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Abstract

This paper provides a comprehensive econometric framework for the empirical analysis of buyer power. It encompasses the two main features of pricing schemes in business-to-business relationships: nonlinear price schedules and bargaining over rents. Disentangling them is critical to the empirical identification of buyer power. Testable predictions from the theoretical analysis are delineated, and a pragmatic empirical methodology is presented. It is readily implementable on the basis of transaction data, routinely collected by antitrust authorities. The empirical framework is illustrated using data from the UK brick industry. The paper emphasizes the importance of controlling for endogeneity of volumes and for heterogeneity across buyers and sellers.

JEL Classification: D43, L11, L12, L14, L42, C23, C78

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1 Introduction

Buyer power is a paramount concern in competition analysis. It is a line of inquiry in many competition investigations focussing on business-to-business dealings. Quintessential high profile examples are the relationships between supermarkets and their suppliers.[1] Another recent topical example is the relationship between Chinese steel mills and Australian and Brazilian iron ore miners.[2]

At the center of many competition inquiries are often generic products, e.g. groceries or raw materials. Then, the focus is on per unit prices, usually obtained by antitrust bodies as revenue per unit sold. This price measure typically constitutes a combination of the respective portion of a nonlinear unit price schedule and a lump sum payment, e.g. a franchise fee, rebate, retrospective quantity discounts or other incentive payment that is the outcome of bargaining over joint surplus between buyer and supplier. Hence, one of the primary difficulties in the analysis of buyer power on the basis of unit prices is the important distinction between nonlinear pricing and the appropriation of rents by means of bargaining.[3]

The conceptual contribution of this paper is a framework that connects the analysis of buyer power with the design of optimal nonlinear pricing schemes, while at the same time incorporating bargaining over rents. It thereby illuminates how buyer power is enhanced by the buyer's ability to switch between suppliers, and is constrained by the suppliers' outside options and capacity; in

[1]On the European level, the European Commission considered buyer power issues in the German - Austrian merger Rewe/Meinl (1999) and the French - Spanish merger Carrefour/Promodès (2000); see also European Commission (1999). On the national level, see, for example, the recent market inquiry into UK grocery retailing by the UK Competition Commission, in particular Provisional Findings Appendix 8; the report can be downloaded from the Competition Commission website.

[2]See Financial Times UK online, 09 July 2008. In spite of shipping costs per tonne from Brazil being twice those from Australia, Brazilian and Australian miners receive the same freight-on-board price. This is interpreted as a reflection of superior negotiating power of Brazilian miners when bargaining with Chinese mills, given the size of Chinese demand for, and the limitations on Australian miners' capacity in the supply of, iron ore.

[3]See also Bonnet et al. (2004) who investigate manufacturer-retailer relationships involving nonlinear pricing. They present empirical tests of two-part tariffs with versus without retail price maintenance embedded in a structural model of competition in differentiated product markets (e.g. Berry (1994), Berry et al. (1995)) using market level data.

particular, in contrast to Chipty and Snyder (1999), Smith and Thanassoulis (2008) and some conventional wisdom, this paper shows that, in the face of suppliers' capacity constraints, buyer size may diminish buyer power.

The paper proceeds as follows. After a brief review of the relevant background, section 2 outlines the theoretical model that guides the analysis. The modelling framework is essentially nonparametric and, while amenable to further refinements, is primarily intended to illuminate the main issues that an econometric analysis of buyer power has to confront. Section 3 deduces some conclusions about the empirical analysis of buyer power from the theoretical analysis; it delineates testable implications and comments on important (nonparametric) identification issues. It then presents the data used in the applied part of the paper, which relate to the UK bricks industry, and summarizes the empirical analysis. Section 4 concludes.

1.1 Buyer Power Analysis in Antitrust

The analysis of buyer power is often an integral part in antitrust inquiries. The UK Competition Merger Guidelines (2003) consider buyer power in merger assessment: Do buyers, either because of their size or commercial significance to their suppliers, have the ability to prevent the exercise of market power by suppliers? This ability, if present, is akin to Galbraith' (1952) notion of countervailing buyer power. The Competition Commission consider such countervailing power as one potential mitigating factor, next to others such as entry and switching costs, in the assessment of upstream mergers. In the competition assessment in its market investigations (Competition Commission Market Investigation Guidelines (2003)), it investigates the relative importance to each other of each firm's business with the counterparty; there is an additional question whether any price reductions, obtained by virtue of buyer power, are passed on to consumers. The guidelines enumerate several factors that are viewed as potentially affecting buyers' ability to constrain suppliers: buyers' ability to find alternative suppliers; the ease with which buyers can switch suppliers; the extent to which buyers can credibly threaten to set up their own supply arrangements, e.g. by backward integration or by sponsoring entry; the extent to which buyers can impose costs on suppliers, e.g. by delaying or stopping purchases or by transferring risk. It is worth noting in this regard that a buyer's size can cut both ways: while size enhance the significance of the buyer's business vis-à-vis the supplier, it makes switching more difficult when alternative suppliers' capacities are constrained.

A prototypical buyer power analysis is the Competition Commission's investigation as part of its inquiry into grocery retailing in the UK (2008). Based on their size, pricing and margins, the Commission concluded that all large retailers, wholesalers and buying groups have buyer power vis-à-vis their suppliers. However, the Commission considered that their buyer power is offset by market power of suppliers of branded goods; and that lower prices arising from buyer power in part are passed on to consumers. The Commission substantiated these findings with an analysis of panel data, which for various store-keeping-units (SKUs) comprised yearly prices, volumes and some cost information. The Commission's methodology consisted of fixed-effects regressions of unit prices on volumes.

The Commission's analysis raises several questions. Panel data methods allow to capture unobserved heterogeneity. The analysis modelled SKU-level idiosyncratic effects, but is this the appropriate level of heterogeneity? Moreover, does aggregation to annual data mask latent heterogeneity across time? The analysis may also raise concerns about the treatment of volumes: If business-to-business relationships involve bargaining over both volumes and prices, then volumes should be treated as endogenous regressors. Furthermore, the caveat about the ambiguous volume effect notwithstanding, the Commission's analysis focussed on volume effects on prices as evidence of buyer power, without attempting to quantify buyer's ability to switch suppliers. But volume effects on unit prices might just reflect suppliers' nonlinear pricing and self-selection of buyers into the appropriate part of the tariff, irrespective of buyer power. Hence, this type of reduced form analysis might be critiqued along various dimensions, and it highlights that the treatment of potential heterogeneity across buyers and suppliers, endogeneity of prices and volumes and the distinction between nonlinear pricing and bargaining over rents are the primary empirical challenges of the empirical analysis of buyer power.

1.2 Related Literature

Its growing importance and policy relevance notwithstanding, the academic literature on buyer power is still relatively sparse. Inderst and Mazzarotto (2006) survey its main theoretical strands to date, as they relate to sources and consequences of, as well as policy responses to, buyer power of retailers vis-à-vis manufacturers. With regard to applied work, the academic literature offers very little towards a comprehensive, structural empirical framework for the analysis of buyer power. Giulietti (2007) presents a reduced form analysis of the Italian grocery retail sector, approximating suppliers' bargaining power by a concentration measure for the respective product level industry they operate in. Chipty and Snyder's (1999) approach exhibits more detailed structural features. It provides an empirically testable condition - concavity of the supplier's revenue function - that needs to be satisfied for larger buyers, e.g. arising from buyer mergers, to obtain lower transfer prices when bargaining over surplus with their suppliers. This framework captures the anecdotal view that larger buyers enjoy greater buyer power.[4] It is useful when the analysis focuses on revenues for bespoke goods or services; this is the case in Chipty and Synder's application of their model to the US cable television industry. Ellison and Snyder (2001) build on this approach and, next to buyer size, investigate the role of substitution possibilities. They focus on price differences in wholesale pharmaceutical markets between different types of buyers, controlling for various institutional differences with regard to drug administration.[5] Related work by Villas-Boas (2007) examines vertical relationships between manufacturers and retailers under data limitations, when wholesale prices for transactions between them are not observed; her

[4]This is often referred to as countervailing (buyer) power, a term coined by Galbraith (1952) and theoretically developed in a dynamic setting by Snyder (1996). Recent work by Smith and Thanassoulis (2008) demonstrates how upstream competition can endow large buyers with market power by inducing supplier-level volume uncertainty. There is also some empirical evidence supporting countervailing buyer power; see Adelman (1959), Brooks (1973), Buzzell et al. (1975), Lustgarten (1975), McGukin and Chen (1976), McKie (1950), Clevenger and Campbell (1977), Boulding and Staelin (1990). Dobson and Waterson (1997) and von Ungern-Sternberg (1996) examine the effect on countervailing power on consumer prices.

[5]Drugs can be branded and subject to patent protection, branded and subject to generic competitors, or generic and subject to some form of oligopolistic competition. Buyers such as HMOs and hospitals have wider substitution possibilities through the use of restrictive formularies relative to chain drugstores and independent drugstores. Ellison and Snyder (2001) empirically examine the effects of different features of drugs on the difference in prices paid by various types of buyers. Using cross-section data, their analysis cannot model unobserved heterogeneity across buyers. The empirical analysis presented in this paper demonstrates that there exist circumstances in which the conclusion about buyer power critically hinges on accounting for unobserved heterogeneity.

objective is to indirectly identify the strategic model appropriate for their interaction, with a particular focus on the existence of double marginalization pricing model, from demand and cost estimates.

2 Theory

The formal analysis proceeds under the following assumptions. Suppose there is a single buyer. This buyer is characterized by a revenue function $Y(q)$, defined over inputs q; $Y(\cdot)$ embodies the technology for the production of, and the competitive conditions in the market for, the final output good and is assumed to be monotonically increasing, concave and differentiable.

The buyer faces suppliers who are characterized by supply functions $S(w,t)$, defined over the per unit (of q) price w and the supplier's type parameter t. Assume S is strictly increasing in w for any t; t is the supplier's private information.[6] The supply function $S(w,t)$ is the inverse marginal cost function of the supplier. Let $C(q,t)$ be the cost function of the supplier of type t; assume it is strictly convex with respect to q and differentiable. Given w, the supplier's objective is $\max_q wq - C(q,t)$, which implies $w = C'(q,t)$ and therefore $q = C'^{(-1)}(w,t) \equiv S(w,t)$, where the superscript $^{(-1)}$ denotes the inverse function, which exists in light of the strict convexity of $C(q,t)$. Suppliers are assumed to produce perfectly substitutable inputs to the buyer's revenue generating technology. Note that $C(q,t) = C(S(w,t),t) = wS(w,t) - \int_0^w S(v,t)dv$.

When Nash bargaining bilaterally over rents, the buyer's bargaining weight parameter is $\alpha \in (0,1)$ while the supplier's bargaining weight is $1-\alpha$.

The analysis proceeds as follows. Given a set of suppliers, parameterized by their respective types, the monopsonistic buyer presents them with a set of optimal, possibly nonlinear per-unit prices. The joint rent that is induced on the part of the buyer and suppliers is then bargained over bilaterally between the buyer and each supplier separately. This paper thereby attempts to conceptualize buyer power as a buyer's ability to present suppliers with possibly nonlinear tariffs that are shifted up or down according to the respective bilateral bargaining strengths.

[6] The supplier's type gets indirectly revealed, at least in certain ranges, by the supplier's choice of the optimal portion in a nonlinear tariff; the degree of nonlinearity determines the degree to which t is indirectly revealed.

It is worth emphasizing at the outset that the theoretical framework outlined below is not intended to capture all the intricacies of business-to-business relationships, but that it is intended instead to motivate the main issues that econometric analyses of buyer power have to deal with.

2.1 Bargaining over surplus

Consider, first, the Nash bargaining stage. It will be shown that the buyer's bargaining outcome is a linear function of the surplus that is bargained over. This implies that, when designing optimal (marginal) pricing schemes, the buyer's objective is simply to maximize total surplus. In contrast to the analysis in Chipty and Snyder (1999), in this analysis the strength of the respective bargaining position is shown to be endogenous, as is the feature that the design of optimal nonlinear prices maximizes joint surplus that the buyer and sellers bargain over.[7]

The following result considers a situation of bilateral monopsony-monopoly and provides a useful benchmark.

Lemma 1: *Suppose a monopsonistic buyer faces a single supplier, whose outside option is zero. Nash bargaining takes place over a positive, finite surplus s. The buyer's and supplier's bargaining weight is parameterized by $\alpha \in (0,1)$ and $1-\alpha$, respectively. Then, the buyer's bargaining outcome is αs, while the supplier's bargaining outcome is $x = (1-\alpha)s$.*

The proof follows from straightforward algebra. Situations with more than one supplier permit equilibria in which suppliers compete with each other. Before turning to results characterizing such equilibria, consider the following recursive definition of Nash bargaining equilibria in situations where a single buyer faces a set of n potential suppliers, $\mathcal{I} = \{1, \cdots, n\}$. Let $a_i(k_j)$ denote supplier i's outside option if bargaining between i and the buyer breaks down in a situation where the buyer is contemplated to reach efficient bargaining outcomes with suppliers in $\mathcal{I}_{k_j} \subseteq \mathcal{I}$ with $k = \#\mathcal{I}_{k_j}$, $k = 1, \cdots, n$ and $j = 1, \cdots, \binom{n}{k}$. Suppose also that $0 < s(1) \leq \cdots \leq s(n) < \infty$, and that, in bilateral bargaining, the buyer's bargaining weight is $\alpha \in (0,1)$, while the supplier's bargaining weight is $1-\alpha$.

[7] Chipty and Snyder's analysis focusses on firm size as the primary source of buyer power in bilateral bargaining. This paper incorporates firm size indirectly, via the number of suppliers from whom the buyer sources its input.

Definition: *A Nash bargaining equilibrium constitutes a collection of suppliers* $\mathcal{I}_{k_j^\star} \subseteq \mathcal{I}$ *and a corresponding allocation of bargaining outcomes* $\{x_i(k_j^\star), i \in \mathcal{I}_{k_j^\star}; a_i(k_j^\star), i \in \mathcal{I} \setminus \mathcal{I}_{k_j^\star}\}$ *such that:*

(i) *the buyer's bargaining outcome satisfies*

$$b(k_j^\star) = s(k_j^\star) - \sum_{i \in \mathcal{I}_{k_j^\star}} x_i(k_j^\star) \geq s(t_l) - \sum_{m \in \mathcal{I}_{t_l}} x_m(t_l) \geq 0,$$

for all $t = 1, \cdots, n$ *and* $l = 1, \cdots, \binom{n}{t}$*;*

(ii) *supplier i's bargaining outcome satisfies*

$$x_i(k_j^\star) = \arg\max_z |s(k_j^\star) - z - \sum_{m \in \mathcal{I}_{k_j^\star} \setminus \{i\}} x_m(k_j^\star) - b|^\alpha |z - a_i(k_j^\star)|^{1-\alpha} \geq a_i(k_j^\star),$$

for all $i \in \mathcal{I}_{k_j^\star}$, $b = \max\{b(t_l); t = 1 \cdots, n; l = 1 \cdots, \binom{n}{t}\}$*; and* $x_i(k_j^\star) = a_i(k_j^\star)$ *for all* $i \in \mathcal{I} \setminus \mathcal{I}_{k_j^\star}$.

Note that part (ii) of the equilibrium definition requires implicitly that supplier $i \in \mathcal{I}_{k_j^\star}$ hold the belief that the buyer reaches an efficient bargaining outcome $x_m(k_j^\star)$ with all other suppliers $m \in \mathcal{I}_{k_j^\star} \setminus \{i\}$ from whom the buyer sources in this equilibrium.

The next result introduces competition among suppliers in the simplest setup with 2 potential suppliers whose outside options are zero.

Proposition 1: *Suppose a monopsonistic buyer faces two suppliers, whose outside options are zero. Assume that individual bargaining between the buyer and suppliers 1 and 2, respectively, results in the buyer's bargaining outcomes* $b(1_1)$ *and* $b(1_2)$*. Nash bargaining takes place over a positive, finite surplus* $s(2)$ *that is induced by optimal per-unit prices for both suppliers. The buyer's and supplier's bargaining power is parameterized by* $\alpha \in (0, 1)$ *and* $1 - \alpha$*, respectively. Then, the suppliers' Nash bargaining equilibrium outcomes are* $x_i(2) = \frac{1-\alpha}{1-(1-\alpha)^2}[\alpha s(2) - (b(1_j) - (1-\alpha)b(1_i))]$*, for* $i, j = 1, 2$ *and* $i \neq j$*; and the buyer's equilibrium bargaining outcome is* $s(2) - x_1(2) - x_2(2)$*, provided* $b(2) = s(2) - x_1(2) - x_2(2) \geq \max\{b(1_1), b(1_2)\}$*.*

The proof follows from Lemma 1, the equilibrium definition and straightforward algebra. The result shows that the buyer's ability to substitute between suppliers implies that the buyer's disagreement outcome in bilateral Nash bargaining enhances his bargaining position and reduces the suppliers' rents. Similarly, a relatively favorable bargaining outcome for the buyer when dealing with just supplier i, i.e. $b(1_i)$ high relative to $b(1_j)$, weakens supplier j's bargaining position and thereby lowers the share of the surplus that j receives relative to i. The proposition, trivially, implies that the buyer is better off facing two suppliers, rather than a single supplier; clearly, the equilibrium outcome of the game with one supplier is the solution to the constrained game with two supplier, with the constraint that the amount bought from one supplier be zero. It is also easy to show that collective bargaining on the part of the suppliers vis-à-vis the buyer increases their joint bargaining outcome relative to exclusive individual bargaining.

The following result expands on the preceding insights by allowing the two suppliers to have different bargaining power, arising from their respective outside options. Specifically, suppose that there are two suppliers, not necessarily symmetric, whose disagreement outcomes are $a_i(k)$, where $i = 1, 2$ indexes the supplier and $k = 1, 2$ the disagreement outcome when there are k suppliers in supply relationships with the buyer.[8]

Proposition 2: *Suppose a buyer faces two suppliers, whose outside options are $a_i(k) > 0$, $i = 1, 2$, where k indexes the number of suppliers whom the buyer has supply relationships with. Assume that individual bargaining between the buyer and suppliers 1 and 2, respectively, over the respective total surplus $s(1_1) > a_1(1)$ and $s(1_2) > a_2(1)$ results in the buyer's bargaining outcomes $x_1(1)$ and $x_2(1)$. Nash bargaining takes place over a positive, finite surplus $s(2)$ that is induced by optimal per-unit prices for both suppliers. The buyer's and suppliers' bargaining weight is parameterized by $\alpha \in (0, 1)$ and $1-\alpha$, respectively. Then, supplier i's Nash bargaining equilibrium outcome is*

$$\begin{aligned} x_i(2) &= \frac{1-\alpha}{1-(1-\alpha)^2}\left[\alpha s(2) - (x_j(1) - (1-\alpha)x_i(1))\right] \\ &\quad + \frac{\alpha}{1-(1-\alpha)^2}\left[(a_i(2) - (1-\alpha)a_j(2))\right] \end{aligned}$$

where $x_i(1) = \alpha(s(1_i) - a_i(1))$, for $i, j = 1, 2$ and $i \neq j$, provided that

(i) $x_i(2) > a_i(2), \quad i = 1, 2;$

(ii) $s(2) - x_1(2) - x_2(2) > \alpha \max\{s(1_1) - a_1(1), s(1_2) - a_2(1)\}.$

[8] This raises the somewhat more subtle question, however, how to interpret the supply function that the buyer is faced with. Strictly speaking, the buyer can then no longer be thought of as a monopsonist; instead, for the suppliers there exists some possibility of supply side substitution.

The result shows that supplier i's disagreement outcome enhances his bargaining position and raises his equilibrium bargaining outcome, while an enhanced bargaining position of i's competitor j reduces i's equilibrium bargaining outcome. With a larger number of heterogeneous buyers, results about the characterization of equilibria become more intricate, since the outcomes of bargaining with various subsets of heterogeneous suppliers depend on the respective composition of these sets. The following results characterizes equilibria with suppliers who are heterogeneous with regard to their outside options.

Proposition 3: *Suppose a buyer faces n heterogeneous suppliers whose outside options are $a_i(k)$, $i = 1 \cdots, n$, when the buyer sources from k suppliers, $k = 1, \cdots, n$. Given the buyer's Nash bargaining equilibrium outcome $b(n-1) = \max\{b(m) : \mathcal{I}_m \subset \mathcal{I}\} > 0$ in a situation with $n-1$ potential suppliers, suppose total surplus $s(n)$ satisfies $s(n) - \sum_{i=1}^{n} a_i(n) > b(n-1)$. Then, the buyer's equilibrium bargaining outcome is*

$$b(n) = \frac{n(1-\alpha)}{\alpha + n(1-\alpha)} b(n-1) + \frac{\alpha}{\alpha + n(1-\alpha)} \left(s(n) - \sum_{i=1}^{n} a_i(n) \right).$$

The result shows that, in equilibrium, the buyer's bargaining outcome is a weighted average of his equilibrium outcome when sourcing from a strict subset of $\mathcal{I}$, $b(n-1)$, and the excess surplus beyond the suppliers' outside options generated by sourcing from all of them, $s(n) - \sum_{i=1}^{n} a_i(n)$. Proposition 3 provides a recursive result, conditional on $b(n-1)$. In the presence of supplier heterogeneity, there is no straightforward and succinct way to characterize the outcomes of the $\sum_{k=1}^{n-1} \binom{n}{k}$ alternative bargaining scenarios. The following result, therefore, considers a restricted situation where all suppliers are identical and is a straightforward corollary to Proposition 3.

Corollary 1: *Suppose a buyer faces n identical suppliers whose outside options are $a(k) = a_i(k)$ for all $i = 1, \cdots, n$, when the buyer sources from k suppliers, $k = 1, \cdots, n$. Nash bargaining takes place over a sequence of positive, finite surplus $s(k)$, satisfying $s(k) - ka(k) > b(k-1) > 0$ that is induced by optimal per-unit prices for all k suppliers that the buyer sources from, $k = 1, \cdots, n$ and $b(0) \equiv 0$. The buyer's and suppliers' bargaining power is parameterized by $\alpha \in (0, 1)$ and $1 - \alpha$, respectively. Then, a supplier's* *bargaining outcome is*

$$
\begin{aligned}
b(n) \quad &= \quad \frac{\alpha}{\alpha + n(1-\alpha)} \left(s(n) - na(n) \right) \\
&+ \sum_{k=1}^{n-1} \left[\left(\prod_{t=k+1}^{n} \frac{t(1-\alpha)}{\alpha + t(1-\alpha)} \right) \frac{\alpha}{\alpha + k(1-\alpha)} \left(s(k) - ka(k) \right) \right].
\end{aligned}
$$

Note that the result demonstrates that the buyer's equilibrium bargaining outcome is linear in the surplus $s(k)$, $k = 1, \cdots, n$. This equilibrium property will become significant when combining, below, Nash bargaining over rents with optimally set marginal prices per unit of factor input.

Under the restriction of identical suppliers and finite total surplus $s(n)$ for all n, the Proposition has the following second corollary.

Corollary 2: *Under the assumptions of Corollary 1, with* $0 < s(n) < \infty$ *for any* n, $b(n) - b(n-1) \searrow 0$ *as* $n \to \infty$.

The proof follows from straightforward algebra and the fact that the surplus that is bargained over is finite. Hence, the buyer enjoys positive, but declining increments to his bargaining outcome as the number of suppliers tends to infinity. This is a necessary, although not sufficient condition for paid per-unit prices to decline with the number of suppliers.

The preceding propositions demonstrate that the buyer's bargaining outcome is linear in the surplus that the buyer and the suppliers bargain over. This implies for the further development of the theory of optimal nonlinear prices in business-to-business relationships that the buyer's objective is to determine a set of marginal prices so as to maximizes the total surplus. The combination of optimal marginal price and Nash bargaining equilibrium share of surplus induces a nonlinear pricing structure, and there exist circumstances, illustrated by a worked example below, under which this nonlinear pricing scheme induces average, per unit prices that decline with the number of potential suppliers.

2.2 Optimal nonlinear prices

Recall that the buyer's revenue function is $Y(q)$, defined over inputs q; it is assumed to be monotonically increasing, concave and differentiable; and suppliers present the buyer with supply functions $S(w, t)$, defined over the per unit (of q) price w and the supplier's type parameter t. Suppliers are assumed to produce perfectly substitutable inputs to the buyer's revenue generating technology. Suppose that the buyer can observe a supplier's type t.

Consider, first, the situation where the buyer faces a single supplier whose type is t. Then, the buyer's objective is to choose w such as to maximize $Y(S(w,t)) - wS(w,t) + \int_0^w S(v,t)dv$; the first two terms capture the buyer's surplus when unit price w is paid to the supplier, and the second term captures the supplier's rent under this price. Straightforward algebra reveals that the optimal price satisfies

$$w^\star = Y'(S(w^\star, t))$$

provided that the supplier's rent is positive, given $w^\star$. With more than one supplier, say n, if the buyer can appropriate the entire surplus, i.e. when $\alpha = 1$ in the setup of the preceding subsection, then the buyer's objective is

$$\begin{aligned} & \max_{w_i, i=1,\cdots,n} Y\left(\sum_{i=1}^n S(w_i,t_i)\right) - \sum_{i=1}^n C(S(w_i,t_i),t_i) \\ = & \max_{w_i, i=1,\cdots,n} Y\left(\sum_{i=1}^n S(w_i,t_i)\right) - \sum_{i=1}^n \left[w_i S(w_i,t_i) - \int_0^{w_i} S(v,t_i)dv\right] \end{aligned}$$

This implies that, at the optimal resource allocation, the marginal cost is the same for all suppliers,

$$C'(S(w_j^\star, t_j)) = C'(S(w_k^\star, t_k)) = Y'\left(\sum_{i=1}^n S(w^\star, t_i)\right), \quad j,k = 1,\cdots,n.$$

Given prices $w_i^\star$, $i = 1,\cdots,n$, that satisfy this condition, the resource allocation is efficient and avoids the well-known double marginalization problem. Note that, if the supplier's marginal costs are the same (so $t = t_i$ for all i) and constant in the relevant range, say c, then $w^\star = w_i^\star$ and $q^\star = S(w^\star,t) = S(w_i^\star,t_i)$ for all i, and $Y'(nq^\star) = c$, and it follows that the quantities the buyer purchases from each of the suppliers are indeterminate, except that their total equals $nq^\star$. In this case, the entire surplus that buyer and sellers bargain over does not depend on n. On the other hand, if marginal costs are identical and increasing, then the buyer purchases the same amount from each supplier, while decreasing marginal costs imply that the buyer purchases solely from the supplier with the lowest marginal cost.

Consider the special case where $n = 2$ and the suppliers are identical, with increasing supply function $S(w)$. If the buyer cannot appropriate the entire surplus, then, from the preceding results, the buyer's objective is

$$\begin{aligned}\max_{w} \quad & \frac{\alpha^2}{|A_2|}\left[Y(2S(w)) - 2wS(w) + 2\int_0^w S(v)dv\right. \\ & \left. +2(1-\alpha)\left[Y(S(w)) - wS(w) + \int_0^w S(v)dv\right]\right].\end{aligned}$$

Now, the optimal unit price $w^\star$ satisfies

$$w^\star = (2-\alpha)^{-1}\left[Y'(2S(w^\star)) + (1-\alpha)Y'(S(w^\star))\right],$$

Comparing this to the unit prices when there is a single supplier, $\tilde{w}^\star = Y'(S(\tilde{q}^\star))$, and when there are two identical suppliers and the buyer has all the bargaining power, $\hat{w}^\star = Y'(2S(\hat{w}^\star))$, the above expression shows that $\hat{w}^\star \leq w^\star \leq \tilde{w}^\star$, provided the marginal revenue function is decreasing, i.e. the revenue function is strictly concave. In other words, with limited bargaining power $\alpha \in (0,1)$, the opportunity to switch between suppliers permits the buyer to demand lower unit prices than in a bilateral monopsony-monopoly situation. But the risk of having to resort to a single supplier as a consequence of a supplier's countervailing power constrains the buyer to higher prices than in a situation with absolute bargaining power $\alpha = 1$.

Now consider the limit as the number of suppliers tends to infinity. When the suppliers have no outside options, the buyer appropriates the entire surplus in this case. Suppose that the limiting distribution of types is given by $F(t)$, for $t \in \mathcal{T}$, some compact set. The buyer's objective is now to maximize

$$Y\left(\int_t S(w(t),t)dF(t)\right) - \int_t w(t)S(w(t),t)dF(t) + \int (1-F(t))S(w(t),t)dw(t)$$

with respect to the (smooth) price schedule $w(t)$. To facilitate the exposition, suppose that $Y(\cdot)$ is linear, $Y(q) = yq$, $y > 0$. Taking a functional derivative then yields the optimal nonlinear pricing schedule which satisfies

$$\frac{y - w^\star(t)}{w^\star(t)} = \frac{1-F(t)}{tf(t)} \frac{S(w^\star(t),t)}{w^\star(t)S_w(w^\star(t),t)} \frac{tS_t(w^\star(t),t)}{S(w^\star(t),t)},$$

where $f(t)$ is the density of $F(t)$ and the subscripts w and t of S denote the respective partial derivatives. Note that optimal nonlinear prices contrast with a constant unit price $\bar{w}$ applied across all types t, satisfying

$$\frac{y - \bar{w}}{\bar{w}} = \frac{\int_{\bar{t}} S(\bar{w},t)dF(t)}{\bar{w}\int_{\bar{t}} S_w(\bar{w},t)dF(t)}\left[1 - \frac{S(\bar{w},t)}{\int_{\bar{t}} S(\bar{w},t)dF(t)}(1-F(\bar{t}))\right],$$

where $\bar{t}$ is the marginal supplier who provides a positive supply, given the associated lump sum rebate, i.e.

$$\int_0^{\overline{w}} S(v, \bar{t})dv = 0.$$

The smooth optimal price schedule $w^\star(t)$ can be approximated by a piece-wise linear tariff, with associated lump sum rebates, whose limit is given by $w^\star(t)$.

2.3 Worked Examples

The following two stylized examples illustrate the preceding theoretical results and their implications for econometric work.

1. Suppose that the supplier's cost function is $C(q,t) = \left(\frac{1}{t}\right)^{\frac{1}{\alpha}} q^{1+\frac{1}{\alpha}}$, for $t > 0$ the supplier's type and $\alpha > 0$ a positive parameter. Then, the supply function is $S(w,t) = tw^\alpha$. Assume furthermore that t is distributed with density $f(t) = \lambda \exp(-\lambda t)$, with parameter $\lambda > 0$. With constant marginal revenue for the buyer y, this implies relative margins $\frac{y - w^\star(t)}{w^\star(t)} = \frac{1}{t\lambda}\frac{1}{\alpha}$, where $w^\star(t)$ denotes the optimal fully nonlinear price schedule. The induced supply is $S(w^\star(t), t) = t\left(\frac{y}{1+\frac{1}{\alpha\lambda t}}\right)^\alpha$. Figure 1 provides a graphical illustration of this case. In particular, it demonstrates how supplier self-selection in the presence of nonlinear tariffs can induce optimal price-quantity pairs that induce a positive price-volume relationship in regression analysis.

2. For the purpose of illustration, this subsection presents a simple example with two symmetric suppliers that illustrates the preceding results. In particular, it demonstrates that, provided the suppliers' outside options are not too advantageous, then there exists a bargaining equilibrium in which the buyer sources from both suppliers and the unit prices that they receive are lower than in a situation in which the buyer only contracts with one of them.

Suppose that the buyer's revenue function is given by $Y(q) = \frac{1}{\theta}q^\theta$, for $\theta \in (0,1)$. The suppliers' inverse marginal cost functions are assumed to be $C'^{(-1)}(w) = S(w) = w$, where the type argument is omitted in light of the assumed symmetry of the suppliers.

Consider, first, the situation in which the buyer only deals with a single supplier. Given w, the total surplus to be bargained over is

$$s(1) = \frac{1}{\theta}w^\theta - \int_0^w v dv = \frac{1}{\theta}w^\theta - \frac{1}{2}w^2.$$

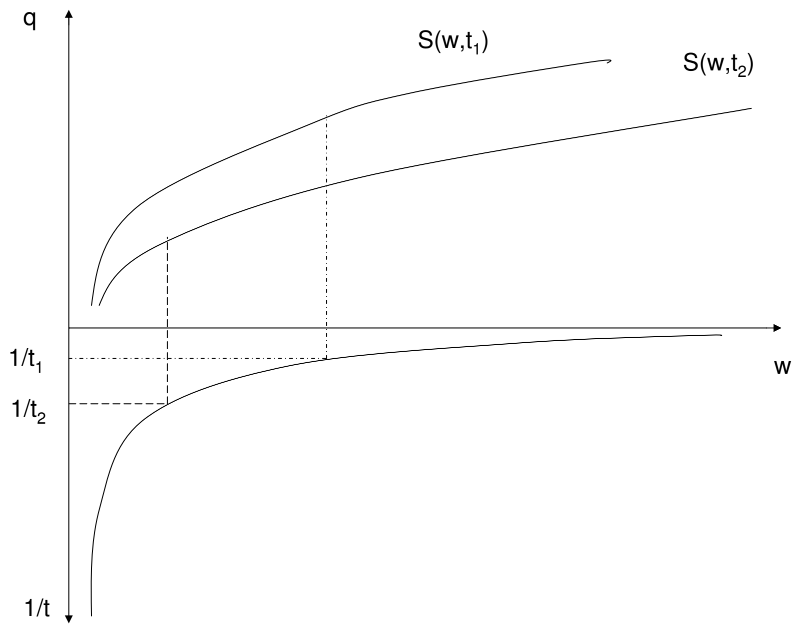

Figure 1: Nonlinear pricing example: selection effect.

Hence, the optimal factor price that maximizes total surplus is $w^\star(1) = 1$. It induces $s(w^\star(1)) = \frac{1}{\theta} - \frac{1}{2}$. If the buyer's bargaining power parameter is $\alpha \in (0,1)$ and the supplier's outside option is β, with $0 < \beta < \frac{1}{\theta} - \frac{1}{2}$, then the buyer receives $b(1) = \alpha\left(\frac{1}{\theta} - \frac{1}{2} - \beta\right)$, while the supplier earns $x(1) = (1-\alpha)\left(\frac{1}{\theta} - \frac{1}{2}\right) + \alpha\beta$.

Now consider the situation in which the buyer faces two symmetric buyers. In this case, given w, the total surplus to be bargained over is

$$s(2) = \frac{1}{\theta}(2w)^\theta - 2\int_0^w v dv = \frac{1}{\theta}(2w)^\theta - w^2.$$

Hence, with two symmetric suppliers the optimal factor price is $w^\star(2) = \left(\frac{1}{2}\right)^{\frac{1-\theta}{2-\theta}} < w^\star(1)$, and the corresponding maximal surplus is

$$\begin{aligned} s(w^\star(2)) &= \frac{1}{\theta}\left(2\left(\frac{1}{2}\right)^{\frac{1-\theta}{2-\theta}}\right)^\theta - \left(\frac{1}{2}\right)^{\frac{2(1-\theta)}{2-\theta}} \\ &= \left(\frac{1}{2}\right)^{-\frac{\theta}{2-\theta}}\left(\frac{1}{\theta} - \frac{1}{2}\right) > s(w^\star(1)). \end{aligned}$$

Assuming the same assignments of bargaining weights, each of the suppliers earns a share

$$\begin{aligned} x(2) &= \frac{1-\alpha}{1-(1-\alpha)^2}\left[\alpha\left(s(w^\star(2)) - b(1)\right) + \frac{\alpha^2}{1-\alpha}\beta\right] \\ &= \frac{1-\alpha}{2-\alpha}\left[\left(\left(\frac{1}{2}\right)^{-\frac{\theta}{2-\theta}} - \alpha\right)\left(\frac{1}{\theta} - \frac{1}{2}\right)\right] + \alpha\beta \end{aligned}$$

of the total surplus, while the buyer receives the remainder

$$\begin{aligned} b(2) &= s(w^\star(2)) - 2x(2) \\ &= \frac{\alpha}{2-\alpha}\left(\left(\frac{1}{2}\right)^{-\frac{\theta}{2-\theta}} + 2(1-\alpha)\right)\left(\frac{1}{\theta} - \frac{1}{2}\right) - 2\alpha\beta. \end{aligned}$$

For $\theta = \frac{1}{2}$ and various bargaining weights α, table 1 presents bounds on the suppliers' outside option β that ensure that the participation conditions (i) for the suppliers ($x(2) > \beta$) and (ii) for the buyer ($s(w^\star(2)) > s(w^\star(1))$) hold and thereby guarantee the existence of an equilibrium in which the buyer sources from both suppliers. The last column shows that these bounds are jointly sufficient for the per unit prices paid by the buyer to be lower in the multi-sourcing equilibrium than in the case of a bilateral monopoly.[9]

[9] The per unit price is $w^\star(n) + x(n)/S(w^\star(n)) = w^\star(n) + x(n)/w^\star(n)$, $n = 1, 2$, and $x(n)$ is decreasing in α while $w^\star(n)$ is independent of α. Since $x(1)$ decreases more slowly in α than $x(2)$, the multi-sourcing condition on β becomes increasingly stringent.

θ	α	(i)	(ii)	multi-sourcing
$\frac{1}{2}$	$\frac{1}{4}$	$\beta < 1.2843$	$\beta < 0.866$	$\beta < 7.8969$
$\frac{1}{2}$	$\frac{1}{3}$	$\beta < 1.4287$	$\beta < 0.834$	$\beta < 5.8362$
$\frac{1}{2}$	$\frac{1}{2}$	$\beta < 1.7818$	$\beta < 0.760$	$\beta < 3.6769$

Table 1: Constraints on suppliers' outside option β: Participation and multi-sourcing.

2.4 Capacity constraints

The framework of the preceding subsection can easily embed capacity constraints. Suppose that, in the previous setting, there are two suppliers of type t and t', with positive capacities k and k', respectively. Then, the buyer's objective is

$$\begin{aligned}\max_{w(t),w(t')} \quad & Y(S(w(t),t)+S(w(t'),t')) - w(t)S(w(t),t) - w(t')S(w(t'),t') \\ & + \int_0^{w(t)} S(v,t)dv + \int_0^{w(t')} S(v,t')dv \\ & +\lambda(t)(k - S(w(t),t)) + \lambda(t')(k' - S(w(t'),t')).\end{aligned}$$

Here, $\lambda(t)$ and $\lambda(t')$ are the positive shadow values of the suppliers' capacities. If the capacity constraints do not bind at the solution $w^\star$ of the preceding subsection, then nothing changes. Suppose, instead, that the type t supplier is constrained, while the type t' supplier is not. Then,

$$Y'(S(w^\star(t),t) + S(w^\star(t')t')) = w^\star(t) + \lambda(t)S_w(w^\star(t),t) = w^\star(t').$$

Hence, the type t' supplier benefits from supplier t's capacity constraint in terms of relatively higher per unit prices for its output; this is also to the detriment of the buyer. Provided Y is strictly concave in q and S is strictly convex in w, it follows that

$$w^\star(t') = S^{(-1)}\left(Y'^{(-1)}\left(S^{(-1)}(k,t) + \lambda(t)S_w(S^{(-1)}(k,t))\right), t'\right),$$

where the superscript $^{(-1)}$ denotes the inverse of a function. The above expression shows that, in the presence of capacity constraints, t's competitor's price $w^\star(t')$ is a function of t's capacity and its shadow value $\lambda(t)$.

3 Empirical Analysis

3.1 Empirically Testable Predictions

This subsection delineates a few preliminary conclusions with regard to the empirical analysis of buyer power.

Note first that, in order to account for buyer and supplier specific effects that are not directly attributable to measurable costs, it is desirable to have panel data.

Typically, empirical analyses are carried out on the basis of average prices per transacted unit. The preceding theoretical analysis suggests that, when relating average prices to costs and quantities, quantities should be treated as endogenous. Hence, appropriate instruments are required. Considering transactions in a specific buyer-supplier relationship, apart from lagged quantities, transaction volumes from contemporaneous transaction with alternative suppliers may be an option: They are correlated via the buyer's revenue function, but uncorrelated with the primary determinants of the bilateral relationship under consideration, at least under the hypothesis of the absence of buyer power.

Furthermore, an empirical finding of average prices declining with transaction volume is consistent with nonlinear pricing, whether or not the buyer exerts any bargaining power.

However, the theoretical analysis suggests that, in the absence of buyer power, (i) in the presence of constant marginal costs of suppliers, the number of supplier relationships should not affect average prices; and (ii) in the presence of declining marginal costs of suppliers, the buyer optimally only deals with a single supplier. Hence, in these circumstances, a statistically significant effect of the number of suppliers on the average price in a specific buyer-supplier relationship constitutes evidence against the hypothesis of no buyer power. On the other hand, if suppliers' marginal costs are increasing, e.g. as a consequence of capacity constraints, then average prices per transacted unit are unlikely to embed sufficient information to identify buyer power.

Similarly, statistically significantly different supplier effect are consistent with differential bargaining power on the part of the suppliers, at least if all essential costs are accounted for. Although the theoretical part of the paper does not model it explicitly, one would expect a supplier's outside option to be a increasing function of the number of actual and potential buyer relationships that this supplier entertains. These could be quantified by the observed number of existing relationships with buyers, or by measures of how extensive a supplier's business network is, e.g. number of plants or distribution outlets and density of the supplier's plant or distribution network etc.

3.2 Background and Data[10]

The data for the empirical part of this paper come from the UK brick industry. This sector has been the focus of a recent merger inquiry by the UK competition authorities where the question of potential countervailing buyer power was also investigated, as bricks are a relatively standardized product and there are several manufacturers in the UK. There are four main suppliers of bricks in the UK, and the data comprise their transactions with all their UK customers in the period 2001 - 2006. Customers are construction firms, or builders, and intermediaries, or builders' merchants.

Each of the four brick manufacturers is involved in all stages of the brick manufacturing process. This process starts from extracting clay from the soil and processing it, including shaping it, and eventually burning the bricks in large furnaces or kilns. As transportation costs are significant in this industry, most manufacturing plants are close to clay deposits. Two main types of bricks emerge from these processes: facing bricks, used as cladding material for the outside of buildings, distinguishing the more expensive soft-mud brick from the more conventional extruded variety; and engineering bricks, used to erect structures and accordingly meeting special requirements with regard to load-bearing capacity and water retention.

The industry has been experiencing some decline over the last decades. Industry sources attribute this to reductions in the number of houses built, the change in the housing mix from detached and semi-detached houses to apartments, and different choices for structural and cladding materials, such as timber, concrete blocks, steel and curtain walling (glass, laminates etc.).

With regard to the procurement of bricks, there are two primary channels.

[10]The description of the industry background follows the UK Competition Commissions provisional findings report on Wienerberger Finance Service BV / Baggeridge Brick plc (2007), Appendix C. The report is available from the Competition Commission website.

One possibility is for buyers to purchase through framework agreements at pre-determined prices. These agreements set out a matrix of prices and brick specifications, including brick type and transport costs to different locations. Prices can be quoted as ex-works or delivered prices. Buyers can thereby negotiate the terms of the agreement, including retrospective rebates, potentially on the basis of historic and prospective volumes. Eventually, once a framework is agreed upon, there is, however, no firm commitment on the part of the buyer, who can call off supplies according to the needs as they arise. Builders' merchants also use framework agreements, albeit typically with less detailed specificity. Framework agreements are typically negotiated annually.

Alternatively, bricks can be purchased ad hoc at spot prices. Buyers may still enjoy eventual retrospective rebates, and many buyers who sign framework agreements may still buy ad hoc, e.g. when a manufacturer wishes to sell off stock or a buyer experiences an unusual demand in terms of brick type, location or volume. While the main manufacturers do have price lists, these list prices do not apply to the bulk of bricks transactions.

The analysis presented here focuses on ex works prices per one thousand bricks, i.e. net of transport costs, and also net of any rebates. Since the data from one of the suppliers do not permit us to separate transport costs from total transaction price, this supplier's data have been excluded from most of the analysis.

There are just below 7000 customers that purchased bricks from the four suppliers over the six year period 2001 - 2006. Table 2 shows that there is a fair amount of switching of these between the four suppliers. But often, suppliers are able to make up the loss of customers by selling increased volume to those customers who are retained, e.g. supplier 3 in the periods 2001 - 2002; or even compensating for loss of volume by raising prices on the retained volume, e.g. supplier 1 in the period 2005 - 2006. Hence, while Table 2 suggests that buyers' switching to and from suppliers is a salient feature of the UK brick industry and hence provides the kind of conditions that potentially incubate buyer power, it also provides some evidence that manufacturers' may have market power when setting prices.

Supplier	2001-02	2002-03	2003-04	2004-05	2005-06
Customers					
Supplier 1	-0.061	0.017	0.015	-0.061	-0.045
Supplier 2	-0.119	0.099	-0.109	0.060	-0.100
Supplier 3	-0.208	0.0217	0.075	0.086	0.005
Volume					
Supplier 1	0.046	0.046	-0.017	0.004	-0.029
Supplier 2	-0.197	0.363	-0.056	0.136	-0.0777
Supplier 3	0.001	0.030	0.010	-0.003	-0.079
Revenue					
Supplier 1	0.084	0.113	0.044	0.006	0.0695
Supplier 2	-0.179	0.416	-0.011	0.181	-0.030
Supplier 3	0.030	0.088	0.039	0.050	-0.002

Table 2: Switching, relative to base year.

A brief description and summary statistics of the variables used in the analysis are provided in an appendix.

3.3 Methodology and Results

The empirical methodology aims at uncovering the reduced form relationship between brick price and various determinants of price. The specific focus thereby is on the question whether buyers who have established a greater number of contractual relationships in the period 2001-2006 - as an indication of their switching possibilities - benefit from lower prices, on average. The empirical analysis attempts to control for various characteristics of the transaction. First, there may be volume effects when price schedules are potentially nonlinear. Second, as in this industry transport costs are significant, relative to brick price, there may be distance effects: Buyers with construction or delivery sites that are more distant to the manufacturer's plants may be given discounts to capture their business. Third, the analysis controls for brick attributes: On average, extruded bricks are cheaper than soft-mud bricks, and similarly engineering bricks are cheaper than facing bricks.

In light of the foregoing theoretical analysis, transaction volume may be endogenous. The analysis therefore, next to ordinary regressions, presents results obtained from instrumenting volume. The decision to have the bricks delivered is likely to be correlated with the transaction size, but, in the absence of bundling, uncorrelated with the transaction price which is net of delivery costs. Therefore, a variable indicating whether the transaction volume was arranged to be delivered, as opposed to being picked up, is used as instrument for volume, next to time trends captured by month and year. First stage regressions are also in the appendix.

Moreover, as is now increasingly recognized in applied demand analysis, heterogeneity across economic decision makers is an empirical regularity that should be accounted for, if possible. Panel data permit to control for buyer specific effects if they are present. Hence, the empirical analysis in addition presents panel data estimators that exploit the entire richness of the data.

Table 3 presents the estimation results from different estimation methodologies.[11] Two main conclusions emerge when comparing the columns of the table. First, comparing standard with instrumental variables regressions, failure to instrument transaction volume induces a downward bias, in absolute value, of the distance and multi-sourcing effects. The source of the biases is likely to be that the size of the buyer business determines both prices and volumes. Large transactions are generated by larger businesses that entertain a larger number of supplier relationships, and these tend to get lower prices. Also, large transactions entail higher transport costs, and in order to secure such deals suppliers grant more significant discounts. Second, comparing standard with panel data estimators, failure to account for heterogeneity across buyers biases the empirical results of this analysis towards a finding of buyer power, albeit only at the 10 percent level of statistical significance. Controlling also for supplier specific effects eliminates any buyer power effect reflected in negative coefficients on the sourcing variable and captures the distance effects that were present in the first five specifications.[12] Supplier effects arise due to the different capacities and plant network configurations of the three suppliers included in the analysis: Supplier 3 is by far the largest supplier, with the largest number of plants and the widest geographic spread of its plants.[13] Hence, from a methodological point of view, accounting for

[11] The various acronyms are: OLS - ordinary least squares; IV/2SLS - instrumental variables/2-stage least squares; RE - random effects panel data estimator; BE - between effects estimator.

[12] In light of the suppliers' plant network configurations, the distance variable is highly correlated with the suppliers' capacities, measured by the number of plants they operate.

[13] Appendix B provides further details on capacity. See also the Provisional Findings report

	Price per 1k bricks									
	OLS	IV/2SLS	RE	BE	IV, BE	OLS	IV/2SLS	RE	BE	IV, BE
Supplier 2	-	-	-	-	-	-152.734***	-241.288***	-411.24 ***	-313.102**	-886.255***
	-	-	-	-	-	(20.247)	(20.704)	(113.323)	(148.138)	(163.588)
Supplier 1	-	-	-	-	-	-161.075***	-161.075***	-327.710**	-160.214	-926.606***
	-	-	-	-	-	(26.227)	(26.381)	(168.489)	(355.583)	(371.260)
week	0.541***	0.373***	0.574***	-	-	0.526***	0.356***	0.572***	-	-
	(0.077)	(0.077)	(0.081)	-	-	(0.077)	(0.077)	(0.081)	-	-
Volume	-0.063***	0.007*	-0.072***	-0.183***	0.070**	-0.061***	0.007*	-0.072***	-0.172***	0.104***
	(0.002)	(0.004)	(0.002)	(0.018)	(0.034)	(0.002)	(0.004)	(0.002)	(0.019)	(0.036)
distance	-0.380	-1.799***	-0.019	-0.916	-8.413***	-0.004	-1.195***	0.089	-0.253	-1.756
	(0.390)	(0.396)	(0.469)	(2.758)	(2.921)	(0.413)	(0.418)	(0.475)	(4.492)	(4.566)
sourcing	-23.255***	-37.032***	-81.441	-35.913	-283.930*	47.655***	72.815***	89.001	68.183	114.837
	(5.270)	(5.316)	(108.062)	(167.257)	(171.954)	(11.378)	(11.454)	(118.624)	(188.698)	(191.758)
extruded	-111.623***	-66.595***	-69.049***	-678.588***	-836.253***	-102.172***	-53.751***	-68.043***	-655.565***	-765.662***
	(15.195)	(15.357)	(16.634)	(139.946)	(143.082)	(15.244)	(15.425)	(16.636)	(140.360)	(143.115)
engineering	-57.638 **	-218.712***	-17.243	-55.923	-920.774***	-67.602**	-227.878***	-17.890	-52.953	-932.777***
	(27.181)	(28.228)	(29.890)	(292.519)	(312.150)	(27.207)	(28.287)	(29.892)	(293.035)	(313.542)
constant	794.751 ***	423.487***	1009.102***	2054.644***	1458.645***	746.965***	365.962***	951.470***	1956.799***	1075.753***
	(14.060)	(29.639)	(128.248)	(207.901)	(221.216)	(26.002)	(31.725)	(130.605)	(226.322)	(250.164)

Table 3: Regression results; standard errors in parenthesis; instruments for Volume: month, year, delivery
* significant at 10 percent level
** significant at 5 percent level
*** significant at 1 percent level

both endogeneity of transaction volume and heterogeneity of buyers appears to be critical for the empirical identification of buyer power.

4 Conclusions

This paper provides a comprehensive framework for the empirical analysis of buyer power that is useful for practitioners, such as competition economists in antitrust authorities. This framework encompasses the two main features of pricing schemes in business-to-business relationships: nonlinear price schedules and bargaining over rents. Disentangling these two features is critical to the empirical identification of buyer power. A structural theoretical model investigates the principal determinants of optimal pricing schemes, with buyers' switching possibilities identified as the primary source of buyer power. It forms the basis for the delineation of testable predictions that enable the empirical identification of buyer power. The empirical part of the analysis presents an illustration of the conceptual approach offered in this paper, for the UK brick industry. It presents a reduced form methodology to estimate the impact of buyers' switching possibilities on prices. This methodology is readily implementable on the basis of transaction data, as they are requested routinely by antitrust authorities at the outset of their inquiries. The paper emphasizes the importance to control for endogeneity of volumes and for heterogeneity across buyers.

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A Proofs

A.1 Lemma 1

The Nash bargaining problem can be cast as

$$\max_{x \geq 0} |s_2 - x|^\alpha |x|^{1-\alpha},$$

from which the solution follows. □

A.2 Proposition 1

The Nash bargaining problem with respect to the buyer and supplier 1 can be cast as

$$\max_{x_1 \geq 0} |s_2 - x_1 - x_2(2)|^\alpha |x_1|^{1-\alpha},$$

and analogously for supplier 2. Solving yields the reaction functions

$$\begin{aligned} x_2(2) + (1-\alpha)x_1(2) &= (1-\alpha)(s(2) - \alpha s_1(1)) \\ x_1(2) + (1-\alpha)x_2(2) &= (1-\alpha)(s(2) - \alpha s_2(1)), \end{aligned}$$

from which the result follows. □

A.3 Proposition 2

The Nash bargaining problem with respect to the buyer and supplier 1 can be cast as

$$\max_{x_1 \geq 0} |s_2 - x_1 - x_2(2) - s(1_1)|^{\alpha} |x_1 - a_1(2)|^{1-\alpha},$$

where $s(a1_1) = \alpha(s(1) - a_1(1))$, and analogously for supplier 2. Solving yields the reaction functions

$$\begin{aligned} x_2(2) + (1-\alpha)x_1(2) &= (1-\alpha)(s(2) - \alpha s(1_1)) + \alpha a_2(1) \\ x_1(2) + (1-\alpha)x_2(2) &= (1-\alpha)(s(2) - \alpha s(1_2)) + \alpha a_2(1), \end{aligned}$$

from which the result follows. Condition (i) is necessary to ensure participation of the suppliers, while condition (ii) is necessary to ensure that multi-sourcing benefits the buyer. □

A.4 Lemmas 2 and 3

The following Lemmas are useful for the proof of subsequent results.

Lemma 2: *Let A_n be an $n \times n$ matrix that has $A_n(i,i) = 1$ for $i = 1, \cdots, n$, and $A_n(i,j) = 1 - \alpha$, $\alpha \in (0,1)$, for $i, j = 1, \cdots, n$ and $i \neq j$. Then,*

$$|A_{n+1}| = \alpha^n(\alpha + (n+1)(1-\alpha)).$$

Proof: Notice, first, that elementary rules for matrix inverses imply that the diagonal elements of A_{n+1}^{-1} are $|A_{n+1}|^{-1}|A_n|$. Denote the off-diagonal elements of A_{n+1}^{-1} by z. Then,

$$\begin{aligned} 1 &= |A_{n+1}|^{-1}(|A_n| + n(1-\alpha)z) \\ 0 &= z + (1-\alpha)|A_n| + (n-1)(1-\alpha)z. \end{aligned}$$

The second equation implies that $z = -(1-\alpha)|A_n|/(\alpha + n(1-\alpha))$.

The proof proceeds by induction. The result can easily be verified for $n = 1$ and $n = 2$. Suppose it holds for n. Then, the first equation above, together with the expression for z, implies

$$\begin{aligned} |A_{n+1}| &= \alpha^{n-1}(\alpha + n(1-\alpha) - n(1-\alpha)\alpha^{n-1}(1-\alpha) \\ &= \alpha^n(\alpha + (n+1)(1-\alpha)). \end{aligned}$$

This also implies $z = -(1-\alpha)\alpha^{n-1}$. $\square$

Lemma 3: *For k an integer between 1 and n, let $B_{n,k}$ be an $n \times n$ matrix that has $B_{n,k}(i,j) = 1-\alpha$, $\alpha \in (0,1)$, for $i,j = 1,\cdots,n$ and $i \neq j$, and $B_{n,k}(i,i) = 1$ for $i \neq k$ and $B_{n,k}(k,k) = 1-\alpha$. Then,*

$$|B_{n,k}| = \alpha^{n-1}(1-\alpha),$$

independent of k.

Proof: Without loss of generality, the proof establishes the result for $k=1$. Denote $C_{n,k} := B_{n,k}^{-1}$. Since $C_{n,k}(i,j) = 0$ for $i,j = 2,\cdots,n$, $i \neq j$, while $C_{n,1}(i,i) = |B_{n,1}|^{-1}|B_{n-1,1}|$ and $C_{n,1}(1,i) = C_{n,1}(i,1) = -|B_{n,1}|^{-1}|B_{n-1,1}|$ for $i = 2,\cdots,n$, $C_{n,1}B_{n,1} = \mathbf{I}_n$ implies that $\alpha|B_{n,1}|^{-1}|B_{n-1,1}| = 1$. Iterating from $|B_{2,1}| = \alpha(1-\alpha)$ yields the result. $\square$

A.5 Proposition 3

Define

$$x_i(n) = \arg\max_z |s(n) - z - \sum_{j\neq i} x_j(n) - b(n-1)|^{\alpha}|z - a_i(n)|^{1-\alpha}, \ \ i = 1,\cdots,n.$$

Then, using the definition of A_n in Lemma 2,

$$-A_n\mathbf{x}(n) + \iota(1-\alpha)(s(n) - b(n-1)) + \alpha\mathbf{a}(n) = \mathbf{0},$$

where $\mathbf{x}(n) = (x_1(n),\cdots,x_n(n))'$, $\mathbf{a}(n) = (a_1(n),\cdots,a_n(n))'$ and ι is an $n\times 1$ vector of 1s. Using the results of Lemma 2 and Lemma 3, it follows that

$$\mathbf{x}(n) = \frac{1}{|A_n|}\begin{bmatrix} |A_{n-1}| & -|B_{n-1}| & \cdots \\ -|B_{n-1}| & |A_{n-1}| & \cdots \\ \vdots & & \ddots \end{bmatrix}\left[\iota(s(n) - b(n-1)) + \alpha\mathbf{a}(n)\right],$$

and therefore

$$\begin{aligned} x_i(n) &= \frac{1-\alpha}{\alpha + n(1-\alpha)}(s(n) - b(n-1)) \\ &\quad + \frac{\alpha}{\alpha + n(1-\alpha)}a_i(n) - \frac{1-\alpha}{\alpha + n(1-\alpha)}\sum_{j\neq i} a_j(n). \end{aligned}$$

The condition $s(n)-\sum_{i=1}^{n} a_i(n) > b(n-1)$ implies that $x_i(n) > a_i(n)$, so that condition (ii) of the equilibrium definition is satisfied. It then follows that

$$\begin{aligned} b(n) &= s(n) - \sum_{i=1}^{n} x_i(n) \\ &= \frac{n(1-\alpha)}{\alpha+n(1-\alpha)} b(n-1) + \frac{\alpha}{\alpha+n(1-\alpha)} \left(s(n) - \sum_{i=1}^{n} a_i(n) \right) \end{aligned}$$

and the condition $s(n)-\sum_{i=1}^{n} a_i(n) > b(n-1) > 0$ implies that $b(n) > b(n-1)$ so that condition (i) of the equilibrium definition is satisfied as well. □

A.6 Corollary 2

The result of Proposition 3 implies that

$$b(n) - b(n-1) = \frac{\alpha}{\alpha+n(1-\alpha)} \left(s(n) - b(n-1) - na(n) \right).$$

Property (ii) of the Nash bargaining equilibrium implies that $s(n)-b(n-1)-na(n) > 0$ so that $b(n) - b(n-1) > 0$ for any n. Furthermore, $s(n) < \infty$ for all n implies that this expression is bounded above. Therefore, it follows that $s(n) - b(n-1) - na(n) = o(1)$. □.

B Data and Auxiliary Regressions

The data comprise roughly six hundred thousand individual contracts between UK buyers and the (three) manufacturers used in the analysis. Prices per one thousand bricks are in GBP. Volume is measured in the number of bricks. Distance is measured in kilometers between the manufacturing plant and the construction or delivery site. The sourcing variable is the number of manufacturers that the respective buyer entertains contractual relationships with during the observation horizon 2001 - 2006. There are dummy variables indicating whether the bricks of the respective transaction are of the extruded (as opposed to soft mud) variety, whether they are engineering (as opposed to facing) bricks, and whether the buyer chose to have the supplier arrange the delivery or collected the bricks.

The following table provides summary statistics.

Variable	Obs.	Mean	Std.Dev.	Min	Max
Price per 1k	637015	344.802	5093.57	0.0008306	3097000
Volume	637015	5991.746	3910.012	2	264000
sourcing	637015	2.567056	1.325533	1	4
distance	581112	4.089677	17.90908	0	341.3
extruded	637015	.6811441	.4660334	0	1
engineering	637015	.0723782	.2591133	0	1
delivery	637015	0.58792	.4922097	0	1

Table B1: Summary statistics.

Table B2 presents the first stage regression for the IV/2SLS estimation results presented in Table 3.

	Volume
month	2.639**
	(1.331)
year	105.661***
	(16.219)
delivery	3620.443***
	(8.843)
constant	-211541.4 ***
	(32446.6)

Table B2: First stage regression results.

* significant at 10 percent level

** significant at 5 percent level

*** significant at 1 percent level

The four UK brick suppliers have different capacities. Suppliers 1 has 7 plants and supplier 2 has 20 plants. Supplier 3 is the largest supplier, with 23 plants and the largest geographic spread.[14] For the three suppliers included in the analysis, supplier 1 produced an average of 87.3 million bricks per year, supplier 2 195.2 million and supplier 3 353.7 million bricks per year.

[14]This information is sourced from the Provisional Findings report of the Competition Commission.