Competitive Price Discrimination in a Spatially Differentiated Intermediate Goods Market*

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Abstract

Intermediate product markets are distinct in several ways, including the large size of the transactions, and the ability to price discriminate using buyer-specific prices. We study a competitive intermediate goods market in which there are buyer-specific prices. Using a rich dataset of transactions from the UK brick industry—in which transportation costs play an important role—we estimate a model of price setting in which the price is set specifically for each transaction. We estimate two specifications, one in which the sellers make take-it-or-leave-if offers to buyers, and one in which prices are negotiated between the buyer and seller. We analyse the effect of bargaining power, location, and transaction size on prices.

Preliminary and Incomplete. Comments welcome.

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1 Introduction

Intermediate product markets are distinct from final product markets because of the greater sophistication of the buyers, the large size of the transactions, and the prevalence of price discrimination using buyer-specific prices. Price discrimination often depends on the volume sold or the location of the buyer. These features of intermediate goods markets are reflected in competition policy: the protection of small downstream firms was the motivating factor behind the Robinson-Patman Amendments (to Section 2 of the Clayton Act) in the US, which prohibit price discrimination, while discrimination between buyers based on their location has been a recurrent issue (for products with high weight-to-value ratio) in Europe and the US. Despite its importance for public policy, there has been very little empirical analysis of intermediate goods pricing.

We study intermediate pricing empirically using a unique dataset of transactions for intermediate products. We use data from the UK brick industry and focus on sales to large construction firms. Each transaction requires the bricks to be delivered to a specific location (building site) so that the choice set varies by transaction. Given the bulky nature of the product, transport costs are important and we exploit the exogenous variation in buyer size and location. We consider demands by the large national housebuilders, who negotiate directly with the brick manufacturers on an order-by-order basis. The data comprise transactions and cost information from the largest brick manufacturers over the period 2001-06. There are more than 2 million transaction records, containing prices, volumes, brick characteristics, manufacturing plant location, and delivery location. The cost data are monthly over the same period, at the plant level.

We estimate a bargaining model in which prices are negotiated between the buyer and seller specifically for each transaction. Our model nests as a special case a model in which the buyers have no negotiating power (similar to Thisse and Vives (1988)) and sellers set prices to each buyer individually depending on their spatial location and order size (i.e., Bertrand-Nash model). We analyze the effect of location and transaction size on the prices that are negotiated. We estimate the importance of buyer size and location effects on the distribution of prices.

Our estimation results suggest that the data reject the Bertrand-Nash model against our bargaining model. Using the estimated parameters, we perform counterfactual analyses to highlight the importance of competition and location effects. Specifically, we solve the model with the following changes to the environment: (i) eliminating joint ownership of plants, (ii) setting the transport cost parameter to zero, thereby eliminating geographic differentiation, and (iii) banning price discrimination based on the size of transaction and location of the buyer. In the first scenario, we find that the largest seller enjoys significant market power, as prices fall by 10.6% when there is a de-merger of its plants. This is approximately 20% of the average markup. In the second scenario, for one of the four sellers the price effect is negative, consistent with the idea that transport costs confer market power. However, for other sellers the price increases when transport costs go to zero. One possible reason for this is that firms that are located further from consumers are able to raise their prices when transport costs are eliminated. In the third scenario, we find that the uniform price restriction results in higher equilibrium prices and sellers' profit, while it significantly reduces buyers' utility. Overall, the total surplus decreases by 5% due to the uniform price restriction.

There is now a large theoretical literature on intermediate goods pricing (see surveys by Katz (1989) and Rey and Tirole (2007)). Some models use a leader-follower interface between sellers and buyers, in which the downstream firms are price-takers (e.g. Rey and Tirole (1986), Katz (1987)). Others use a bargaining interface (see Dobson and Waterson (1996), Chipty and Snyder (1997), Inderst and Wey (2003), Chen (2003), Smith and Thanassoulis (2012) and de Fontenay and Gans (2013)). Many of these models feature prices set specifically to individual buyers. Of particular interest to us is discrimination by volume sold or location of the buyer, as studied in Katz (1997), Inderst and Valetti (2009), and Thisse and Vives (1988).

Compared to the theoretical literature, there is relatively little empirical literature on intermediate goods pricing. Those papers that have studied intermediate prices directly are in three groups. The first uses regression analysis rather than structural modelling (see Ellison and Snyder (2010) and Sorenson (2001)); these papers establish the existence of buyer power, particularly in cases when there is upstream competition. The second group studies spatial competition and market power arising from geographic differentiation (see Houde (2012), Chicu (2013), Miller and Osborne (2014)); they provide evidence that transport (travel) costs and consumer location are important determinants of demand and market power exercised by producers. A third group of papers estimate structural bargaining models, typically assuming bilateral oligopoly (see Crawford and Yurucoglu (2010), Grennan (2013), and Gowrisankaran, Nevo and Town (2013)). These all use a specific bargaining model: the "Nash-in-Nash" bargaining solution proposed in Horn and Wolinsky (1988). Our paper develops this approach to allow greater focus on the "endogenous" sources of bargaining power (as in Katz (1997) and Inderst and Valetti (2009)), most notably location of the buyer.

In section 2 we discuss the industry. In 3 we develop the theoretical model of price determination, and derive the likelihood functions for estimation of parameters in Section 4. In Section 5 we describe the data. Section 6 discusses results and performs several counterfactual analyses. Section 7 concludes.

2 The Market for Bricks

In this section we discuss relevant features of the brick market.[1] The main players are manufacturers and builders. Our study focuses on the larger builders, who source directly from the manufacturers. To preserve anonymity we will not discuss the identities of the buyers and sellers.

There are 51 brick manufacturing plants in Great Britain, owned by four main firms. Apart from the size and spread of their plant network, the four manufacturers are very similar, offering broadly the same range of brick products.

Plants are next to clay deposits. Production consists of extracting clay from the ground, grinding shaping and drying the bricks, and then firing them in kilns at temperatures of 1000C. The main costs are labour and gas, the latter being 17%-26% of production costs. There is heterogeneity in marginal costs across plants due to the extent of robotic systems and more energy efficient kilns. There is no entry of plants during the six years of our data. A few plants closed because firms had too much capacity.

There are significant inventories of bricks stored at each plant. At any point in time stocks are equivalent to about one third of the annual flow of production. Manufacturers hold brick inventory to allow an order to be supplied quickly from stock and to allow "smoothing" of production relative to demand, which peaks between March and September. Developers generally require a just-in-time delivery and therefore rely on the manufacturers' ability to hold sufficient stock and deliver bricks at short notice.

Bricks may be divided into two broad classes: facing bricks (80%-90% of the total) used for external walls and engineering bricks used for load-bearing walls. There are a few key characteristics. Some of these characteristics are relevant for aesthetics, in particular the color and the manufacturing method. A number of other characteristics affect the performance of the brick, such as

[1] This section draws heavily on Chapter 4 and Appendix C of Competition Commission (2006). We make references to this source throughout the section.

strength, water absorption, and durability to frost. A more detailed discussion of brick characteristics is in Section 5. The color of the brick is set by the building specification plans well before the choice of supplier is determined.

Geographic differentiation is very important. Delivery costs are 25% of the cost of delivered bricks, including costs of loading and unloading. 50% of bricks are sold within a 110 km radius (80% within a 200 km radius). Figure 1 shows the locations of the plants, where the largest circles drawn have a radius of 200 km. Distribution is carried out by third party haulers using purpose-built vehicles, arranged either by the manufacturer or the buyer.

The main demand for bricks is either as a cladding material (facing bricks) or for structural purposes (engineering bricks). This paper studies the largest house building construction firms, who buy facing bricks only. A developer building houses must first make a choice of whether to use facing bricks or some other cladding material, and then which brick to choose. As our dataset is sales of bricks we do not directly observe the number of orders for other (non-brick) types of facing material. We can indirectly compute a figure for this by assuming that the total market size—the maximum potential demand for bricks—is determined by the number of new houses being built in any region. There are government statistics on the number of new housing starts each region and period, including a breakdown by type of house (apartment or house). From this we compute the number of bricks that would be demanded if everyone used bricks, using estimates of how many bricks are needed for a typical house. The total number of houses being built in any region is therefore a good measure of the size of the market. (As bricks are only a very small fraction of the cost of building a house we treat the demand for houses as exogenous.) Table 1 shows for each UK region the computed market size, the volumes of bricks delivered, and the implied market share of the outside option s_0. Figures (in millions) are totals for the period 2001-2006. We can see that market share s_0 varies from region to region. These shares are partly affected by variations across regions in the distance to a brick plant. For regions where there are few local brick plants the market share of other cladding materials is relatively high (an example of such a region is Scotland, as can be seen from Figure 1).

The color of the brick is usually determined by the architect or the government planner at an early stage of the design process, taking into account any planning requirements or preferences (planners may stipulate brick cladding of a particular color to fit with local conditions). Thus for any particular project the color is not usually determined by the builder.

Builders can buy bricks directly from the brick manufacturers or from a merchant, who is an intermediary. About 19% by volume is sold directly to major developers and housebuilders. For a builder, bricks are on average only about 3% of the overall cost of buildings for developers. Given that bricks form a small proportion of marginal costs, it is reasonable to assume that a change to the terms that one buyer agrees with a manufacturer does not have any externalities on other buyers.

There has been a high degree of consolidation among the major developers in recent years. The size distribution of builders is given in Table 2, showing that the top 15 buyers purchase 85% of brick volumes sold to builders and developers. (The proportions in the table relate to the 19% of that are made sales to builders and developers.) The major builders and developers do not consider buying from merchants. The table also shows that most builders purchase from more than one seller. The plant size distribution of the sellers is asymmetric, so it is not surprising that many of the buyers do not use all the sellers. This could be because of the geographic match between the buyer and the seller, or a preference to buy from some sellers rather than others. For any given brick and location however the buyer only sources from a single firm. We consider the top 20 buyers in our model.

Prices are negotiated with buyers individually, with prices depending on the volume, the historic relationship with the manufacturer, buyer size, and distance from plant. Some buyers agree annual "framework agreements" that set out a detailed matrix of prices for bricks of many different specifications and locations. However, there is generally no firm commitment to purchase these or any volumes. Manufacturers said they frequently vary ex works prices for locations further from the plant to compete for business with more local plants. While some major developers deal with all the four sellers, a few place the great majority of their business with only one of them. Developers do not change brick supplier part way through a development, but they will source from different manufacturers for different developments. There is no real sign of switching costs: switching between manufacturers is relatively easy, with no real or contractual barriers.

We model price formation at the level of the individual brick transaction. We define a brick "transaction" as a unique combination of: brick product, buying firm, selling firm, delivery location, and year. A brick product is the most detailed level of specific individual brick specification. A given buying firm is associated with many transactions in any year. There are no externalities between the transactions. We assume these transactions are conducted independently so it is convenient to use the same index for "buyer" and "transaction". (This is a slight abuse of terminology since there are many transactions per buying firm).

3 A Model of Price Formation

3.1 Utility and Cost

A buyer i has a construction project whose scale q_i and location is determined outside the model. The buyer must choose a cladding j for the project, which may be a brick product or a non-brick cladding (the outside option). We let $j = 0$ represent the outside option. Each (inside) brick product j has a unique plant a and manufacturer g. The plants and manufacturers associated with the product are denoted $a(j)$ and $g(j)$. The color of bricks sought by buyer i is determined by the architect. There are several other characteristics such as strength and water absorption, which will be discussed in detail in Section 5. Within each color and other characteristics, there are a number of possible products. These differ in terms of the plant at which they are made. This has an effect on the clay the bricks are made from, which in turn affects the appearance of the brick. The plant also has an effect on the transport costs, as plants are in general located at different distances from buyer i. Let the set of products of the color required by buyer i be denoted $\mathcal{J}_i$. Those offered by seller g are denoted $\mathcal{J}_{ig}$ so that $\mathcal{J}_i = \bigcup_g \mathcal{J}_{ig}$.

The buyer requires bricks j to be delivered a distance $d_{ia(j)}$ from the plant $a(j)$ to the buyer's location. We assume linear transportation costs, with parameter τ. The transport costs are proportional to volume q_i, as the number of trucks needed to deliver the bricks is approximately proportional to the volume of bricks.

We assume that the buyer has a utility $\lambda_{ig(j)}$ of transacting with each seller that is independent of the volume of bricks in the transaction. We specify that

$$\lambda_{ig(j)} = \lambda_1 \varkappa_{ig(j)} + \lambda_2 (1 - \varkappa_{ig(j)}),$$

where $\varkappa_{ig(j)}$ is a binary indicator variable for whether firm g is one of buyer i's regular suppliers.[2] This allows the buyer to prefer to deal with some sellers rather than others because of historical buying relationships, so differences in $\lambda_{ig(j)}$ reflect the cost of using an unfamiliar business relationship.

The gross utility u_{ij} to buyer i of q_i units of product j is given by

$$u_{ij} = \left(\beta_{a(j)} + \beta x_j - \tau d_{ia(j)} + \epsilon_{ij}\right) q_i + \lambda_{ig(j)}, \tag{1}$$

where $\beta_{a(j)}$ is a plant dummy, reflecting quality differences at plant level, β is the per-brick marginal utility of brick characteristics x_j, ϵ_{ij} is an unobserved per-brick taste disturbance. $\lambda_{ig(j)}$ is the transaction-level seller effect. The outside option is $u_{i0} = (0 + \epsilon_{i0})\, q_i$ and represents a choice of some facing

[2]This is defined as sellers that contribute more than 10% of the buyer's transactions.

product other than bricks for the project. We assume that ϵ_{ij} is IID according to a Type-1 Extreme Value distribution.

The seller produces product j in plant $a(j)$. The q_i units of supply required for transaction i incur a cost of supply given by a marginal component $c_{a(j)}$ per unit of q_i and a per-transaction fixed cost $F_{a(j)}$, i.e.:

$$c_{a(j)}q_i + F_{a(j)}. \tag{2}$$

The cost term $F_{a(j)}$ is a per-transaction fixed cost, rather than a per-plant fixed cost. Examples of activities that cause a per-transaction cost include the labour time costs of contracting with the seller as well as those elements of the loading, delivery, and unloading costs that are independent of the number of bricks.

The marginal component $c_{a(j)}$ is derived from the total plant-level cost function

$$\ln C_{at} = \gamma_{0a} + \gamma_1 \ln Q_{at} + \gamma_2 \ln G_t + \gamma_3 \ln W_{at} + \gamma_D' D_t + \eta_{at}, \tag{3}$$

where C_{at} is the total cost of plant a at time t, Q_{at} is the total production of bricks in plant a at time t, G_t is the (national) price of natural gas at time t and W_{at} is regional wage data at time t for the region of plant a. D_t is a quarterly dummy and η_{at} is unobserved cost. The seller supplies from the inventory at the plant. $c_{a(j)}$ is therefore assumed to be the marginal cost of production of the plant when operating at average total output levels for the year. As discussed in Section 2 there is sufficient inventory for us to assume that the seller can treat the cost of supply of transaction i as being independent of other transactions.

3.2 Price, Profits, and Joint Surplus

The buyer makes a transaction-specific total payment T_{ij} to pay for the bricks. The average price per brick p_{ij} is $p_{ij} = T_{ij}/q_i$. The indirect net utility u_{ij} of buyer i when purchasing product j is given by

$$\begin{aligned} u_{ij} &= \left(\beta_{a(j)} + \beta x_j - \tau d_{ia(j)} - \alpha p_{ij} + \epsilon_{ij}\right) q_i + \lambda_{ig(j)} \quad (4) \\ &= \left(\beta_{a(j)} + \beta x_j - \tau d_{ia(j)} + \epsilon_{ij}\right) q_i + \lambda_{ig(j)} - \alpha T_{ij}, \quad (5) \end{aligned}$$

where α is the marginal utility of money. The main variables affecting utility are product characteristics x_j, the distance, the price, the idiosyncratic utility, and the transaction level seller effect $\lambda_{ig(j)}$. For a relatively large order (a large value of q_i) the last of these effects is of lower importance relative to the effects that appear inside brackets in equation (4).

The profit that seller $g(j)$ receives from the transaction is

$$\pi_{ij} = \left(p_{ij} - c_{a(j)}\right) q_i - F_{a(j)}$$

so that for a large order the transaction-specific fixed costs $F_{a(j)}$ are spread over more units.

The joint surplus that is generated when i buys from j is

$$\begin{aligned} S_{ij} &= u_{ij} + \alpha \pi_{ij} \\ &\equiv \left(\beta_{a(j)} + \beta x_j - \tau d_{ia(j)} - \alpha c_{a(j)} + \epsilon_{ij}\right) q_i - \alpha F_{a(j)} + \lambda_{ig(j)}, \end{aligned}$$

where we have scaled profits using α (the marginal utility of money). The socially efficient match, that generates the highest surplus, is determined by a combination of the effects of transportation distance $d_{ia(j)}$, plant efficiency $c_{a(j)}$ for product j, x_j, the unobserved effects summarized in ϵ_{ij}, and transaction-level fixed effects $F_{a(j)}$ and $\lambda_{ig(j)}$.

3.3 Product Choice and Equilibrium Price

We consider a model that allows buyers to have bargaining power. In the extreme case where the buyer has no bargaining power the prices are as given by the model of buyer-by-buyer Nash pricing, as in Thisse and Vives (1988). When the buyer has bargaining power he is able to reduce the price below the Bertrand Nash level towards the seller's marginal cost. We assume that all players have complete information, including $\epsilon_i = \{\epsilon_{ij}\}_{j \in \mathcal{J}}$.

To develop the model consider first the special case where the buyer has no bargaining power, which is equivalent to buyer-by-buyer Bertrand Nash pricing. Assume that sellers simultaneously post prices. Define j^* and j^{**} as follows

$$j^* = \arg\max_{j' \in \mathcal{J}_i} S_{ij'} \qquad\qquad j^{**} = \arg \max_{j' \in \mathcal{J}_i \setminus \mathcal{J}_{g(j^*)}} S_{ij'}.$$

j^* is the product that maximizes social surplus. j^{**} is the product that maximizes social surplus if all products produced by the seller producing j^* are eliminated. In equilibrium the buyer will buy from $g(j^*)$ and the transaction payment $T_{ij^*|j^{**}}$ is given by the solution to the following indifference condition[3]

$$\begin{aligned} & \left(\beta_{a(j^*)} + \beta x_{j^*} - \tau d_{ia(j^*)} + \epsilon_{ij^*}\right) q_i + \lambda_{ig(j^*)} - T_{ij^*|j^{**}} \\ = \; & \left(\beta_{a(j^{**})} + \beta x_{j^{**}} - \tau d_{ia(j^{**})} - c_{a(j^{**})} + \epsilon_{ij^{**}}\right) q_i + \lambda_{ig(j^{**})} - F_{a(j^{**})}. \end{aligned}$$

Solving this indifference equation for $T_{ij^*|j^{**}}$ we obtain the price per brick

$$\begin{aligned} p_{ij^*|j^{**}} &= \frac{T_{ij^*|j^{**}}}{q_i} \\ &= \beta_{a(j^*)} - \beta_{a(j^{**})} + \beta(x_{j^*} - x_{j^{**}}) + \tau(d_{ia(j^{**})} - d_{ia(j^*)}) + \epsilon_{ij^*} - \epsilon_{ij^{**}} \\ &\quad + c_{a(j^{**})} + \frac{(\lambda_{ig(j^*)} - \lambda_{ig(j^{**})}) + F_{a(j^{**})}}{q_i}. \end{aligned}$$

[3] The notation $T_{ij^*|j^{**}}$ recognises that j^{**} is relevant.

From this we see that the Bertrand Nash price per brick is increasing in (i) the distance to the second best plant $(d_{ia(j^{**})} - d_{ia(j^{*})})$, (ii) the cost of the second best plant $c_{a(j^{**})}$. We can also see that the volume discount depends positively on $(\lambda_{ig(j^{*})} - \lambda_{ig(j^{**})}) + F_{a(j^{**})}$.

We now discuss the general version of our model which nests this Bertrand Nash special case and allows the buyers to have some active role in price determination, provided they have some bargaining skill. We allow buyers to have heterogeneous bargaining split parameters, reflecting differential bargaining power e.g. depending on the size of the buyer.

From seller g's set $\mathcal{J}_{ig}$ we assume that i and g would choose to transact product j^* as defined above. The payoffs for the buyer and seller, respectively, from transfer payment $T_{ig(j)}$, are given by

$$\left\{ \left(\begin{array}{c} \left(\beta_{a(j^*)} + \beta x_{j^*} - \tau d_{ia(j^*)} + \epsilon_{ij^*}\right) q_i \\ + \lambda_{ig(j^*)} - T_{ig(j^*)} \end{array} \right), \left(T_{ig(j^*)} - c_{a(j^*)} q_i - F_{a(j^*)}\right) \middle| \, T_{ig(j^*)} > 0 \right\}$$

and the disagreement points to each agent are as follows

$$\left(\left(\begin{array}{c} \left(\beta_{a(j^{**})} + \beta x_{j^{**}} - \tau d_{ia(j^{**})} - c_{a(j^{**})} + \epsilon_{ij^{**}}\right) q_i \\ + \lambda_{ig(j^{**})} - F_{a(j^{**})} \end{array} \right), 0 \right)$$

where product j^{**} is as defined above. The assumption in the buyer's disagreement point is that the buyer can always obtain the product at the Bertrand Nash price from the second best seller as a disagreement point in negotiations with the best seller.

The Nash product between buyer i and seller $g\,(j)$ for product j is given by

$$N_{ig(j)} = \left[\begin{array}{c} \left(\begin{array}{c} \left(\beta_{a(j^*)} + \beta x_{j^*} - \tau d_{ia(j^*)} + \epsilon_{ij^*}\right) q_i \\ +\lambda_{ig(j^*)} - T_{ig(j^*)} \end{array} \right) \\ -\left(\begin{array}{c} \left(\beta_{a(j^{**})} + \beta x_{j^{**}} - \tau d_{ia(j^{**})} - c_{a(j^{**})} + \epsilon_{ij^{**}}\right) q_i \\ +\lambda_{ig(j^{**})} - F_{a(j^{**})} \end{array} \right) \end{array} \right]^{1-\theta_i} \times \left[\left(T_{ig(j^*)} - c_{a(j^*)} q_i - F_{a(j^*)}\right)\right]^{\theta_i}, \tag{6}$$

where θ_i is the bargaining power of the seller against buyer i. For simplicity we assume the sellers have identical bargaining power.

The solution to this maximization problem is given by

$$T_{ig(j^*)} = \left[\begin{array}{c} (1-\theta_i)\left(c_{a(j^*)} q_i + F_{a(j^*)}\right) \\ +\theta_i \left(\left(\begin{array}{c} \beta_{a(j^*)} - \beta_{a(j^{**})} + \beta(x_{j^*} - x_{j^{**}}) \\ -\tau\left(d_{ia(j^*)} - d_{ia(j^{**})}\right) + c_{j^{**}} + \epsilon_{ij^*} - \epsilon_{ij^{**}} \end{array} \right) q_i \\ +F_{a(j^{**})} + \left(\lambda_{ig(j^*)} - \lambda_{ig(j^{**})}\right) \right) \end{array} \right] \tag{7}$$

When $\theta_i = 0$ the buyer has all the bargaining power and can push the price to the seller's cost. When $\theta_i = 1$ the buyer has no bargaining power and in this case we can see from (7) that the buyer obtains exactly the same transfer price $T_{ij^*|j^{**}}$ as the Bertrand Nash case above.

It is useful to derive the price per brick:

$$\begin{aligned} p^*_{ij} &\equiv \frac{T_{ig(j^*)}}{q_i} \\ &= \left[\begin{array}{c} (1-\theta_i)\left(c_{a(j^*)} + \frac{F_{a(j^*)}}{q_i}\right) \\ +\theta_i \left(\left(\begin{array}{c} \beta_{a(j^*)} - \beta_{a(j^{**})} + \beta(x_{j^*} - x_{j^{**}}) \\ -\tau\left(d_{ia(j^*)} - d_{ia(j^{**})}\right) + c_{j^{**}} + \epsilon_{ij^*} - \epsilon_{ij^{**}} \end{array} \right) \\ + \frac{F_{a(j^{**})} + \left(\lambda_{ig(j^*)} - \lambda_{ig(j^{**})}\right)}{q_i} \right) \end{array} \right]. \end{aligned} \tag{8}$$

To understand how the negotiated price varies depending on the buyer, consider the expression for the price per brick (8). We note that a buyer with a low value for θ_i (and hence a high bargaining power) attains a lower price, other things equal. However there are some other variables that determine the price, conditional on any value for θ_i. First consider the effect of volumes q_i. If fixed costs per transaction $F_{a(j^*)} > 0$ and $F_{a(j^{**})} > 0$ then there will be buyer discounts, because the average cost of supply falls as q_i increases, and the buyer is able to appropriate some of this. In a similar way, if $\left(\lambda_{ig(j^*)} - \lambda_{ig(j^{**})}\right) > 0$, then provided $\theta_i > 0$ there will be further buyer discounts, because the average benefit of supply from a preferred supplier falls as q_i increases, so the favorite seller is able to appropriate less per unit. Second, consider the effect of distance $d_{ia(j)}$. Provided $\theta_i > 0$ then buyers who have to go a greater distance $\left(d_{ia(j^*)} - d_{ia(j^{**})}\right)$ to get to the second best plant will pay a higher price as the seller can extract some of the surplus it generates because of its favorable location.

We now explain why the buyer chooses product j^*. If we substitute (8) into (4) and rearrange we can show that the utility of buyer i is given by

$$u_{ij^*|j^{**}} = (1 - \theta_i)S_{ij^*} + \theta_i S_{ij^{**}}.$$

We now ask if the buyer i can do any better than this. Let us suppose that the buyer chooses product j to negotiate over and chooses product k as its disagreement product (i.e. the product it would buy at a Bertrand Nash price if the bargaining broke down). Then the utility of the buyer is given by

$$u_{ij|k} = (1 - \theta_i)S_{ij} + \theta_i S_{ik}. \tag{9}$$

It is natural to impose that the buyer selects j and k subject to $S_j > S_k$, i.e. the product k chosen as a disagreement point offers less surplus than the product j the consumer wishes to buy. Then from (9) we see that for any given k the consumer will maximize $u_{ij|k}$ if it chooses

$$j = \arg\max_{j' \in \mathcal{J}_i} S_{ij'}.$$

4 Estimation

4.1 Step 1: Cost Function Estimation

The cost function (3) is estimated in a first step. To allow for the possible endogeneity of the quantity variable Q we use instrumental variables. The instrumental variables are demand shifters which affect quantity demanded but not costs. The demand shifters are (i) the number of new houses that builders have started to build (housing starts) and (ii) number of houses completed (completions) in the region of the plant $a(j)$ for that quarter. These are available from official government sources. We allow for plant fixed effects which control for unobserved productivity heterogeneity across plants.

4.2 Step 2: Transaction Estimation

In this step we use the implied marginal cost from the estimated cost function in the first step everywhere $c_{a(j)}$ appears in the model. In the discussion we will treat $c_{a(j)}$ as though it is observed.

We have N observations of transactions. Each transaction consists of two observed components: a chosen product j and a transaction price per unit at which the chosen product was sold, p_i. We also observe the brick characteristics x_j, for all $j \in \mathcal{J}$, the distance to all the plants $d_{ia(j)}$, the transaction volume q_i, and the seller associated with the chosen product $g(j)$.

4.2.1 Parameterization

It is difficult to estimate the bargaining parameter θ_i separately for all buyers, so we use the following specification:

$$\theta_i = \frac{\exp(\theta_a)}{\exp(\theta_a) + \exp(\theta_b z_i)},$$

where z_i is the size of buyer i, defined as the total volume that buyer i purchased in the data set. This way, we can capture the effect of buyer size on the average transaction price. We also assume that the per-transaction fixed cost F is seller-specific, rather than plant-specific.

We define the percentage difference between the observed transaction price and the predicted transaction price as the prediction error ν_{ij^*}. We assume that ν_{ij^*} follows a normal distribution with mean zero and variance σ_v^2.[4] We estimate σ_v along with the scale parameter σ_ϵ of the Type-1 Extreme Value distribution for ϵ (an unobserved per-brick taste disturbance).

The parameters to be estimated in the Bargaining model are

$$\{\lambda_1, \lambda_2, \tau, \{\beta_a^{red}\}_{a=1}^{A}, \{\beta_a^{buff}\}_{a=1}^{A}, \{\beta_h\}_{h=1}^{H}, \{F_g\}_{g=1}^{4}, \theta_a, \theta_b, \sigma_v, \sigma_\epsilon\},$$

where H is the number of characteristics in vector $x_j = (x_{j1}, .., x_{jh}, .., x_{jH})$ and A is the total number of plants.[5] As was discussed in Section 2, the color of the brick is set by the building specification plans. We focus on two different colors, red and buff. Across these two colors, the market shares of plants are very different. This is probably because some plant is good at producing bricks with a particular color than others. To capture this,

[4] This prediction error involves various components. We approximate its distribution by this normal distribution. Details of this approximation are provided in the Appendix.

[5] There are several plants that do not produce bricks with particular colors. The total number of β_a is 73. The number of observable characteristics (H) is 5. Thus, the total number of parameters estimated is 89.

we estimate plant-level fixed effects for each color separately. This yields $11 + H + 2A$ parameters.

4.2.2 Likelihood Function

We assume that all transactions are independent. The likelihood contribution of a transaction is given by the joint probability of the price and the choice of product. This is given by the density of the prediction error ν_{ij^*} conditional on choice of j^* multiplied by the probability that j^* maximizes the surplus from the transaction:

$$f_{\nu_{ij^*}}(\nu_{ij^*}|j^* = \arg\max_{j' \in \mathcal{J}_i} S_{ij'})\mathcal{P}_{ij^*}, \tag{10}$$

where $\mathcal{P}_{ij}$ is the probability that buyer i chooses seller j, defined as

$$\begin{aligned}\mathcal{P}_{ij} &= \Pr\left[j = \arg\max_{j' \in \{0, \mathcal{J}_i\}} S_{ij'}\right] \\ &= \Pr\left[\frac{S_{ij}}{q} \geq \frac{S_{ij'}}{q}, \forall j' \in \{0, \mathcal{J}_g\}\right].\end{aligned}$$

Letting

$$\begin{aligned}\tilde{S}_{ij} &= \frac{S_{ij}}{q_i} = \left(\beta_{g(j)} + \beta x_j - \tau d_{ia(j)} - \alpha c_{a(j)}\right) + \frac{\lambda_{ig(j)} - \alpha F_{a(j)}}{q_i} + \epsilon_{ij} \\ &= \delta_{ij} + \epsilon_{ij},\end{aligned}$$

we can write the choice probability as follows:

$$\mathcal{P}_{ij} = \frac{\exp(\delta_{ij}/\sigma_\epsilon)}{\sum_{j' \in \{0, \mathcal{J}_i\}} \exp(\delta_{ij'}/\sigma_\epsilon)},$$

where

$$\delta_{ij} \equiv \beta_{g(j)} + \beta x_j - \tau d_{ia(j)} - \alpha c_{a(j)} + \left(\lambda_{ig(j)} - \alpha F_{a(j)}\right)/\, q_i$$

and $\delta_{i0} = 0$.

Next, to compute the density of the observation error ν_{ij^*} conditional on choice of j^*, we derive expressions for the expected transaction price conditional on choice of product. From (8), it is easy to show that

$$p^*_{ij} = c_{a(j^*)} + \frac{F_{a(j^*)}}{q_i} + \frac{\theta_i \left[S_{ij^*} - S_{ij^{**}}\right]}{q_i}.$$

One difficulty is that the price depends on the buyer's second best option j^{**}, which is not observed. However, by integrating out the runner up j^{**}, we can obtain the following closed-form solution (see Brannman and Froeb (2000)):

$$\begin{aligned} E\left[p^*_{ij}|j=j^*\right] &= c_{a(j^*)} + \frac{F_{a(j^*)}}{q_i} + \theta_i E\left[\widetilde{S}_{ij^*}|j=j^*\right] - \theta_i E\left[\widetilde{S}_{ij^{**}}|j=j^*\right] \\ &= c_{a(j^*)} + \frac{F_{a(j^*)}}{q_i} + \theta_i\left(\delta_{ig^*} - \sigma\ln\left(P_{ig^*}\right)\right) - \theta_i\left[\delta^*_i + \sigma\frac{\ln\left(1-P_{ig^*}\right)}{P_{ig^*}}\right] \\ &= c_{a(j^*)} + \frac{F_{a(j^*)}}{q_i} + \theta_i\left[\delta_{ig^*} - \delta^*_i - \sigma\ln\left(P_{ig^*}\right) - \sigma\frac{\ln\left(1-P_{ig^*}\right)}{P_{ig^*}}\right], \end{aligned}$$

where

$$\delta^*_i = \sigma\ln\left(\sum\nolimits_{g=0}^{4}\exp\left(\frac{\delta_{ig}}{\sigma}\right)\right)$$

and

$$\delta_{ig} = \sigma\ln\left(\sum\nolimits_{k\in\mathcal{J}_{ig}}\exp\left(\frac{\delta_{ik}}{\sigma}\right)\right).$$

We assume that the observed price $p^{\text{obs}}_{ij^*}$ is equal to the predicted price p_{ij^*}, multiplied by a prediction error, denoted by ν_{ij^*}; i.e.

$$p^{\text{obs}}_{ij^*} = p_{ij^*}e^{\nu_{ij^*}}. \tag{11}$$

The prediction error has a density $f_{\nu_{ij^*}}()$ with a closed form which results from the distribution of ϵ_{ij^*}.[6] The contribution to the likelihood function of

[6] For this approximation, see the Appendix.

this transaction (10) is therefore given by the density of ν_{ij^*}, evaluated at difference between log of observed and predicted prices, multiplied by $\mathcal{P}_{ij^*}$:

$$f_{\nu_{ij^*}}\left(\ln p_{ij^*}^{\text{obs}} - \ln\left(\begin{array}{c} c_{a(j^*)} + \frac{F_{a(j^*)}}{q_i} + \theta_i\left[\delta_{ig^*} - \delta_i^*\right] \\ -\theta_i\sigma\left[\ln\left(P_{ig^*}\right) + \frac{\ln\left(1-P_{ig^*}\right)}{P_{ig^*}}\right] \end{array}\right)\right)\mathcal{P}_{ij^*}.$$

5 Data

There are two data sources. The first source is Competition Commission inquiry (2007) into the merger of two large UK brick manufacturers. The data from this source combine transaction and cost data for the four largest UK brick manufacturers (in terms of capacity), over the period 2001-06. This amounts to about 85 per cent of the UK brick market[7]. There are more than 2 million records of brick deliveries, containing prices, volumes, brick characteristics, manufacturing plant location, buyer identity (including buyer type, i.e. position in supply chain), and delivery location. The cost data are monthly at the plant level. The second source of data is public data on: energy prices (natural gas is the energy used to heat clay to high temperatures); number of new housing starts by county (a very good demand-side instrumental variable for cost estimation); and coordinates associated with the locations of the plants and buyers.

Our analysis focuses on facing bricks. Facing bricks differ along various dimensions, and our data have measures on the most important brick characteristics. The most prominent characteristics relate to a brick's aesthetic look. In the first instance, this is determined by the brick color, and most bricks in our data (about two thirds of transactions) are red; buff (beige) and blue are the second most frequent colors. The texture of the brick is another potentially significant aesthetic aspect of a brick, a result of the manufacturing process. Soft mud bricks are made using a "mould" (which can yield an

[7] Market shares are given in CC (2007).

attractive irregular shape) and "wirecut" bricks are cut by wires and have a more regular shape.

Other observed attributes are technical standards. Brick strength measures the safe load bearing of the brick in Newton per mm^2, and there are three strength categories. Water absorption—the ability to release and reabsorb moisture (a "breathing" process)—helps to regulate the temperature and humidity of atmosphere in a house. The desirable water absorption for clay bricks is between 12% and 20%, and we observe whether or not a brick falls into this category. Frost resistance is another consideration, and we use three categories: passive, moderate and severe frost exposure.

We noted in Section 2 that the color and quantity of bricks are determined at an early stage in the design process by the architect and government planner without reference to price. Then, the builder must decide on several characteristics, including manufacturing process, strength, and water absorption. We define brick *types* as a specific combination of the following discrete brick characteristics: manufacturing process (two), strength (three), and water absorption (three). This classification leads to 18 different brick types. These are produced at 48 plants. There are many hundreds of "brick products" with individual names, such as "Durham Red Multi" offered by one of the firms so that the builder typically has a choice of products within each type. Therefore, a product is defined by a pair of type and plant where the type is produced. We aggregate all records by plant, buyer identity, construction site, brick type, and year, resulting in 27,193 transactions. Using the location of the respective construction site and the list of products we obtain the distances to the plants in the choice set. This allows us to construct choice sets for a given brick type and buyer.

Finally, we drop outliers. The distribution of the volume of transaction is extremely skewed to the right. The median size is around 44 thousands bricks, while the mean is 69 thousands. The maximum volume is over 1,100 thousands bricks. While an analysis on such large transactions would be interesting, we drop transactions whose volume is over top 1 percentile, since outliers would obscure the central tendency. On the other hand, the minimum transaction level is 77 bricks, which is exceptionally small for business-to-business relationships. Thus, we also drop the bottom 1% of the sample according to the size of transaction. For the same reason, we also drop the top and bottom 1% of the sample according to the price level. As a result, we use 25,793 transactions for estimating the models.

Table 3 describes the cost data. This is at the plant-quarter level. There are 61 plants and 6 years. The variables are: total cost (L), Quantity produced (Q), Gas Price (G), Regional Earnings (G). We can see that average cost per 1000 bricks is about £157. We use these data to estimate a total cost function, from which marginal costs are derived.

Before estimating the model, we provide several raw data analyses. Figure 2 plots a density estimate for the transaction prices (the price per 1,000 bricks). The price variation is large, with the 90% of prices ranging from 144 to 246. This figure also shows the substantial heterogeneity among sellers.

Next, we restrict the sample to a few brick types that are most common in our data set.[8] Figure 3 plots the distribution of prices for this subsample. As expected, the variance of the price decreases significantly, but even within the same type, the transaction price still has a large variation. The 90% of prices ranges from 144 to 218.

Finally, to control for price differentials according to the transaction size, Figure 4 plots the distribution of prices for only transactions whose volume lies between 45th and 55th percentiles of the sample used in Figure 3.[9] The 90% of prices ranges from 144 to 213, and thus we confirm that the large part of the price variation remains.

To understand how the transaction price is determined we now look at the

[8]We choose red extruded/wirecut bricks with the medium-level water absorption. The number of observations is 4,994.

[9]The 45th and 55th percentiles of the sample volume are 40,000 and 58,000, respectively. The number of observations is 503.

transactions data. Table 4 presents descriptive statistics. We use these data to regress the price per 1,000 bricks on the volume, buyer size (defined as the total volume purchased by the buyer), seller dummies, plant fixed effects, other product characteristics, and on some spatial competition variables. Table 5 summarizes the results. The first specification only includes volume, and buyer size. This confirms the existence of the significant size discount. If the number of bricks increases by 1,000 units, then the unit price decreases by 3.605. In addition, the buyer size is negative and significant. That is, if the buyer is large, it can obtain a larger price discount.

The second specification includes plant fixed effects and controls for product characteristics. The fit of the regression measured by the adjusted R^2 shows that plant- and product-level characteristics are important explaining the price variation. The magnitude of the size discount becomes smaller, but it is still economically important and statistically significant. Marginal costs are included here, and are (unsurprisingly) an important determinant of price.

Third specification includes variables which aim to establish importance of spatial competition in price setting. For each transaction, we can identify the seller. Associated with the seller, we count the number of plants within 200km of the buyer that are owned by other competing sellers. This variable is "competition 200km" and is significant and negative. The negative coefficient on the number of competing plants indicates that competition puts a downward pressure on the transaction price.

We also calculate the distance between the nearest plant and the second nearest plant (dist diff). This has a positive effect on price, as we expect: if the competing plants are located farther away, the seller can charge a higher price to the buyer. The table suggests upstream competition and location are part of what determines price setting in the industry.

6 Results

6.1 Parameter Estimates

Table 6 presents the cost parameters estimated in the first step. The signs on the gas price (G) and wage (W) parameters are as expected. The parameter on Q indicates that there are diminishing returns to scale. The parameter on Q in the IV estimates with fixed effects are not very different from the OLS parameter, suggesting that there is no bias on the quantity parameter in the OLS results. For the second stage estimation, we use the third set of estimates which include fixed effects.

Table 7 and Figure 5 present the markups implied by the cost estimates. The markups are rarely negative, as we expect, and show considerable price dispersion after allowing for differences in production costs c.

Table 8 presents the parameters from the second estimation step. The values of θ_a and θ_b that are estimated imply that sellers bargaining power is around 0.852 to 0.999, with lower values when buyers are large, although these parameters are not precisely estimated. We perform the loglikelihood ratio test to compare the Bertrand-Nash model against our bargaining model. The result suggests that the Bertrand-Nash model is rejected at the 1% significance level. That is, buyers have some power over the transaction prices.

The distance coefficient is the correct sign (i.e. a positive transport cost) and statistically significant. The magnitude of the coefficient implies transportation costs of £108 (108 UK Pounds) per 1,000 bricks for 100 km. Since the average price is £188 per 1,000 bricks, haulage costs are 36% of the total cost to the buyer of delivered bricks (=108/(108+188)), assuming that the average delivered distance is around 100km.Our data include haulage costs too, so we use this to check how reasonable our estimates are. The direct estimate from the data is £80 per 1,000 bricks for 100 km, which implies that our model slightly overestimates the haulage costs. Furthermore, CC (2006) reports that haulage costs are about 25% of the overall cost to the buyer of delivered bricks. Our estimate suggests that haulage costs are about 36% of the overall costs. Thus, our estimate of haulage costs is reasonable.

There is a large amount of heterogeneity across sellers particularly in the per-transaction fixed cost. The fixed cost of seller 4 is significantly lower than other sellers, particularly than seller 2. The order of these fixed costs across sellers is consistent with seller-level market shares. Other parameters $(\lambda_1, \lambda_2, \sigma_v, \sigma_\epsilon)$ are all estimated precisely.

To evaluate goodness-of-fit of the estimated model, for each transaction we randomly draw ϵ_i and ν_{ij} from the estimated distributions and solve the model. Then, we compute mean price, the standard deviation of the price, and the choice probability for the four sellers. Table 9 summarizes the results. The model slightly overstates the average price. The standard deviation is predicted to be higher than the empirical counterpart. This may suggest that a more flexible distribution for the prediction error should be used. The model does a good job fitting the predicted choice probabilities.

6.2 Counterfactual Analysis

6.2.1 Source of Market Power

Table 10 presents some counterfactual analysis. We solve the model with the following changes to the environment: (i) eliminating joint ownership of plants and (ii) setting the transport cost parameter to zero, thereby eliminating geographic differentiation. The first column gives the model prediction for prices under the baseline market conditions.

The second and third columns show the effect of eliminating joint ownership, under the assumptions of the Bertrand model. Recall that seller 4 is the largest of the four firms (as can be seen from the choice probabilities in Table 9). The counterfactual analysis suggests that it enjoys significant market power, as prices fall by 10.6% when there is a de-merger of its plants.

This is approximately 20% of the average markup. (Under the Bargaining model there would be no effect however, as competition plays no role in price determination).

The fourth and fifth columns show the effect of setting transport costs to zero. For one of the sellers the price effect is negative, consistent with the idea that transport costs confer market power. However, for other sellers the price increases when transport costs go to zero. One possible reason for this is that firms that are located further from consumers—who previously had to cut their prices to be competitive—-are able to raise their prices.

6.2.2 Effect of Uniform Price Restriction

In the terminology of Thisse and Vives (1988), there is price discrimination when sellers do not set uniform FOB prices in a geographical context. In a product differentiation context, on the other hand, there is price discrimination if two varieties are sold at different base prices. In our application, products are differentiated both in terms of geography and product characteristics. As our estimates indicate, price discrimination exists in both dimensions in the UK brick industry.

To investigate the effect of such price discrimination on welfare, we consider a counterfactual scenario where price discrimination is banned in the same spirit as Grennan (2013) and Miller and Osborne (2014) to analyze how sellers' optimal prices will change. Under this restriction, there should be a single price for any given product (combination of product characteristics and plant). Sellers cannot price-discriminate based on the location of construction site, the size of the transaction, and the identity of buyers. To compute optimal prices, we impose the following assumptions. First, we solve the one-shot Bertrand-Nash pricing game. When sellers set prices for their products, they do not observe the random shock ϵ. Third, once sellers choose their prices, they cannot change their prices during the course of the sample period.

Thus, the profit of seller g when the price vector is given by $\mathbf{p}$ is

$$\Pi_g(\mathbf{p}) = \sum_{i=1}^{N} \sum_{j \in \mathcal{J}_{ig}} \mathcal{P}_{ij}(\mathbf{p}) \left[p_j q_i - c_{a(j)} q_i - F_{a(j)} \right]$$

where $\mathcal{P}_{ij}(\mathbf{p})$ is the probability that buyer i chooses product j when the price vector is $\mathbf{p}$.

The first-order conditions are

$$\sum_{i=1}^{N} \sum_{j' \in \mathcal{J}_g} \frac{\partial \mathcal{P}_{ij'}(\mathbf{p})}{\partial p_j} \left[p_{j'} q_i - c_{a(j')} q_i - F_{a(j')} \right] + \mathcal{P}_{ij}(\mathbf{p}) q_i = 0 \text{ for } j = 1, ..., J \tag{12}$$

where

$$\mathcal{P}_{ij}(\mathbf{p}) = \frac{\exp(\beta_{a(j)} + \beta x_j - \tau d_{ia(j)} + \lambda_{ig(j)} / q_i - p_j)}{1 + \sum_{j' \in \mathcal{J}_i} \exp(\beta_{a(j')} + \beta x_{j'} - \tau d_{ia(j')} + \lambda_{ig(j')} / q_i - p_{j'})} \tag{13}$$

and

$$\frac{\partial \mathcal{P}_{ij'}(\mathbf{p})}{\partial p_j} = \begin{cases} -\mathcal{P}_{ij}(\mathbf{p})(1 - \mathcal{P}_{ij}(\mathbf{p})) & \text{if } j = j' \\ \mathcal{P}_{ij}(\mathbf{p}) \mathcal{P}_{ij'}(\mathbf{p}) & \text{if } j \neq j' \end{cases}.$$

We numerically find a J-dimensional vector $\mathbf{p}$ that satisfies J first-order conditions in (12).[10]

Table 11 summarizes the results. Under the uniform price restriction, the average price increases by 20%. The average markup is around £130 per 1,000 bricks, which is substantially higher than the factual markup (see

[10] As we discuss in Section 3, in our model, choice probabilities can be calculated based on surplus without using prices. But in this couterfactual exercise, choice probabilities are calculated using (13), where the mean utility is defined as the gross utility minus price. This means that the share of outside option would be lower than in the original scenario even if observed prices are used in (13). Therefore, we assume that the utility from the outside option is $u_{i0} = (c + \epsilon_{i0}) q_i$ and choose a negative constant c such that the share of the outside option computed based on (13) with observed prices is exactly the same as in the original scenario. Then, using such c, we find a vector $\mathbf{p}$ that satisfies (12). Thus, any change in the share of outside option in the couterfactual scenario can be attributed to the change in equilibrium prices.

Figure 5). Accordingly, all sellers have higher profits. One interesting finding is that the change in profit differs widely across sellers. The profit earned by seller 1 and seller 2 increased by more than 50%, while the increase in profit earned by seller 4 is only 17%. This difference is mostly due to the change in market shares. Under the counterfactual scenario, seller 4 lost its market share by 7.7%, while sellers 1 and 2 both increased their market shares. Remember that seller 4 has the largest number of transactions. Therefore, we can argue that in the factual scenario, seller 4 can exploit its ability to price discriminate the most. Once price discrimination is banned, however, seller 4 loses competition against its competitors for a fraction of transactions and decreases its market share.

Higher equilibrium prices have two consequences. First, buyers' utility decreases for transactions where inside products are chosen. Second, some buyers switch to the outside option, and so the share of outside option increases by 8.3%. Because of this, the total decrease in buyers' utility outweighs the increase in sellers' profit, resulting in a drop in the total surplus. Overall, the total surplus is reduced by 5% due to the uniform price restriction.

7 Conclusions

Intermediate product markets are distinct from final product markets because of the greater sophistication of the buyers, the large size of the transactions, and the prevalence of price discrimination using buyer-specific prices. We develop a model of intermediate product market with price setting in which the prices are negotiated between the buyer and seller. We estimate the model using a rich dataset of transactions from the UK brick industry to analyze the effect of competition, location, and transaction size on the prices that are negotiated.

The estimation results show that our bargaining model does a better job explaining the data than the Bertrand-Nash model. Using the estimated parameters, we perform counterfactual analyses, solving the model with the following changes to the environment: (i) eliminating joint ownership of plants, (ii) setting the transport cost parameter to zero, thereby eliminating geographic differentiation, and (iii) banning price discrimination based on the volume of transaction and location of the buyer. In the first scenario, we find that the markup that the largest seller charges falls approximately by 20%. In the second scenario, for one of the four sellers the price effect is negative, while for other sellers the price increases when transport costs go to zero. One possible reason for this price increase is that sellers that are located further from buyers are able to raise their prices when transport costs are eliminated. In the third scenario, we find that the uniform price restriction leads to higher equilibrium prices and sellers' profit, while it significantly reduces buyers' utility. Overall, the total surplus is reduced by 5% due to the uniform price restriction.

8 Appendix

8.1 Prediction Errors

This appendix characterizes three components of approximation that are implicit in the error specification (11). For the sake of argument, we work with a simple bargaining model in which buyer's outside option is zero. The argument can be easily extended to our full bargaining model.

The predicted unit price paid by buyer i to winning supplier j^* resulting from Nash bargaining is

$$\begin{aligned} p_{ij^*} &= c_{a(j^*)} + \frac{F_{a(j^*)}}{q_i} + \theta_i \mathbb{E}[\tilde{S}_{ij^*}] \\ &= c_{a(j^*)} + \frac{F_{a(j^*)}}{q_i} + \theta_i \left[\delta_{ij^*} + \sigma_\epsilon \left(\gamma - \ln P_{ij^*}\right)\right], \end{aligned}$$

where γ is Euler's constant, $\mathbb{E}[\tilde{S}_{ij^*}] = \mathbb{E}[\max\{\tilde{S}_{ij}, j \in \mathcal{J}_i\}]$, and $\tilde{S}_{ij} = \delta_{ij} +$

$\sigma\epsilon_{ij}$, $j \in \mathcal{J}_i$, for $\epsilon_{ij} \overset{iid}{\sim} EV(1)$. This implies that the observed price $p_{ij^*}^{\text{obs}}$ is equal to the predicted price p_{ij^*}, plus a prediction error, denoted by u_{ij^*}; i.e.

$$p_{ij^*}^{\text{obs}} = p_{ij^*} + u_{ij^*}.$$

The distribution of the prediction error results from the distribution of $\epsilon_{ij^\star}$. It is the same as the distribution of the maximum order statistics of the $EV(1)$, expect for the shift by the mean $[\delta_{ij^\star} + \sigma_\epsilon (\gamma - \ln P_{ij^\star})]$ and scaling by θ_i.

Consider the marginal cost term $c_{a(j^*)}$ in the above expression. If costs are measured with error $\xi_{a(j^*)}$, then

$$c_{a(j^*)} = \bar{c}_{a(j^*)} + \xi_{a(j^*)},$$

where $\bar{c}_{a(j^*)}$ is predicted cost. Therefore,

$$p_{ij^*}^{\text{obs}} = \bar{c}_{a(j^*)} + \frac{F_{a(j^*)}}{q_i} + \theta_i \left[\delta_{ij^*} + \sigma_\epsilon \left(\gamma - \ln P_{ij^*}\right)\right] + \xi_{a(j^*)} + u_{ij^*},$$

where the combined residual term $\nu_{ij^*} = \xi_{a(j^*)} + u_{ij^*}$ has a distribution that is a mixture of the (shifted) distribution of the maximum order statistics of the $EV(1)$ and the distribution of $\xi_{a(j^*)}$. With a convenient choice for the distribution of $\xi_{a(j^*)}$, this distribution, $F_{\nu_{ij^*}}$, is analytically tractable, but computationally cumbersome. Formally, the contribution to the likelihood function of this transaction is then given by the density of ν_{ij^*}, evaluated at the difference between observed and predicted prices, multiplied by P_{ij^*}:

$$f_{\nu_{ij^*}}\left(p_{ij^*}^{\text{obs}} - \bar{c}_{a(j^*)} + \frac{F_{a(j^*)}}{q_i} + \theta_i \left[\delta_{ij^*} + \sigma_\epsilon \left(\gamma - \ln P_{ij^*}\right)\right]\right) P_{ij^*}.$$

For all practical purposes, it may be reasonable to approximate $f_{\nu_{ij^*}}$ by a practical alternative, e.g. the pdf ϕ of $N(0, \sigma_\nu^2)$. (Approximation 1)

Denote the predictable part of $p_{ij^*}^{\text{obs}}$ by $\bar{p}_{ij^*}$; i.e.

$$\bar{p}_{ij^*} = \bar{c}_{a(j^*)} + \frac{F_{a(j^*)}}{q_i} + \theta_i \left[\delta_{ij^*} + \sigma_\epsilon \left(\gamma - \ln P_{ij^*}\right)\right].$$

If the skewness of the distribution of prices is better matched by considering the logarithmic transform of prices, then

$$\begin{aligned} \ln\left(p_{ij^*}\right) &= \ln\left(\bar{p}_{ij^*} + \nu_{ij^*}\right) \\ &= \ln\left(\bar{p}_{ij^*}\right) + \frac{1}{\bar{p}_{ij^*}}\nu_{ij^*} + HOT, \end{aligned}$$

where HOT denotes higher order terms. This suggests two further approximations: (Approximation 2) replaces the scale factor on ν_{ij^*}, $\frac{1}{\bar{p}_{ij^*}}$, by a constant (subsumed in σ_ν); and (Approximation 3) ignore the HOT.

8.2 Outside Option

When a buyer chooses the outside option, the choice is not observed in the dataset. Therefore, we augment the dataset as follows. For each region, we randomly draw a transaction from its empirical distribution and add the transaction to the data as a sample (observation) in which the outside option is chosen. We repeat this until the share of added transactions equals to the outside option share s_0 for the region, which we observe in the data (see Section 2). Consider the following example. Suppose s_0 is 0.2 for a region and the number of transactions in the region was 800 in the data. Then, we randomly draw a transaction with replacement from the empirical distribution in the region. We repeat this 200 times and assume that buyers of these 200 transactions chose the outside option.

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UK Nation	Region	Market Size	Brick Deliveries	s_0
England	North East England	554	435	0.22
	North West England	1,490	1,040	0.30
	Yorkshire & Humber	1,190	728	0.38
	East Midlands	1,350	1,250	0.08
	West Midlands	1,150	1,020	0.11
	East Anglia	1,540	1,080	0.30
	London	840	659	0.22
	South East	1,850	1,420	0.23
	South West	1,320	602	0.54
Wales		709	366	0.48
Scotland		1,920	573	0.70

Table 1: Outside Option Market Share by Region
Note: The unit for market size and brick deliveries is millions of bricks.

	Share of	Average # of	
	Volume	Sellers	Transactions
Top 5 buyers	61.2%	3.8	533
Top 10 buyers	77.6%	2.7	337
Top 15 buyers	85.8%	2.6	227
Top 20 buyers	91.0%	1.8	154
Top 100 buyers	99.9%	1.4	90

Table 2: Size Distribution of Top Builders and Developers

	Mean	St Dev	Min	Max
L (£/1000)	490.66	259.41	102.86	1715.05
Q (Million)	3.63	2.49	0.56	24.21
Gas Price (G)	1.03	0.40	0.65	2.23
Regional Earnings (W)	8.77	0.72	7.45	10.48
C/Q (Ave. Cost Per 1,000 bricks)	157.73	61.16	42.74	537.72
#obs=1,063, #years=6, #plants 51				

Table 3: Data for Cost Regression

Variable	Mean	St Dev	Min	Max
Price (1000 bricks)	207.22	206.14	12.50	7317.14
Dist diff (km)	55.65	58.08	0.11	268.45
buyersize	22.57	14.23	0.60	42.40
Volume (10000s)	6.94	7.69	0.10	117.83
Strength Category	3.07	0.90	2.00	5.00
Water Absorption level	1.05	0.79	0.00	2.00
Hand Made Brick	0.26	0.44	0.00	1.00
Color Buff	0.70	0.46	0.00	1.00
Competition 200km	1.80	1.24	0.00	4.00
Marginal Cost (1000 bricks)	84.98	24.92	43.32	249.31
#Obs=27193				

Table 4: Data for Cost Regression

	Est	Std Err	Est	Std Err	Est	Std Err
constant	210.470	1.030	214.870	20.498	216.666	20.501
Vol (1000)	-3.605	0.166	-2.600	0.158	-2.622	0.158
Buyer size	-0.442	0.032	-0.290	0.033	-0.285	0.033
Water Abs 1			-7.067	2.266	-7.374	2.266
Water Abs 2			-18.039	2.439	-18.353	2.440
Hand Made			34.984	5.201	34.024	5.203
Color Buff			-6.146	1.085	-5.833	1.087
Str 1			20.932	2.831	20.781	2.830
Str 2			50.634	2.544	50.414	2.543
Marginal Cost			0.622	0.033	0.623	0.033
Competition 200km					-1.209	0.384
Dist diff (km)					0.022	0.011
plnt fixd effct	No		Yes		Yes	
Adjusted R^2	0.0323		0.171		0.1718	
$N = 27,193$						

Table 5: Price Regression
Note: The marginal cost is the cost to produce 1,000 additional bricks.

	Pooled OLS		Pooled IV		IV with Fixed Effects	
Parameter	Estimate	Std. Err.	Estimate	Std. Err.	Estimate	Std. Err.
lnQ	0.66	0.01	0.59	0.06	0.65	0.21
lnG	0.12	0.03	0.13	0.03	0.15	0.05
lnW	1.30	0.11	1.21	0.14	1.21	0.18
Quarter 2	-0.07	0.02	-0.06	0.02	-0.06	0.02
Quarter 3	-0.08	0.02	-0.07	0.02	-0.07	0.02
Quarter 4	-0.03	0.02	-0.03	0.02	-0.03	0.01
Constant	2.59	0.24	2.86	0.34	2.80	0.29
R-squared		0.77		0.76		0.76
#Obs		1,063		1,063		1,063

Table 6: Estimates of Cost Parameters
Note: Instruments for ln Q in the IV: regional housing starts, regional housing completions .

#obs=27,193	Mean	St Dev	Min	Max
MC	84.97	24.92	43.32	249.31
Price	207.22	206.14	12.50	7317.14
Markup	122.24	204.35	-68.73	7229.75

Table 7: Data for Cost Regression

	Bargaining Model	
Parameter	Estimate	Std. Err.
θ_a	9.919	7.131
θ_b	0.020	0.017
τ	10.786	0.118
F_1	0.823	0.096
F_2	1.819	0.230
F_3	0.833	0.060
F_4	0.612	0.095
λ_1	1.060	0.234
λ_2	-19.314	1.453
σ_ϵ	0.796	0.005
σ_v	0.206	0.003
Log-likelihood	-110892.00	
Test against BN	0.000	

Table 8: Estimates of Strucutural Parameters

Note: Standard errors are calculated using 200 bootstrapped samples. The test result shows that the Bertrand-Nash model was rejected against the bargaining model at the 1 percent significance level.

	Price		Choice Probability				
	Mean	Std.	Outside	Seller 1	Seller 2	Seller 3	Seller 4
Observed	188.4	77.2	0.341	0.060	0.033	0.179	0.388
Bargaining	194.5	104.8	0.311	0.074	0.054	0.186	0.374

Table 9: Model Fit

			Eliminate Ownership		Setting $\tau = 0$	
	Observed	Model Prediction	Average Price	% Change in Price	Average Price	% Change in Price
Seller 1	177.3	162.3	158.4	-2.4	163.6	0.8
Seller 2	174.2	171.3	167.4	-2.3	169.1	-1.3
Seller 3	179.5	184.3	172.1	-6.6	190.7	3.5
Seller 4	195.4	209.4	187.3	-10.6	227.5	8.6

Table 10: Source of Market Power

	% Change in Average Price	Change in Market Share (%)	Change in Profit (mil. £)	% Change in Profit	Change in Surplus (mil. £)	% Change in Total Surplus
Seller 1	20.6	0.6	105.3	53.0	21.6	5.3
Seller 2	18.7	0.5	857.4	51.4	22.2	6.4
Seller 3	20.2	-1.7	142.7	30.8	-38.6	-4.4
Seller 4	19.1	-7.7	144.6	16.7	-160.5	-11.0
Total			478.4	28.3	-155.3	-5.0

Table 11: Effect of Uniform Price Restriction

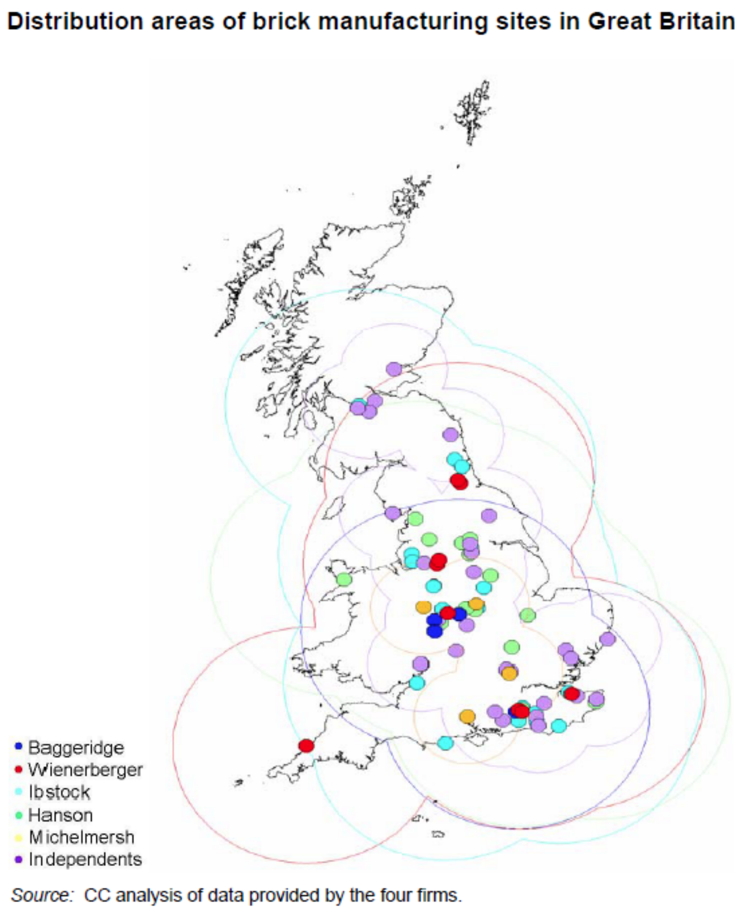

Figure 1: Location of Brick Manufacturing Plants

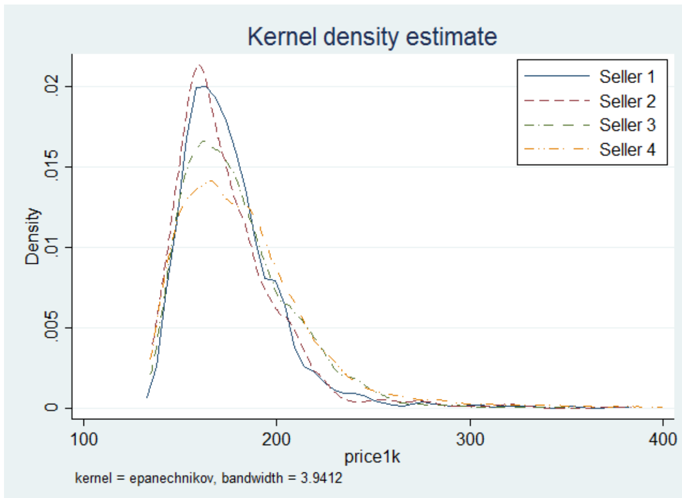

Figure 2: Price Distribution by Sellers

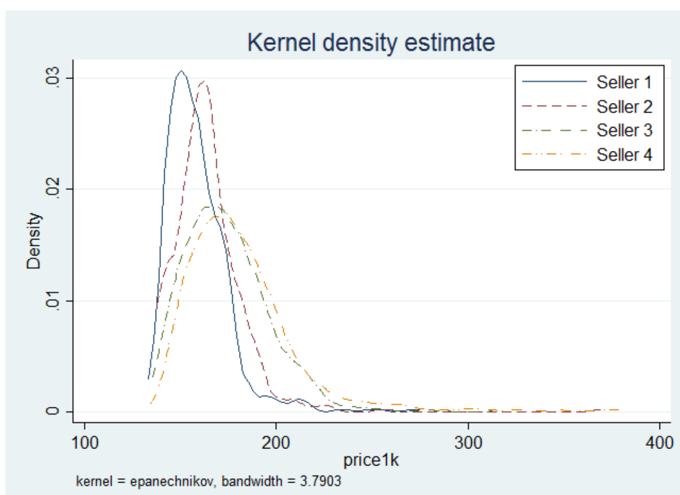

Figure 3: Price Distribution of Selected Product Types

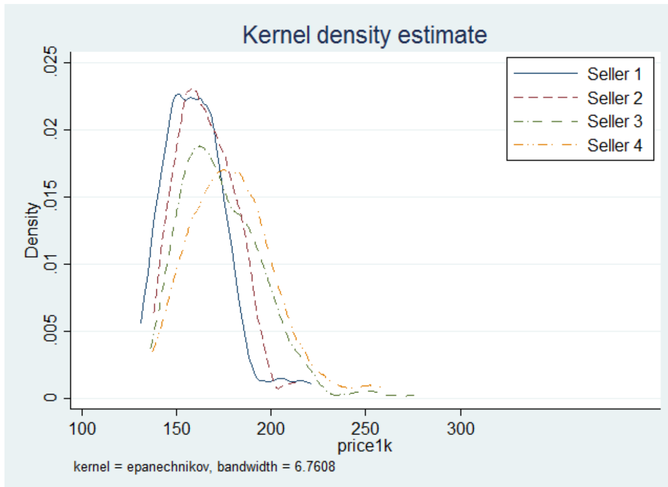

Figure 4: Price Distribution Conditional on Volume

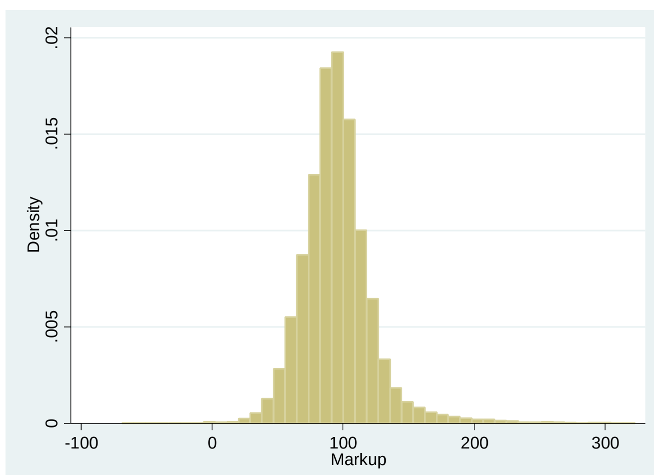

Figure 5: Frequency of Markups between Price and Estimated Marginal Costs