a different
supply chain.
15 In October 2006 one industry source estimated that the total market share of these suppliers to the super-
markets was 91% with market shares of 39% for Arla, 33% for Wiseman and 19% for Dairy Crest.
equality in the size of the buyers allows scope for buyer power effects.\textsuperscript{16}

\textit{The Supermarket - Supplier Interface}

To terminate a contract it is standard for the suppliers to require only three months’ notice from a supermarket. Supermarkets regularly initiate new negotiation rounds, contacting the potential processors to ask for indicative bids. One supplier reported being told unexpectedly by one of the supermarkets it was supplying:

“...the chips are all up in the air, tell us how you would like them to come down.”

On receiving invitations to tender, the suppliers claimed to assess the chances that other supermarkets would also re-tender. The supplier tries to estimate medium term volume demands and makes an indicative price per liter bid.

Once the indicative bids are in, a supermarket chooses a supplier and negotiates more fully on the volumes required, packaging, logistics, etc. The price is then set in a further round of bargaining. One supplier noted that this bargaining happens in an iterative fashion:

“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.”

This picture from the industry interviews is consistent with published sources. The KPMG (2003) report into the dairy supply chain notes that:

“The trigger [for negotiations] is usually an invitation to tender by the supermarket or a periodic supplier review programme... 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).

This behavior by supermarkets generates considerable output uncertainty for suppliers, as noted in the Competition Commission (2003) merger investigation:

“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

\textsuperscript{16}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.
parties told us that the national multiples were fully aware of this fact and play off the major processors against each other. [The national retailers] 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)

Table 1 shows the variability of individual processor sales to the large four supermarkets, mainly caused by supermarkets switching 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.

Finally, we note a recent trend in upstream investment. Processors have chosen to build a number of large plants, characterized by greater economies of scale than the smaller dairies they replaced.\footnote{17These plants are capable of processing over 300 million liters of milk per annum. Wiseman have built large dairies in Glasgow, Manchester and Droitwich, Arla in Leeds and London, and Dairy Crest in London and Gloucester.} Section 9 offers one explanation why suppliers might have switched to this technology in the presence of increasing buyer power. Note also that the building of these large dairies was initiated by Wiseman but quickly copied by other firms, justifying our use of anticipatory equilibrium in Section 8 and 9.

Summary
Our model draws on the following insights from the interviews:

1. Supermarkets unilaterally start new procurement rounds at unpredictable points in time.
2. Suppliers face uncertainty regarding tender successes and consider this when bidding for new contracts.
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 with one less potential supplier in the current procurement exercise.

3 The Model
This section proposes a model of upstream-downstream bargaining. Although the model is motivated by the case study 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. The bargaining model itself has been designed to explore how 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.

3.1 Industry Configuration
Suppose 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 $C(q) : [0, Q] \rightarrow \mathbb{R}_+$ 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 $Q$.\footnote{The buyer power result we propose is robust to some capacity limitations as long as they are not too binding. We discuss further in Section 5.}

We assume that upstream firms do not coordinate to minimize joint costs of production. Thus where costs are convex buyers do not coordinate to achieve marginal cost equalization
across firms; and where costs are concave buyers do not coordinate to allocate all production to
a single firm.

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
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 high-
light the role that output uncertainty plays in the bargaining stance of each size of downstream
firm. 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
are then $(C(q + x) - C(q))/x$.

3.2 The Bargaining Model

Before discussing 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 $\kappa$ 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.
Each downstream firm ultimately 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. In addition the buyer will only make payments to the winning supplier, i.e. we rule out side payments to other potential suppliers.\textsuperscript{19}

We assume the \( U \) upstream firms are symmetric. Each buyer randomizes to determine the order to negotiate with the upstream firms. As the suppliers are identical the ordering will be irrelevant. A 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).\textsuperscript{20} That is, the two parties make alternating offers and after each offer there exists a small exogenous probability \( \varepsilon \) that the bargaining breaks down.

As Binmore et al (1986) show the solution to this bargaining session is that the parties evenly split the joint surplus from the relationship relative to their respective alternatives when bargaining breaks down.\textsuperscript{21} 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) \( \kappa \).

The overall solution to the game is built up by iteration through the the \( U \) upstream firms in the buyer’s ordering and the buyer’s ultimate outside option of \( \kappa \) per unit.\textsuperscript{22}

This overall solution is given by an equal split between buyer and seller 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. Thus we capture the idea that should

\textsuperscript{19}This assumption is violated by other current approaches to studying the bargaining interface which extend Shapley value type results. See the further discussion in the Introduction.

\textsuperscript{20}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.

\textsuperscript{21}The 50-50 rule is not essential however. Had the probabilities of breakdown been \( \varepsilon_U \) when an upstream firm proposes and \( \varepsilon_D \) otherwise the split of the gains from trade above the outside options would be split according to the ratio of \( \varepsilon_U \) to \( \varepsilon_D \).

\textsuperscript{22}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.
negotiations with $U_1$ break down the downstream firm will be able to go to $U_2$ and derive a known surplus, thus 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.

The $D$ negotiations between the downstream buyers and their suppliers happen simultaneously and with no communication between a seller’s different sales representatives. 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 simultaneously with no communication between hotels. Thus each upstream firm’s sales representative is ignorant of how well his firm’s negotiations are progressing with other buyers. This way the bargaining game is kept independent of the order in which buyers bargain, which facilitates the analysis of the effects of uncertainty.

**Assumption of Simultaneous and Independent Bargaining**

The assumption of simultaneous bargaining between buyers and the seller(s) has been used widely in the literature with a single upstream firm (e.g. Dobson and Waterson (1997), Inderst and Wey (forthcoming)). In our model there is more than one upstream firm and each upstream firm bargains with each downstream buyer without knowing the outcome of bargaining with the other downstream buyers. Thus the seller is uncertain of its final output at the point of negotiation 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 $\{q_1, q_2, \ldots, q_D\}$, and the shape of the cost function). This assumption of simultaneous bargaining is designed to capture in a static framework the essence of a dynamic bargaining game in which buyers may decide to re-tender for the business at some unpredictable points in time.

### 3.3 Solution for the Bargained Transfer Price per Unit

To allow us to analyze the effect of buyer size on buyer power, we must first establish the transfer price agreed between a given buyer and the suppliers. If downstream firm $i$ negotiates with one of $u$ possible suppliers where $u \in \{1, 2, \ldots, U\}$ then the bargaining game would result in a transfer price for the input of $t : \{1, 2, \ldots, D\} \times \{1, 2, \ldots, U\} \rightarrow \mathbb{R}_+$ denoted $t_i(u)$.

**Lemma 1** The price per unit agreed by a downstream firm of type $i$ which seeks $q_i$ units of input when it has $u$ upstream firms left to bargain with is given by

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

\[ \Delta C_i = E \left( \begin{array}{c|c} \text{total cost} & \text{win contract with type } i \\ \hline \end{array} \right) - E \left( \begin{array}{c|c} \text{total cost} & \text{lose contract with type } i \\ \hline \end{array} \right) \]

\( \Delta C_i / q_i \) is therefore the expected average incremental cost of supplying buyer \( i \). The expectation is taken over the set of volumes which the supplier might win from all other negotiations. Thus using (1) we see that the agreed price per unit exceeds the expected average incremental costs \( \Delta C_i / q_i \) by an amount which depends upon the number of suppliers and the ultimate outside option facing the downstream firm: to obtain supply at price \( \kappa \) 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. Thus consider a downstream firm of type \( i \) 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

\[ q_i t_i (n) + E (\text{payments from other negotiations}) - E \left( \begin{array}{c|c} \text{total cost} & \text{win contract with type } i \\ \hline \end{array} \right) \]

The expected profits in the event of this bargain breaking down can similarly be derived. Note that as bargaining is simultaneous, capturing the uncertainty of the environment, the expected payment from other negotiations is independent of the success or otherwise of this current negotiation. Therefore 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 (1986) bargaining game requires the gains from trade to be equal and so we have the difference equation

\[ q_i [t_i (n-1) - t_i (n)] = q_i t_i (n) - \Delta C_i, \]

where \( t_i (0) = \kappa \), whose solution is given in the lemma. ■

Equation (1) shows how the transfer price agreed varies with the suppliers’ expected average incremental costs of supplying the buyer and the number of competing suppliers. It is immediate from equation (1) that the incremental costs of \( q_i \) (as opposed to simply marginal cost) will play
an important role in the bargaining and price setting process.

4 Motivating Example

Before exploring the effect of the cost function’s shape on buyer power in a general setting we first establish the main results in a simple motivating example. Suppose that there are two downstream firms: $D_1$ wishes to buy 1 unit of the input while $D_2$ wants 2 units. Both of these firms can always buy the input at a price of $\kappa$ 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 $(C, c, c)$. Further, when negotiating with retailer $D_1$, each supplier sees its probability of winning business from $D_2$ as $\frac{1}{2}$. Therefore we have

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

The lower expected average incremental cost for $D_2$ ($\frac{\Delta C_2}{2} < \frac{\Delta C_1}{2}$) is a result of increasing returns to scale. That is, if negotiating with the smaller buyer $D_1$, 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 expected average incremental cost is $\frac{1}{2} (C + c)$. When dealing with the larger buyer $D_2$, 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 incremental cost is smaller when dealing with the large buyer, who therefore bargains a lower transfer price $t$. In fact, using (1) we have

$$t_{D_1} = \frac{\kappa}{4} + \frac{3}{8} (C + c) \quad \text{and} \quad t_{D_2} = \frac{\kappa}{4} + \frac{3}{16} (C + 3c) \quad (2)$$

which give the prices per unit each buyer pays. The larger buyer ($D_2$) enjoys buyer power as $t_{D_2} < t_{D_1} \iff c < C$. This result follows because with increasing returns to scale sellers desire large as opposed to small volumes. Obtaining the large contract carries better news about volumes and incremental costs; large buyers therefore receive a better price.
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:

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

Now the situation is reversed and the smaller buyer now enjoys buyer power with the intuition paralleling that above: with decreasing returns to scale securing the large contract is bad news about final incremental costs, so large buyers receive a worse price.

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

5 How Large Buyers Wield Buyer Power

We have noted that previous literature with bargained transfer prices and a monopoly supplier has found that increasing returns to scale hands the greatest buyer power to small buyers (e.g. Chipty and Snyder (1999), Inderst and Wey (forthcoming)), a result which sits at odds with policy discussion in many industries characterized by increasing returns to scale.

In the example in the previous section we 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

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

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 anticipated 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 seller to discount the possibility of success in the simultaneous negotiations. With this reference point and increasing returns to scale the larger buyer can be supplied at a lower 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 the likely final 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.
If negotiating with the large buyer

\[
\text{Total Cost} \quad \text{Gradient} = \text{Average Incremental Cost}
\]

\[
\Pr \frac{1}{U}: \text{other contract won}
\]

\[
\Pr \frac{U-1}{U}: \text{other contract lost}
\]

\[
q_2 \quad q_1 \quad q_1 + q_2 \quad \text{Volume won}
\]

If negotiating with the small buyer

\[
\text{Total Cost}
\]

\[
\Pr \frac{1}{U}: \text{other contract won}
\]

\[
\Pr \frac{U-1}{U}: \text{other contract lost}
\]

\[
q_2 \quad q_1 \quad q_1 + q_2 \quad \text{Volume won}
\]

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

Part 4 gives a sufficient condition for the general class of cost functions being considered. The theorem has particular relevance when \( \max \left\{ \inf C''(\cdot), \sup C''(\cdot) \right\} \) 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.

The Effects of Capacity Constraints

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We here briefly consider the effect of having upstream firms with increasing returns to scale initially but then decreasing returns to scale at high volumes, e.g., because of capacity constraints. In such settings as the total cost function is initially concave and subsequently convex, Theorem 1 does not apply. Nevertheless, the intuition underlying Theorem 1 provides a clear indication on who wields buyer power. If the probability of winning enough contracts to push a supplier on to the decreasing returns part of its cost function is low then it is given little weight in the supplier's strategic considerations and so large buyers would wield buyer power. By the same reasoning, if the probability of hitting the decreasing returns to scale part of the production function is high then large buyers would not wield buyer power as suppliers would consider large buyers very likely to push average incremental costs up.

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 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.

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 inverse or standard) 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 seller output of the average incremental cost function. 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 prices to the other buyers fall with increasing returns to scale. 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 affecting the volumes demanded by any of the other downstream buyers \( i \in \{2, 3, \ldots, D\} \). Then

1. With concave total costs (increasing returns to scale), all other buyers receive a lower 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, which hereafter we denote $I_x(q)$. This gives the average cost of producing $x$ more units from a base level of $q$ units of production:

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

Our results depend on whether this is convex or concave in the seller’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 unaffected. 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 firms (a standard waterbed effect), 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 firms (an inverse waterbed effect), for any number of competing suppliers $U \geq 2$.

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

To see the result, suppose the downstream firms become more concentrated while the total volumes demanded stay unaffected. The expected volume a supplier will win is $\frac{Q}{U}$ (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

$$I''_x = \frac{1}{2}[C''(q + x) - C''(q)] = C''(q + \tilde{x}) \quad \text{for some} \quad \tilde{x} \in [0, x] \quad \text{by a Taylor expansion. Therefore} \quad C'' \geq 0 \Rightarrow I''_x \geq 0.$$
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.

The average incremental cost

\[ I_{q_3} \]

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

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

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 \( q^{\text{equal}} \); subsequently buyer 1 acquires some of 2 so that \( q_1 > q_2 \). The graph depicts the
average incremental cost for a given supplier of serving buyer 3, \( I_{q_3} \), which is assumed convex.
The downstream acquisition doesn’t alter the probability with which the supplier will win both 1
and 2 or neither. However the volumes won if only the business of one of 1 or 2 is won undergoes
a mean preserving spread; and so the expected average incremental costs of serving buyer 3 rise.
Hence buyer 3 receives a higher transfer price as a result of the acquisition by 1 of part of 2: the
standard waterbed effect.

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

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

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

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

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

Whether a given cost structure has a convex average incremental cost is an empirical question. 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 23): then marginal costs would gradually fall to some constant level as volumes rose. In contrast for the marginal cost function to be concave \( (C'' < 0) \) one would require the unnatural condition that marginal costs collapsed at an ever increasing rate towards 0. If marginal costs (and so average costs) are convex as this reasoning would suggest, then an increase in downstream concentration would lead, by Theorem 3, to a standard waterbed effect: other retailers not involved in the concentration increase would see their input prices rise.\( ^{24} \) 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.

### 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:

\[24\text{The case of increasing returns to scale in upstream production appears, from industry interviews of the UK milk supply chain, to be the relevant one in this UK industry at least. The ability to optimize logistics and delivery is one feature which appears to contribute to these upstream increasing returns to scale.}\]
**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 differential between large and small buyers grows if the upstream firms have convex declining marginal costs (increasing returns to scale), and if \(U\) is sufficiently large.
2. The absolute transfer price differential between large and small buyers shrinks if the upstream firms have concave increasing marginal costs (decreasing returns to scale), and if $U$ is sufficiently large.

To see the intuition for this result, suppose there are upstream economies of scale and note that if supplier numbers increase then a supplier’s chances of securing any given other contract decline. In particular, when negotiating with the smaller buyer the chances of securing a given large contract are only $\frac{1}{U}$ and this falls as the number of competing suppliers increases. The supplier therefore puts more weight on lower volumes. To ascertain the magnitude of this effect for the large and small buyers we now turn to the assumption that marginal costs are convex (and so average incremental costs are convex by footnote 23). 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. 25

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 1 it reduces the chance of downstream buyers ultimately having to source at the expensive marginal cost of $\kappa$. Thus transfer prices fall towards the expected average incremental cost ($\frac{\Delta C_i}{q_i}$ in equation (1)). 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 costs so the two effects work in the same direction, and transfer prices fall as supplier numbers rise.

25 We note the discussion on page 22 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 field.
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 (forthcoming) 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 seller’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 inventive 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 seller. 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.\footnote{The milk case study of Section 2 noted the simultaneous building of large dairies by all processors as a manifestation of the reciprocal investment story outlined here.}

### 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

$$\frac{1}{2} (C + 2c) + \frac{1}{2} (2C + c) = \frac{3}{2} (C + c)$$

Hence from (2) the ex ante expected profit for each supplier is

$$E(\Pi_{\text{supplier}}) = \frac{1}{2} \left\{ tD_1 + 2tD_2 - \frac{3}{2} (C + c) \right\} = \frac{3}{8} (\kappa - C)$$

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 which the supplier’s marginal cost at the $x^{th}$ unit is lowered by some small amount $\delta$. Formally we suppose a supplier can invest in an innovation parameterized by $(x, \delta)$ with $\delta$ 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 $\bar{Q}$ is approximately equal to the marginal cost per unit at volumes $\bar{Q}$. 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 $\varepsilon$ and $\delta$ 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 $\varepsilon$ 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 $\Delta C_{\text{new}}L q_L$ 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

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

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.\footnote{A fuller exposition of this point is offered in Smith and Thanassoulis (2006, p31)}

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

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

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 $(x, \delta)$ 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. \footnote{In the interviews for the case study offered in Section 2, executives of suppliers claimed that they prioritized investment in core production facilities ahead of peak load facilities.}

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).

\section{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
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 (forthcoming) 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 sufficiently 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 $(0, \frac{1}{U})$ 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 $\kappa$ 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.

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 (7) in the proof of Theorem 6 that the profit gain from changing technology vanishes as $U$ tends to infinity, even if $q_L = 1$.

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

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29The 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 $\kappa$). 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

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.\textsuperscript{30} 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 sequential 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 to bid more aggressively for a large contract, since a large contract is a good signal of average incremental costs.

\textsuperscript{30}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 final product were over £30 million in 2005.
10.2 The Effect of Endogenous Downstream Demand

We have assumed for simplicity that the quantity demanded by each buyer is exogenous. It would be desirable to explore a relaxation of this assumption. We are considering this extension as part of ongoing work. If there is efficient bilateral bargaining, and hence no double marginalization, then our 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.

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 seller. 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 $D_1$. $A$ 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 $D_1$. Thus supplier $A$ will reason that any contracts with $\{D_2, D_3, \ldots\}$ 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 sellers competing to supply a homogeneous product to downstream buyers. With upstream competition, suppliers are likely to face uncertain output as buyers re-tender for business at unpredictable points in time.

We offered a formal analysis of this bargaining set up motivated by a case study of bargaining.
in the UK liquid milk supply chain. The model allowed us to make the following contributions.

If the suppliers’ technology has increasing returns to scale, we find that the buyer power advantage is with large downstream firms; this is the reverse of previous surplus shape buyer power results, derived under conditions of upstream monopoly, and thus output certainty. For industries with economies of scale our result is consistent with the concerns competition authorities often voice, for instance, regarding the buyer power of the largest supermarkets.

We also analyzed the effects resulting from changes in buyer and seller concentration. Here we showed that the curvature of the average incremental cost curve was an important determinant of the results. An increase in the size of the largest buyers, keeping downstream volumes constant, acts as a mean preserving spread on the volumes that any supplier expects to win. If the average incremental costs of supplying the buyer are convex then the increase in downstream concentration pushes the input prices for all the smaller buyers upwards. (That is we have a standard waterbed effect). We also explored the price and welfare effects of other types of change in upstream and downstream concentration.

We then analyzed the incentives for upstream firms to invest in innovations that reduce the marginal costs of some units of output. The introduction of supplier uncertainty diminishes the incentive to locate these innovations at the final units of output. The most desired investments are those that affect the first units of output—i.e. innovation is not focused on costs “at the margin”. This result applies regardless of the shape of the upstream cost function, i.e. whether convex or concave.

Finally, we made the shape of the cost function endogenous. We found that the presence of large buyers creates a force towards increasing upstream returns to scale, which then engenders a disparity between the transfer prices of large and small buyers.

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. salt, car parts, milk, and other private label products. However there are cases where a supplier has been able to differentiate itself to final consumers; notably Intel and silicon chips.\(^\text{31}\) 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.\(^\text{32}\) How bargaining in the supply chain adapts to the evolution of an asymmetric supply sector is an extension of this paper which is worthy of future research.

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\(^\text{31}\)For further discussion see Duguid (2006).
\(^\text{32}\)Source: http://pcpitstop.com/research/cpuintel.asp
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 seller sees of winning exactly subset $j$ from these $D - 2$ possible buyers. Let the total demand supplied by this seller when serving subset $j$ be $Q^j$. Now consider a seller negotiating with buyer $i = 1$. We have

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

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

Combining we have

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

Now we repeat for the negotiation with buyer 2 and using Lemma 1 we establish that

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

which is true if (but not only if)

$$\frac{1}{U} \left[ \frac{C(Q^j + q_1 + q_2) - C(Q^j + q_2)}{q_1} \right] + \frac{U - 1}{U} \left[ \frac{C(Q^j + q_1) - C(Q^j)}{q_1} \right] \quad (5)$$

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

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 $\frac{C(x + q) - C(x)}{q} = \ldots$
$b - aq - 2ax$ so that (5) can be rewritten

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

**Decreasing Returns to Scale (Convex Costs)**

If the total cost function is convex then we have ($II$) > ($IV$) as the chord on the cost curve between $Q^j$ and $Q^j + q$ becomes more steeply sloped as $q$ increases. Therefore the opposite inequality to (5) holds and we have $\frac{\Delta C_1}{q_1} > \frac{\Delta C_2}{q_2}$ if $U$ is sufficiently large. This implies that smaller buyers get lower 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 $C(x + q) - C(x) = b - aq - 2ax$ so that using (5) we have

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

Thus we have parts 1, 2 and 3 of the Theorem. For part 4 of the theorem suppose that costs are concave so that $C'' < 0$. In this case a sufficient condition for (5) to be true is if

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

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

$$\frac{1}{U} \int_{\tilde{Q} - q}^{\tilde{Q}} \left(-qC'' \left(\tilde{Q} - q\right) + C \left(\tilde{Q}\right) - C \left(\tilde{Q} - q\right)\right) dz > \frac{U - 1}{U} \int_{Q^j + q}^{Q^j + q_2} \left(C' \left(Q^j + q\right) - C \left(Q^j + q\right) + C \left(Q^j\right)\right) dz$$

Hence (5) holds if

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

and $q \in [q_2, q_1]$

We assumed that $C'' < 0$ and so a sufficient (but not necessary) condition for the above inequality...
to hold is
\[ \frac{U - 1}{U} \sup C'' - \frac{1}{U} \inf C'' < 0 \Rightarrow U > 1 + \frac{\inf C''}{\sup C''} \]
which gives the required condition. If costs are convex then analogous reasoning to determine
when the opposite inequality to (5) holds gives the required result. ■

Proof of Theorem 2. Using (1) we have \( \frac{\partial}{\partial q_1} t_2 (U) = \text{sign} \frac{\partial}{\partial q_1} \Delta C_2 \). Let \( W_j \) denote the winning
set drawn from the \( D-2 \) downstream buyers numbered \( \{3, 4, \ldots, D\} \). The probability of winning
\( W_j \) is denoted \( f (j) \) and would involve supplying quantity \( Q^j \). Now apply the decomposition for
\( \Delta C_2 \) found by applying (4). Noting that \( Q^j \) and \( f (j) \) are independent of \( q_1 \) we have

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

If upstream total costs are concave (increasing returns to scale) then the term in square brackets
is negative. That is with increasing returns to scale organic growth by downstream buyer 1 leads
to a lower 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 1 the transfer price is proportional
to \( \Delta C_3 / q_3 \) where \( \Delta C_3 \) is the difference in the expected costs incurred when \( q_3 \) is won versus
not. Now note that

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

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

Using the fact that \( q_1 + q_2 \) is constant by assumption we have

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

If \( I_{q_3} \) is convex then \( q_1 > q_2 \) implies that \( I'_{q_3} (Q^j + q_1) > I'_{q_3} (Q^j + q_2) \) 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

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

Using fact that \( q_1 + q_2 \) is constant by assumption we have

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

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

\[ t_2(U) - t_1(U) = \left[ 1 - \frac{1}{2U} \right] \left[ \frac{\Delta C_2}{q_2} - \frac{\Delta C_1}{q_1} \right] \tag{1} \]

It is immediate that (1) is increasing in \( U \). We therefore turn to (2). 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 \( D - 2 \), which depends on the number of competing suppliers \( U \), multiplied by the probability of winning exactly the set \( W_j \) conditional on having won \( |W_j| \) buyers, which doesn’t depend on \( U \). That is, using (4) and letting \( z_U \sim \text{Bin}(D - 2, \frac{1}{U}) \) we have

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

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

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

\[
G_{n+1}(\bar{q}) \leq \Pr (\text{deliver volumes} \leq \bar{q}| \text{win } n + 1 \text{ buyers but one is } q_D) \\
= \Pr (\text{deliver volumes} \leq \bar{q} | \text{win } n + 1 \text{ buyers but one is } q_D) \\
= \Pr (\text{deliver volumes} \leq \bar{q} | \text{win } n \text{ buyers from } \{q_3, \ldots, q_{D-1}\}) \\
\leq \Pr (\text{deliver volumes} \leq \bar{q} | \text{win any } n \text{ buyers from } \{q_3, \ldots, q_D\}) = G_n(\bar{q})
\]

We can rewrite (6) as

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

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

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

\[
\frac{C'(Q_j + q_2) - C'(Q_j)}{q_2} < \frac{C'(Q_j + q_1) - C'(Q_j)}{q_1}
\]

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

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

**Proof of Theorem 6.** We begin the proof by establishing that if the number of small buyers is large enough then the volumes suppliers will win from small buyers is known. To see this, consider the demand from the \( D_S \) small firms, each requiring output \( q_S = \frac{1-q_L}{D_S} \). 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 \( w_S \sim Bin \left( D_S, \frac{1}{T} \right) \approx N \left( \frac{D_S}{T}, D_S \frac{U-1}{T^2} \right) \) as for large \( D_S \) we can use the

\[ 39 \]
normal approximation to the Binomial distribution. Hence

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

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, \( G^r(\cdot) \) indexed by \( r \) which coincides with the benchmark \( C(\cdot) \) when \( r = 0 \) and with a linear cost function when \( r = 1 \):

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

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

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

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

We also establish the expected costs of each supplier as

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

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

\[
E(\Pi^{\text{sup}}) = \frac{1}{U} [q_L t_L + (1 - q_L) t_S] - E(\text{costs}) \quad \text{with } t_S, \ t_L \text{ given by (1)}
\]
and so we have

\[
\frac{\partial}{\partial r} \left[ E(\Pi^{\text{sup}}) \right] = \frac{1}{U} \left( 1 - \frac{1}{2r} \right) \left\{ q_L \frac{\partial}{\partial r} \Delta C_L(q_L) + (1 - q_L) \frac{\partial}{\partial r} \Delta C_S(q_S) \right\} - \frac{\partial}{\partial r} E(\text{costs})
\]

\[
= \frac{1}{U} \left( 1 - \frac{1}{2r} \right) \left\{ \begin{array}{c}
UC \left( \frac{1}{r} \right) - C \left( q_L + \frac{1 - q_L}{U} \right) + C \left( \frac{1 - q_L}{U} \right) \\
- \frac{U - 1}{U} C \left( \frac{1 - q_L}{U} \right) + \frac{1}{U} C \left( q_L + \frac{1 - q_L}{U} \right)
\end{array} \right\}
\]

\[-C \left( \frac{1}{U} \right) + \frac{U - 1}{U} C \left( \frac{1 - q_L}{U} \right) + \frac{1}{U} C \left( q_L + \frac{1 - q_L}{U} \right)\]

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

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

But the benchmark cost function, \( C(\cdot) \) is convex by assumption and so \( C \left( \frac{1}{r} \right) < \frac{1}{r} C(1) + \left( 1 - \frac{1}{r} \right) C(0) = \frac{1}{r} C(1) \). Hence \( \lim_{q_L \to 1} \frac{\partial}{\partial r} [E(\Pi^{\text{sup}})] > 0 \) at any \( r \in [0,1] \) which implies that if the large buyer is sufficiently big, the industry would rather move to a linear production technology as claimed.

**Part 2 of 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 \( \hat{C}(q) \).\(^{33}\) 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 \( \hat{G} \left( \frac{1}{r} \right) = C \left( \frac{1}{r} \right) \) so that the cost of producing the ex ante expected volumes of \( \frac{1}{U} \) remains constant. We proceed exactly analogously to the above working to deduce that

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

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. \( \blacksquare \)

\(^{33}\)Hence \( \hat{C}(1/U) = C(1/U) \), and \( \hat{C}(0) = 0 \) by assumption.
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