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Competition in a spatially-differentiated product market with negotiated prices*

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Abstract

In many markets the buyer pays an individually-negotiated price. Theoretically, relative to uniform-pricing, this has an ambiguous impact on market power and the effects of merger. To analyze competition in the UK brick industry—where individually-negotiated pricing is used, and the market is highly concentrated—we develop a model of negotiated pricing and discrete-choice demand which permits alternative specifications for how the buyer's runner-up product affects price negotiations. We derive a likelihood for observed choices and prices and estimate the model using transaction-level data. We use the model to reject the hypothesis of price-taking buyers, calculate the distribution of markups, and measure the effect on markups of multi-product ownership and buyer location. A counterfactual policy of uniform pricing increases average markups by about one-third, harms most buyers, and magnifies the price-increasing effect of merger. Average markups increase because uniform pricing is intrinsically less competitive and because it imposes buyer price-taking.

Keywords: individualized pricing, bargaining, price discrimination, spatial differentiation, merger analysis, construction supplies

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1 Introduction

In many markets the buyer makes a choice between differentiated products and pays an individualized price; the price is often the outcome of negotiations involving more than one potential seller.[1] This is common in intermediate goods markets where the sellers know the identity and tastes of the buyers. An important group of markets with individualized pricing is construction materials—e.g. cement, steel, bricks—where much of the product-differentiation is spatial.[2]

Economic theory suggests that individualized pricing can make a major difference to market power and the effects of merger. In the case of price-taking buyers, individualized pricing enhances profit in a monopoly, but may reduce it in an oligopoly; in the standard duopoly Hotelling model, for example, individualization brings benefits to all consumers and reduces average price-cost margins (PCMs) by 50% (see Thisse and Vives (1988), and Armstrong (2006)). Individualized pricing can likewise reduce the average price effect from a merger (see Cooper et al. (2005)). The literature typically adopts the assumption of price-taking buyers; bargaining provides an additional source of divergence from the uniform pricing case. A distinctive feature of discrete-choice models with individualized pricing—both when buyers are price-takers (see Lederer and Hurter Jr (1986), Thisse and Vives (1988)), and when they have bargaining power (see Binmore (1985), Bolton and Whinston (1993) and Manea (2018))—is that the buyer's *runner-up* seller has a key role in determining markups. This role is recognized in antitrust practice—e.g. the US Merger Guidelines (section 6.2) suggest that, with individualized pricing, anti-competitive effects depend on the (pre-merger) frequency with which merging parties jointly occupy first-best and runner-up status.

Markets for construction materials have attracted much antitrust interest over many years. The interest has been focused on two policy areas. The first is pricing policy. One broad question in this area is whether individualization of pricing is associated with a greater intensity of competition than uniform pricing. A specific version of this question compares alternative pricing policies for delivered products, such as uniform ("free-on-board") pricing, under which the price before transportation costs is the same for all buyers, and spatial pricing where the price is set differently

[1] As the 2010 US Merger Guidelines (paragraph 6.2) note: "In many industries [...] buyers and sellers negotiate to determine prices and other terms of trade. In that process, buyers commonly negotiate with more than one seller, and may play sellers off against one another. [..]."

[2] See CMA (2016) paragraph 6.26 for a description of purchases that applies to aggregates, cement, and concrete in the UK and paragraph 7.170 which states "cement prices are negotiated with customers, and can depend on a number of factors, including delivery distance, type of cement, size of order and the customer's bargaining power." Other products with spatial differentiation where price is individualized include lead, plywood, and wood-pulp. See Scherer and Ross (1990), p. 504.

depending on buyer location; this debate dates back at least to *FTC vs. Cement Institute* 1948 (see Thisse and Vives (1988) and Scherer and Ross (1990)). The second policy area is controls on market concentration; here there have been numerous inquiries—e.g. the US cement merger case *Holcim Ltd. and Lafarge S.A.* in 2017 and the UK market inquiry into construction supplies (CMA (2016)).

The brick industry in Great Britain uses individualized pricing. In CC (2007) the Competition Commission (CC) investigated the industry and judged it to be highly concentrated—with a two-firm concentration ratio of 60%, and a Herfindahl-Hirschman Index (HHI) of 2113—but, despite this, assessed its profitability as at, or below, average for industries with comparable risk, and approved a merger even though the HHI increase exceeded the normally-acceptable threshold in its merger guidelines (which are implicitly based on the assumption of uniform pricing). In effect they took the view that competition in this market is more intense, and the merger less of a concern, than usual for a market at its concentration level.[3]

This paper has two principal objectives. First, we develop for empirical analysis a model of discrete-choice demand and individually-negotiated pricing with multi-product sellers and differentiated products, and derive a likelihood function that is convenient for estimation using transactions data. Second, we estimate the model using transactions data from the brick industry in Great Britain, and use it (i) to measure market power and its variation across buyers, and (ii) to carry out analysis of counterfactuals relevant to the two public policy areas noted above.

In the model the buyers of bricks are construction firms, each with multiple projects in predetermined locations, and the suppliers are manufacturers with multiple products and production locations. Each project requires cladding using either a brick product or an outside good. Products are valued differently across projects. For a given project, a price is negotiated for the first-best and runner-up product (ranked in terms of joint surplus) and the buyer's choice depends on indirect utility. The two negotiated prices (for a given project) are assumed to satisfy a contract equilibrium (see Cremer and Riordan (1987)). In a discrete-choice setting, this concept does not imply a unique price; to obtain uniqueness we assume that the buyer and first-best seller use a surplus-sharing rule based on the Nash Bargaining problem (and the runner-up seller agrees a marginal cost price). We consider two specifications of the surplus-sharing rule which

[3] CC (2007) reports (paragraph 5.47) that the current HHI was 2,113 and the HHI change implied by the merger was 390; the CC merger guidelines regard a market with an HHI above 1,800 as highly concentrated, and (in such a market) identifies an increase in HHI of more than 50 as giving potential competition concerns; summing up they say that "the market is thus already highly concentrated and would become more so if the merger were to proceed." The assessment that profits are at or below normal levels is in Appendix B of CC (2007).

differ in the role given to the runner-up seller: in the first, the disagreement point in the Nash Bargaining problem is the option of not buying *any* brick product and the runner-up seller is relevant only if it constrains the bargaining problem; in the second, the disagreement point in the Nash Bargaining problem *is* the utility from the runner-up good. These specifications each have non-cooperative micro-foundations in bargaining theory; moreover, the first specification is implied by the one-buyer multiple-seller discrete-choice bargaining models in Binmore (1985) and Manea (2018) and does not impose that the two negotiations are conducted independently. Each specification nests the price-taking case.

To estimate the model we use (i) a dataset of 13,788 transactions between manufacturers and house builders, which records the chosen product, price, delivery location, production location, and transaction volume, and (ii) a dataset of brick characteristics. The patterns in the data indicate that prices vary across transactions—controlling for brick product, house builder and year—and that spatial differentiation is important.

There are two main econometric challenges. First, the runner-up product, which plays a key role in determining prices, is unobserved, and, relatedly, we do not observe prices the buyer would have paid for products that are not chosen, so choice estimation cannot proceed in the standard way as in Berry et al. (1995), etc. Second, since the price of the chosen product is individualized, it is correlated with individual-specific tastes which are unobserved (to the econometrician) and which also affect the choice of product, so that conditional on choice of product the regressors in the pricing equation (such as product characteristics) are endogenous, similar to the problem studied in Dubin and McFadden (1984). To overcome these challenges we estimate the choice and pricing parts of the model jointly, and we integrate out unobserved tastes along with their implications for the runner-up product and its price. Since our application has many products this is a high-dimension integration problem which is computationally burdensome using numerical methods; we show that when idiosyncratic tastes are characterized by a Generalized Extreme Value (GEV) distribution there is a tractable discrete-continuous likelihood expression for the joint probability of the observed choice and individualized price.

Our estimates reject the assumption of price-taking buyers. They imply price-cost margins (PCM) that are relatively low on average (8%) but with a high coefficient of variation (0.74) across individual buyers. PCMs are enhanced when a buyer is relatively close to its first-best seller and when the first-best seller has a large portfolio of products. In counterfactual analysis we find that, relative to individually-negotiated pricing, a policy of uniform pricing harms more buyers than it benefits, and increases average PCMs by about 36%, of which 24% is from the move from bargaining to price-taking and 12% is from the move to uniform pricing (taking price-taking as given). We use the estimated model to evaluate the effects of changes to market concentration and find the market power effect of mergers is lower with individualized than with uniform pricing. Numerical results in this paragraph are for the first bargaining specification; we get similar results for the second.

Related literature There is a large literature on price discrimination with differentiated products. The theoretical literature dates from Thisse and Vives (1988), Bester (1989), Holmes (1989) and Corts (1998). The framework we use relaxes the assumptions imposed in some of this literature, including uniform differentiation along a line and the absence of an outside good. Our paper builds on empirical papers on oligopoly price discrimination including Miller and Osborne (2014) and D'Haultfoeuille et al. (2017) by studying fully-individualized (rather than third-degree) discrimination, in the use of transaction-level data, and by relaxing price-taking.

Our paper relates to the empirical literature on bargaining between multiple buyers and sellers, based on the Nash-in-Nash solution introduced in Horn and Wolinsky (1988) and given non-cooperative micro-foundations in Collard-Wexler et al. (2019). The literature includes Chipty and Snyder (1999), Draganska et al. (2010), Crawford and Yurukoglu (2012), Grennan (2013), Gowrisankaran et al. (2015), Ho and Lee (2017), Crawford et al. (2018), and Dubois et al. (2019). In these papers, the buyer trades in equilibrium at every negotiated price, and these (inherently observed) prices, and the passive beliefs assumption, are used to compute the disagreement payoff for each bilateral relationship. In our model the buyer also bargains with multiple sellers, but only one is selected for trade (i.e. choice alternatives are mutually-exclusive), so that we must account for the *inherent unobservability* of prices for products not selected.

The model has non-cooperative micro-foundations in multiple-seller one-buyer bargaining models, with mutually-exclusive choice alternatives, developed in Binmore (1985), Binmore et al. (1989), Bolton and Whinston (1993) and Manea (2018), which were developed for the single-sourcing set up in our model and adapted by Ho and Lee (2019) to allow for multi-sourcing buyers.

The paper is also related to those that study single-sourcing buyers with individualized pricing, notably Allen et al. (2019) and Salz (2017); these consider settings where buyers are numerous and have search costs, and use a take-it-or-leave-it pricing framework. In contrast in our model the agents do not search—they are familiar with products, costs and preferences, which suits our application which has few buyers and sellers and little innovation—and we do not assume price-taking. Finally, the paper is related to the literature on auctions in the presence of transportation costs (e.g. Porter and Zona (1999)) and those with GEV taste shocks (e.g. Brannman and Froeb (2000)), and joins a growing literature on competition in construction materials markets; in addition to Miller and Osborne (2014), this includes Hortaçsu and Syverson (2007), Ryan (2012), and Hall and Rust (2020).

2 The market and data

Institutional details Bricks have been used in construction for millennia. The largest buyers of bricks in Great Britain are national house-building firms, which buy bricks directly from manufacturers for cladding purposes. We study transactions of domestically-produced bricks bought by these firms, hereafter *buyers*. In any year each buyer develops multiple housing projects of different sizes in different locations. The buyers are responsible for all the key aspects of their projects including choice of cladding. The buyers source from different manufacturers for different projects. The market is concentrated: there are four main manufacturers with an 85% share of brick sales (CC (2007), paragraph 5.46). Buyers negotiate prices that hold good for a given year; for any buyer the negotiated prices vary with the brick variety, quantity and project location. Third-party hauliers, arranged by the manufacturer, deliver the bricks to the project location and are paid separately.[4]

Description of the data We use a data set which records all deliveries of bricks from the four main manufacturers in Great Britain in the period 2003-2006. For each delivery we observe the date, variety (with unique production location), destination location, buyer, quantity, and payment. We treat a unique buyer-variety-destination-year as defining a project. We obtain the four main characteristics of each variety from the manufacturers' catalogs—color, shaping method, strength, and water absorption; the first two are aesthetic and the other two are technical. Transport costs to the buyer for each delivery are also recorded (for three of the manufacturers). We consider the largest 16 buyers, which account for 94.1% of direct-delivery volume in the data. We aggregate the data over deliveries within each year to buyer-variety-destination-year level, which corresponds to a negotiated transaction, giving 13,788 transactions over

[4]Hereafter *bricks* refers to bricks used for cladding. Cladding is 80-90% of brick production (CC (2007), paragraph 4.2). Alternative cladding materials include timber, stone, and plaster. Direct-supply bricks are about 20% of brick production; the rest is sold through intermediaries whose final customers are households or small builders, often for repair, maintenance and improvement of existing dwellings (CC (2007), paragraphs 4.42 and 4.47). Imported bricks are about 8% of volume (CC (2007), paragraph 4.21). For further discussion of institutional details see Appendix B.5.

	Mean	SD
A: Price, quantity, distance, transport costs		
Price (£/1000 bricks)	182.256	24.843
Quantity (1000s)	84.072	83.950
Delivery distance (100km)	0.109	0.075
Transport cost (£/1000 bricks)†	23.850	10.530
B: Agent size (#transactions per year)		
Manufacturer	861.750	755.180
Buyer	231.864	221.038
C: Variety characteristics of chosen product: aesthetic and technical		
Color: red (indicator variable)	0.718	0.450
Shaping method: wire (indicator variable)	0.720	0.449
Strength, Newton/square meter (100s)	0.398	0.182
Water absorption, percentage units (100s)	0.143	0.043
D: Weather and input prices of project's region-year		
Frost: Average monthly (#days with frost, by region)	4.669	0.619
Rainfall: Average daily rainfall (mm/sq meter, by region)	2.396	0.742
Wage: Gross household income/head (£1000s, by region-year)	13.786	1.352
Fuel: annual natural gas index (1990=100, by year)‡	0.991	0.198
Fuel: annual haulage price (£/L, by year)‡	0.861	0.069
E: Competition [notation in italics used in Table 2]		
#Manufacturers within 50 km: *N(50)*	1.555	1.182
#Manufacturers within 100 km: *N(100)*	2.680	1.044
Distance advantage of nearest manufacturer w.r.t. next-nearest: DA (km)	33.986	42.381

Notes: 13,788 observations. †11,855 observations. ‡*BEER Quarterly Energy Prices Report* (2008): Gas price index Table 3.3.1 (three-year moving average); Haulage fuel price, Table 4.1.2. Appendix B.3 discusses product characteristics and weather data. Regions are the NUTS1 definition.

Table 1: Transactions data: summary statistics

four years sold from 36 plants; hereafter we refer to this as the transactions dataset.[5]

Since there are hundreds of varieties, and many are very similar, we define for choice modeling the less granular concept *product*, using unique combinations of the four brick characteristics above and the plant's location. This results in 75 products.[6]

Table 1 reports summary statistics from the transactions data. Panel A describes

[5]To prepare the transactions dataset we drop a shaping type (pressed, 1.2% of volume) and colors other than red and yellow (0.04% of volume) which are rarely used in new housing projects, products with a mean of less than 7.5 annual transactions (which removes a tail of low market share products which together are 4.2% of volume), low-quantity (<5000 bricks) deliveries (3.1% of volume), and, to avoid outliers, transactions with unit prices in the top and bottom percentiles. See Appendix B.4 for further details. See Beckert (2018) for a discussion of the data.

[6]To do this we discretize strength and water absorption—measured in N/m^2 and percent units respectively—using intervals of 5, resulting in 5 absorption and 13 strength levels, and use the midpoint of the interval as the product's characteristic. See Appendix B.3. See also footnote 8.

prices, quantities, distances, and transport costs. Panel B describes agent (manufacturers and buyers) size, measured by annual number of transactions. Panel C reports statistics for the main brick characteristics other than location. Panel D summarizes weather data in the region of the delivery location, which can affect the buyer's valuation of the technical characteristics, along with key input price data. Panel E reports two measures of competition: the number of manufacturers within a given radius of a project, and the distance between a project's nearest and second-nearest manufacturer.

Finally, we calculate the market share of the outside good: non-brick cladding, bricks from minor manufacturers, and imports. For each region-year market m this is given by $s_{m0} = (H_m - B_m)/H_m$ where H_m is the number of new houses and B_m is the number of new houses that use bricks from the top four manufacturers. We calculate H_m from official house-building data and obtain B_m using information on brick deliveries and an estimate of the number of bricks per house. See Appendix B.7 for details. The market share of the outside good has a mean of 0.272 and a standard deviation 0.141 across region-year markets. The number of buyers of the outside good is given by $N_{0m} = N_{Jm}s_{0m}/(1 - s_{0m})$ where N_{Jm} is the number of buyers of inside goods in region-year m in the transactions data.

Data patterns I: prices To characterize price variation, Panel A of Table 2 reports the R^2 and root mean square error (RMSE) for price regressions with dummies at the following alternative levels: none, year, variety-year, and buyer-variety-year. Column (i) uses the full set of brick transactions and—to help characterize intra-buyer price dispersion—column (ii) includes only transactions with more than five transactions for each buyer-variety-year. Year effects explain only a small amount of price variation. The specification with buyer-variety-year effects absorbs more variation, but still leaves much unexplained—which shows the presence of intra-buyer (cross-project) variation conditional on variety-year. Panel B explores the relationship between prices and variables that vary across projects. All specifications include variety dummies. The four specifications use alternative measures of local competition, based on the distance-advantage DA of the nearest manufacturer or on counts $N(DST)$ of local manufacturers as defined in Table 1. The estimates indicate that prices are decreasing in quantity, increasing in input prices, decreasing with the buyer-seller size ratio, and that competition variables have the expected signs. While these estimates describe correlation we do not interpret them causally: the specification conditions on variety choice, which is endogenous, and which for example implies seller, and hence seller size.

A: Price regressions: price dispersion with alternative controls		(i)		(ii)	
		R^2	RMSE	R^2	RMSE
Dummy variables included:	none	0.000	24.843	0.000	21.195
	year	0.118	23.340	0.130	19.771
	variety-year	0.775	11.780	0.816	9.098
	buyer-variety-year	0.918	7.114	0.867	7.740
Observations included		all observations		buyer-variety-year with > 5 locations	
Number of observations		13,788		6,587	
Mean price (£/1000)		182.256		176.141	

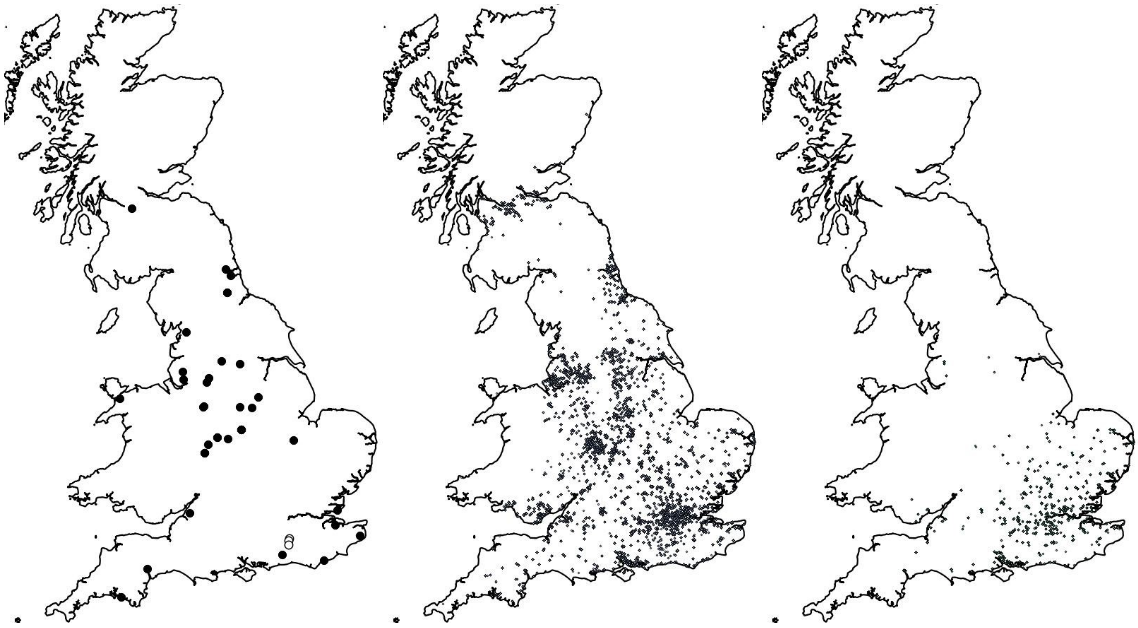
B: Price regressions	(i)		(ii)		(iii)		(iv)	
Constant	59.371	(10.042)	59.492	(10.020)	63.673	(9.964)	63.856	(9.997)
Quantity (units 100,000)	-0.383	(0.133)	-0.421	(0.133)	-0.446	(0.132)	-0.454	(0.133)
Wage (units £1000)	8.281	(0.847)	8.270	(0.846)	8.107	(0.840)	8.299	(0.843)
Gas price (index)	27.200	(1.824)	27.239	(1.821)	27.499	(1.809)	27.084	(1.815)
ln(buyer size/seller size)	-2.510	(0.147)	-2.558	(0.147)	-2.446	(0.146)	-2.558	(0.146)
1[DA>DST], indicator	0.482	(0.237)	2.204	(0.293)				
N(DST), count					-1.531	(0.101)	-1.487	(0.124)
R^2	0.754		0.755		0.758		0.756	
DST:	20km		40km		50km		100km	

Notes. Dependent variable: price in £/1000 bricks. Panel A reports measures of fit (not adjusted for d.f.) for alternative specifications. Panel B: Observations: 13,788. Variety dummies in all regressions. Seller refers to manufacturer. Seller and buyer size, seller's distance advantage (DA), local seller count N(DST), and other variables, are as defined Table 1. Standard errors in parentheses.

Table 2: Results from unit price regressions

Data patterns II: product choice The relationship between project location and product choice is illustrated in Figure 1. The first two maps respectively give the locations of the plants and projects in the data. The third shows projects that use varieties produced in four plants in Sussex, identified by (the far-south) hollow circles in the left-hand map: these projects have lower mean distances from the four identified plants, although in many cases buyers could have used a more closely-located plant.[7] In a similar vein, Panel A1 of Table 3 presents the proportion of buyers that select a product from the nearest x plants, for $x = (1, 5)$: buyers do not exclusively select the nearest plant, but do so more often than if they randomly selected one of the 36 plants. The second row of A1 shows that a consumer does not exclusively select the nearest

[7] A separate point: although not obvious from the map, the distribution of plants and projects yields a *positive* correlation (across projects) between the distances to the nearest plant for any pair of manufacturers—i.e. if a project is located relatively close to one manufacturer, then it tends to be relatively close to each of the others. This contrasts with standard Hotelling duopoly model where the correlation is -1 and where the manufacturers disagree about their strong locations (a feature sometimes known as "strategic asymmetry").



(a) Plants (○–Sussex, ●–others) (b) Deliveries (all plants) (c) Deliveries (Sussex plants)

Map (a) shows plant locations, including the four (far-south) Sussex plants in hollow circles, map (b) shows all deliveries 2003-2006, and map (c) shows the subset of these deliveries from the Sussex plants.

Figure 1: Plant and delivery locations

plant of the chosen manufacturer, suggesting there is differentiation at product level rather than (or in addition to) firm level. Whilst the Euclidean distances we use do not fully measure transport cost—e.g. grid references may be inaccurate, roads are not straight-lines, and they do not account for congestion—the mean distance difference between the nearest and the chosen plant reported in panel A2 is large and unlikely to be entirely attributable to measurement factors. In sum, spatial differentiation is important but does not dominate the other factors that drive choice.

To explore the variables that are related to product choice, Panel B shows parameter estimates for a simple choice model where we condition on choice of an inside good. We assume the payoff for project i and product j is $u_{ij} = \beta' x_j + \gamma' y_{ij} + \varepsilon_{ij}$ where x_j is a vector of product j's non-price characteristics, y_{ij} is a vector of interactions between project i and product j, and ε_{ij} is an iid Type-1 EV effect (e.g. unobserved transport costs or local tastes). Included in x_j is the log of the number of varieties in product j.[8] In specification (i) parameters β are significant, but, since price is not included, we do not have strong priors as to their sign; in (ii) we replace $\beta' x_j$ with unreported product dummies β_j which absorb the mean effects of product characteristics. The signs of the

[8] The log term accounts for unobserved product differentiation at the level of variety nested within product j (see Ackerberg and Rysman (2005)); this effect is absorbed into the product-specific dummy in specification (ii).

A: Product choice		
A1: Proportion of choices in nearest $x \in \{1, 5\}$ plants to the project	x=1	x=5
All manufacturers (36 plants) [Comparison: $1/36 = 0.028$, $5/36 = 0.140$]	0.119	0.401
Chosen manufacturer	0.243	0.726
A2: Comparison of chosen and nearest product	Mean	SD
Extra distance of chosen relative to nearest product (km)	56.017	63.106

B: Estimated parameters for descriptive logit product choice model	(i)		(ii)	
Product characteristics (x_j)				
Color: red	0.235	(0.021)		
Shaping method: wire-cut	0.407	(0.028)		
Strength	-0.026	(0.004)		
Absorption	0.015	(0.007)		
ln (#varieties in product j)	0.713	(0.013)		
Buyer-product characteristics (y_{ij})				
Distance from buyer (DST_{ij}) 100km	-1.168	(0.036)	-1.357	(0.039)
Square of distance from buyer (DST_{ij})	-0.007	(0.011)	0.017	(0.012)
Buyer frost × strength	0.379	(0.084)	1.032	(0.108)
Buyer rainfall × absorb	-1.048	(0.300)	-0.709	(0.355)
Log likelihood	-48202.6		-48202.6	
Product dummies (β_j)	No		Yes	

Notes: The number of observations is 13,788. Standard errors in parentheses.

Table 3: Analysis of product choice

parameters γ in both specifications are as expected and mostly significant: distance has an overall negative effect, while there are negative synergies between rainfall and absorption and positive synergies between frost and strength. A limitation with this specification is that prices are omitted, because, when prices are individualized, they are only observed for the chosen product; we now develop a model that allows us to account for the presence of unobserved prices.

3 The model

3.1 Players, payoffs and products

Let the set of projects be $\mathcal{I} = \cup_{h \in \mathcal{H}} \mathcal{I}_h$, where $\mathcal{I}_h$ belongs to buyer $h \in \mathcal{H}$, and let the set of inside products be $\mathcal{J}_J = \cup_{k \in \mathcal{K}} \mathcal{J}_k$, where $\mathcal{J}_k$ belongs to manufacturer $k \in \mathcal{K}$. For each project the buyer selects a product $j \in \mathcal{J} = \mathcal{J}_J \cup \{0\}$ where $j = 0$ is the outside good. In project i, with quantity need q_i, product j has money-metric value

$v_{ij} = v_{ij}(q_i)$ which includes the effect of location.[9] The manufacturer's cost of supply is $c_{ij} = c_{ij}(q_i)$ where we allow for project-specific cost effects. The surplus generated by project i and product j is $w_{ij} = v_{ij}(q_i) - c_{ij}(q_i)$ and the surplus from the outside good is w_{i0}. We assume that agents have complete information.[10]

Definition. For project i, the *first-best* product $j(i,1)$, produced by first-best manufacturer $k(i,1)$, has the greatest surplus among all products in $\mathcal{J}$, and the *runner-up* product $j(i,2)$, produced by runner-up manufacturer $k(i,2) \in \mathcal{K} \setminus k(i,1)$, has the greatest surplus among those not produced by $k(i,1)$, i.e.

$$j(i,1) = \underset{j \in \mathcal{J}}{\arg\max}\ w_{ij} \quad \text{and} \quad j(i,2) = \underset{j \in \mathcal{J} \setminus \mathcal{J}_{k(i,1)}}{\arg\max}\ w_{ij}. \tag{1}$$

The first-best product's *surplus advantage* is $\Delta w_i = w_{ij(i,1)} - w_{ij(i,2)}$.

We adopt the notation convention that $n \in \{1,2\}$ labels the position of a product or manufacturer defined in this way and that for $n \in \{1,2\}$, n' represents the other product or manufacturer, i.e. $n' = \{1,2\} \setminus \{n\}$.

3.2 Negotiation, prices and choice

In this subsection we consider the price negotiation problem, conditioning on a given project i; we suppress i subscripts to simplify notation. The buyer and two manufacturers, namely the first-best and runner-up, negotiate to generate price vector $p = [p_{j(n)}]_{n \in \{1,2\}}$, where p denotes *total payment* for quantity q. In the hypothetical situation where the buyer and the manufacturers are unable to conclude negotiations—which we call the *impasse* point (see Binmore et al. (1989))—the buyer is able to source the outside good $j = 0$ and receive the payoff w_0 and the manufacturers get nothing. The outside good may be the first-best or runner-up product; we initially consider the case where it is neither and later generalize the discussion.

When bargaining is completed, the buyer selects the product $j \in \{j(1), j(2)\}$ that generates the highest utility $v_j - p_j$, and pays the negotiated price. Let $d_j \in \{0,1\}$ indicate the buyer's choice for each j. Given p, the indicator for choice of product is

$$d_{j(n)}(p) = 1[v_{j(n)} - p_{j(n)} > v_{j(n')} - p_{j(n')}] \text{ for } n \in \{1,2\}. \tag{2}$$

[9] We assume the location and quantity requirements of a project are predetermined. In practice they are determined when the land is acquired, before the choice of cladding material is made.

[10] In our application there is an absence of product and process innovation, a small number of agents on each side of the market, and repeated market activity across locations; moreover, the surplus from a product varies across projects because of well-established factors namely locally-varying aesthetic tastes of final house-buyers, weather conditions, and transportation costs. These conditions are likely to familiarize agents with the products in $\mathcal{J}$ and their joint surplus in alternative situations.

If (2) is a tie we assume the buyer selects $j(1)$: in this case $k(1)$ is always able to reduce price by an arbitrary amount without making a loss. The buyer's payoff is $u(p) = \sum_{n\in\{1,2\}} d_{j(n)}(p)[v_{j(n)} - p_{j(n)}]$, and manufacturer $k(n)$'s payoff is $\pi_{k(n)}(p) = d_{j(n)}(p)[p_{j(n)} - c_{j(n)}]$. The feasible payoffs for the buyer and nth manufacturer, given the price $p_{j(n')}$ with the n'th, is

$$\Big\{u(p', p_{j(n')}),\ \pi_{k(n)}(p', p_{j(n')}) \mid p' \in [c_{j(n)}, v_{j(n)}]\Big\} \text{ for } n \in \{1, 2\}, \tag{3}$$

where we assume $p' \in [c_{j(n)}, v_{j(n)}]$ to rule out equilibria in which a manufacturer sets a price below its cost of supply.

In the case where manufacturers make take-it-or-leave-it (TIOLI) offers, the best-reply function of manufacturer $k(n)$ given price $p_{j(n')}$ is

$$p^N_{j(n)}(p_{j(n')}) = \arg\max_{p'} \pi_{k(n)}(p', p_{j(n')}) \tag{4}$$

for $n \in \{1, 2\}$ and Nash equilibrium prices are

$$p_{j(1)} \;=\; c_{j(1)} + w_{j(1)} - w_{j(2)} = c_{j(1)} + \Delta w \qquad \text{and} \qquad p_{j(2)} = c_{j(2)}. \tag{5}$$

The buyer (marginally) chooses $j(1)$ and gets a payoff equal to $w_{j(2)}$.

In the general case in which price-taking is relaxed, we assume a contract equilibrium (see Cremer and Riordan (1987)), i.e. each price is bilaterally-efficient given the other price. Price p' maximizes the bilateral surplus of buyer-manufacturer pair $(i, k(n))$ given price $p_{j(n')}$ in the other negotiation:

$$p^C_{j(n)}(p_{j(n')}) \in \arg\max_{p'} \Big\{\ d_{j(n)}(p', p_{j(n')})w_{j(n)} + d_{j(n')}(p', p_{j(n')})[v_{j(n')} - p_{j(n')}]\Big\} \tag{6}$$

for each $n \in \{1, 2\}$. When $d_{j(n)} = 1$ the maximand (bilateral surplus) is joint surplus $w_{j(n)} = [v_{j(n)} - c_{j(n)}]$ but when $d_{j(n')} = 1$ it is limited to utility $u_{j(n')} = [v_{j(n')} - p_{j(n')}]$ because $k(n)$ makes no sales. The conditions for contract equilibrium imply choice of the first-best product and the set of price pairs $\mathcal{P}^C = [c_{j(1)}, c_{j(1)} + \Delta w] \times [c_{j(2)}, v_{j(2)}]$.

Proposition 1. Contract equilibrium prices (i) induce choice of the first-best product and (ii) are characterized by the set $\mathcal{P}^C = [c_{j(1)}, c_{j(1)} + \Delta w] \times [c_{j(2)}, v_{j(2)}]$.

Proof. See Appendix. □

To select a unique equilibrium from the set $\mathcal{P}^C$ we consider two bargaining specifications (labeled S1 and S2) for negotiation $n = 1$, which differ in how the anticipated runner-up price influences the negotiation; each specification is summarized by a bargaining function of the form $p^B(p_{j(2)}) : [c_{j(2)}, v_{j(2)}] \longrightarrow [c_{j(1)}, c_{j(1)} + \Delta w]$. In S1 the negotiated price is given by the minimum of (i) the solution to the Nash bargaining problem in which the disagreement payoffs are those from the impasse point, giving $(w_0, 0)$ to buyer and manufacturer respectively, and (ii) the manufacturer's best TIOLI reply to anticipated price $p_{j(2)}$, i.e.

$$p^B(p_{j(2)}) = \min \Big[\text{ arg max}_{p'} [v_{j(1)} - p' - w_0]^{b_i} \times [p' - c_{j(1)}]^{b_{j(1)}} \ , \ p^N_{j(1)}(p_{j(2)}) \Big]$$

where $b_i \geq 0$ and $b_{j(1)} \geq 0$ are the bargaining skill parameters of buyer and the manufacturer respectively. In S2 the negotiated price is the solution to the Nash bargaining problem in which buying the runner-up good *is* the disagreement point—i.e. $(v_{j(2)} - p_{j(2)}, 0)$ are the disagreement payoffs—giving

$$p^B(p_{j(2)}) = \text{arg max}_{p'} [(v_{j(1)} - p') - (v_{j(2)} - p_{j(2)})]^{b_i} \times [p' - c_{j(1)}]^{b_{j(1)}}. \tag{7}$$

Now consider negotiation $n = 2$. Conditioning on any anticipated price $p_{j(1)} \in [c_{j(1)}, c_{j(1)} + \Delta w]$ in negotiation $n = 1$ the prices $p_{j(2)} \in [c_{j(2)}, v_{j(2)}]$ all induce the first-best choice and are thus payoff-equivalent for each of the parties in negotiation $n = 2$. Given first-best bargaining function $p^B(p_{j(2)})$ the negotiations $n = 1$ and $n = 2$ are thus mutually consistent for the set of price pairs $\{(p_1, p_2) \ : \ p_1 = p^B(p_2), p_2 \in [c_{j(2)}, v_{j(2)}]\}$. We assume that the price pair that is selected is the (unique) Pareto-dominant equilibrium for the agents in negotiation $n = 2$; since $p^B(p_2)$ is increasing in p_2 this assumption implies $p_2 = c_{j(2)}$.[11,12] Equilibrium prices are

$$p = \{(p_1, p_2) \ : \ p_1 = p^B(p_2), p_2 = c_{j(2)}\} \tag{8}$$

which implies the first-best price

$$p_{j(1)} = c_{j(1)} + \begin{cases} \min \ [b_{ij(1)}(w_{j(1)} - w_0), (w_{j(1)} - w_{j(2)})] & \text{for S1} \\ b_{ij(1)}(w_{j(1)} - w_{j(2)}) & \text{for S2} \end{cases} \tag{9}$$

where $b_{ij(1)} \in [0, 1]$ is given by $b_{ij(1)} = b_{j(1)}/(b_i + b_{j(1)})$.[13]

[11] An alternative way to motivate this assumption is to note that if, instead of simultaneous negotiations, (i) prices were negotiated in the optimal sequence for the buyer i.e. the runner-up manufacturer first and the first-best second, and (ii) agents in the first negotiation use the Pareto criterion to select price, then (8) is implied by the unique subgame perfect equilibrium.

[12] In S1, $p^B(p_2)$ is strictly increasing in p_2 only if $p^N(c_{j(2)}) <$ arg $\max_{p'} [(v_{j(1)} - p') - w_0]^{b_i} \times [p' - c_{j(1)}]^{b_{j(1)}}$. Otherwise p_2 is irrelevant and there is a unique first-best price.

[13] Manufacturer bargaining skill does not affect buyer's choice of product: the payoff of the buyer

The two specifications differ in terms of the effect of the runner-up on the first-best price. In S1 the runner-up only has an effect on the first-best price if the markup under TIOLI (i.e. the surplus advantage) is less than the manufacturer's share of the gains relative to the impasse point, i.e. if $(w_{j(1)} - w_{j(2)}) < b_{ij(1)}(w_{j(1)} - w_{i0})$. In S2 the runner-up is always relevant to first-best price as it determines the (bargained-over) surplus advantage. In the interest of robustness we use both specifications.[14] Both nest the TIOLI case, given by setting $b_{ij(1)} = 1$.

When the outside good is runner-up, $w_{j(2)} = w_0$ and the two specifications in (9) are identical; when it is first-best, the buyer selects the outside good and receives utility $w_{j(0)}$ without negotiation.

Non-cooperative microfoundations Both specifications can be supported as a limiting subgame perfect equilibrium, as time discounting goes to zero, of the alternating offers framework of Rubinstein (1982). Two approaches have been taken in the literature to establish non-cooperative foundations for multilateral bargaining models.

The first approach uses an "independent agents" representation in which the buyer sends a separate agent to each manufacturer, and each negotiation proceeds bilaterally with alternating offers and no information flow between negotiations (see Chipty and Snyder (1999) and Crawford and Yurukoglu (2012) for a discussion). Each of the two bargaining specifications above for negotiation $n = 1$ can be supported in this approach depending on the source of time discounting.[15] As for negotiation $n = 2$, no trade is anticipated here in equilibrium and alternative values for the price are payoff-equivalent for any reasonable anticipated first-best price; if the buyer moves first it follows trivially that a marginal cost price is an equilibrium outcome of negotiation $n = 2$ as the manufacturer cannot achieve a higher payoff by rejection and counter-offer and will accept any price $p \in [c_{j(n)}, v_{j(n)}]$.

In the second approach the buyer acts as a single agent negotiating with both manufacturers, allowing information flow between the two negotiations. The outcomes from specification S1 are supported in this approach for several specifications—in which future payoffs are discounted because of time-preference—which differ in the timing

when selecting $j(1)$ is never lower than $w_{j(2)}$ even when $b_{ij(1)} = 1$ as the first-best manufacturer must offer at least the payoff the buyer can get when buying $j(2)$ at marginal cost.

[14]The possibility that in applied work there is more than one plausible specification for the impact of a runner-up alternative is pointed out in Binmore et al. (1989) which notes that "in applications there is often more than one candidate for the disagreement point." The two surplus sharing rules we use in S1 and S2 correspond to the two alternatives, namely namely "deal me out" and "split the difference," in Binmore et al. (1989) which presents experimental evidence in support of the former.

[15]If discounting of future payoffs derives from time-preference, S1 is implied (see Binmore et al. (1989), "deal-me-out" case) but if it derives from an exogenous probability of breakdown at each stage then S2 is implied (see Binmore et al. (1986), "split the difference" case).

of offers. (We are not aware of a bargaining protocol in this second approach that supports S2.) For example, in the one-buyer two-seller "auctioning model" discussed in Binmore (1985), Binmore et al. (1992) and Osborne and Rubenstein (1990) (derived formally in chapter 9.3) the buyer begins by announcing a number, which represents the utility she requires if agreement is to be reached, which both sellers hear. If $k(1)$ accepts then there is trade but if he rejects then $k(2)$ can decide whether to accept or to reject. If both reject there is a delay before the two sellers make simultaneous offers to the buyer and the buyer can select one to accept. If the buyer rejects both then there is another delay before the buyer can offer again. Bolton and Whinston (1993), is similar but assumes that when it is the buyer's turn it can make an offer to either manufacturer or can make no offers. More recently, Manea (2018) presents a model in which, in any period, the buyer selects an upstream seller $k \in \mathcal{K}$. With probability $\varrho \in (0, 1)$ the buyer proposes a price and seller k decides whether to accept; roles are reversed with probability $1 - \varrho$. In either event if the offer is rejected the game proceeds to the next period and the process is repeated. This protocol is adapted by Ho and Lee (2019) to allow for situations where the buyer benefits from trading with multiple manufacturers in equilibrium; this a generalization we do not require given that in our framework the buyer single-sources for any negotiation situation. Finally, Ghili (2018) (appendix) finds the outcome of S1 in a model in which single-sourcing is optimal and the timing of moves similar to the protocol in Collard-Wexler et al. (2019).

Relation to cooperative games The bargaining outcomes have the property that they are in the core of the coalition game involving three parties—i.e. they (i) maximize and fully distribute the total surplus, (ii) ensure that no sub-coalition of the parties can be made better off without another being made worse off, and (iii) imply a zero allocation of surplus to the null player (i.e. the player that does not contribute anything to the overall surplus), namely $k(2)$. Each possible allocation in the core can be achieved by some value of the relative bargaining skill b_{ij} in the range $[0, 1]$. In Specification 2, b_{ij} can be interpreted as describing how the surplus in the core is split, without appealing to a specific non-cooperative bargaining model.

3.3 Specification of payoffs and bargaining skill

We now reintroduce i subscripts. We assume that the valuation of q_i units of product j in project i is written $v_{ij}(q_i) = \mu_{ij} q_i$ where the taste effect μ_{ij} is given by

$$\mu_{ij} = \delta_j + \beta' z_{ij}^{(1)} - \alpha' z_{ij}^{(2)} + \varepsilon_{ij}. \tag{10}$$

In equation (10) δ_j is a constant that captures mean utility and β and α are parameter vectors for product j taste-shifters $z_{ij}^{(1)}$ and transport cost shifters $z_{ij}^{(2)}$ respectively.[16] The vector $z_{ij}^{(1)}$ includes regional dummies to allow taste variation for inside goods as a group, interactions of product characteristics and regional weather, interactions of regional dummies and aesthetic characteristics, indicators for whether j is local to i (to capture home-preference), and buyer-manufacturer indicators (to allow buyer-specific preferences over manufacturers).[17] The vector $z_{ij}^{(2)}$ includes distance and fuel costs (and their interaction). The ε_{ij} term captures a project-specific effect which we assume is known to buyers and manufacturers, including (i) the benefits of marketing a housing project to final consumers using brick product j given established attitudes to brick style and color local to project i, which are an important aspect of brick demand (e.g. traditional aesthetic tastes and environmental sensitivities), (ii) technical benefits of a brick given weather conditions prevailing at project i (e.g. altitude or coastal proximity) and (iii) differences between measured (based on Euclidean distance) and actual transport costs, because of congestion, topography, road quality, etc. We assume ε_{ij} is iid across projects i according to a GEV distribution G_ε (nesting the inside goods) with parameters $\sigma = (\sigma_J, \sigma_\varepsilon)$, where $\sigma_J \in [0, 1]$ is the nesting and σ_ε the scale parameter.[18] The cost $c_{ij} = c_{ij}(q_i)$ to manufacturer $k(j)$ of product j in project i is

$$c_{ij} = \gamma_0 + [\gamma' \mathrm{w}_{ij}^c + \nu_i] q_i \tag{11}$$

where γ_0 is a fixed cost which allows transaction-level scale effects, γ is a parameter vector and w_{ij}^c is a vector of cost-shifters including input prices, a dummy for the plant at which j is produced, and an indicator for whether product j has a below-median ratio of strength to water absorption (which captures whether the brick has low-cost

[16] Our framework permits random taste coefficients on product characteristics. We do not use them as we have taste heterogeneity through product-project interactions in the z_{ij} variables.

[17] CC (2007) (paragraph 4.71) notes that buyers consider some quality factors that vary by manufacturer such as continuity of supply, consistent quality, complementary services, quality of just-in-time production and after-sales service.

[18] Given the inclusion of the δ_j terms, the specification is consistent with a choice between varieties (nested) within each j; this follows from the maximum stability property of the GEV distribution (see Ackerberg and Rysman (2005) and footnote 8).

characteristics). Finally $\nu_i \sim N(\sigma_\nu, 0)$ is iid across projects and allows projects to vary in supply cost—e.g. different production timing requirements within the year or whether some bespoke shapes are required. The surplus per unit, denoted $\bar{w}_{ij} = w_{ij}/q_i$, from product j in project i, is

$$\bar{w}_{ij} = \delta_j + \beta' z_{ij}^{(1)} - \alpha' z_{ij}^{(2)} - (\gamma_0/q_i + \gamma' \mathrm{w}_{ij}^c + \nu_i) + \varepsilon_{ij}. \tag{12}$$

We normalize surplus such that $\bar{w}_{i0} = 0 + \varepsilon_{ij}$.

The bargaining skill of agent $l \in \mathcal{K} \cup \mathcal{H}$ is

$$b_l = \exp(\eta_0 + \eta_1 1_{[l \in \mathcal{K}]} + \eta_2 y_l) \tag{13}$$

where $\eta = (\eta_0, \eta_1, \eta_2)$ are parameters, $1_{[l \in \mathcal{K}]} \in \{0, 1\}$ indicates whether l is a manufacturer, and y_l is agent size, defined as the log of l's number of transactions in the period of the data. These parameters enter the model through $b_{ij} = b_{k(j)}/(b_{k(j)} + b_{h(i)}) \in [0, 1]$ and we can normalize $\eta_0 = 0$.

For later use, let $x_{ij} = (z_{ij}^{(1)}, z_{ij}^{(2)}, \mathrm{w}_{ij}^c, q_i)$ gather the data in (12), so we write $\bar{w}_{ij} = \omega_{ij} + \varepsilon_{ij}$ where $\omega_{ij} = \omega(x_{ij}, \nu_i)$ is per-unit surplus up to ε_{ij}. Similarly, let $y_{ij} = [y_{h(i)}, y_{k(j)}]$ gather the relevant agent size data for project i and product j and let relative bargaining power be written $b_{ij} = b(y_{ij})$.

Conditional on the primitives of the model, the specification implies that choice and price outcomes in a given project are independent of those in other projects. This rules out at least three potential forms of non-independence. First, intra-manufacturer effects generated by plant-level capacity constraints; we regard these as negligible in our application, given that plants are not operating close to capacity, have high levels of inventory, and have a large capacity relative to individual transactions (see CC (2007) para 7.8).[19] Second, inter-buyer interdependence could arise because buyers compete in the retail market for new houses; however, in our framework bargaining induces the efficient buyer choice, so negotiations over price transfer bilateral surplus without impacting the buyer's retail price or output decisions. Third, consider intra-buyer interdependence. Given that the projects are spatially separate there is no obvious role for intrinsic taste synergies. There is also little role for synergies arising from shopping costs—i.e. costs per manufacturer used across all transactions in any buying period: buyers are already multi-sourcing (in different transactions) and according to

[19]The framework we use permits a relaxation of this where buyers and sellers condition on the equilibrium outcomes of negotiations in other projects (the approach in Chipty and Snyder (1999)), e.g. let costs to k from project i be $c_k(q_i, Q_{-i})$ where Q_{-i} is a vector of quantities in other projects, and assume Q_{-i} is unaffected by the bargaining process for i.

CC (2007) (paragraph 7.7) face no significant switching costs. Moreover while, with non-individualized pricing, multi-product firms may have bundling incentives—loosely, cutting price on one product to attract a buyer to another—these do not arise when prices are individualized, with or without shopping costs, since negotiated prices induce the buyer to choose the first-best product separately in each transaction.[20]

4 Likelihood and estimation

Overview For each project i in the set $\mathcal{I}_J$ of projects using inside goods we observe (i) the first-best product and its negotiated price, $[j(i,1), p_i]$, (ii) shifters of joint surplus $x_i = [x_{ij}]_{j \in \mathcal{J}_J}$, and (iii) shifters of bargaining skill with the first-best seller $y_{ij(i,1)}$. We also observe the market share s_{0m} (and hence the number of projects N_{0m}) of the outside good for each region-year market $m \in \mathcal{M}$.

There are two main econometric challenges. First, for any i, we do not observe the buyer's runner-up good, which is an argument in her first-best pricing equation (9), and relatedly we do not observe prices the buyer would have paid for products she did not choose, which are used in standard choice models as in Berry et al. (1995).[21] Second, there is a selection issue in the pricing equation, similar to that in Dubin and McFadden (1984): both the choice of product, and the individualized price p_i, depend on unobserved shocks (ν_i, ε_i), so that, conditional on product choice, variables in the price equation (9) are endogenous.

To address these challenges we derive a joint likelihood for the choice of product and the individualized price, which uses the model to predict the runner-up product and its price, given any realization of the unobservables; we then integrate out the unobservables, the runner-up products, and their prices. As there are many candidate runner-up products, this is a high-dimensional integration problem which is computationally demanding using numerical methods; we show that when idiosyncratic tastes are GEV there is a tractable likelihood for the joint probability of the individualized price and the observed choice. As we estimate the pricing and choice parts of the model jointly, we avoid the selection issue.

[20] As Nalebuff (2000) points out, while a seller in a market with non-individualized pricing might sell a bundle of complementary items at a discount relative to its individual items, the presence of such discounts "depends on an unstated assumption: that firms set a single price in the market to all customers. This is a quite reasonable assumption for a typical consumer good, such as Microsoft Office. But it is not a reasonable assumption for the sale of large commercial products in which the two parties engage in extensive negotiation as part of the sale process. If firms can price discriminate or negotiate with each customer, then the advantage to bundling disappears."

[21] The standard solution with transactions data—to use the price observed for product j' in another transaction where j' *is* chosen—is not appropriate when prices are individualized.

4.1 Probability expressions

Inequality conditions for choice and price We first derive a set of inequality conditions for product choice and price. We have from Proposition 1 the property that equilibrium prices induce choice of the first-best product

$$j = j(i,1) \quad \Longleftrightarrow \quad \bar{w}_{ij} \geq \bar{w}_{ij'} \quad \forall j' \in \mathcal{J}. \tag{14}$$

It is convenient to use per-unit markups $\rho_{ij} = \bar{p}_{ij} - \bar{c}_{ij}$ where $\bar{p}_{ij} = p_{ij}/q_i$, and $\bar{c}_{ij} = c_{ij}/q_i$. Conditional on j being first-best the price equation (9) can be written

$$\rho_{ij} = \min\{[b_{ij}^{S}(\bar{w}_{ij} - \bar{w}_{ij'})]_{j' \in \mathcal{J} \backslash \mathcal{J}_{k(j)}.}, b_{ij}(\bar{w}_{ij} - \bar{w}_{i0})\}, \tag{15}$$

where the index $S \in \{0,1\}$ takes the values 0 and 1 for specifications S1 and S2 respectively. When $S = 0$ the minimization operator selects the runner-up good only if it constrains the buyer's surplus-sharing problem with the first-best good, and when $S = 1$ it selects the runner-up good. The markup equation (15) implies the following necessary and sufficient conditions for ρ_{ij} to be greater than or equal to arbitrary $\rho \geq 0$

$$\rho_{ij} \geq \rho \iff \bar{w}_{ij} \geq \bar{w}_{ij'} + \rho \times (b_{ij}^{-S} 1_{[j'>0]} + b_{ij}^{-1} 1_{[j'=0]}) \quad \forall j' \in \mathcal{J} \backslash \mathcal{J}_{k(j)}. \tag{16}$$

The inequalities in (16) are comparisons of product j with products j' in the set of rival products $\mathcal{J} \backslash \mathcal{J}_{k(j)}$, unlike the inequalities in (14) which apply to all products. For each $j' \in \mathcal{J} \backslash \mathcal{J}_{k(j)}$ the condition in (16) implies the corresponding one in (14); pooling the conditions in (14) and (16) therefore gives the following conditions for i to choose j and ρ_{ij} to be greater than or equal to $\rho > 0$

$$(j = j(i,1) \text{ and } \rho_{ij} \geq \rho) \iff \bar{w}_{ij} \geq \bar{w}_{ij'} + \rho \chi_{jj'} (b_{ij}^{-S} 1_{[j'>0]} + b_{ij}^{-1} 1_{[j'=0]}) \quad j' \in \mathcal{J} \tag{17}$$

where $\chi_{jj'} = 1_{[j' \in \mathcal{J} \backslash \mathcal{J}_{k(j)}]}$ is an indicator for whether j and j' have separate ownership. The conditions are intuitive: for any ρ the inequalities are more likely to be violated if $k(j)$'s product ownership portfolio is smaller, or her relative bargaining power b_{ij} decreases, or if surplus differences $\bar{w}_{ij} - \bar{w}_{ij'}$ are relatively small.

Choice probabilities To derive choice probabilities we write per-unit surplus in the form $\bar{w}_{ij} = \omega(x_{ij}, \nu_i) + \varepsilon_{ij}$ for all $j \in \mathcal{J}_J$, and $\bar{w}_{i0} = 0 + \varepsilon_{i0}$, as introduced in Section 3.3. The probability s_{ij} that product $j \in \mathcal{J}_J$ is chosen for project i of type (x_i, ν_i) is given by integrating over the values for ε that satisfy (14), i.e.

$$s_{ij} = \int_{\varepsilon} 1\{\omega_{ij} + \varepsilon_{ij} \geq \max[(\omega_{ij'} + \varepsilon_{ij'})_{j' \in \mathcal{J}_J}, \varepsilon_{i0}]\} dG_{\varepsilon} \tag{18}$$

where $\omega_{ij} = \omega(x_{ij}, \nu_i)$. Since $\varepsilon \sim$ GEV where $j \in \mathcal{J}_J$ are nested with parameter σ_J, we have from McFadden (1978) that $s_{ij} = s_{ij|J} s_{iJ}$ where

$$s_{ij|J} = \frac{\exp\{\sigma_\varepsilon \omega_{ij}/\sigma_J\}}{\Sigma_{j' \in \mathcal{J}_J} \exp\{\sigma_\varepsilon \omega_{ij'}/\sigma_J\}}, \quad s_{iJ} = \frac{\exp\{\sigma_J W_i\}}{1 + \exp\{\sigma_J W_i\}} \tag{19}$$

and

$$W_i = \ln[\Sigma_{j' \in \mathcal{J}_J} \exp\{\sigma_\varepsilon \omega_{ij'}/\sigma_J\}]. \tag{20}$$

Joint probability measure for choice and price The discrete-continuous probability measure for choice of product and negotiated price is derived from the probability that product $j \in \mathcal{J}$ is chosen and its markup exceeds arbitrary ρ, for a project of type (x_i, ν_i) with observed bargaining skill shifters y_{ij}. This probability is given by integrating over the set of values for ε that satisfy the inequalities in (17), i.e.

$$\begin{aligned} r_{ij}(\rho) =& \Pr(j = j(i,1) \text{ and } \rho_{ij} \geq \rho | x_i, y_{ij}, \nu_i) \\ =& \int_{\varepsilon} 1\{\omega_{ij} + \varepsilon_{ij} \geq \max[(\omega_{ij'} + \varepsilon_{ij'} + \rho \chi_{jj'} b_{ij}^{-S})_{j' \in \mathcal{J}_J}, \rho b_{ij}^{-1} + \varepsilon_{i0}]\} dG_{\varepsilon} \end{aligned} \tag{21}$$

where $\omega_{ij} = \omega(x_{ij}, \nu_i)$ and $b_{ij} = b(y_{ij})$. Since $\varepsilon_{ij} \backsim$ GEV, nested by $\mathcal{J}_J$, with nesting parameter σ_J, and the inequalities in the second line of (21) have the same structure as those in (14), it follows that $r_{ij}(\rho) = r_{ij|J}(\rho) r_{iJ}(\rho)$ where

$$r_{ij|J}(\rho) = \frac{\exp\{\sigma_\varepsilon \omega_{ij}/\sigma_J\}}{\Sigma_{j' \in \mathcal{J}_J} \exp\{\sigma_\varepsilon [\omega_{ij'} + \rho \chi_{jj'} b_{ij}^{-S}]/\sigma_J\}}, \tag{22}$$

$$r_{iJ}(\rho) = \frac{\exp\{\sigma_J R_i(\rho)\}}{\exp\{\sigma_\varepsilon [\rho b_{ij}^{-1}]\} + \exp\{\sigma_J R_i(\rho)\}} \tag{23}$$

and

$$R_i(\rho) = \ln(\Sigma_{j' \in \mathcal{J}_J} \exp\{\sigma_\varepsilon [\omega_{ij'} + \rho \chi_{jj'} b_{ij}^{-S}]/\sigma_J\}). \tag{24}$$

Given the definition of $r_{ij}(\rho)$ in (21) it follows that the discrete-continuous probability measure $f_{ij}(\rho)$ of observing choice j and markup ρ for project i is given by

$$f_{ij}(\rho) = -\partial r_{ij}(\rho)/\partial \rho \tag{25}$$

which has a convenient closed form given in the following proposition.

Proposition 2. If $\varepsilon_{ij} \backsim$ GEV, nested by $\mathcal{J}_J$, with nesting parameter σ_J, then the discrete-continuous probability measure (25) for bargaining specifications S1 and S2 is

$$f_{ij}(\rho) = \sigma_\varepsilon \times \begin{cases} r_{ij}(\rho)[1 - r_{ik}(\rho) - (1 - \sigma_J^{-1})(1 - r_{ik|J}(\rho))] - (1 - b_{ij}^{-1})r_{ij}(\rho)r_{i0}(\rho) & \text{S1} \\ r_{ij}(\rho)[1 - r_{ik}(\rho) - (1 - \sigma_J^{-1})(1 - r_{ik|J}(\rho))]b_{ij}^{-1} & \text{S2} \end{cases}$$

where $r_{ik}(\rho) = \Sigma_{j \in \mathcal{J}_k} r_{ij}(\rho)$ and $r_{ik|J}(\rho) = \Sigma_{j \in \mathcal{J}_k} r_{ij|J}(\rho)$. In either specification the TIOLI model is obtained by setting $b_{ij} = 1$.

Proof. See Appendix A. □

Since f_{ij} is a function of unit markup ρ we need to rewrite it in terms of unit price $\bar{p}$. We define $f^*_{ij}(\bar{p}) \equiv f_{ij}(\bar{p} - \bar{c}_{ij})$ as the probability measure of jointly observing j and $\bar{p}$ for a consumer of type (x_i, ν_i).

We write the probability expressions explicitly in terms of consumer type, i.e. $s_j(x_i, \nu_i)$ and $f^*_j(\bar{p}_i|x_i, y_{ij}, \nu_i)$, and integrate over ν to obtain

$$s_j(x_i) = \int_\nu s_j(x_i, \nu) dG_\nu \quad \text{and} \quad f^*_j(\bar{p}_i|x_i, y_{ij}) = \int_\nu f^*_j(\bar{p}_i|x_i, y_{ij}, \nu) dG_\nu. \tag{26}$$

These integrals do not have a closed form and we compute them by simulation.[22]

The market share s_{mj} of product j in region-year market m is given by $s_{mj} = \Sigma_x s_j(x) g(x|m)$ where $g(x|m)$ is the distribution of x-types across projects in market m. For $g(x|m)$ we assume that projects are geographically distributed across NUTS2 subregions within m in proportion to official data on the number of new houses completed for the 4-year period of the data, and that x is distributed within any NUTS2 subregion and year according to its empirical distribution in the transactions data.[23]

[22]In the integral for $f^*_j(\bar{p}_i|x_i, y_i)$ in (26) we use importance sampling to avoid cost shocks ν_i that are uninformative because they imply negative markups, which have zero probability. Let ν_i^c be the highest cost shock consistent with non-negative markups, i.e. $\bar{p}_i \equiv \bar{c}_{ij} + \nu_i^c$ which implies

$$f^*_j(\bar{p}_i|x_i, y_{ij}) = \int_{-\infty}^{\nu_i^c} f^*_j(\bar{p}_i|x_i, y_{ij}, \nu) g_\nu(\nu) d\nu = G_\nu(\nu^c) \int_{-\infty}^{\nu_i^c} f^*_j(\bar{p}_i|x_i, y_{ij}, \nu) \tilde{g}_\nu(\nu) d\nu, \tag{27}$$

where the first equation follows because the likelihood is zero outside the limit of integration and in the second equation $\tilde{g}_\nu(\nu) = g_\nu(\nu)/G_\nu(\nu_i^c)$ is the density for the truncated normal distribution and G_ν is the cumulative distribution function. We simulate the integral for each i using 200 independent draws from $\tilde{g}_\nu(\nu)$ in the range $(-\infty, \nu_i^c)$.

[23]To be concrete let $m = (\kappa, t)$ where κ is a NUTS1 region and t is a year. Then $g(x|m) = \Sigma_{\tau \in \Omega_\kappa} g_1(x|\phi, t) g_2(\phi|\kappa)$ where ϕ indexes NUTS2 regions, Ω_κ is the set of NUTS2 regions in κ, $g_1(x|\phi, t)$ is the distribution of x in the transactions data for ϕ and t, and $g_2(\phi|\kappa)$ is the distribution of the number of new houses completed in the 4-year period of the data, from the Office for National Statistics *House Price Statistics for Small Areas*; since these data on completions are presented by dwelling size class we standardize by giving a detached house a weight of 1, a semi-detached house 0.75, a terraced house 0.5 and an apartment 0.40. There are 39 NUTS2 regions in Great Britain. We consider NUTS2 regions to be sufficiently granular that we do not need to distribute projects

4.2 Likelihood function

Let $Y = \{[j(i,1), p_i, x_i, y_{ij(i,1)}]_{i \in \mathcal{I}_J}, (N_{0m})_{m \in \mathcal{M}}\}$ summarize the data. The log-likelihood function, for parameters (θ, δ), where $\theta = (\beta, \alpha, \sigma, \gamma, \eta)$ and $\delta = (\delta_j)_{j \in \mathcal{J}_J}$, is

$$l(\theta, \delta, Y) = \Sigma_{i \in \mathcal{I}_J} \ln f^*_{j(i,1)}(\bar{p}_i, \theta, \delta | x_i, y_{ij(i,1)}) + \Sigma_{m \in \mathcal{M}} N_{m0} \ln s_{m0}(\theta,\delta) \tag{28}$$

where the first term is the sum of contributions from inside goods and the second is the sum of contributions from the outside good. To reduce the dimension of the maximization problem we concentrate (28) with respect to the vector of mean utilities δ by inverting the market share functions $s_M(\theta,\delta) = [s_{Mj}(\theta,\delta)]_{j \in \mathcal{J}}$ where market M is Great Britain over the full 4-year period of the data. To obtain the vector of mean utilities $\delta(\theta, s_M)$ for any candidate value of θ and observed market share vector s_M we follow Berry et al. (1995) and iterate the system $\delta^{\iota+1} = \delta^{\iota} + \ln[s_M] - \ln[s_M(\theta, \delta^{\iota})]$ where ι is an iteration count. The jth element of s_M is given by $\Sigma_i d_{ij}/N$ where $N = |\mathcal{I}_J| + \sum_{m \in \mathcal{M}} N_{0m}$. We use a convergence criterion of $\|\delta^{\iota+1} - \delta^{\iota}\| < 1 \times 10^{-12}$. The parameters that maximize the log-likelihood function are given by $\hat{\theta} = \text{argmax}_{\theta}\ l(\theta, \delta(\theta, s), Y)$.

4.3 Informal discussion of identification

Identification differs in three ways from the standard discrete-choice setting with micro data (as discussed in Berry and Haile (2020)). First, the issue of endogenous prices does not arise as prices are modeled as endogenous. Second, the scaling parameter σ_{ε} cannot be normalized because the price equation requires utility to be denominated in money units. Third, the model has bargaining parameters.

Since we have data on transport costs we estimate transport cost parameters α directly in a first step using the regression model $T_{ij} = \alpha_0 + \alpha' z^{(2)}_{ij} + \epsilon_{ij}$ where T_{ij} is the observed transport costs in project i per unit of volume. We assume that ϵ_{ij} is measurement error such that $E[\epsilon_{ij} | 1, z^{(2)}_{ij}] = 0$. The estimated values of parameters α are treated as known when maximizing the likelihood with respect to remaining parameters; α_0 is absorbed into mean utility δ_j (see equation (10)).[24]

The remaining parameters in buyer valuation follow standard arguments. With α in hand, variation in the distance variable in $z^{(2)}_{ij}$ across projects, similar to a price instrument, is informative for σ_{ε}. The correlation, at region-year m level, between

geographically within them using external data such as postal addresses

[24]The transport cost parameters α can be identified without using observing transport costs, using the same information that is useful for identifying the β parameters, namely variation in choice sets and chosen products across projects. Note also that transport costs were not available from one of the four manufacturers; we assume these observations are missing at random.

surplus shifters x_{ij} and outside good market shares s_{m0} is informative for the nesting parameter σ_J. The mean utility effects δ are uniquely identified, given any θ, by matching the predicted and observed product market shares (since the model satisfies the conditions in Berry et al. (2013)), while choice set variation is informative for taste parameters β that govern the interaction of project and product characteristics.

Turning to the cost parameters we leverage the transaction-level information in the price: the relationship between per-unit price and quantity q_i is informative about the transaction-specific fixed cost γ_0 and the relationship between price and cost-shifters w_{ij}^c is informative about γ. The variance of prices, holding fixed the GEV parameters, is informative about the parameter σ_ν on the transaction-specific cost shock.

Finally, the bargaining parameters η do not affect joint surplus and have no effect on market shares. Information on the bargaining parameters is available from the relationship between transaction price and observed variables that shift markups including bargaining skill shifters $y_{ij(i,1)}$ and shifters of surplus advantage $\Delta\bar{w}_i = \bar{w}_{ij(i,1)} - \bar{w}_{ij(i,2)}$ such as $x_{ij(i,1)}$ and the set of products $\mathcal{J}_{k(i,1)}$ from which $j(i,2)$ is excluded.

5 Estimates and model fit

Parameter Estimates Transport cost parameters α in Panel A of Table 4 are estimated by regression in a first step; remaining parameters in Panels B-D are estimated by maximum likelihood. We adjust standard errors to account for two-step estimation using the method in Murphy and Topel (1985).

To help with interpretation note that the model is scaled in units of £100 per 1000 bricks. The estimates for α imply the average transport cost for $i \in \mathcal{I}_J$ is £23.74 per 1000 bricks, which is 13% of average unit prices reported in Table 1. These costs vary across i depending on distance and annual fuel prices: the 1st and 99th percentiles are £9.30 and £50.11 per 1000 bricks respectively, consistent with executive testimony in CC (2007) on the upper bound of transport costs.[25] The negative sign for the square of distance is consistent with the simple choice model in Section 2.

There is a separate set of likelihood estimates for specification S1, S2, and TIOLI, which show only minor differences (apart from bargaining parameter η_1 as discussed below). The utility estimates are in Panel B and mostly have the expected signs, including those on the interactions between weather and technical brick characteristics.

[25] Paragraph 4.60 of CC (2007) states that companies told the CC that "transport costs could be up to nearly one-quarter of the cost of delivered bricks". The mean production cost reported later in this section (Panel E, Table 5) is about £167 for 1000 bricks. The 99th percentile transport cost, £50.11, is 23% of the cost of delivered bricks, £50.11 + £167.00 = £217.11.

A: *Transport cost parameters*							
DST_{ij}	α_1	(100km)				0.116	(0.004)
$DST_{ij} \times \mathrm{w}_i$	α_2	(100km × £/L)				0.048	(0.004)
DST_{ij}^2	α_3					-0.010	(0.001)
R^2						0.825	
B: *Parameters in valuation* v_{ij}		S1		S2		TIOLI	
Absorption × rainfall	β_1	-0.048	(0.045)	-0.038	(0.046)	0.015	(0.039)
Strength × frost	β_2	0.267	(0.128)	0.195	(0.129)	0.103	(0.112)
Same-region-produced	β_3	0.023	(0.004)	0.023	(0.004)	0.015	(0.003)
Within-100km-produced	β_4	0.040	(0.004)	0.043	(0.005)	0.017	(0.003)
North × red	β_5	0.046	(0.006)	0.048	(0.006)	0.041	(0.005)
North × wirecut	β_6	0.127	(0.007)	0.132	(0.007)	0.114	(0.006)
GEV nesting	σ_J	0.615	(0.023)	0.846	(0.023)	0.769	(0.019)
GEV scaling	σ_ε	0.208	(0.008)	0.167	(0.004)	0.145	(0.003)
Product effect ($\bar{\delta}$ is mean δ_j)	$\bar{\delta}$	0.861	(0.015)	0.525	(0.015)	0.553	(0.014)
C: *Parameters in cost* c_{ij}							
Fixed per-transaction cost	γ_0	0.151	(0.029)	0.149	(0.029)	0.138	(0.029)
Gas price index	γ_1	0.881	(0.030)	0.919	(0.024)	0.918	(0.023)
Wages (£10k/year)	γ_2	0.412	(0.048)	0.230	(0.037)	0.196	(0.035)
Low-quality product (1/0)‡	γ_3	-0.038	(0.007)	-0.036	(0.007)	-0.038	(0.007)
Scaling term for cost shock	σ_ν	0.071	(0.001)	0.073	(0.001)	0.069	(0.001)
Plant effect ($\bar{\gamma}$ is median)	$\bar{\gamma}$	0.792	(0.059)	1.037	(0.046)	1.079	(0.044)
D: *Bargaining parameters*							
Manufacturer dummy $1[l \in \mathcal{K}]$	η_1	1.145	(0.122)	-0.120	(0.081)	-	-
Agent l size y_l	η_2	0.265	(0.046)	0.225	(0.026)	-	-
Log likelihood			-46299.014		-46429.863		-446476.686
LR test statistic $\backsim \chi^2(2)$			355.345		93.647		–

E: *Manufacturer relative bargaining skill* $b_{ij} \in [0,1]$			
	S1	S2	TIOLI
Mean	0.540	0.810	1
SD	0.061	0.045	0
Min	0.401	0.693	1
Max	0.702	0.908	1

Notes. S1 and S2 refer to the two bargaining specifications. Panel A: regression of transport costs; observations: 11,855. Panels B-D: estimates by maximum likelihood. Standard errors adjusted for two-step estimation. Observations: $N = |\mathcal{I}_J| + \Sigma_m N_{0m} = 19,036$. Specifications include regional and buyer-manufacturer dummies in value and plant dummies in cost. $\bar{\delta}$'s standard error obtained by regressing $(\delta_j)_{j \in \mathcal{J}_J}$ on a constant. ‡Indicator for whether a brick has a below-median ratio of strength to water absorption. LR test statistic is for the restriction imposed by the TIOLI model. The 0.1% significance level for the χ^2 distribution with 2 d.f. is 16.26. Statistics in Panel E for b_{ij} are for $i \in \mathcal{I}_J$. Units for transport costs and surplus estimates is £100 per 1000 bricks. Standard errors in parentheses; those in panels C-D are adjusted to account for two-step estimation.

Table 4: Estimated parameters

There is a positive home-region taste effect for each of the two home-region variables used.[26] We include a regional effect for aesthetic characteristics; for parsimony we use two large regions, north and south.[27] The GEV parameters σ imply that the εs for inside goods are positively correlated. There are three further groups of unreported utility parameters: product-specific effects δ_j, dummies that allow regional variation in tastes for inside goods, and effects that allow buyer-specific preferences over manufacturers.[28] The cost estimates are in Panel C. Their signs are as expected. The per-transaction fixed cost parameter γ_0 is about £15 per transaction, about 9% of the unit cost of 1000 bricks. The spread parameter σ_ν on project-specific cost draws implies a standard deviation that is about 4% of average unit costs. We estimate a set of unreported effects for the 36 plants. Finally, the bargaining skill coefficients in Panel D comprise an mean effect η_1 for manufacturers, which is lower in S1 than S2, as discussed in the next paragraph, and an effect η_2 for agent size which as expected is positive for both specifications.

Panel E reports the implications for bargaining parameter $b_{ij} = b_{k(i,1)}/(b_{k(i,1)}+b_{h(i)})$. In both specifications S1 and S2 there is variation across transactions because of agent size. In S1 the mean b_{ij} across $i \in \mathcal{I}_J$ of 0.540 indicates approximately equivalent bargaining skill on both sides of the market while in S2 the mean of 0.810 indicates manufacturers have greater skill. The difference between S1 and S2 is a consequence of the different magnitudes of bargained-over surplus: in S1 the bargained-over surplus is $w_{ij(i,1)} - w_{i0}$, and in S2 it is $w_{ij(i,1)} - w_{ij(i,2)}$ which by definition is smaller. Since the markup represents the manufacturer's share of bargained-over surplus, a given markup for the manufacturer corresponds to a smaller surplus share in S1 than in S2.

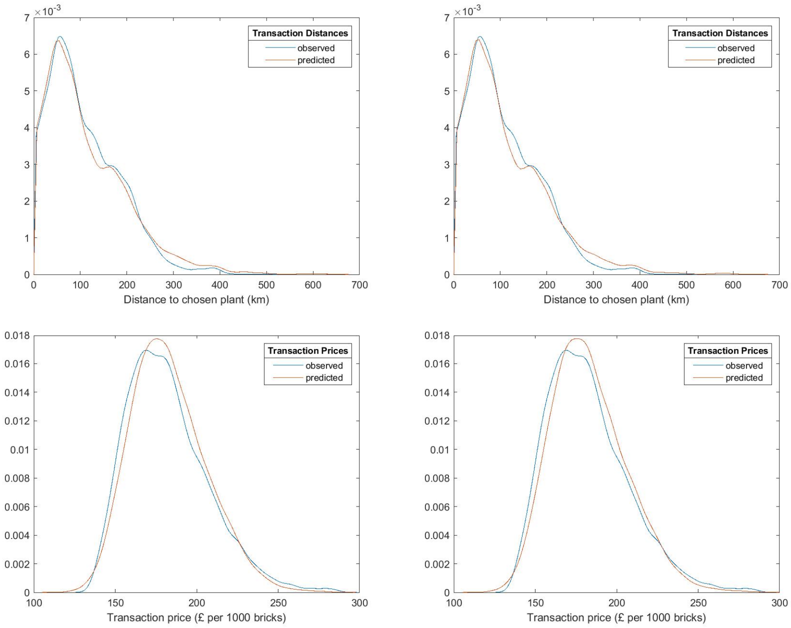
Model fit The TIOLI model restricts S1 and S2 by setting $b_{ij} = 1$, which eliminates two parameters. The test statistics in Table 4 for S1 and S2 exceed the critical value 13.82 of the $\chi^2(2)$ distribution at a significance level of 0.1% so we reject the restriction. As S1 and S2 are not mutually nested we proceed to discuss both, which allows us to show that results are robust between S1 and S2.

To consider the fit of the model we simulate a price, cost, and distance prediction

[26]The CC report, CC (2007), mentions this effect in paragraph 5.26, where they say that there was evidence of distinct regional brick preferences existed which "seemed to be driven by historical factors, particularly customer preferences for bricks which historically had been produced locally."

[27]The south region is NUTS1 regions H-K and the north region is other NUTS1 regions. This partition of GB reflects what is said on regional preference in CC (2007) paragraph 5.26: "soft mud [molded] bricks were, we were told, predominantly used in the South, and extruded [wirecut] bricks in the Midlands and North." Our estimates are consistent with this pattern.

[28]If a buyer never trades with a manufacturer we drop it from the choice set; equivalent to setting its buyer-manufacturer effect to a large negative number. On average across in $i \in \mathcal{I}_J$ the buyer $h(i)$ trades with 3.6 of the 4 manufacturers in the 4-year period of the data.



Notes: The observed data are per-unit prices and distances for all transactions of inside goods. Predicted outcomes from the model are simulated for each project, conditional on choice of an inside good and observable type, as described in Section 5. The left-hand and right-hand figures are for bargaining specifications S1 and S2 respectively.

Figure 2: Distance and price densities

for each $i \in \mathcal{I}_J$ conditioning on an inside good being chosen and on the project's observed characteristics (x_i, y_i) where $y_i = [y_{ij}]_{j \in \mathcal{J}_J}$.[29] The densities of the simulated and observed prices and distances are shown in Figure 2 and summarized in Table 5. Panels A-C present statistics for prices. We include a measure of the within-product standard deviation, a decomposition by transaction size, and a decomposition by relative agent size. Panel D reports statistics on distances to product choices. We regard the overall fit of prices and distances as satisfactory.

Panel E compares the model's unit cost predictions (given by $\Sigma_{i \in \mathcal{I}_J} c_{ij} / \Sigma_{i \in \mathcal{I}_J} q_i$) with external plant-month accounting data supplied by the firms. The external accounting data consists of operating costs C_n for each plant-month n. We compute unit costs using $(1/|\mathcal{N}|) \times \Sigma_{n \in \mathcal{N}} (C_n / Q_n)$ where Q_n is the number of delivered bricks for n and $\mathcal{N}$ is a set of plant-months. We use two definitions of $\mathcal{N}$ based on the extent to which plants specialize in facing bricks. The figures (a) and (b) in the table respectively define $\mathcal{N}$ as the set of plants for which 90% and 99% of volume over the study period is facing bricks (this results in 182 and 106 plant-months respectively). We do not expect a very close match with the cost data as the predicted and observed concepts do not exactly

[29]For each i we draw a realization from $G_{\nu|J}(x_i)$, the distribution of ν_i conditional on choice of an inside good, a product $j \in \mathcal{J}_J$ using conditional choice probabilities $[s_{j|J}(x_i)]_{j \in \mathcal{J}_J}$ (from which ν_i cancels out), and a price from conditional density $f_j^*(\bar{p}|x_i, y_{ij}, \nu_i)/s_j(x_i)$. The ν_i implies a cost c_{ij}.

		Data	S1	S2
A: Price (£/1000 bricks)				
Mean		182.26	182.99	183.22
Standard deviation		24.84	23.05	23.20
Pooled standard deviation (product groups)		14.74	14.63	14.85
B: Mean price, transaction quantity				
Smallest 25% (of transactions)		179.21	181.03	181.25
Largest 25%		186.48	184.93	185.09
C: Mean price, buyer/manufacturer size ratio				
Smallest 25% (of transactions)		190.64	191.48	192.17
Larges 25%		177.77	179.01	179.01
D: Distance (km) DST_{ij}				
Lower quartile		51.42	49.34	49.51
Median		91.62	91.22	91.03
Upper quartile		157.90	165.19	165.38
E: External data	Data (a)	Data (b)	S1	S2
Unit cost $\bar{c}$ (£/1000 bricks)	167.75	170.00	167.89	167.39

Notes: S1 and S2 refer to the two bargaining specifications. The simulated values are calculated as described in the text. In Panel E the external cost figures are from plant-level data supplied by the manufacturers. Cost measures (a) and (b) is for plants for which 90% and 99% respectively of volume is facing bricks (the type of bricks modeled).

Table 5: Fit: prices, distances, costs

correspond conceptually, mainly because accounting costs do not correspond exactly to the relevant economic cost concept. Subject to this caveat the match between external cost data provides a useful indicative validation of the model.

6 Markups, pricing policy and concentration

In this section we measure the distribution of markups and analyze the impact on markups of changes to pricing policy and concentration. To avoid inter-year cost variation we consider a single year, 2005; in this section the sets $\mathcal{I}$ and $\mathcal{I}_J$ include only projects for that year. To avoid repetition we note at this point that (i) the results throughout are very similar for bargaining specifications S1 and S2 and (ii) when discussing a numerical result from the tables we write them in the form X_1 [X_2] where X_1 is for S1 and X_2 is for S2.

Elasticities, diversion ratios and surplus advantage In our model, project-level price elasticities are zero (for positive buyer bargaining skill) because negotiations

A: Elasticities and diversion ratios wrt cost of product $j \in \mathcal{J}_J$		S1		S2	
		Mean	SD	Mean	SD
Own-elasticity		-12.80	1.37	-12.65	1.39
Cross-product elasticity	10% with lowest inter-product distance	0.29	-	0.28	-
	10% with highest inter-product distance	0.07	-	0.07	-
Diversion ratio	to firm $k(j)$'s other products	0.42	0.17	0.40	0.17
	to other inside products	0.88	0.03	0.85	0.03
B: Surplus advantage of first-best $E_\varepsilon[\Delta\bar{w}_i \vert j(i,1)]\ \forall\ i \in \mathcal{I}_J$		S1		S2	
£/1000 bricks		Mean	SD	Mean	SD
Manufacturer advantage	$\Delta\bar{w}_i = \bar{w}_{ij(i,1)} - \bar{w}_{ij(i,2)}$	20.07	17.79	18.98	16.14
Product advantage	$\Delta\bar{w}_i = \bar{w}_{ij(i,1)} - \max_{j\in\mathcal{J}}$	13.51	12.73	13.75	12.97

Notes S1 and S2 refer to the two bargaining specifications. Elasticities are with respect to $c_j = \gamma \mathrm{w}^c_{ij}$. In Panel A the SD are for a product-level unit of observation. Cross elasticities are for top and bottom decile of product pairs by distance between products. The two diversion ratio are defined as follows, respectively: $1 - (\partial s_{k(j)}/\partial c_j)/(\partial s_j/\partial c_j)$ and $1 - (\partial s_J/\partial c_j)/(\partial s_j/\partial c_j)$. In Panel C the SD are at a project-level unit of observation. Product's advantage excludes portfolio effects. Year 2005.

Table 6: Demand elasticities, diversion ratios, and surplus advantage

leave no buyer marginal between her first-best and runner-up products so we instead compute elasticities with respect to cost. To do this we change the component $c_j = \gamma \mathrm{w}^c_{ij}$ of unit cost (which is uniform across i for a given year). The own-product cost elasticities in Panel A of Table 6 are on average -12.80 [-12.65]. This magnitude indicates the extent of product differentiation and the incentive of a single-product manufacturer to raise prices above costs. Given that the buyers are businesses we are not surprised to see an elasticity with a greater magnitude than in many studies of consumer products. The cross-elasticities are lower for the more distantly-located product pairs, as we expect from the spatial differentiation in the market. To measure the importance of multi-product ownership, we report the diversion ratio from product j to other products of the same manufacturer. This diversion ratio is relatively high (about 0.42 [0.40]) and varies across products in part because manufacturers vary in portfolio size. The diversion ratio to inside products as a class is 0.88 [0.85], greater than a simple logit model would imply (as reported in section 2, mean outside good region-year market share is 0.272).

A key determinant of market power is the first-best manufacturer's surplus advantage which we decompose as follows

$$\Delta\bar{w}_i \equiv \bar{w}_{ij(i,1)} - \bar{w}_{ij(i,2)} \;=\; [\bar{v}_{ij(i,1)} - \bar{v}_{ij(i,2)}] - [\bar{c}_{ij(i,1)} - \bar{c}_{ij(i,2)}]. \tag{29}$$

The first and second terms on the right hand side are a utility-difference and a cost-difference effect. A factor that affects both terms is the portfolio of the first-best manufacturer, which changes the residual set of products $\mathcal{J} \setminus \mathcal{J}_{k(i,1)}$ that are candidates to be runner-up. Project location enters the utility difference effect alongside non-spatial product differentiation. Panel B presents statistics for $\Delta\bar{w}_i$ (for $i \in \mathcal{I}_J$).[30] In addition we report a measure that strips out portfolio effects so that the runner-up is selected from $\mathcal{J} \setminus j(i,1)$; this shows the proportion of the surplus-advantage accounted for by portfolio effects is 32.7% [27.6%]. The measure without portfolio effects has a large standard deviation, which rises substantially when the manufacturer's portfolio effect is added, both because projects have different first-best manufacturers and because the relevance of a given first-best manufacturer's portfolio varies across projects.

Market power To measure market power we compute a PCM, denoted M_i, for each $i \in \mathcal{I}_J$—conditioning on an inside good being chosen, and on the project's observed characteristics (x_i, y_i)—using the prices and costs we simulated in Section 5. The resulting sample $\{M_i\}_{i \in \mathcal{I}_J}$ is described in column (1) of Table 7. PCMs have mean 8.0% [7.9%] and coefficient of variation 0.7 [0.8]. Mean PCMs are relatively low which suggests that firms are not able to benefit greatly from the large portfolio effects, consistent with CC (2007)'s assessment that that the industry was characterized both by high concentration and average or below-average profit levels. PCMs do however vary a lot across projects. Project location is one of a number of factors driving this variation; to measure its role we numerically integrate out for each $i \in \mathcal{I}_J$ all variables affecting markups other than observed location l_i to obtain the expected markup conditional on location $E(M|l_i)$ for each $i \in \mathcal{I}_J$.[31] The results in column (2) show that about a fifth of the standard deviation of PCMs can be attributed to measured location. Finally, to characterize high- and low-PCM locations, in column (3) we sort projects by $E(M|l_i)$: markups are greatest for projects where the expected distance to the first-best manufacturer is relatively low.

Counterfactual pricing policies We now study the impact that the industry's individualized pricing policy has on market power by comparing it with uniform pricing. Since uniform markups do not necessarily induce the first-best choice, we write the choice indicator for product j in project i in a more general form. Let $\tau_i = (x_i, y_i, \nu_i, \varepsilon_i)$

[30] For each i we calculate $\Delta\bar{w}_i$ by simulating price, cost, and $j(i,1)$ as in footnote 29 setting $b_{ij} = 1$ (as in TIOLI) and using the TIOLI result (5) that $\Delta\bar{w}_i = p_{ij(i,1)} - c_{ij(i,1)}$.

[31] To do this we follow the steps in footnote 29 repeatedly and take the average PCM for each project i, where each repetition involves a fresh set of all draws including a draw for x from g_x holding l_i at its observed level.

	Simulated PCMs $\{M_i\}_{i\in\mathcal{I}_J}$		Expected PCMs given locations $\{E[M\|l_i]\}_{i\in\mathcal{I}_J}$		Expected distance minus mean distance $\{E[DST_{ij(i,1)}\|l_i] - \widehat{DST}_i\}_{i\in\mathcal{I}_J}$	
	(1)		(2)		(3)	
	S1	S2	S1	S2	S1	S2
Mean, $i \in \mathcal{I}_J$	0.080	0.079	0.082	0.079	-80.245	-79.789
CV, $i \in \mathcal{I}_J$	0.738	0.761	0.159	0.155	–	–
Mean, bottom 10%	0.009	0.008	0.060	0.062	-69.958	-70.209
Mean, top 10%	0.205	0.208	0.106	0.104	-153.587	-147.082

Notes: S1 and S2 refer to the two bargaining specifications. The mean and coefficeint of variation (CV) are for projects $i \in \mathcal{I}_J$. Top and bottom deciles refer to the top and bottom 10% of projects sorted by margin measure. In column (3) projects are sorted by the margin measure in column (2) and in the other columns by the margin measure in the same column. $\widehat{DST}_{ij} = (1/|\mathcal{J}_J|) \times \Sigma_{j\in\mathcal{J}_J} DST_{ij}$ is mean distance of inside products from i. Year: 2005.

Table 7: Market power: PCMs M_i.

denote the type of consumer i and let G_τ denote its distribution in the population. We write markups in the general form $\rho_\tau = (\bar{p}_{\tau j} - \bar{c}_{\tau j})_{j\in\mathcal{J}_J}$, where where $\bar{p}_{\tau j} = \bar{p}_j(\tau)$ if individualized and $\bar{p}_{\tau j} = \bar{p}_j$ if uniform. Then the choice indicator can be written

$$d_{\tau j}(\rho_\tau) = 1\{\bar{w}_{\tau j} - \rho_{\tau j} \geq \max[(\bar{w}_{\tau j'} - \rho_{\tau j'})_{j'\in\mathcal{J}_J}, \bar{w}_{\tau 0}]\}$$

and aggregate market share s_J, profit Π, and buyer surplus U, are given by[32]

$$\begin{aligned} s_j &= \mathbb{E}_\tau[d_{\tau j}(\rho_\tau)] \\ \Pi_j &= N\Sigma_{j\in\mathcal{J}_J}\mathbb{E}_\tau[q_\tau \rho_{\tau j} d_{\tau j}(\rho_\tau)] \\ U &= N\mathbb{E}_\tau[q_\tau \max((\omega_{\tau j} - \rho_{\tau j})_{j\in\mathcal{J}_J}, \bar{w}_{\tau 0})]. \end{aligned}$$

To compute uniform prices we assume a multi-product Nash equilibrium. Let prices $\bar{p} = (\bar{p}_k, \bar{p}_{-k})$ where $\bar{p}_k$ is the vector for manufacturer k's products and $\bar{p}_{-k}$ is the

[32]We do not condition on choice of an inside good here, since a change to uniform pricing can change whether a project chooses an inside good; to simulate demand and prices, we now follow the steps in footnote 29 except that instead of using $i \in \mathcal{I}_J$ (and their observable types x_i), we draw project characteristics from the density g_x. Note also that, using the GEV distribution for ε_i, we compute U as follows

$$U = \mathbb{E}_{\tilde{\tau}}[q_{\tilde{\tau}}\sigma_\varepsilon \ln\{1 + [\Sigma_{j'\in\mathcal{J}_J} \exp(\omega_{\tilde{\tau}j'} - (1-I)\rho_{ij'})/\sigma_\varepsilon)]^{\sigma_J}\}] + I\Pi \qquad (30)$$

where $\tilde{\tau}$ is consumer type up to ε and where I is an indicator for individualized pricing. When $I = 0$ (30) is the standard expression for consumer surplus. When $I = 1$ on the other hand socially efficient choices are always induced and the first term in (30) is total welfare and the second term Π is the part of total welfare that goes to the manufacturers.

	Mean ρ in £/1000 bricks			Mean	Market-level outcomes		
	All	Min 10%	Max 10%	$1_{[p<p_B]}$	s_J	U/U_B	Π/Π_B
Pricing policy	(1)	(2)	(3)	(4)	(5)	(6)	(7)
S1 [Mean $\bar{p}_B$ = £187.45]							
Negotiated (B)	15.02	1.69	38.47	0.00	0.75	1.00	1.00
TIOLI ($b_{ij} = 1$)	18.64	2.04	49.32	0.00	0.75	0.88	1.24
Uniform	20.40	15.60	24.91	0.31	0.56	0.89	0.99
S2 [Mean $\bar{p}_B$ = £189.87]							
Negotiated (B)	14.60	1.54	38.05	0.00	0.74	1.00	1.00
TIOLI ($b_{ij} = 1$)	17.67	1.79	45.09	0.00	0.74	0.84	1.21
Uniform	18.99	15.29	22.41	0.22	0.51	0.88	0.90

Notes S1 and S2 refer to the two bargaining specifications. The baseline is labeled B. Columns 2 and 3 give average markups for the top and bottom 10% of transactions ranked by markup. Column 4 is the proportion of projects enjoying a lower price for the first-best good relative to baseline. Column 5 is the market share of inside goods. Columns 6 and 7 report the ratio of buyer and manufacturer surplus to the corresponding baseline surplus. Year: 2005.

Table 8: Markups ρ_i under alternative pricing policies

vector for the other manufacturers. In the case of uniform prices, markups are given by $\rho_i = (\bar{p}_j - \bar{c}_{ij})_{j \in \mathcal{J}_J}$ at Nash prices solving

$$\bar{p}_k(\bar{p}_{-k}) = \arg\max_{\bar{p}_k} \mathit{\Pi}_k(\bar{p}_k, \bar{p}_{-k}) \quad \forall k \in \mathcal{K}$$

where $\mathit{\Pi}_k(\bar{p}_k, \bar{p}_{-k})$ is the function that gives firm k's profits when prices are uniform. In Table 8 we break the change to uniform pricing into two steps: (i) a change from the baseline case to TIOLI pricing and (ii) a change from TIOLI pricing to uniform pricing. In the first, average markups increase by about 24% [21%] relative to baseline markups: the effect of removing the buyer's bargaining power. In the second step, markups to increase by a further 12% [10%] of baseline markups: the effect on market power of removing individualization (while maintaining price-taking). The dispersion that remains after the second stage is inter-product. As we also report, some projects get a better price, but a large majority (69% [78%]) do not. Aggregate buyer welfare falls by 11% [12%] and the market share for inside goods as a whole falls by 25% [31%]. Partly because of the fall in inside-good market share, manufacturers do not jointly gain from a switch to the uniform pricing policy.[33,34] In summary, the counterfactual

[33]This contrasts with Thisse and Vives (1988) which imposes choice of an inside good.

[34]We also considered two other counterfactual pricing policy cases: regional- and quantity-based pricing. In regional pricing firms set uniform Nash prices within each of the 39 NUTS2 regions in Great Britain; we find this gives markups that are intermediate between TIOLI and nationally-uniform prices (the mean markup is £19.72 [£18.10]), suggesting that competition is somewhat intensified

Market structure	Price policy	Markups (ρ) in £/1000 bricks						Market-level outcomes		
		mean	$\rho - \rho_A$	$k=1$	$k=2$	$k=3$	$k=4$	p_j	s_J	Π/Π_B
	I	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
S1										
Single-product	1	11.50	0.00	11.78	11.18	11.10	11.64	183.84	0.75	1.00
(A)	0	13.46	0.00	13.50	13.15	13.39	13.51	186.82	0.64	1.00
Baseline‡	1	15.02	3.52	12.81	11.96	13.36	16.37	187.45	0.75	1.30
(B)	0	20.40	6.94	17.06	15.46	18.85	23.12	193.96	0.56	1.33
Merge	1	17.96	6.46	12.81	11.96	18.81	19.10	190.43	0.75	1.55
$k \in \{3,4\}$	0	24.68	11.22	18.30	16.24	27.84	27.79	197.45	0.52	1.45
S2										
Single-product	1	10.82	0.00	10.49	10.22	11.00	10.87	183.11	0.75	1.00
(A)	0	13.63	0.00	13.69	13.37	13.60	13.66	186.99	0.59	1.00
Baseline‡	1	14.60	3.78	11.46	10.99	13.20	16.02	187.06	0.75	1.35
(B)	0	18.99	5.36	16.35	15.18	17.86	20.92	192.96	0.51	1.20
Merge	1	18.19	7.37	11.46	10.99	19.67	19.42	190.80	0.75	1.68
$k \in \{3,4\}$	0	22.05	8.42	16.96	15.57	24.48	24.14	195.34	0.47	1.28

Notes: S1 and S2 refer to the two bargaining specifications. $I = 1$ for individualized pricing and $I = 0$ for uniform. The baseline market structure is labeled B and alternatives labeled A. The two outcomes marked ‡ are not counterfactual. Column (2) indicates the added markup—and (9) the proportional effect on profit—relative to the case of single-product firms. Columns (3-8) show the average markups for each manufacturer separately. Column (7) is the simple average price across products in £/1000 bricks. Year 2005.

Table 9: Markups ρ at alternative market structures

indicates that the pricing policy adopted in the bricks market benefits buyers in most (but not all) projects and is consistent with the finding in CC (2007) of a normal or low profit level for the manufacturers.

Counterfactual ownership: merger and demerger In this section we analyze changes to market structure by reallocation of product ownership; we hold fixed the set of inside products $\mathcal{J}_J$, their production costs, and the set of bargaining parameters b_{ij}. The rows labeled B in Table 9 are for the observed (baseline) market structures.

The first counterfactual changes ownership to the case of single-product firms. This measures the market power that is attributable to multi-product ownership. Comparing this market structure with the baseline, the change reduces markups by 3.52 [3.78] (i.e. by about a quarter) under individualized pricing ($I = 1$), consistent with the size

relative to nationally-uniform pricing. In quantity-based pricing prices are nationally-uniform within each of 10 bands determined by deciles of the empirical distribution of transaction quantities; here quantity discounts have only a minor effect on average markups relative to nationally-uniform pricing (the mean markup is £20.58 [£19.11]).

of the multi-product effects we found in the first-best surplus advantage (in Table 6).

The second counterfactual merges the two largest manufacturers $k \in \{3, 4\}$. When prices are individualized, the mechanism by which mergers change prices, unlike the uniform pricing case, works as follows: a change in product ownership has an effect on the markup for project i only if it changes i's runner-up product. The effect of the merger is therefore limited to those whose first-best *and* (pre-merger) runner-up products are both insiders to the merger (i.e. a subset of those buying from insiders to the merger), in contrast to the case of uniform pricing where it affects all buyers (including those who buy from outsiders to the merger). We see this difference in the table where markups increase for insider firms under individualized pricing, and for all firms under uniform pricing. The table suggests that this merger, even under individualized pricing, would have a significant average adverse on buyers, which is not surprising given that they are the largest two firms. We found (in unreported results) that a merger of the two smallest firms $k \in \{1, 2\}$, considered (and allowed) in CC (2007), had a very small effect on margins.[35]

To see how pricing policy and market structure interact, we compute the results for both individualized and uniform pricing. The results in the table can be summarized as follows. First, for any given market structure, average markups are always higher under uniform pricing, suggesting that individualized pricing intensifies competition not just at the observed market structure (used in the pricing policy counterfactual in Table 8) but also at a range of alternative market structures. Second, individualized pricing abates the effects of a merger: the markup change either from single-product manufacturers to the observed structure, or from the observed structure to the merger of $k \in \{3, 4\}$ tends to be lower under individualized than uniform pricing. Third, despite this abatement, mergers tend to increase industry profit proportionately *more* than under uniform pricing (see column 9); this is because with individualized pricing firms do not lose market share from the merger. Overall, we see that the trade-off between concentration and market power is shifted in a more competitive direction by the pricing policy.

[35] Note the following caveats for the merger analysis: (i) larger price increases would result if we allowed products for the merged entity to inherit the bargaining skill associated with the more skilled of the insiders to the merger, (ii) lower price increases would result if we allowed cost efficiencies, and (iii) as discussed in Section 2 the analysis is for national housebuilders, which are a subset of the manufacturer's customers.

7 Conclusions

We develop for estimation a model of demand and markups for differentiated-products markets with multi-product firms and individually-negotiated prices. The model allows alternative specifications for the disagreement point in the bargaining model and nests the case of price-taking buyers. We derive a joint likelihood for the buyer's choice and price and estimate the model using transaction-level data from the brick industry in Great Britain. In our results we reject the hypothesis of price-taking buyers and find that mean markups are low on average but dispersed across projects, with some of the variation attributable to project location. Multi-product ownership adds to the mean and variance of markups. A counterfactual change from individualized to uniform pricing adds market power and harms more buyers than it helps; decomposing this counterfactual we find that the increase in market power is partly because uniform pricing imposes price-taking and partly because it less competitive even with price taking buyers. We also find that individualized pricing mitigates the change in market power from merger.

The results are consistent with the CC inquiry CC (2007), which found that the brick industry was characterized both by average or below average profits (for industries with comparable risk) and by high concentration, and allowed a merger of the 3rd and 4th-largest manufacturers, despite the concentration increase exceeding the standard threshold in their own merger guidelines.

More broadly, the results have policy implications in two areas. First, in the debate over the competitiveness of alternative pricing policies for delivered goods—which has taken place for many products in many countries (as discussed in Thisse and Vives (1988) and Scherer and Ross (1990))—they support the view that, in an oligopoly context, uniform ("free on board") pricing is a softer form of competition than alternatives that discriminate between buyers. It is sometimes argued—e.g. in the CMA (2016) construction materials market inquiry, in Denmark's concrete market Albæk et al. (1997)—that price dispersion tends to be associated with greater competition because it makes coordinated pricing more difficult; our analysis points to a different advantage, namely that it reduces mean non-coordinated prices. Second, in the area of merger analysis, our results—in particular the shift in the trade-off between concentration and market power relative to uniform pricing—suggest it is appropriate to account for individualized pricing in merger assessment criteria, including in cases where prices are negotiated.

References

Ackerberg, D. A. and M. Rysman (2005). Unobserved product differentiation in discrete-choice models: Estimating price elasticities and welfare effects. *The RAND Journal of Economics 36*(4), 771–788.

Albæk, S., P. Møllgaard, and P. B. Overgaard (1997). Government-assisted oligopoly coordination? a concrete case. *The Journal of Industrial Economics 45*(4), 429–443.

Allen, J., R. Clark, and J.-F. Houde (2019). Search frictions and market power in negotiated-price markets. *Journal of Political Economy 127*(4), 1550–1598.

Armstrong, M. (2006). *Recent Developments in the Economics of Price Discrimination*, Volume 2 of *Econometric Society Monographs*, pp. 97â141. Cambridge University Press.

Beckert, W. (2018). An empirical analysis of countervailing power in business-to-business bargaining. *Review of Industrial Organization*, 1–34.

Berry, S., A. Gandhi, and P. Haile (2013). Connected substitutes and invertibility of demand. *Econometrica 81*(5), 2087–2111.

Berry, S., J. Levinsohn, and A. Pakes (1995). Automobile prices in market equilibrium. *Econometrica 63*(4), 841–90.

Berry, S. T. and P. A. Haile (2020). Nonparametric identification of differentiated products demand using micro data. Working Paper 15276, Yale University.

Bester, H. (1989). Noncooperative bargaining and spatial competition. *Econometrica 57*(1), 97–113.

Binmore, K. (1985). *Game Theoretic Models of Bargaining*, Chapter Bargaining and Coalitions, pp. 269–304. Cambridge University Press.

Binmore, K., M. J. Osborne, and A. Rubinstein (1992). Chapter 7 Noncooperative models of bargaining. Volume 1 of *Handbook of Game Theory with Economic Applications*, pp. 179 – 225. Elsevier.

Binmore, K., A. Rubinstein, and A. Wolinsky (1986). The Nash bargaining solution in economic modelling. *The RAND Journal of Economics 17*(2), 176–188.

Binmore, K., A. Shaked, and J. Sutton (1989). An outside option experiment. *The Quarterly Journal of Economics 104*(4), 753–770.

Bolton, P. and M. D. Whinston (1993). Incomplete contracts, vertical integration, and supply assurance. *The Review of Economic Studies 60*(1), 121–148.

Brannman, L. and L. M. Froeb (2000). Mergers, cartels, set-asides, and bidding preferences in asymmetric oral auctions. *Review of Economics and Statistics 82*(2), 283–290.

CC (2007). *Wienerberger Finance Service BV / Baggeridge Brick plc.* TSO, London.

Chipty, T. and C. M. Snyder (1999). The role of firm size in bilateral bargaining: A study of the cable television industry. *Review of Economics and Statistics 81*(2), 326–340.

CMA (2016). *Aggregates, cement and ready-mix concrete market investigation.* TSO, London.

Collard-Wexler, A., G. Gowrisankaran, and R. S. Lee (2019). "Nash-in-Nash" bargaining: A microfoundation for applied work. *Journal of Political Economy 127*(1), 163–195.

Cooper, J. C., L. Froeb, D. P. O'Brien, and S. Tschantz (2005). Does price discrimination intensify competition? implications for antitrust. *Antitrust Law Journal 72*(2), 327–373.

Corts, K. S. (1998). Third-degree price discrimination in oligopoly: all-out competition and strategic commitment. *The RAND Journal of Economics*, 306–323.

Crawford, G. S., R. S. Lee, M. D. Whinston, and A. Yurukoglu (2018). The welfare effects of vertical integration in multichannel television markets. *Econometrica 86*(3), 891–954.

Crawford, G. S. and A. Yurukoglu (2012). The welfare effects of bundling in multichannel television markets. *The American Economic Review 102*(2), 643–685.

Cremer, J. and M. H. Riordan (1987). On governing multilateral transactions with bilateral contracts. *The RAND Journal of Economics 18*(3), 436–451.

D'Haultfoeuille, X., I. Durrmeyer, and P. Fevrier (2017). Automobile prices in market equilibrium with unobserved price discrimination. *Unpublished*.

Draganska, M., D. Klapper, and S. B. Villas-Boas (2010). A larger slice or a larger pie? An empirical investigation of bargaining power in the distribution channel. *Marketing Science 29*(1), 57–74.

Dubin, J. A. and D. L. McFadden (1984). An econometric analysis of residential electric appliance holdings and consumption. *Econometrica 52*(2), 345–362.

Dubois, P., A. Gandhi, and S. Vasserman (2019). Bargaining and international reference pricing in the pharmaceutical industry. Technical report.

Ghili, S. (2018). Network formation and bargaining in vertical markets: The case of narrow networks in health insurance.

Gowrisankaran, G., A. Nevo, and R. Town (2015, January). Mergers when prices are negotiated: Evidence from the hospital industry. *American Economic Review 105*(1), 172–203.

Grennan, M. (2013, February). Price discrimination and bargaining: Empirical evidence from medical devices. *American Economic Review 103*(1), 145–77.

Hall, G. J. and J. P. Rust (2020). Econometric methods for endogenously sampled time series: The case of commodity price speculation in the steel market. *Journal of Econometrics*.

Ho, K. and R. S. Lee (2017). Insurer competition in health care markets. *Econometrica 85*(2), 379–417.

Ho, K. and R. S. Lee (2019, February). Equilibrium provider networks: Bargaining and exclusion in health care markets. *American Economic Review 109*(2), 473–522.

Holmes, T. J. (1989). The effects of third-degree price discrimination in oligopoly. *The American Economic Review 79*(1), 244–250.

Horn, H. and A. Wolinsky (1988). Bilateral monopolies and incentives for merger. *The RAND Journal of Economics*, 408–419.

Hortaçsu, A. and C. Syverson (2007). Cementing relationships: Vertical integration, foreclosure, productivity, and prices. *Journal of Political Economy 115*(2), 250–301.

Lederer, P. J. and A. P. Hurter Jr (1986). Competition of firms: discriminatory pricing and location. *Econometrica: Journal of the Econometric Society*, 623–640.

Manea, M. (2018). Intermediation and resale in networks. *Journal of Political Economy 126*(3), 1250–1301.

McFadden, D. (1978). Modelling the choice of residential location. In F. S. A. Karlqvist and J. Weibull (Eds.), *Spatial Interaction Theory and Planning Models.* North Holland.

Miller, N. H. and M. Osborne (2014). Spatial differentiation and price discrimination in the cement industry: evidence from a structural model. *The RAND Journal of Economics 45*(2), 221–247.

Murphy, K. M. and R. H. Topel (1985). Estimation and inference in two-step econometric models. *Journal of Business & Economic Statistics 3*(4), 370–379.

Nalebuff, B. (2000). Competing against bundles. In P. Hammond and G. Myles (Eds.), *Incentives, Organization, and Public Economics*. Oxford: Oxford University Press.

Osborne, M. and A. Rubenstein (1990). *Bargaining and Markets*. Academic Press.

Porter, R. H. and J. D. Zona (1999). Ohio school milk markets: An analysis of bidding. *The RAND Journal of Economics 30*(2), 263–288.

Rubinstein, A. (1982). Perfect equilibrium in a bargaining model. *Econometrica 50*(1), 97–109.

Ryan, S. P. (2012). The costs of environmental regulation in a concentrated industry. *Econometrica 80*(3), 1019–1061.

Salz, T. (2017). Intermediation and competition in search markets: An empirical case study. SSRN 2961795.

Scherer, F. and D. Ross (1990). *Industrial market structure and economic performance.* Houghton Mifflin.

Thisse, J.-F. and X. Vives (1988). On the strategic choice of spatial price policy. *The American Economic Review*, 122–137.

A Appendix: Propositions 1 &2

Proposition 1 Negotiation $n = 1$ is bilaterally efficient iff $d_{j(1)} = 1$. This follows because $w_{j(1)} > w_{j(2)} \geq [v_{j(2)} - p_{j(2)}]$ given our assumption that $p_{j(2)} \in [c_{j(2)}, v_{j(2)}]$. Negotiation $n = 2$ is also bilaterally efficient if $d_{j(1)} = 1$ when $w_{j(2)} < [v_{j(1)} - p_{j(1)}]$, which holds for any $(p_{j(1)}, p_{j(2)}) \in [c_{j(1)}, c_{j(1)} + \Delta w] \times [c_{j(2)}, v_{j(2)}]$ because at $(p_{j(1)}, p_{j(2)}) = (c_{j(1)} + \Delta w, c_{j(2)})$ the buyer is indifferent between the first-best and the runner-up product (and in such ties selects first-best) and at all other $(p_{j(1)}, p_{j(2)}) \in [c_{j(1)}, c_{j(1)} + \Delta w] \times [c_{j(2)}, v_{j(2)}]$ prefers first-best.

Proposition 2 Suppress i subscripts. Let $\omega_j = \omega(x_j, \nu)$ and let $r_{-k|J} = \Sigma_{j' \in \mathcal{J}_J \setminus \mathcal{J}_k} r_{j'|J}$. Then, using $\partial \omega_{j'} / \partial \rho = \chi_{jj'} \times b_j^{-S}$ when j' is an inside product, definitions (22),(23), and (24), and standard results of differentiation for nested logit functional forms, we have

$$\begin{aligned}
\frac{\partial r_{j|J}}{\partial \rho} &= -\frac{\sigma_\varepsilon}{\sigma_J} b_j^{-S} r_{j|J} r_{-k|J}, \\
\frac{\partial R}{\partial \rho} &= \frac{\sigma_\varepsilon}{\sigma_J b_j^S} \frac{\sum_{j' \in \mathcal{J}_J} \chi_{jj'} \exp\{\sigma_\varepsilon [\omega_{j'} + b_{ij}^{-S} \rho] / \sigma_J\}}{\sum_{j' \in \mathcal{J}_J} \exp\{\sigma_\varepsilon [\omega_{j'} + \chi_{jj'} b_{ij}^{-S} \rho] / \sigma_J\}} = \frac{\sigma_\varepsilon}{\sigma_J b_j^S} r_{-k|J}, \\
\frac{\partial r_J}{\partial \rho} &= \sigma_J r_J \frac{\partial R}{\partial \rho} - \exp\{\sigma_J R\} \frac{\partial}{\partial \rho} \frac{1}{\exp\{\sigma_\varepsilon \rho / b_j\} + \exp\{\sigma_J R\}} \\
&= \sigma_J r_J \frac{\partial R}{\partial \rho} - r_J \frac{\frac{\sigma_\varepsilon}{b_j} \exp\{\sigma_\varepsilon \rho / b_j\} + \sigma_J \exp\{\sigma_J R\} \frac{\partial R}{\partial \rho}}{\exp\{\sigma_\varepsilon \rho / b_j\} + \exp\{\sigma_J R\}} \\
&= \sigma_\varepsilon r_{-k|J} r_J b_j^{-S} - \sigma_\varepsilon r_J (1 - r_J) b_j^{-1} - \sigma_\varepsilon r_J^2 r_{-k|J} b_j^{-S} \\
&= -\sigma_\varepsilon r_J (1 - r_J) [b_j^{-1} - r_{-k|J} b_j^{-S}].
\end{aligned}$$

Since $r_j = r_{j|J} r_J$ it follows that

$$\begin{aligned}
-\frac{\partial r_j}{\partial \rho} = -r_J \frac{\partial r_{j|J}}{\partial \rho} - \frac{\partial r_J}{\partial \rho} r_{j|J} &= \sigma_\varepsilon r_{j|J} r_{-k|J} r_J b_j^{-S} / \sigma_J + \sigma_\varepsilon r_J (1 - r_J) [b_j^{-1} - r_{-k|J} b_j^{-S}] r_{j|J} \\
&= \sigma_\varepsilon r_j (r_{-k|J} b_j^{-S} / \sigma_J + (1 - r_J) [b_j^{-1} - r_{-k|J} b_j^{-S}])
\end{aligned}$$

so, using $r_{-k|J} r_J + r_k + r_0 = 1$ and $r_{-k|J} = 1 - r_{k|J}$, we have

$$-\frac{\partial r_j}{\partial \rho} = \begin{cases} \sigma_\varepsilon [r_j \{(1 - r_k) - (1 - \sigma_J^{-1})(1 - r_{k|J})\} - (1 - b_{ij}^{-1}) r_j r_0] & \text{if } S = 0 \\ \sigma_\varepsilon r_j [(1 - r_k) - (1 - \sigma_J^{-1})(1 - r_{k|J})] b_j^{-1} & \text{if } S = 1. \end{cases}$$

B Online appendix: Data

B.1 Variables in the deliveries dataset

We use a data set provided to us by the four main manufacturers that records each delivery of a brick variety within Great Britain (GB) in the period 2003-2006 from these firms. The smallest two of these firms, Baggeridge Brick and Wienerberger, merged in 2007, following the investigation reported in CC (2007). The dataset used here was also used in this investigation. The following is a complete list of the variables. We give the exact name of the variable as it appears in the data in square brackets [], the exact wording of the description of the variable as it appears in the data is in round brackets (), and the unbracketed words at the end are our own description of the variable.

1. Manufacturer information: (a) [Manufacturer], (Brick manufacturer), Name of the brick manufacturer; (b) [Plant code cat], (Plant code), Name of plant where the bricks were manufactured and from which delivery was made.

2. Buyer information: (a) [Buyer_name], Name of buyer; (b) [Town], Town to which delivery is made; (c) [Original postcode], Delivery postcode.

3. Delivery information: (a) [Price], (Transaction price (GBP)), The total payment for the delivery; (b) [Volume], (Volume bricks), The number of bricks in the delivery; (c) [Date], (Transaction date), The date on which the delivery and transaction happened; (d) [Delivery], (Delivery arrangement), Whether the delivery was arranged by buyer or manufacturer; (e) [Haulage price], (Haulage price (GBP)). Transportation cost.

4. Characteristics of the delivered product variety: (a) [Description], (Description of individual brick variety), The name of the product variety; (b) [Use_cat], (End use classification), Indicator variable for whether the delivered product variety is a facing brick or some other use type; (c) [Manuf cat], (Manufacturing process category), Classifies bricks by the way the brick is made, e.g. wire-cut, molded.

B.2 Geocoding deliveries and classification of buyer type

To obtain a grid reference we use the postcode which takes the form of two groups of alphanumeric variables e.g. OX1 3UQ with increasing geographic precision moving from left to right. The Central Postcode Directory (CPD), available from the the UK Post Office, gives a grid reference for each postcode. The address of each plant is public information. The project's postcode is in the variable [Original postcode] in section B.1. In some cases the postcode was recorded with error (a common feature of address datasets). Where part of the postcode is reported (e.g. OX1) we take the average of the grid reference points consistent with what is reported. Where the postcode did not appear in the CPD we search for the nearest postcode consistent with the most important letters in the postcode, starting with alternatives to the final letter, followed by alternatives to the final two letters, and so on, until available postcodes are found; where this results in multiple postcodes we take the average grid reference. Where the postcode was missing but the town in the postal address was given (i.e. the variable [Town] in section B.1) we use the postcodes consistent with this and take an average of their grid references. Finally, for one of the manufacturers, the delivery postcode was not recorded for 11.4% of its deliveries to the top 16 buyers (whereas for the other three suppliers there were very few missing address observations—1.014%, 0.004% and 0.000% respectively). To avoid mis-representing transactions for one manufacturer we dropped delivery addresses at random from each of the other three firms so that the same proportion of delivery addresses are removed for all manufacturers. We classify buyers as either a builder or merchant using the name of the buyer (i.e. variable [Buyer_name] in section B.1) and the business website associated with that name. The name of the same buyer sometimes appears in different forms for different deliveries—e.g. (i) "Taywood Homes" and "Taylor Woodrow Developments" and (ii) "PERS01" and "Persimmon Homes". In the case of (i) the former is a fully owned subsidiary of the latter; in the case of (ii) the former is a code name used for the latter firm. We checked ownership of all firm names to determine those that were under the same ownership in which case they were treated as being the same firm. Finally, where code names were used, we identified the builder that had the most consecutive letters in common with the code; as a safeguard against errors we checked by online search that delivery locations for code names in the data matched known housing projects from the matched building firm.

B.3 Products and characteristics

The deliveries dataset includes a limited number of product characteristics for each variety. We supplement these using the manufacturers' catalogs.[36] Figure 3 shows a page from a manufacturer's brick catalog, giving a list of varieties and their characteristics (along with pictures of some of the varieties). We obtain the following five

[36]We are grateful to a number of students at Oxford University who provided research assistance obtaining product characteristics.

	TYPE	LOCATION	SIZE TOLERANCE		DURABILITY	ACTIVE SOLUBLE SALTS	COMPRESSIVE STRENGTH (N/mm^2)	WATER ABSORPTION (%)	PACK QUANTITY	TYPICAL PACK WEIGHT kg
			MEAN	RANGE	EN 771-1	EN 771-1	EN 771-1	EN 771-1		
Bamburgh Red Stock	S	Todhills	T1	R1	F2	S2	≥20	≤14	500	1113
Bisque Red Multi	W	Waresley	T2	R1	F1	S2	≥25	≤24	500	1113
Blended Red Multi Gilt Stock	S	Waresley	T2	R1	F2	S2	≥21	≤24	500	1166
Blue Velvet	S	Hull & Dartford	T2	R1	F2	S2	≥12	≤15	528	1308
Blueberry Multi	W	Ewhurst	T2	R1	F2	S2	≥60	≤10	400	923
Brampton Blend	W	Cheadle	T2	R1	F2	S2	≥40	≤20	400	882

S = Stock W = Wirecut

Notes: The page is from the section for red bricks of a manufacturer's brick catalog. It lists 6 brick varieties and shows pictures of three of them. In the first two columns the type, listing whether the brick is wirecut (W) or molded (S), and plant location, of the brick are given and in the seventh and eighth the strength and water absorption.

Figure 3: Typical page from a brick manufacturer catalog

characteristics, two of which are from the deliveries dataset and three from the brick catalogs. We have discretized the last two brick characteristics. For each product characteristic we note the the data source, the units (if applicable), the number of discrete alternative values, and why it is important to a buyer.

1. *Color* (2 colors). [Source: brick catalogs]. Important for aesthetic reasons. The alternatives are: buff (yellow) and red. A small number of brick varieties are listed as orange and we class these as red since they are very close in appearance. Different types of clay and hence different plants (located at different clay deposits) are associated with different brick shades within any given color.

2. *Plant* (36 plants). [Source: deliveries data set]. Important primarily for spatial reasons. However plant location also affacts visual appearance of the product (as described under color). This is lower than the total number of brick plants because we count co-located plants of the same firm as a single plant, we drop plants that produce non-facing bricks or low market share bricks.

3. *Manufacturing type* (2 types: wire-cut and molded). [Source: deliveries data set]. The manufacturing type—i.e. the variable [Manuf_cat] in section B.1, which we

	Color	Shaping	Strength	Absorption	Plant
			N/m^2 (100s)	percent (100s)	
Number of discrete values	2	2	13	5	36
Set of categorical values	{R,Y}	{W,M}	-	-	{D,E,...}
Discretization interval			0.05	0.05	
Products [example varieties]					
Product 1 [Cheshire Red Multi, Bowden Red]	R	W	0.40	0.15	D
Product 2 [Hadrian Buff, Hadrian Bronze]	Y	W	0.60	0.10	T
⋮					
Product 75 [Arden Red Multi, Dorset Red Stock]	R	M	0.20	0.20	E

Notes. Number of products: 75. Number of varieties 416. The variables *strength* and *absorb* are defined in the text and are discretized to the nearest 0.05 units. D, E and T denote the Desford, Ellistow and Throckley plants; R and Y denote the colors red and yellow; W and M denote wire-cut and molded bricks.

Table 10: Classification of varieties into products by observable characteristics

refer to in the paper as *the shaping* method—is the method of cutting the bricks from clay. The two main shaping method alternatives are wire-cut and molded. This is an aesthetic characteristic as it affects the appearance of the brick. We include handmade, clamp, and softmud bricks (categories in the variable [Manuf cat]) in molded as they use the same shaping method as molded bricks.

4. *Compression strength* (in N/mm^2). We round strength to the nearest $5N/mm^2$, giving 13 distinct levels $(10, 15, \ldots, 70, 75)$. The compression strength is the maximum load at which a brick is crushed measured in Newtons per square millimeter. This variable, also known as *durability*, improves the performance of the brick in areas with exposure to frost attack.

5. *Water absorption* (units: % of mass): this variable is defined as $(m_2 - m_1)/m_1$ where m_1 is the mass of the brick when dry and m_2 is its mass after 24 hours of complete immersion in water. We round this to the nearest 5 percent, giving 5 distinct levels $(5, 10, \ldots, 20, 25)$. A lower level is a higher quality: bricks with low water absorption should be used in areas of high rainfall where there is a risk that brickwork will be persistently wet (see B.6).

Other technical characteristics listed in the catalog do not vary across the bricks considered by house builders in our data so we do not include them.[37] There are 416

[37]For a discussion of brick characteristics see Section 6 of Brick Development Association (2011) *Design Note* at *http://www.brick.org.uk/admin/resources/g-brickwork-durability.pdf.*

A: Counts of deliveries and transactions		
Number of deliveries		110,726
Number of buyer-variety-location-years (i.e. transactions)		13,788
B: Summary statistics for deliveries in a transaction	Mean	SD
Number of deliveries in a transaction	8.031	7.978
Proportion (by volume) of deliveries in a transaction		
(i) sold at modal price for transaction	0.860	0.201
(ii) sold within 1% of modal price for transaction	0.924	0.152

Notes. The table reports statistics from the deliveries dataset before and after aggregation to transaction level. See text for the definition of a transaction

Table 11: Aggregation: deliveries to transactions

distinct varieties in the transaction dataset and we classify these into 75 groups, referred to as *products*, using these five characteristics. The product classification is illustrated in Table 10. The table gives three example products, lists some illustrative varieties in each product, and gives their observable characteristics.

B.4 Determination of transaction dataset

The transaction dataset is obtained from the deliveries dataset in appendix B.1 as follows. We include deliveries of facing bricks in the years 2003-2006 from GB plants to one of the top-16 builders by volume over 2003-2006; in this appendix we refer to these deliveries as *brick sales*. The top-16 builders account for 94.1% of direct deliveries by volume in the data. We exclude pressed bricks (known as flettons, as indicated by the [Manuf_cat] variable, 1.2% of brick sales volume) which are not used for new houses. (They are used in the repair, maintenance, and improvement of existing houses, see CC (2007) paragraphs 5.8-5.10.) We drop deliveries of less than 5,000 bricks (3.1% of brick sales volume) to remove a tail of small deliveries that are likely to correspond to idiosyncratic requests and top-ups and which have some extreme unit prices; as a reference point, note that the median individual delivery to builders is 10,000 which represents both (i) approximately the number needed for an individual detached house and (ii) the typical capacity of a brick truck. We drop deliveries of brick varieties that are not buff (i.e. yellow) or red (0.04% of brick sales volume). A *transaction* is defined to be a buyer-variety-location-year (where location refers to the location of use); a variety implies a unique production location (its plant) so a transaction is associated with a unique pair of (production and use) locations. To remove a tail of small products we drop products (defined in B.3) with less than 7.5 annual transactions on average (which in total are 4.2% of brick sales volume). Table 11 presents information on the aggregation of the deliveries dataset to the transactions dataset. Panel A shows the number of deliveries and the number of transactions. Panel B shows the extent to which transactions vary in terms of the number of deliveries (a consequence of scale differences across projects) and the dominance of a modal price for deliveries within a transaction (a consequence of the negotiation of project price at annual rather than delivery level).

B.5 Institutional details

The prices are either agreed in a collection of concurrently-negotiated price agreements (known as framework agreements) or isolated agreements at other times (known as ad hoc agreements). The agreements are about conditions of trade and do not commit the buyer to purchase (CC (2007) para 4.65, 4.66). Buyers prefer not to hold stocks of bricks at their project locations and thus take a number of deliveries, sometimes at short notice, over time as the project proceeds. To facilitate this manufacturers hold large stocks of inventory (see CC (2007) paragraphs 4.44). Negotiations result in prices which vary across varieties, annual volumes, and locations for a given buyer as described in Section 2 and which hold good for a year.

B.6 Weather data

We use data from the UK Meteorological Office's *UKCP09* data series. This data series gives weather for each 5×5 km grid cell in the UK. We take the average of the 5×5 km grid cell values that fall within each NUTS1 region where the cell values are themselves averages measured between 1981-2010. Rainfall is measured of daily mm per square meter and frost by the total number of days of air frost per month.

B.7 Outside good share

The share of the outside good in region-year m is given by $s_{0m} = (H_m - B_m)/H_m$where H_m is the number of standardized houses needing cladding and B_m is the number that use bricks. To calculate B_m we use $B_m = kQ_m$ where k is the number of houses per brick and Q_m is the number of bricks delivered to market m by the manufacturers. We obtain k using $s_0 = 1 - k\Sigma_m Q_m/(\Sigma_m H_m)$ where s_0 (0.238) is the national share of the outside good in the period of the data, given by $s_0 = 1 - s_K s_N$ where s_K (0.850) is the share of the manufacturers in our study (CC (2007), para 5.46) and s_N (0.897) is the national proportion of new houses using facing bricks in the period of study is given as in the *English Housing Survey* published by the Department for Communities and Local Government (2008).[38] To calculate H_m we use the number of house building completions, from the UK's Office for National Statistics *House Price Statistics for Small Areas* (HPSSA).[39] Given lumpiness in the data on completions relative values across regions are constant for the period of the study. The relative value for region κ is $\varrho_\kappa = \Sigma_t H^*_{\kappa t}/\Sigma_\kappa \Sigma_t H^*_{\kappa t}$ where $H^*_{\kappa t}$ is completions in market $m = (\kappa, t)$. Then $H_m = \varrho_\kappa H^*_t$ where H^*_t is the 3-year moving average of total housing completions in Great Britain. This method is used because the timing of completions does not coincide exactly with the stage in a construction project's life cycle when brick delivery is needed and the data are somewhat volatile given the large size of individual housing projects being recorded. Similarly, we assume relative demand across regions for inside goods is stable over time and for region κ is given by $\varrho^Q_\kappa = \Sigma_t Q^*_{\kappa t}/\Sigma_\kappa \Sigma_t Q^*_{\kappa t}$ where $Q^*_{\kappa t}$ is observed bricks delivered. Then $Q_m = \varrho^Q_\kappa Q^*_t$, where Q^*_t is $\Sigma_\kappa Q_{\kappa t}$. The approach adopted here is consistent with the spatial distribution of projects detailed in footnote 23.

[38] This survey includes 2708 dwellings that were built recently (between 1990 and 2008) where a physical inspection was carried out between April 2007 and March 2009. Table 1.3 of this publication reports that the percentage of these dwellings that used facing bricks (referred to as "masonry pointing") as their predominant type of wall finish is 0.897.

[39] These data are recorded by category: (i) detached houses (that require cladding on all four sides); (ii) semi-detached houses (requiring cladding on three sides); (iii) terraced houses (requiring cladding on two sides); and (iv) apartments. This breakdown is not available in Scotland, where we assume the average proportions for the rest of Great Britain apply there. To aggregate we give a detached house a weight of 1, a semi-detached house 0.75, a terraced house 0.5 and an apartment a weight of 0.40; the last of these is based on CC (2007), paragraph 4.30.