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

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Abstract

In many markets, buyers make discrete choices between differentiated products and negotiate prices that are specific to the choice. We develop for estimation a model for this class of markets which is consistent with non-cooperative models of bargaining between a buyer and competing sellers. We show that when the buyer's utility has GEV disturbances, the model has a tractable likelihood function which can be used with transaction-level data giving the selected product and its price. We estimate the model using data from the UK brick industry and use it to measure market power and analyze mergers. We analyze how spatial differentiation and ownership concentration affect the distribution of market power across transactions. In counterfactuals we find that switching from individually-negotiated to uniform pricing causes markups, and merger price effects, to increase on average but to decrease for a minority of transactions.

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

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1 Introduction

In many markets, buyers make discrete choices between differentiated products and negotiate prices specific to the individual choice. We use the term *negotiated pricing* for this type of setting. The theoretical literature suggests that negotiated pricing can impact market power, and merger effects, relative to the standard case of uniform pricing. The impact depends, among other things, on product differentiation, market structure, and the bargaining power of sellers.[1] The theoretical literature also highlights the prominent role played by the first-best and runner-up goods ranked in terms of the surplus from trade. This role is found in non-cooperative models both where sellers set take-it-or-leave-it (TIOLI) prices (see Thisse and Vives (1988)) and those where buyers have bargaining power (see Binmore (1985), Bolton and Whinston (1993) and Manea (2018)). This contrasts with uniform-price competition where market power and merger effects depend on market-level elasticities (see Nevo (2001)).

Negotiated pricing is recognized by antitrust authorities to be a feature of many oligopoly markets. In 2010 the US Merger Guidelines were revised to consider merger policy with negotiated pricing. They state that buyers "commonly negotiate with more than one seller, and may play sellers off against one another" and suggest that, with negotiated pricing, anti-competitive effects arise from a merger if there are buyers for which the merging parties jointly occupy (pre-merger) first-best and runner-up status.

An important group of markets in which negotiated pricing is found is construction materials. Markets for these materials have seen public discussion for two policy questions. The first is the merits of price discrimination. A classic debate, for delivered products, which dates back at least to *FTC vs. Cement Institute* 1948, compares uniform pricing, where the price before transport cost is the same for all buyers, with discriminatory pricing, where prices depend on buyer location (see discussion in Thisse and Vives (1988)). The second is mergers and market concentration; there have been many recent merger and market inquiries. In this paper we consider both policy questions for one such market: sales of bricks to house-builders in Great Britain. The Competition Commission (CC) investigated a merger between two of the four brick manufacturers in this industry (see CC (2007)). They judged the market to be highly concentrated—with a two-firm concentration ratio of 0.60, 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 the merger, even though the implied

[1] In the simple Hotelling linear city case, for example, with a bargaining protocol in which sellers make take-it-or-leave-it offers, negotiated pricing causes mean markups to fall relative for all buyers (see Thisse and Vives (1988)). In a similar setting the effects of mergers on market power can be be reduced by negotiated pricing (see Cooper et al. (2005)).

HHI increase exceeded the normally-acceptable threshold in its merger guidelines (implicitly based on uniform pricing). In effect the CC took the view—in line with some of the theoretical literature noted above—that competition in this market is more intense, and the merger less of a concern, than usual for a market at its concentration level.[2]

This paper makes two main contributions. First, we develop an empirical model of negotiated pricing in which buyers make a discrete choice between differentiated products and negotiate prices of choice alternatives with competing multi-product sellers. Although the model is well-founded in the theoretical literature, it has not been estimated empirically in the discrete-choice literature. Second, we estimate the model and analyze market power using transactions data from the UK brick industry.

The model adapts the differentiated products choice framework in Berry et al. (1995) to the case of negotiated pricing. It can be applied to a multi-product firm setting, where the relevant definition of the runner-up good is the highest-surplus good not jointly owned with the first-best. In our solution concept, the buyer negotiates simultaneously and bilaterally with (at least) the sellers of the the first-best and runner-up products. In each negotiation the buyer's gain from trade is defined relative to the alternative of not buying any inside product, and the buyer has an "outside option" of buying the runner-up (inside) product at its anticipated negotiated price (see Binmore et al. (1989) for a discussion of bargaining with an outside option). Equilibrium is achieved when the bilateral negotiations are mutually consistent. In equilibrium the buyer buys the first-best product at a negotiated price which is the minimum of (i) the price implied by standard bilateral Nash bargaining with the first-best product's seller and (ii) the Nash equilibrium TIOLI price. Although the model has an axiomatic bargaining solution, namely Nash bargaining constrained by an outside option, a desirable feature of our specification is that the equilibrium outcomes are micro-founded in the non-cooperative multi-seller complete-information bargaining literature (e.g. the models in Binmore (1985), Bolton and Whinston (1993), and the simple no-intermediary version of the model in Manea (2018)). The case of TIOLI prices is nested in the model.

There are two main econometric challenges in taking the model to transactions data giving the price and chosen product for each choice. First, we usually observe neither the runner-up product nor (unlike standard discrete choice settings) the prices the buyer would have paid for products he does not choose. Second, similar to the discrete-

[2]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).

continuous choice model of Dubin and McFadden (1984), the choice of product and the negotiated price are jointly determined. To overcome these challenges, we estimate the choice and pricing parts of the model jointly, and integrate out unobserved tastes along with their implications for the runner-up product. Since our application has many products, this is a high-dimension problem. We show that when idiosyncratic tastes are characterized by a Generalized Extreme Value (GEV) distribution there is a tractable likelihood for the joint probability of the observed choice and negotiated price.

Although we apply the model to the brick market, we regard the empirical modeling framework as being more widely applicable. The framework is suitable for a complete information setting where prices are negotiated transaction-by-transaction. We believe that this will apply to many settings where the buyers and sellers are few, particularly business-to-business settings.[3] One obvious set of applications is construction inputs as discussed above. More widely, however, potential applications include the industries where the negotiated pricing framework in the merger guidelines has been applied, which are quite diverse and include inputs in retailing, shipping and aerospace.[4]

In the model, the buyers are house-building firms, with multiple construction projects in separate locations, and the suppliers are manufacturers of brick products. Each construction project requires cladding using a differentiated brick product or some alternative cladding option (the outside good). Products are valued differently across projects and prices are negotiated separately for each project. A buyer single-sources for an individual project, i.e. the alternatives are mutually exclusive.

The data set has 13,788 transactions between manufacturers and house-building firms, giving, for each construction project and year, the chosen product, price, production and delivery locations, volume, transport costs, and brick characteristics. In the data, prices vary across transactions, controlling for brick product, house builder and year. Spatial differentiation is an important feature of the market. In particular, there is price heterogeneity for the same brick product across different projects of the same buyer, and this depends on measures of local competition from rival firms. We also have plant-month production cost data.

Using the estimated model we reject the (nested) case of TIOLI offers in a likelihood

[3]For example, in the aerospace market, Nalebuff (2009) notes that "customers are large and powerful. A vendor cannot ignore an airline that asks for a better price. Nor are vendors uninformed as to their customers' preferences. [...] Vendors take into account previous purchases as well as technical performance differences between their products and those of competitors."

[4]Examples from the US and Europe include sellers of consumer-generated ratings platforms, whose clients include online retailers (*Power Reviews/Bazaarvoice*, 2014), marine water treatment products, whose clients run fleets of ships (*Wilhelmsen/Drew Marine*, 2018), supply of private label breakfast cereals to retailers (*Post Holdings/TreeHouse Foods Inc*, 2020), and the *GE/Honeywell* avionics merger case in 2001. See Sweeting et al. (2020) and Nalebuff (2009).

ratio test. The estimated model implies a distribution (across transactions) of prices that matches the data well. As an external validity check, we find a good match between the costs implied by our estimates and the plant-month level cost data (not used in estimation). Estimated price-cost margins (PCM), in Lerner index form, are low on average (with a mean of 0.08) but vary quite widely across transactions (a coefficient of variation of 0.78). We find that project location plays a role in markup variation—sellers set higher margins to buyers that are relatively close, i.e. they take advantage of the low transport costs of the buyer—and manufacturer portfolios play a role too as the relevance of multi-product ownership varies across projects.

We consider counterfactuals in two policy areas. The first is pricing policy. We find that average markups increase—by 34% at the observed market structure—if there is a policy switch to uniform pricing. The changes in individual transactions, however, vary widely, and in some transactions markups fall. This contrasts with the all-markups-rise result found for the simple Hotelling specification used in Thisse and Vives (1988). Comparing buyers, we find that the switch to uniform pricing tends to benefit buyers in transactions with relatively little competition from a runner-up good, which is intuitive because these buyers tend to have a relatively weak bargaining position.

The second policy area is the effect of market concentration. With negotiated pricing—holding bargaining skill and marginal costs constant—a change in product ownership does not influence a transaction's markup unless it changes the runner-up good for the transaction, e.g. brings the first-best and runner-up products under joint ownership. A demerger to the case of single-product manufacturers reduces total manufacturer surplus substantially (by 25%) but the impacts are very unequal across transactions, i.e. multi-product effects are important overall but vary greatly across individual transactions. The remaining counterfactuals are pairwise mergers of the manufacturers. The merger of the two largest firms in terms of market share generates an increase in total manufacturer surplus in the industry of 19%. However, markup increases are very unequal across transactions. Finally, we find that a change to pricing policy has a major impact on the effects of mergers: comparing the same mergers under the two pricing policies, we find that negotiated pricing abates markup-increasing effects of mergers on average but makes them worse for a minority of transactions.

Our paper joins an existing literature that estimates the effects of non-uniform pricing. The results vary depending on the characteristics of the market being studied. Miller and Osborne (2014) look at spatial price discrimination in the cement market using a spatial price discrimination model. Unlike our paper, buyers are price takers and pricing is spatial only. Like our paper they find some buyers benefit and others lose if uniform pricing is imposed although unlike ours they find average prices fall. Grennan

(2013) finds that negotiated pricing intensifies competition and lowers average prices in a different bargaining model from ours (i.e. standard Nash-in-Nash, see below). Marshall (2020), using a model in which consumers have search costs, finds that banning price discrimination increases consumer surplus.

Our paper is related to the empirical demand estimation literature in the presence of price discrimination. Miller and Osborne (2014) and D'Haultfœuille et al. (2018) estimate models of price discrimination without using transaction-level data on prices. We build on these papers in three ways. First, we extend the analysis to fully-individualized, rather than third-degree, price discrimination in which there is a distinct price for each choice occasion. Second, we allow buyers to have bargaining power as opposed to being price-takers. Third, we use transaction-level, rather than market-level, data to estimate the model, which leverages the data on prices paid in individual transactions.

Our paper contrasts with the empirical bargaining literature based on the standard Nash-in-Nash (NiN) solution in Horn and Wolinsky (1988). The papers in this literature, which are often applied to media and healthcare industries, include 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 this framework, a buyer negotiates just one price for each product and trades positive quantities of all the products with negotiated prices. The buyers in our model, on the other hand, negotiate different prices for each discrete (single-sourcing) choice occasion.[5] The framework used in the paper is also related to Nash-in-Nash with Threat of Replacement (NNTR), the bargaining solution in Ho and Lee (2019), which extends the standard NiN framework to allow a competitive role for sellers with which a (multi-sourcing) buyer does not trade.

The data that the econometrician observes in our setting are different from the standard NiN and NNTR setting. In the standard Horn and Wolinsky (1988) NiN framework, since each buyer consummates trade at each negotiated price, all the negotiated prices are observed in the transactions data. In our model, by contrast, only one of the choice alternatives (the first-best) is selected for trade. Therefore transaction datasets will not include the runner-up or its price. One of our contributions is that we derive a likelihood function that accounts for the inherent unobservability of the runner-up product and its negotiated price.

[5]A comparison with Grennan (2013) is useful. Like our model, Grennan (2013) considers a procurement setting in which the buyer uses a single product j (i.e. single-sources) at the individual need level i. The key difference between the "needs" in the two models is scale: the value of bricks needed for cladding a building project (as in our model) is much higher than the value of a stent for a patient (as in Grennan's model) and as a consequence it is worthwhile for the price in the former to be negotiated at the level of the individual need whereas in the latter it is negotiated at the level of the buyer (with the same prices applying to all the buyer's needs).

The paper is related to the literature on individualized pricing in a discrete-choice setting. Similar to our paper, Marshall (2020) and Salz (2022) study decentralized business-to-business markets. Our approach differs from theirs by employing a differentiated-products utility framework with multi-product firms and without search costs. Our model relates to Miller (2014) and Allen et al. (2019) which consider a differentiated products setting, using an auction setting to model competition. Our approach differs by moving away from an auction setting to consider cases in which buyers are not price-takers. Allen et al. (2019) requires an "incumbent" seller which is not applicable to all settings including our own. We complement the price-taking model in Miller (2014) (which is nested within ours) by deriving a closed form likelihood expression for it.[6]

2 The brick market and the transactions data

Institutional details The largest users of bricks in Great Britain are national house-building firms, hereafter *buyers*, which buy bricks directly from manufacturers for cladding purposes. We study transactions of domestically-produced bricks bought by these buyers. In any year, each buyer has multiple housing projects with different sizes and locations. The buyers are responsible for all the key aspects of their projects including choice of cladding. In any year, buyers tend to use one seller (and brick product) per project, single-sourcing at project-level (but using different sellers in different projects). The market is concentrated. In the period we study there were four main manufacturers with an 85% share of brick sales (CC (2007), paragraph 5.46) and subsequently there was a merger (of the two smallest firms) which reduced the number of manufacturers to three. Buyers tend to negotiate prices that hold good for a given year. For any buyer, the negotiated prices vary with the brick variety, quantity and project location, as we describe below.[7] Third-party hauliers, arranged by the manufacturer, deliver the bricks to the project location and are paid separately.[8]

[6]More generally the paper is related to the empirical literature on the effects of mergers when prices are not uniform: e.g. Brannman and Froeb (2000) use an auction setting with GEV taste shocks, Gowrisankaran et al. (2015) use a standard Nash-in-Nash model, and Allen et al. (2014) use reduced form methods in a market with consumer search.

[7]Price lists were used for a very small proportion of brick sales in the period of our study and these price lists were not used for large customers such as the national house builders that we study in our paper (see CC (2007) paragraph 4.62).

[8]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	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	Manufacturer (#annual transactions)	861.750	755.180
	Buyer (#annual transactions)	231.864	221.038
C: Product characteristics	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	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
E: Input prices	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
F: Local competition	#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: 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. Regions: NUTS1 definition. DA is the distance between 1st and 2nd nearest manufacturer

Table 1: Transactions data: summary statistics

Description of the data The data set 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, origin and destination locations, buyer, quantity, and payment. We treat a unique buyer-variety-destination-year transaction as defining a project. We obtain four characteristics of each variety from manufacturer catalogs: color, shaping method, strength, and water absorption. The first two matter for aesthetic reasons and the other two are technical and affect the performance of the brick, depending on weather conditions at the project location. Transport costs to the buyer for each delivery are also recorded for three of the four manufacturers. We aggregate over deliveries within each year to buyer-variety-destination-year level, which corresponds to a negotiated transaction, giving 13,788 transactions over four years sold from 36 plants; hereafter we refer to this as the transactions dataset.[9][10]

[9]This annual period length is chosen for two reasons. First, CC (2007) reports that negotiations are annual. Second, our data on brick deliveries, from which our transactions data are derived, show that prices of a given brick product delivered to any location change at the start of each year and then are held fixed for deliveries through the year. Deliveries to any buyer-destination take place over a short time-span and are highly concentrated in a single year. See Appendix H for further discussion.

[10]See Appendix B.4 for data-preparation and Beckert (2018) for further data discussion.

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.[11] We include the plant in the definition of a product not just because location matters for transport costs but because brick plants use local clay to make bricks and each local clay has a different mineral content which affects the look of the brick (see Appendix B.3).

Table 1 reports transactions data summary statistics. Panel A describes prices, quantities, distances, and transport costs. There is substantial variation across transactions in each. Panel B describes agent size, for manufacturers and buyers respectively, measured by the annual number of transactions. The average buyer has hundreds of transactions in a given year.[12] Panel C reports statistics for the brick characteristics. Panels D and E summarize weather conditions and input prices. Panel F reports measures of competition which vary by project: the number of manufacturers within a given radius, and the distance between the nearest and second-nearest manufacturer.

Finally, we calculate the market share of the outside good, defined as 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 in Great Britain. To define m we use the 11 official NUTS1 regions in Great Britain and the four years 2003-2006 giving a total of 44 region-years. 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). 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 $I_{0m} = I_{Jm}s_{0m}/(1 - s_{0m})$ where I_{Jm} is the number of projects using inside goods (i.e. in the transactions data) in region-year m.

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 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) only includes observations with more than five transactions for each buyer-variety-year. Year effects explain only a small amount of price variation. Adding

[11] 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 mid-point of the interval as the product's characteristic. See Appendix B.3. See also footnote 14.

[12] Buyers tend to source from most of the four manufacturers when all projects are considered: let $\mathrm{f_i}$ denote for project i the number of manufacturers i's buyer sources from when considering *all* its projects in the four years of the data. The average value of this figure across projects is 3.6.

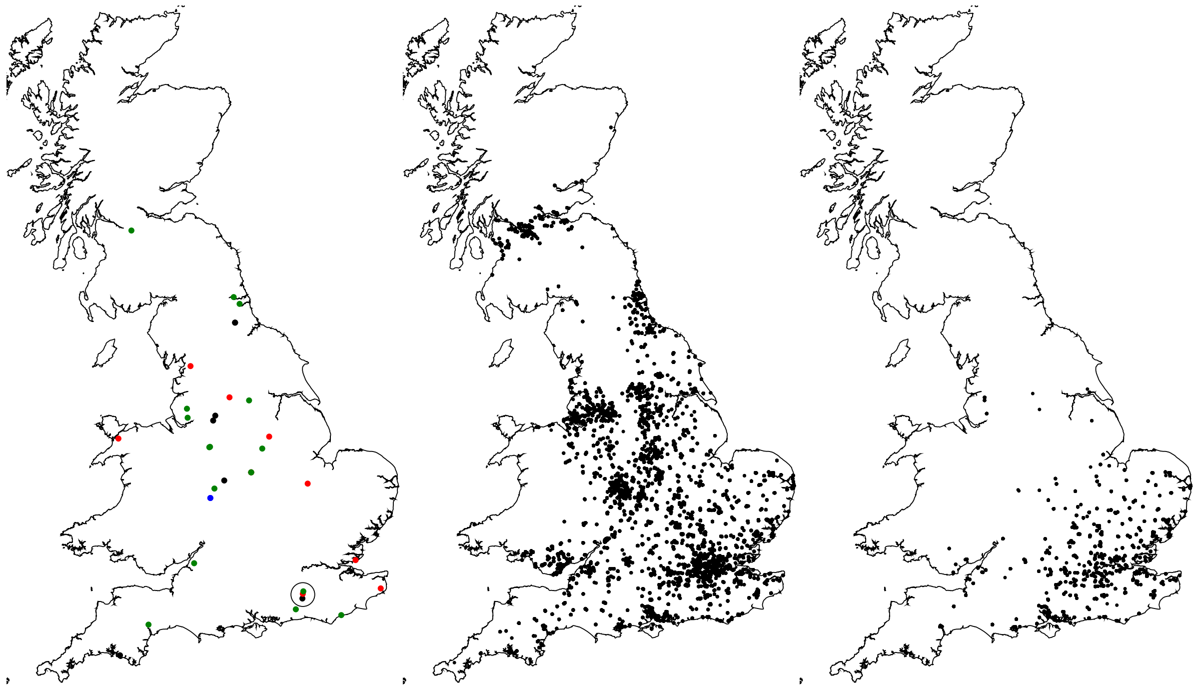
A: Price regressions with alternative controls					(i)		(ii)	
					R^2	RMSE	R^2	RMSE
Dummy variables included:	none				0.000	24.843	0.000	21.195
	year				0.118	23.340	0.130	19.771
	variety-year				0.775	11.780	0.816	9.098
	buyer-variety-year				0.918	7.114	0.867	7.740
Observations included					all observations		buyer-variety-year with > 5 locations	
#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 in Table 1. Standard errors in parentheses.

Table 2: Results from unit price regressions

variety-year and buyer-variety-year effects absorbs more variation, but still leaves much unexplained—i.e. there is intra-buyer (cross-project) variation conditional on product variety and year. Panel B explores the relationship between prices and other variables that vary across projects. All specifications include variety dummies. The four specifications use two alternative measures of local competition—the distance-advantage DA of the nearest manufacturer, and counts $N(DST)$ of local manufacturers—as defined in Table 1. The estimates indicate that prices vary in an intuitive way with quantity, input prices, the ratio of buyer to seller size, and the measures of local competition. While these estimates describe correlation we do not interpret them causally.

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 colors in the first map indicate the ownership of the plants. The third map shows projects that use varieties produced in four plants in Sussex, identified by (the far-south) hollow circles in the left-hand map: it



(a) Plants (b) Deliveries (all plants) (c) Deliveries (Sussex plants)

Map (a) shows plant locations, with colors indicating the owner, and where the four (far-south) Sussex plants are in a circle, 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

appears that these projects have lower mean distances (than those in the second map) from the four identified plants, indicating the importance of transport costs.[13]

To further assess the role of transport costs, Table 3 presents (first row of A1) 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, or even the nearest five plants, but do so more often than the benchmark case where they select one of the 36 plants randomly. Nor does a buyer exclusively select the nearest plant of the chosen manufacturer (second row of A1), suggesting there is differentiation at product level rather than just at firm level. The third row of Panel A1 of Table 3 shows that the buyer often does not select the nearest available plant conditioning on the chosen brick's four non-spatial characteristics and manufacturer (in cases where more than one plant is available). This supports the view, which we discussed above, that the plant itself picks up an unobserved source of product differentiation such as variation in color. Whilst the Euclidean distances we use do not fully measure transport cost, the mean distance difference between the

[13]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 the standard Hotelling set-up where the correlation is -1.

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) [Random benchmark: 1/36 = 0.028, 5/36 = 0.140]			0.119	0.401
Chosen manufacturer			0.312	0.726
Chosen product characteristics (up to plant) & manufacturer†			0.706	–
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 ($\boldsymbol{x}_j$)				
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. † 6,889 transactions for which the buyer could have used a different plant. Standard errors in parentheses.

Table 3: Analysis of product choice

nearest and the chosen plant reported in panel A2 is large and unlikely to be entirely attributable to measurement factors. In sum, Panel A and the maps indicate that transport costs are important but are not the only factor that drives choices.

To explore 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 to project i from product j is $u_{ij} = \boldsymbol{\beta}'\boldsymbol{x}_j + \boldsymbol{\gamma}'\boldsymbol{y}_{ij} + \varepsilon_{ij}$ where $\boldsymbol{x}_j$ is a vector of j's non-price characteristics, $\boldsymbol{y}_{ij}$ is a vector of interactions between i and j, and ε_{ij} is an iid Type-1 EV effect. Included in $\boldsymbol{x}_j$ is the log of the number of varieties in j.[14] In specification (i) parameters $\boldsymbol{\beta}$ are significant, but, since price is not included, we do not have strong priors as to their sign. In specification (ii) we replace $\boldsymbol{\beta}'\boldsymbol{x}_j$ with unreported product dummies β_j which absorb the mean effects of product characteristics. The signs of the parameters $\boldsymbol{\gamma}$ in both specifications are intuitive and mostly significant: distance has an overall negative effect, while synergies between rainfall and absorption, and frost and

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

strength, are negative and positive respectively. A limitation with this specification is that prices are omitted because they are individualized and hence observed only for the chosen product. In the next section we develop a model that allows us to account for the presence of unobserved prices.

We highlight four features of the data that motivate the model. First, buyers have many projects and there is a discrete choice for each project. Second, prices vary across projects even after controlling for product and buyer (inconsistent with standard NiN where prices are buyer-level). Third, sellers have multiple products, which are differentiated spatially and in other ways. Fourth, prices for a given project are lower, other things equal, when there is local competition from firms that are not chosen (inconsistent with standard NiN where no excluded product has a competitive role).

3 The model

3.1 Players, products and payoffs

Each house-building firm, hereafter *buyer*, has a number of independent construction projects. For each project, the buyer requires a product $j \in \mathcal{J} \equiv \mathcal{J}_J \cup \{0\}$ for the purposes of cladding where $\mathcal{J}_J = \{1, \ldots, J\}$ is the set of inside goods (brick products) and $j = 0$ is the outside good (non-brick cladding). There are F brick manufacturers, hereafter *sellers*, in the set $\mathcal{F} = \{1, \ldots, F\}$. Each product $j \in \mathcal{J}_J$ has a distinct seller $f(j) \in \mathcal{F}$, so $\mathcal{J}_J = \cup_{f \in \mathcal{F}} \mathcal{J}_f$ can be partitioned into firm-specific sets $\mathcal{J}_f$ for each f.

Each project i has a fixed quantity requirement and location.[15] We define value, cost, surplus, and prices in per unit terms unless otherwise stated. The money-metric value to project i from product j is v_{ij}. This is net of transport costs which are paid by the buyer. The firm's cost of supplying the project is c_{ij}. The surplus from using brick j in project i is $w_{ij} = v_{ij} - c_{ij}$. The surplus from the outside good is w_{i0}. Surpluses can take any real value, i.e. $(w_{i0}, w_{i1}, \ldots, w_{iJ}) \in \mathbb{R}^{J+1}$. Agents have complete information (we motivate this in section 3.3).

Markups are defined as price minus cost, i.e. $\rho_{ij} \equiv p_{ij} - c_{ij}$. The markup ρ_{ij} is the part of surplus w_{ij} appropriated by the seller and the remainder is enjoyed by the buyer as money-metric utility $v_{ij} - p_{ij} \equiv w_{ij} - \rho_{ij}$. Markups are determined in project-specific negotiations. The most efficient bilateral trade of an inside good for any project is the product with the greatest surplus w_{ij}. Let the *first-best* product, denoted $j(i, 1)$, be the

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

highest-surplus inside product for project i, i.e.

$$j(i,1) = \arg\max_j (w_{ij} | j \in \mathcal{J}_J) \tag{1}$$

and let $f(i,1) = f(j(i,1))$ be the first-best seller. The product is first-best in terms of surplus, but whether it is first best in terms of buyer utility depends on markups which are determined by the bargaining model. Let the *runner-up* product $j(i,2)$ be the highest-surplus inside product for project i not sold by the first-best seller, i.e.

$$j(i,2) = \arg\max_j (w_{ij} | j \in \mathcal{J}_J \backslash \mathcal{J}_{f(i,1)}) \tag{2}$$

where products from the first-best seller are excluded because the role of the runner-up is to compete with the first-best. Let $f(i,2) = f(j(i,2))$ be the runner-up seller. We refer to the difference $w_{ij(i,1)} - w_{ij(i,2)} \geq 0$ as the first-best's surplus advantage. Similarly, the nth-best product, for $n > 2$, is

$$j(i,n) = \arg\max_j (w_{ij} | j \in \mathcal{J}_J \backslash \cup_{n'<n} \mathcal{J}_{f(i,n')}) \tag{3}$$

and $f(i,n)$ is the nth-best seller. We refer to $\{f(i,1), \ldots, f(i,n)\}$ the top n sellers.

3.2 Equilibrium markups and product choice

In this subsection we discuss the bargaining model for a given project i. To simplify notation we suppress i subscripts, so that $j(n)$ is the nth-best product, etc. The outside good is supplied competitively, which implies $\rho_0 = 0$. Let $\bar{N} = \max\{n | w_{j(n)} \geq w_0\}$ be the number of sellers whose highest-surplus product offers more surplus than the outside good. Sellers outside the top $\bar{N}$ cannot offer the buyer more utility than w_0 without making a loss. To derive equilibrium markups we initially assume the runner-up product's surplus exceeds outside good's, i.e. $w_{j(2)} \geq w_0$ which implies $\bar{N} \geq 2$. The buyer enters negotiations with the top $N \in \{2, \ldots, \bar{N}\}$ sellers $\{f(1), f(2), \ldots, f(N)\}$ i.e. the first-best, runner-up etc.. The model's outcomes are invariant to the value N takes in the set $\{2, \ldots, \bar{N}\}$ and we are agnostic about whether N is two or more.[16] We assume the buyer negotiates a markup only for the highest-surplus product of each seller $\{j(1), j(2), \ldots, j(N)\}$ i.e. the first-best, runner-up, etc., products. The assumption is natural since—in any bilateral negotiation between the buyer and a seller—this product gives the greatest surplus to be divided between the two parties. The bargaining model has three parts: (i) a choice problem in which the buyer selects a product

[16] We generalized from $N = 2$ to $N \geq 2$ following the suggestion of a referee.

$j \in \{0, j(1), \ldots, j(N)\}$ given negotiated markups $\{\rho_{j(1)}, \ldots, \rho_{j(N)}\}$, (ii) a set of N bilateral bargaining problems to determine these markups, and (iii) an equilibrium concept to account for interdependence between the N bilateral bargaining problems.

Product choice given negotiated markups Given the negotiated markups $\boldsymbol{\rho} = [\rho_j]_{j\in\{j(1),\ldots,j(N)\}}$, the buyer chooses alternative j from the choice set $\{0, j(1), \ldots, j(N)\}$ to maximize utility. The indicator function $D_j : \mathbb{R}^N_+ \to \{0, 1\}$ is given by

$$D_j(\boldsymbol{\rho}) = \begin{cases} 1[w_j - \rho_j > \max\{w_0, \max_{j'\in\{j(1),\ldots,j(N)\}\setminus\{j\}}(w_{j'} - \rho_{j'})\}] & \text{if } j \neq 0 \\ 1[w_j > \max_{j'\in\{j(1),\ldots,j(N)\}}(w_{j'} - \rho_{j'})] & \text{if } j = 0 \end{cases} \quad (4)$$

where $w_j - \rho_j$ is utility for an inside good and w_0 is the utility from the outside good. We assume for simplicity that in the case of a tie in indirect utility between the first-best $j = j(1)$ and any other product the buyer selects the first-best.

TIOLI best reply The seller's take-it-or-leave-it (TIOLI) best reply to $\boldsymbol{\rho}_{-j}$ is

$$\rho^C_j(\boldsymbol{\rho}_{-j}) = \max[0, w_j - \max_{j'\in\{j(1),\ldots,j(N)\}\setminus\{j\}}(w_{j'} - \rho_{j'}) - \iota_j] \quad (5)$$

where ι_j is small and positive if j is not first-best and zero if it is (since the buyer selects first-best in a tie). In words $\rho^C_j(\boldsymbol{\rho}_{-j})$ is either the highest markup that induces choice of j if this is possible with a non-negative markup or zero otherwise. This is the standard best reply function for a model in which competing firms make TIOLI offers. The markups for the TIOLI model solves the system $\rho^C_j(\boldsymbol{\rho}_{-j}) = \rho_j$ for all j.

Bilateral bargaining model Consider the bilateral negotiation for ρ_j conditioning on the other markups $\boldsymbol{\rho}_{-j} = \{\rho_{j(1)}, \ldots, \rho_{j(N)}\} \setminus \{\rho_j\}$. We assume the agreed markup is non-negative. This rules out a weakly dominated strategy for the seller: for any choice of markup by the other sellers, a negative markup is never better than a zero markup. The set $\{(w_j - \rho), \rho \mid \rho \geq 0\}$ describes the gross payoffs to the buyer and seller respectively from trading product j at markup ρ. The disagreement point is where the buyer uses the outside good $j = 0$. The buyer has an *outside option* to the negotiation given by the best utility $(w_{j'} - \rho_{j'})$ anticipated to be on offer from the other $N - 1$ negotiations $j' \in \{j(1), \ldots, j(N)\} \setminus \{j\}$. This is similar to the approach in Binmore et al. (1989) where the disagreement point is where the negotiating pair do not reach agreement or take up an outside option. The *gains from trade* (GFT), relative to the disagreement point, are $(w_j - \rho) - w_0$ to the buyer and ρ to the seller. Consider the Nash bargaining problem for product $j \in \{j(1), \ldots, j(N)\}$, assuming it is unconstrained by the outside option. The (unconstrained) Nash bargaining solution (NBS) for product j is

$$\rho_j^B = \ \arg\max_{\rho>0}[(w_j-\rho)-w_0]^{\mathrm{a}} \times [\rho]^{\mathrm{a}_j} \ = b_j(w_j-w_0) \tag{6}$$

where a and a_j are bargaining skills for the buyer and seller respectively and $b_j = \mathrm{a}_j/(\mathrm{a}+\mathrm{a}_j)$ is the seller's relative bargaining skill. We apply the *outside option principle* (Binmore et al. (1989)) in which the outside option has no effect on a Nash bargaining problem unless it constrains it, which is based on the argument that a threat from the buyer to use the outside option is not credible unless doing so leaves the buyer better off. Given anticipated markups $\boldsymbol{\rho}_{-j}$ in the other negotiations, the outside option constrains the NBS in negotiation j if and only if the utility from choosing j at the NBS markup ρ_j^B is less than the utility from the outside option, i.e.,

$$w_j - \rho_j^B < \max_{j' \in \{j(1),\ldots,j(N)\}\setminus\{j\}}(w_{j'}-\rho_{j'}). \tag{7}$$

If negotiation j is constrained given markups $\boldsymbol{\rho}_{-j}$, seller j can only retain the buyer by reducing its markup to the seller's TIOLI best reply to $\boldsymbol{\rho}_{-j}$, i.e. $\rho_j^C(\boldsymbol{\rho}_{-j})$ as defined in (5). By definition the NBS is constrained if and only if $\rho_j^C(\boldsymbol{\rho}_{-j}) < \rho_j^B$, so the markup that solves the bilateral bargaining problem for product j given markups $\boldsymbol{\rho}_{-j}$ is

$$\rho_j^A(\boldsymbol{\rho}_{-j}) = \min[\rho_j^B,\ \rho_j^C(\boldsymbol{\rho}_{-j})]. \tag{8}$$

Equilibrium In equilibrium the bilateral bargaining problems are mutually consistent, so that equilibrium markups solve the system

$$\rho_j = \rho_j^A(\boldsymbol{\rho}_{-j}) \text{ for } j = j(1), \ldots, j(N). \tag{9}$$

The equilibrium outcome is characterized in Proposition 1.

Proposition 1. For projects with surpluses $\{(w_0,\ldots,w_J) \in \mathbb{R}^{J+1} | w_0 \le w_{j(2)}\}$ in which the buyer negotiates with the top $N \in \{2,\ldots,\bar{N}\}$ sellers
[i] there is a unique equilibrium in which markups $\boldsymbol{\rho}^* = (\rho^*_{j(1)},\ldots,\rho^*_{j(N)})$ are given by

$$\rho^*_{j(n)} = \begin{cases} \min\ [b_{j(1)}(w_{j(1)}-w_0), (w_{j(1)}-w_{j(2)})] & \text{for } n=1 \\ 0 & \text{for } n \in \{2,\ldots,N\}, \end{cases} \tag{10}$$

[ii] at $\boldsymbol{\rho}^*$ the buyer chooses j if and only if it is the highest-surplus alternative, i.e.

$$D_j(\boldsymbol{\rho}^*) = 1 \qquad \Longleftrightarrow \qquad w_j > w_{j'} \qquad \forall j' \in \mathcal{J}\setminus\{j\}, \tag{11}$$

[iii] parts [i-ii] of this proposition are invariant for $N \in \{2, \ldots, \bar{N}\}$.

Proof. See Appendix A.1 □

Discussion Unlike Binmore et al. (1989), which considers a single bilateral bargaining problem and an exogenous outside option, we study multiple bilateral problems each with an outside option determined in the other bilateral negotiations. The outside options (if they bind) introduce competition between sellers and are the source of interdependence between negotiations. In equilibrium, the negotiations with the runner-up (and lower-ranked sellers) are always constrained by the outside option of buying the first-best. This results in zero markups for the runner-up (and lower-ranked sellers), i.e. $\boldsymbol{\rho}^*_{-j(1)} = \mathbf{0}$. The first-best seller's TIOLI best reply

$$\rho^C_{j(1)}(\boldsymbol{\rho}^*_{-j(1)} = \mathbf{0}) = \max[0, w_{j(1)} - \max_{j' \in \{j(2),\ldots,j(N)\}} w_{j'}] = w_{j(1)} - w_{j(2)} \tag{12}$$

is the highest markup the first-best can set without losing the buyer to the runner-up given $\boldsymbol{\rho}^*_{-j(1)} = \mathbf{0}$. Note that it equals the first-best seller's surplus advantage. It is always the runner-up $j(2)$ that provides the binding constraint since $w_{j(2)} = \max_{j' \in \{j(2),\ldots,j(N)\}} w_{j'}$. Therefore, the negotiation for the first-best is only constrained if the NBS $\rho^B_{j(1)}$ is greater than the TIOLI best reply, i.e. if $\rho^B_{j(1)} = b_{j(1)}(w_{j(1)} - w_0) > (w_{j(1)} - w_{j(2)})$. This constraint is increasingly likely to bind as the bargaining skill $b_{j(1)}$ increases towards one. This explains why the first-best markup in (10) is the minimum of the NBS and the TIOLI best reply to $\boldsymbol{\rho}^*_{-j(1)} = \mathbf{0}$.

This explains why bargaining skills $(b_{j(1)},\ldots,b_{j(N)})$, even though they may affect markups, are irrelevant to the buyer's choice (as Part [ii] of Proposition 1 implies). Bargaining skill cannot increase markups to a level that deters the buyer because it is not the only determinant of markups. Competition matters too. If the first-best bargaining skill were to increase to the point where the NBS markup would switch the buyer's choice to the runner-up, then the outside option would bind the first-best markup and stop this from happening. Formally, since the equilibrium first-best markup in (10) never exceeds the first-best's surplus advantage, i.e. $\rho^*_{j(1)} \leq (w_{j(1)} - w_{j(2)})$, while the runner-up (and other sellers) set zero equilibrium markups, the first-best product always offers the most utility, i.e. $w_{j(1)} - \rho^*_{j(1)} \geq w_{j(n)}$, $\forall n \in \{2, \ldots, N\}$.

This also shows why third-best and lower-ranked products $\{j(3), j(4), \ldots\}$ are irrelevant for the determination of equilibrium choice and markup (as stated in Part [iii] of Proposition 1). The most attractive offer such sellers could make in equilibrium is a zero markup. However this would give the buyer a lower utility than they can obtain from the runner-up product $j(2)$ which also offers a zero markup because of competition from the first-best product $j(1)$.

When $b_{j(1)} = 1$ (and $w_0 \leq w_{j(2)}$), the the first-best negotiation (as well as the others) is constrained because $(w_{j(1)} - w_{j(2)}) < (w_{j(1)} - w_0)$. In this case the equilibrium is the solution of the system of TIOLI best replies in equation (5). Hence, at $b_{j(1)} = 1$ the model is identical to the TIOLI posted-price model and equilibrium markups are

$$\rho^*_{j(n)} = \begin{cases} w_{j(1)} - w_{j(2)} & \text{for } n = 1 \\ 0 & \text{for } n \geq 2. \end{cases} \tag{13}$$

Proposition 1 is derived under the assumption that the outside good offers less surplus than the runner-up, $w_0 \leq w_{j(2)}$. When we relax this, however, the choice and markup results of the proposition are unchanged. There are two exhaustive cases. The first is where the outside good offers more surplus even than the first-best, $w_0 > w_{j(1)}$. The first-best seller cannot attract the buyer without making a loss, so the buyer's best option is to select the outside good and receive utility w_0 with no markup negotiations. The second case is where the outside good offers less surplus than the first-best but more than the runner-up, $w_{j(1)} \geq w_0 > w_{j(2)}$. Now the runner-up cannot constrain the NBS negotiation with the first-best, even with a zero markup, so the buyer chooses first best and its markup is the unconstrained NBS markup in equation (6), i.e. $\rho_{j(1)} = b_{j(1)}(w_{j(1)} - w_0)$. Since $b_{j(1)}(w_{j(1)} - w_0) = \min\ [b_{j(1)}(w_{j(1)} - w_0), (w_{j(1)} - w_{j(2)})]$ when $w_0 > w_{j(2)}$, this is identical to equation (10) in Proposition 1. Proposition 2 summarizes.

Proposition 2. For all projects with surpluses in the set $\{(w_0, \ldots, w_J) \in \mathbb{R}^{J+1}\}$ where the buyer negotiates with the top $N \in \{2, \ldots, \bar{N}\}$ sellers if $w_{j(2)} \geq w_0$, the first-best seller if $w_{j(1)} \geq w_0 > w_{j(2)}$, and no seller if $w_0 > w_{j(1)}$, buyer chooses j at equilibrium markups $\boldsymbol{\rho}^*$ if and only if it is the highest-surplus alternative, i.e.

$$D_j(\boldsymbol{\rho}^*) = 1 \qquad \Longleftrightarrow \qquad w_j > w_{j'} \qquad \forall j' \in \mathcal{J} \setminus \{j\}$$

and, if this alternative is an inside good, then $j = j(1)$, and its markup is

$$\rho_{j(1)} = \min\ [b_{j(1)}(w_{j(1)} - w_0), (w_{j(1)} - w_{j(2)})].$$

Proof. See Appendix A.1 □

Relation to non-cooperative and cooperative game theoretic models In the "Nash Program" tradition it is considered desirable to establish that a bargaining model with an axiomatic component such as ours can be supported by non-cooperative bargaining theory (see Collard-Wexler et al. (2019) which does this for multi-sourcing NiN models). An attractive feature of our model is that the bargaining outcome in (10) is supported in a number of non-cooperative game theoretic specifications where the buyer negotiates with multiple sellers and the buyer must select no more than one seller for trade. Examples include the models in Binmore (1985), Bolton and Whinston (1993), the simple case in Manea (2018), and Ghili (2022).[17] In these models the outcomes are obtained as the limiting equilibrium when time discounting goes to zero in the non-cooperative framework that dates to Rubinstein (1982). All the models assume single-sourcing buyers, have sellers that differ in terms of how much surplus they generate in trade with that buyer, and have the desirable feature that they allow information flow between the negotiations with the two sellers.[18] The models differ in the timing of offers, the identity of who proposes an offer at each stage (and whether this is deterministic or random), and whether offers are observed by both sellers, but all generate the markup and choice outcome in (10).[19] We consider the consistency of our model with such a wide range of specifications to be a desirable feature: even with excellent institutional knowledge, only rarely will a researcher observe in practice the very concrete procedures specified in non-cooperative theory.

The model is also well-founded in *cooperative* game theory: its outcome is in the *core* of the coalition game involving three parties (the buyer and the top-two sellers)—i.e. it satisfies the following principles: it (i) maximizes and fully distributes the total surplus, (ii) ensures that no sub-coalition of the parties can be made better off without another being made worse off, and (iii) implies a zero allocation of surplus to players that contribute nothing to the overall surplus (namely the runner-up). Moreover, each possible allocation in the core (a markup between zero and the surplus difference) can be achieved for some value of the relative bargaining skill b_j in its range $[0, 1]$, and this parameter can be seen as capturing how the parties split the surplus. Hence, the model can also be interpreted as representing an equilibrium that satisfies these principles, without assuming a specific non-cooperative model.[20]

[17] Some of these papers present the problem as a single seller negotiating with multiple buyers while others present it the other way around with a single buyer negotiating with multiple sellers. The strategic problem is formally equivalent in these two alternative cases.

[18] The last of these features is absent from an alternative approach to establishing non-cooperative foundations for multilateral bargaining models, which uses an "independent agents" representation, in which the buyer sends a separate agent to each seller, and each negotiation proceeds bilaterally with alternating offers and no information flow between the negotiations (see Chipty and Snyder (1999)).

[19] See Appendix C for a more detailed discussion of the alternative assumptions used in these models.

[20] The equilibrium is also bilaterally efficient in each negotiation—maximizes the sum of the payoffs of the two negotiating agents given markups in the other negotiations—i.e. is a contracts equilibrium as defined in Cremer and Riordan (1987) (see Appendix A.3).

Alternative definition for GFT As Binmore et al. (1989) notes, there is often more than one plausible definition for the GFT used in the Nash bargaining problem. An alternative is to define the buyer's GFT such that the disagreement point is the best utility available from any other option including inside goods. Thus, instead of constraining the NBS, the rival inside goods serve as the disagreement point in it. To keep things simple, suppose $N = 2$, i.e. that the buyer negotiates only with the first-best and runner up, and that the outside good's surplus is less than the runner-up's, i.e. $w_{j(2)} > w_0$. The outcome of this alternative specification is characterized by the markups

$$\rho^*_{j(n)} = \begin{cases} b_{j(1)}(w_{j(1)} - w_{j(2)}) & \text{for } n = 1 \\ 0 & \text{for } n = 2 \end{cases} \tag{14}$$

and the buyer selects $j(1)$. To see how the expression for $\rho^*_{j(1)}$ in (14) is obtained, given $\rho^*_{j(2)} = 0$, note that the buyer's GFT with the first-best is $[(w_{j(1)} - \rho) - w_{j(2)}]$ so that the NBS is $\arg\max_{\rho>0}[(w_{j(1)} - \rho) - w_{j(2)}]^{\mathrm{a}} \times [\rho]^{\mathrm{a}_j} = b_{j(1)}(w_{j(1)} - w_{j(2)})$. To see how the runner-up markup is obtained, note that the buyer's GFT with the runner-up $[(w_{j(2)} - \rho) - (w_{j(1)} - \rho_{j(1)})]$ is negative for any $\rho \geq 0$, when $\rho_{j(1)}$ is at its value in (14). This implies the runner-up cannot attract the buyer with a non-negative markup. The model assumes that the buyer and runner-up agree a zero markup, since they do not expect to trade. Competition between the two products ensures that there is no equilibrium for which $\rho_{j(2)} > 0$. This specification is discussed further in Appendix A.2, where we show that when the assumption $w_{j(2)} \geq w_0$ is relaxed, the outcomes are identical those for the baseline model when $w_{j(2)} < w_0$. Like the baseline, it nests the TIOLI case when $b_{ij(1)} = 1$. This alternative specification is discussed in Miller (2014). It is not as strongly micro-founded in the non-cooperative bargaining literature as the baseline model.[21] However, as a check on robustness, we also estimate and present results from the alternative specification. We derive in Appendix A.4 the likelihood function for empirical analysis.

3.3 Specification of value, cost and bargaining skill

We now reintroduce i subscripts to specify how value v_{ij}, cost c_{ij}, and the seller's relative bargaining skill b_{ij}, vary across projects. The (money-metric) value in project i, with attributes $\mathbf{d}_i$, of product j, with observed characteristics $\boldsymbol{x}_j$, and observed transport

[21] We are unaware of non-cooperative micro-foundations for the alternative model other than in the "independent agents" representation described in footnote 18, assuming (i) time discounting derives from from an exogenous probability of breakdown at each stage (Binmore et al. (1986), *split-the-difference* case) and (ii) a zero markup is anticipated for the runner-up good.

costs $\mathbf{t}_{ij}$ between i and j is

$$v_{ij} = \boldsymbol{\beta}(\mathbf{d}_i)\boldsymbol{x}_j - \boldsymbol{\alpha}\mathbf{t}_{ij} + \xi_j + \varepsilon_{ij}. \tag{15}$$

The vector $\boldsymbol{x}_j$ is a list of brick characteristics. Project attributes and brick characteristics interact to generate indicators for whether the product is produced near to the project (to pick up home-preference taste effects) and indicators for each buyer-seller pair (to allow buyer-specific preferences over sellers) as well as regional tastes for characteristics.[22] Letting $\boldsymbol{x}_j = [x_{jk}]_{k\in\mathcal{K}}$ and $\mathbf{d}_i = [\mathrm{d}_{ia}]_{a\in\mathcal{A}}$ the taste in project i for the kth characteristic, x_{jk}, is

$$\beta_k(\mathbf{d}_i) = \bar{\beta}_k + \textstyle\sum_{a\in\mathcal{A}}\beta^o_{ka}\mathrm{d}_{ia} + \sigma_k\nu_{ik}$$

where $\bar{\beta}_k$ is a mean effect, a indexes project attributes, β^o_{ka} is the effect of the ath project attribute d_{ia}, ν_{ik} is an iid standard normal random taste effect and σ_k is its scaling parameter. The observable project attributes set $\mathcal{A}$ includes regional dummies and local weather conditions.

The transport cost vector $\mathbf{t}_{ij} = [DST_{ij}, DST_{ij} \times FUEL_{t(i)}, DST^2_{ij}]$, where DST_{ij} is the straight-line distance from the plant to the project, and $FUEL_{t(i)}$ is fuel costs for the year $t(i)$ of the project. The vector $\boldsymbol{\alpha}$ is transport cost parameters. Unobserved mean utility ξ_j is a time-invariant fixed effect.[23]

The scalar ε_{ij} is a project-product match term that captures heterogeneity not measured in $(\boldsymbol{x}_{ij}, \mathbf{t}_{ij})$ because of (e.g.) the imperfect spatial granularity of the regional taste and weather variables, omitted brick characteristics, measurement error from straight-line distance DST_{ij}, etc. We assume ε_{ij} is iid across projects i according to a GEV distribution (with inside goods in a single nest) with nesting parameter $\sigma_J \in [0, 1]$. As in Berry (1994), we can write $\varepsilon_{ij} = [\zeta_{in(j)} + \sigma_J\varepsilon^*_{ij}]/\sigma_\varepsilon$, where ε^*_{ij} is iid extreme value and $\zeta_{in(j)}$ is a random term for nest n which has the unique distribution that ε_{ij} is also extreme value. Within-group utility correlation increases as $\sigma_J \to 0$ and goes to zero as $\sigma_J \to 1$.[24] The scale parameter σ_ε cannot be normalized, as in discrete choice models,

[22] On home preference taste effects the CC report, CC (2007), mentions this effect in paragraph 5.26, where they say that there is evidence of distinct regional brick preferences which "seemed to be driven by historical factors, particularly customer preferences for bricks which historically had been produced locally." On buyer-level preferences over manufacturers CC (2007), paragraph 4.71 mentions that factors that vary by manufacturer include continuity of supply, consistent quality, complementary services, quality of just-in-time production and after-sales service.

[23] We experimented with including time-specific fixed effects to pick up changes in tastes for the inside goods as a whole over time; however, they made little difference to the results consistent with the view that tastes for bricks as a cladding material are slow to change. We do however have time-varying input prices in transport and production costs.

[24] Given the inclusion of the ξ_j term, the specification is consistent with the buyer having a choice between varieties, nested within each j; this follows from the maximum stability property of the GEV

because the model has a continuous outcome, negotiated markups (see section 4.3).

The (unit) cost of supplying project i with quantity q_i of product j is

$$c_{ij} = \boldsymbol{\gamma}\mathbf{w}_{ij} + \gamma_f/q_i + \sigma_\nu \nu_{ic}. \tag{16}$$

The cost-shifters $\mathbf{w}_{ij} = (\mathbf{1}_{pl(j)}, LOW_j, \mathbf{w}_{t(i),reg(i)})$ are as follows. The vector $\mathbf{1}_{pl(j)}$ is plant dummies to allow plant-varying efficiency. The scalar LOW_j is a binary indicator for whether product j is low quality.[25] The vector $\mathbf{w}_{t(i),reg(i)}$ is input factor prices: year-varying gas price and region-year-varying labor costs. Parameter γ_f is a fixed cost which allows transaction-level scale effects. Finally, ν_{ic} is an iid standard normal random project-specific effect—e.g. capturing production timing or bespoke shape requirements.

Let $\boldsymbol{z}_{ij} = (\boldsymbol{x}_j, \mathbf{d}_i, \mathbf{t}_{ij}, \mathbf{w}_{ij}, q_i)$ collect the observable data. Let $\boldsymbol{\nu}_i = ([\nu_{ik}]_{k\in\mathcal{K}}, \nu_{ic})$ collect the unobserved random taste effects. The surplus in project i of product j is

$$w_{ij} = v_{ij} - c_{ij} = \omega(\boldsymbol{z}_{ij}, \boldsymbol{\nu}_i) + \varepsilon_{ij}$$

where, letting $\delta_j = \sum_{k\in\mathcal{K}} \bar{\beta}_k x_{jk} + \xi_j$ collect mean utility effects,

$$\omega(\boldsymbol{z}_{ij}, \boldsymbol{\nu}_i) = [\delta_j + \textstyle\sum_{k\in\mathcal{K}}(\sum_{a\in\mathcal{A}}\beta_{ka}\mathrm{d}_{ia} + \sigma_k\nu_{ik})x_{ijk} - \boldsymbol{\alpha}\mathbf{t}_{ij}] - [\boldsymbol{\gamma}\mathbf{w}_{ij} + \gamma_f/q_i + \sigma_\nu\nu_{ic}].$$

A number of features of the application motivate the simplifying assumption of complete information about values (15) and costs (16). First, sellers and buyers are few and trade repeatedly. Second, there is little process or product innovation. Third, factors affecting the project-product match, including those not observed by the econometrician, tend to be quite transparent and largely driven by project location—e.g. (i) the tastes of the final house-buying public to whom housing is marketed, (ii) local environmental and weather considerations, and (iii) the overall cost of transport from the production location—and sellers are likely to become familiar with these from repeated market activity in multiple locations.

We assume that bargaining skill is determined at the level of the buyer $h(i)$ and seller $f(j)$. The bargaining skill of agent l (a buyer or seller) is $\mathrm{a}_l = \exp(\eta_1 1_{[l\in\mathcal{F}]} + \eta_2 y_l)$ where $\boldsymbol{\eta} = (\eta_1, \eta_2)$ are parameters, $1_{[l\in\mathcal{F}]} \in \{0, 1\}$ indicates whether agent l is a seller, and y_l is agent size, defined as the log of l's number of transactions in the 4-year period

distribution (see Ackerberg and Rysman (2005) and footnote 14).

[25] We define a low quality product as one with a below-median (across $j \in \mathcal{J}$) ratio of strength to water absorption. Low quality bricks have a lower energy requirement in the production process.

of the data. A seller with size difference $y_{ij} = y_{f(j)} - y_{h(i)}$ has relative bargaining skill

$$b_{ij} = \mathrm{a}_{f(j)}/(\mathrm{a}_{f(j)} + \mathrm{a}_{h(i)}) = \exp(\eta_1 + \eta_2 y_{ij})/(1 + \exp(\eta_1 + \eta_2 y_{ij})) \in [0, 1].$$

Buyers have multiple simultaneous projects in any year. The specification implies that the surplus w_{ij} is independent of choices for other projects $i' \neq i$. On the value side, given that projects are spatially separate, there is no obvious role for intrinsic taste synergies. There is also little role for synergies arising from avoiding shopping or switching costs: as we discussed in section 2 buyers use multiple sellers (in different projects) and according to CC (2007) (paragraph 7.7) face no significant switching costs. On the cost side we rule out intra-plant effects generated by non-linear costs such as 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).[26]

Finally, the specification rules out any inter-buyer interdependence that might arise because buyers compete downstream in the retail market for new houses: 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. It also rules out cross-product price effects for the seller or bundling discounts—loosely, cutting price on one product to induce the buyer to choose another product from the same seller—which do not arise when prices are negotiated, with or without shopping costs, since negotiated prices are transaction-specific and are chosen to induce the buyer to choose the first-best product in each transaction.[27]

4 Probability, likelihood function and identification

For each transaction i using an inside good, the transactions data record: (i) the first-best product and its negotiated price, $[j(i,1), p_i]$, (ii) shifters of joint surplus for all inside goods $\boldsymbol{z}_i = [\boldsymbol{z}_{ij}]_{j \in \mathcal{J}_J}$ and (iii) shifters of the first-best seller's bargaining skill relative

[26]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 f from project i be $c_f(q_i, Q_{-i})$ where Q_{-i} is a vector of quantities in other projects, and assume Q_{-i} is unaffected by the bargaining process for i.

[27]As Nalebuff (2009) points out, while a seller in a market with uniform 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."

to the buyer, $y_{ij(i,1)}$. We also observe, using other sources, the number of projects I_{0m} choosing the outside good, for each region-year market $m \in \mathcal{M}$.

There are two main econometric challenges. First, for any project i, we do not observe the buyer's runner-up good or (unlike standard choice models, e.g. Berry et al. (1995)) the prices the buyer would have paid for products they did not choose. Second, there is a selection issue in the markups equation, similar to the discrete-continuous choice model of Dubin and McFadden (1984): the choice of product and the negotiated markup are jointly determined and both depend on unobserved shocks $(\boldsymbol{\nu}_i, \boldsymbol{\varepsilon}_i)$. To address these challenges we estimate the choice and markup parts of the model jointly, using the model to predict the runner-up product and its impact on the first-best price given the unobservables, and then integrate out the unobservables. There are many candidate runner-up products, so this is a high-dimensional integration problem. We show in Proposition 3 that when idiosyncratic tastes are GEV there is a convenient closed form for the joint probability of the observed choice and price. These convenient forms reduce computational costs.

4.1 Joint probability measure for choice and markup

We derive a set of inequalities that are necessary and sufficient conditions for buyer i to choose product j at an endogenous markup ρ_{ij} that exceeds some exogenous constant $\rho > 0$. We combine two sets of inequalities from the bargaining model that are summarized in Proposition 2. The first set state that, at equilibrium markups,

$$(i \text{ chooses } j) \quad \Longleftrightarrow \quad w_{ij} > w_{ij'} \quad \forall j' \in \mathcal{J} \setminus \{j\}. \tag{17}$$

If j is the outside good there is no negotiated markup. If it is an inside good there is a negotiated markup and (17) implies j is the first-best good. The second set of inequalities says the markup of j is the minimum of the NBS and first-best product's surplus advantage over the runner-up good

$$\begin{aligned} \rho_{ij} &= \min[b_{ij}(w_{ij} - w_{i0}), w_{ij} - \max\nolimits_{j' \in \mathcal{J}_J \setminus \mathcal{J}_{f(j)}}(w_{ij'})] \quad (18) \\ &= \min[b_{ij}(w_{ij} - w_{i0}), \{w_{ij} - w_{ij'}\}_{j' \in \mathcal{J}_J \setminus \mathcal{J}_{f(j)}}] \quad (19) \end{aligned}$$

where in the first line we use the definition of the runner-up good from equation (2) and in the second line we use the fact that this definition implies the runner-up good has the lowest surplus difference relative to the first-best good among rival seller's goods. It follows from equation (19) that if the markup is greater than or equal to a positive constant ρ then so must be the Nash bargaining markup and the surplus difference with each rival seller's good, i.e.

$$(\rho_{ij} > \rho) \iff \min[b_{ij}(w_{ij} - w_{i0}), \{w_{ij} - w_{ij'}\}_{j' \in \mathcal{J}_J \setminus \mathcal{J}_{f(j)}}] > \rho \tag{20}$$

or, rearranging

$$(\rho_{ij} > \rho) \quad \iff \begin{cases} w_{ij} > \rho/b_{ij} + w_{ij'} & \text{for } j' = 0 \\ w_{ij} > \rho + w_{ij'} & \forall j' \in \mathcal{J}_J \setminus \mathcal{J}_{f(j)}. \end{cases} \tag{21}$$

The necessary and sufficient conditions for the *joint* outcome in which i chooses j and pays a markup greater than or equal to ρ are given by combining the choice conditions in (17) and the pricing conditions in (21). Notice that, for non-negative ρ, the condition in (21) for a given j' is sufficient for the condition for the same j' in (17). Thus, pooling the two sets of inequalities, we get

$$(i \text{ chooses } j \text{ and } \rho_{ij} > \rho) \quad \iff \begin{cases} w_{ij} > w_{ij'} & \forall j' \in \mathcal{J}_{f(j)} \setminus \{j\} \\ w_{ij} > \rho/b_{ij} + w_{ij'} & \text{for } j' = 0 \\ w_{ij} > \rho + w_{ij'} & \forall j' \in \mathcal{J}_J \setminus \mathcal{J}_{f(j)}. \end{cases} \tag{22}$$

To derive the discrete-continuous probability measure for buyer i's choice and markup we write inequalities (22) as follows

$$(i \text{ chooses } j \text{ and } \rho_{ij} > \rho) \iff w_{ij} > w_{ij'} + \rho\chi_{jj'} + \rho 1_{[j'=0]}/b_{ij} \quad \forall j' \in \mathcal{J} \setminus \{j\} \tag{23}$$

where $\chi_{jj'} = 1_{[j' \in \mathcal{J}_J \setminus \mathcal{J}_{f(j)}]}$ indicates for j whether j' is a rival seller's good. We normalize surplus levels such that $w_{i0} = 0 + \varepsilon_{i0}$ for the outside good. Let $\boldsymbol{\varepsilon}_i = (\varepsilon_{ij})_{j \in \mathcal{J}}$ have probability distribution function $G_{\boldsymbol{\varepsilon}}$. The probability $r_j(\rho|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i)$ that product j is chosen at a markup greater than ρ for a project of type $(\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i)$ is

$$\begin{aligned} r_j(\rho|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i) =& \Pr(i \text{ chooses } j \text{ and } \rho_{ij} > \rho|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i) \\ =& \int_{\boldsymbol{\varepsilon}} 1[\omega(\boldsymbol{z}_{ij}, \boldsymbol{\nu}_i) + \varepsilon_{ij} \\ & > \max(\{\omega(\boldsymbol{z}_{ij'}, \boldsymbol{\nu}_i) + \varepsilon_{ij'} + \rho\chi_{jj'}\}_{j' \in \mathcal{J}_J \setminus \{j\}}, \rho/b(y_{ij}) + \varepsilon_{i0})] \mathrm{d}G_{\boldsymbol{\varepsilon}} \end{aligned} \tag{24}$$

and, since the inequalities in (24) have the same structure as the inequalities of a standard discrete-choice model, it follows from McFadden (1978) that

$$r_j(\rho|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i) = r_{j|J}(\rho|\boldsymbol{z}_i, \boldsymbol{\nu}_i) r_J(\rho|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i) \tag{25}$$

where

$$r_{j|J}(\rho|\boldsymbol{z}_i, \boldsymbol{\nu}_i) = \frac{\exp\{(\sigma_\varepsilon/\sigma_J)\omega(\boldsymbol{z}_{ij}, \boldsymbol{\nu}_i)\}}{\sum_{j'\in\mathcal{J}_J} \exp\{(\sigma_\varepsilon/\sigma_J)[\omega(\boldsymbol{z}_{ij'}, \boldsymbol{\nu}_i) + \rho\chi_{jj'}]\}}, \tag{26}$$

$$r_J(\rho|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i) = \frac{\exp\{\sigma_J W(\rho, \boldsymbol{z}_i, \boldsymbol{\nu}_i)\}}{\exp\{\sigma_\varepsilon \rho/b(y_{ij})\} + \exp\{\sigma_J W(\rho, \boldsymbol{z}_i, \boldsymbol{\nu}_i)\}} \tag{27}$$

and

$$W(\rho, \boldsymbol{z}_i, \boldsymbol{\nu}_i) = \ln(\Sigma_{j'\in\mathcal{J}_J} \exp\{(\sigma_\varepsilon/\sigma_J)[\omega(\boldsymbol{z}_{ij'}, \boldsymbol{\nu}_i) + \rho\chi_{jj'}]\}) \tag{28}$$

are standard nested logit closed forms. To obtain the discrete-continuous probability measure $f_i(\rho|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i)$ of observing choice j and markup ρ, conditional on project type $(\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i)$, we differentiate $r_j(\rho|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i)$ in (24) with respect to ρ: $f_j(\rho|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i) = -\partial r_j(\rho|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i)/\partial\rho$. Proposition 3 states that $f_j(\rho|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i)$ has a closed form.

Proposition 3. If $\varepsilon_i \backsim$ GEV, nested by $\mathcal{J}_J$, with nesting parameter σ_J, the discrete-continuous probability measure of choice j at markup ρ for type $(\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i)$, is

$$\begin{aligned} f_j(\rho|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i) &= -\frac{\partial r_j(\rho|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i)}{\partial\rho} \\ &= \sigma_\varepsilon r_j(\rho|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i)[1 - r_f(\rho|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i) - (1-\sigma_J^{-1})(1 - r_{f|J}(\rho|\boldsymbol{z}_i, \boldsymbol{\nu}_i))] \\ &\quad - (1 - 1/b(y_{ij}))r_j(\rho|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i)(1 - r_J(\rho|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i)) \end{aligned}$$

where $r_f(\rho|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i) = \Sigma_{j\in\mathcal{J}_f} r_j(\rho|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i)$ and $r_{f|J}(\rho|\boldsymbol{z}_i, \boldsymbol{\nu}_i) = \Sigma_{j\in\mathcal{J}_f} r_{j|J}(\rho|\boldsymbol{z}_i, \boldsymbol{\nu}_i)$.

Proof. See Appendix A.4. □

To obtain the expressions in terms of observed price p rather than unobserved markups ρ we write $\rho = p - c_{ij}(\nu_{ic})$ where cost, in equation (16), for product j is written $c_{ij} = c_{ij}(\nu_{ic})$ to make dependence on ν_{ic} explicit. Then we define $f_j^*(p|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i) \equiv f_j(p - c_{ij}(\nu_{ic})|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i)$.

Turning to choice probabilities, the probability $s_j(\boldsymbol{z}_i, \boldsymbol{\nu}_i)$ product $j \in \mathcal{J}_J$ is chosen for a $(\boldsymbol{z}_i, \boldsymbol{\nu}_i)$-type project is the probability $\boldsymbol{\varepsilon}_i$ satisfies the inequalities in (17):

$$\begin{aligned} s_j(\boldsymbol{z}_i, \boldsymbol{\nu}_i) &= \Pr(i \text{ chooses } j|\boldsymbol{z}_i, \boldsymbol{\nu}_i) &(29) \\ &= \int_{\boldsymbol{\varepsilon}} 1\{\omega(\boldsymbol{z}_{ij}, \boldsymbol{\nu}_i) + \varepsilon_{ij} > \max[(\omega(\boldsymbol{z}_{ij'}, \boldsymbol{\nu}_i) + \varepsilon_{ij'})_{j'\in\mathcal{J}_J\setminus\{j\}}, \varepsilon_{i0}]\}\mathrm{d}G_{\boldsymbol{\varepsilon}}. &(30) \end{aligned}$$

Since $\boldsymbol{\varepsilon}_i \sim$ GEV with inside goods in a nest we have from McFadden (1978) that

$$s_j(\boldsymbol{z}_i, \boldsymbol{\nu}_i) = \begin{cases} s_{j|J}(\boldsymbol{z}_i, \boldsymbol{\nu}_i)s_J(\boldsymbol{z}_i, \boldsymbol{\nu}_i) & j \in \mathcal{J}_J \\ 1 - s_J(\boldsymbol{z}_i, \boldsymbol{\nu}_i) & j = 0 \end{cases} \tag{31}$$

where $s_{j|J}(\boldsymbol{z}_i, \boldsymbol{\nu}_i)$ and $s_J(\boldsymbol{z}_i, \boldsymbol{\nu}_i)$ are the probability project i of type $(\boldsymbol{z}_i, \boldsymbol{\nu}_i)$ chooses j conditional on choice of an inside good, and the probability the same project type chooses an inside good, respectively. These probabilities have nested logit closed forms. Since when $\rho = 0$ the inequalities (17) and (22) are identical $s_j(\boldsymbol{z}_i, \boldsymbol{\nu}_i) = r_j(0|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i)$ and $s_J(\boldsymbol{z}_i, \boldsymbol{\nu}_i) = r_J(0|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i)$.

To eliminate the unobserved tastes we integrate numerically with respect to $\boldsymbol{\nu}_i$

$$f_j^*(p|\boldsymbol{z}_i, y_{ij}) = \int_{\boldsymbol{\nu}} f_j^*(p|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}) \mathrm{d}G_{\boldsymbol{\nu}} \quad \text{and} \quad s_j(\boldsymbol{z}_i) = \int_{\boldsymbol{\nu}} s_j(\boldsymbol{z}_i, \boldsymbol{\nu}) \mathrm{d}G_{\boldsymbol{\nu}} \tag{32}$$

where $G_{\boldsymbol{\nu}}$ is the distribution function of the vector $\boldsymbol{\nu}$.[28]

We require market shares s_{mj} in each market $m \in \mathcal{M}$ where $\mathcal{M}$ is the set of 44 region-year markets: 11 NUTS1 regions and four years, as discussed in section 2. The market shares are obtained by summing over all $|\mathcal{I}_m|$ projects in m, i.e.

$$s_{mj} = \tfrac{1}{|\mathcal{I}_m|} \textstyle\sum_{i \in \mathcal{I}_m} s_j(\boldsymbol{z}_i). \tag{33}$$

Equation (33) uses characteristics $\boldsymbol{z}_i$ for each $i \in \mathcal{I}_m = \mathcal{I}_{Jm} \cup \mathcal{I}_{0m}$ where $\mathcal{I}_{Jm}$ and $\mathcal{I}_{0m}$ are sets of projects using inside goods and the outside good respectively. The characteristics $\boldsymbol{z}_i$ are known for projects $i \in \mathcal{I}_{Jm}$ from the transaction data. For projects $i \in \mathcal{I}_{0m}$ we have no transaction data and know only their number $I_{0m} = |\mathcal{I}_{0m}|$ in each market m (see section 2). To obtain characteristics of these projects we simulate from the empirical distribution of project characteristics as follows. First, we use official data on the number of new housing projects by NUTS2 sub-regions to obtain project numbers $I_{0\tilde{m}}$ by sub-region-year $\tilde{m}$ (see Appendix B.8). This gives a granular geographic distribution of the projects. Second, we draw $I_{0\tilde{m}}$ realizations of location and scale from the transactions data for each sub-region-year $\tilde{m}$.

4.2 Likelihood function

Let $\boldsymbol{Y} = \{[j(i,1), p_i, \boldsymbol{z}_i, y_{ij(i,1)}]_{i \in \mathcal{I}_J}, (I_{0m})_{m \in \mathcal{M}}\}$ summarize the data used in the likelihood function. Let the parameters be $(\boldsymbol{\theta}, \boldsymbol{\delta})$, where $\boldsymbol{\theta} = (\boldsymbol{\beta}, \boldsymbol{\alpha}, \boldsymbol{\sigma}, \boldsymbol{\gamma}, \boldsymbol{\eta})$ and $\boldsymbol{\delta} = (\delta_j)_{j \in \mathcal{J}_J}$. Rewriting probability expressions (32) and (33) in terms of the parameters, $f_{j(i,1)}^*(p_i, \boldsymbol{\theta}, \boldsymbol{\delta}|\boldsymbol{z}_i, y_{ij(i,1)})$ is the joint probability measure of a project of type $\boldsymbol{z}_i$ with bargaining skill shifter $y_{ij(i,1)}$ selecting product $j(i,1)$ at price p_i and $s_{m0}(\boldsymbol{\theta}, \boldsymbol{\delta}) = 1 - \sum_{j \in \mathcal{J}_J} s_{mj}(\boldsymbol{\theta}, \boldsymbol{\delta})$ is the market share (i.e. unconditional choice probability) of the

[28] In the integral for $f_j^*(p|\boldsymbol{z}_i, y_i)$ in (32) we use importance sampling to avoid drawing cost shocks ν_{ic} that are uninformative because they imply negative markups at price p, which have zero probability. In estimation we use 100 independent draws per i. See Appendix D.

outside good in region-year market m. The log-likelihood function is given by

$$l(\boldsymbol{\theta}, \boldsymbol{\delta}, \boldsymbol{Y}) = \Sigma_{i \in \mathcal{I}_J} \ln f^*_{j(i,1)}(p_i, \boldsymbol{\theta}, \boldsymbol{\delta} | \boldsymbol{z}_i, y_{ij(i,1)}) + \Sigma_{m \in \mathcal{M}} I_{m0} \ln s_{m0}(\boldsymbol{\theta}, \boldsymbol{\delta}) \tag{34}$$

where the first term is the sum of the contributions from the $|\mathcal{I}_J|$ projects for which inside goods are chosen (for which we have transaction-level data) and the second is the sum of contributions from the $\Sigma_{m \in \mathcal{M}} I_{m0}$ projects for which the outside good is chosen. Parameters are obtained by maximizing the likelihood. To reduce the dimension of the maximization problem we use the inversion method in Berry et al. (1995). We concentrate (34) with respect to the vector of mean utilities $\boldsymbol{\delta}$ by inverting the market share functions $s_M(\boldsymbol{\theta},\boldsymbol{\delta}) = [s_{Mj}(\boldsymbol{\theta},\boldsymbol{\delta})]_{j \in \mathcal{J}}$, where market M is Great Britain over the full 4-year period of the data, obtained by aggregating the market shares in (33). This gives a vector of mean utilities $\boldsymbol{\delta}(\boldsymbol{\theta}, \boldsymbol{s}_M)$ for any candidate value of parameters $\boldsymbol{\theta}$ and observed market share vector $\boldsymbol{s}_M$.[29] The parameters that maximize the log-likelihood function are given by $\hat{\boldsymbol{\theta}} = \text{argmax}_{\boldsymbol{\theta}}\ l(\boldsymbol{\theta}, \boldsymbol{\delta}(\boldsymbol{\theta}, \boldsymbol{s}_M), \boldsymbol{Y})$.[30]

4.3 Informal discussion of identification

Identification differs in three ways from the standard discrete-choice setting with micro data discussed in Berry and Haile (2024). First, the issue of endogenous price regressors does not arise, as prices are modeled as the outcome variable in a markup equation (10), rather than as an explanatory variable in product choice. Second, because the price equation requires utility to be denominated in money units, we cannot re-scale utility to normalize the scaling parameter σ_ε. Third, the model has bargaining parameters.

Since we have data on transport costs we estimate transport cost parameters $\boldsymbol{\alpha}$ directly in a first step using the regression model $T_{ij} = \alpha_0 + \boldsymbol{\alpha}\mathbf{t}_{ij} + \zeta_{ij}$ where T_{ij} denotes observed transport costs (in money units) in project i per unit of volume and we assume that ζ_{ij} is observation error such that $E[\zeta_{ij}|1, \mathbf{t}_{ij}] = 0$.[31] The estimates $\hat{\boldsymbol{\alpha}}$—and therefore fitted transport costs $\hat{\boldsymbol{\alpha}}\mathbf{t}_{ij}$ for each i and j—are treated as known

[29] To obtain $\boldsymbol{\delta}(\boldsymbol{\theta}, \boldsymbol{s}_M)$ we follow Berry et al. (1995) and iterate the system $\boldsymbol{\delta}^{\iota+1} = \boldsymbol{\delta}^{\iota} + \ln[\boldsymbol{s}_M] - \ln[\boldsymbol{s}_M(\boldsymbol{\theta}, \boldsymbol{\delta}^{\iota})]$ where ι is an iteration count. The jth element of $\boldsymbol{s}_M$, i.e. the national market share for product j for the 4-year period of the data, is given by $\Sigma_i D_{ij}/I$ where $I = |\mathcal{I}_J| + \sum_{m \in \mathcal{M}} I_{0m}$ is the total number of projects including those that select the outside good. We use a convergence criterion of $\left\|\delta^{\iota+1} - \delta^{\iota}\right\| < 1 \times 10^{-12}$. The function $\boldsymbol{s}_M(\boldsymbol{\theta}, \boldsymbol{\delta})$ is defined in (33), changing m to M.

[30] The maximization of the likelihood is done in Matlab using numerical gradients. There are 92 parameters. The estimation algorithm takes about 16 hours to converge on an Intel(R) Xeon(R) CPU with 2.60GHz and 64 GB RAM.

[31] 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.

when maximizing the likelihood with respect to remaining parameters, and play a role similar to a consumer-varying price variable in identification (as discussed in the next paragraph). The constant α_0 is absorbed into mean utility δ_j (see equation (15)).

Remaining utility parameters are identified using standard discrete-choice arguments. The covariance between project-product interaction variables $[\mathbf{z}_{ij}]_{j\in\mathcal{J}}$ and product choice is informative about the taste parameters $\boldsymbol{\beta}$ and the spread parameters $[\sigma_k]_{\forall k}$. The mean utility effects $\boldsymbol{\delta}$ are obtained, given any $\boldsymbol{\theta}$, by matching predicted and observed market shares, since the model satisfies the inversion conditions in Berry (1994). The covariance between product choices and fitted monetary transport costs $\hat{\boldsymbol{\alpha}}\mathbf{t}_{ij}$ is informative about σ_ε. The covariance (across region-years m) between observed surplus-shifters for inside goods and outside good market shares s_{m0} is informative about σ_J.

Turning to the cost parameters, the covariance between price and cost-shifters $\mathbf{w}_{ij}$ is informative about marginal cost parameters $\boldsymbol{\gamma}$. The relationship between price and quantity q_i is informative about the transaction-specific fixed cost γ_0. The variance of prices, holding fixed the GEV parameters and other variables, is informative about the parameter σ_ν on the transaction-specific cost shock.

The bargaining parameters impact on prices so, to discuss their identification, we turn to the markups equation (10). Let j and j' be the first-best and runner-up goods respectively, so that surplus advantage is $(w_{ij}-w_{ij'})$, and price $p_{ij} = c_{ij} + \min\ [b_{ij}(w_{ij} - w_{i0}), w_{ij} - w_{ij'}]$, where, in the standard case, $(w_{ij} - w_{i0}) \geq (w_{ij} - w_{ij'}) > 0$. Variation in $(w_{ij} - w_{ij'})$ across projects is fully passed through to price if $b_{ij} = 1$ and has no impact if $b_{ij} = 0$. Despite the runner-up j' being unobserved, the data are informative about $(w_{ij} - w_{ij'})$. This is because we observe (i) the distance between project i and the chosen product j and (ii) the distances between i and products in the set $\mathcal{J} \setminus \mathcal{J}_f$ of candidates for runner-up j'. Hence, other things equal, a project for which (i) is unusually low, or the minimum value of the distances in (ii) is unusually high, will have a relatively high value of $(w_{ij} - w_{ij'})$. Two bargaining parameters enter b_{ij}: η_1 determines the average level of b_{ij} and η_2 determines how it varies with buyer-seller size difference. Thus, conditional on observing first-best product j, the observed covariance of price with observed shifters of $(w_{ij} - w_{ij'})$ is informative about η_1 and the observed covariance of price and buyer-seller size difference y_{ij} is informative about η_2.

5 Estimates and model fit

Parameter Estimates The transport cost parameters $\boldsymbol{\alpha}$ in Panel A of Table 4 are estimated in a first step by OLS. The estimates for $\boldsymbol{\alpha}$ imply a different transport cost in each transaction depending on the distance and annual fuel prices in $\mathbf{t}_{ij}$. The average

A: *Transport cost parameters*					
DST_{ij}	α_1	(100km)		0.116	(0.004)
$DST_{ij} \times FUEL_{t(i)}$	α_2	(100km × £/L)		0.048	(0.004)
DST_{ij}^2	α_3			-0.010	(0.001)
R^2				0.825	
B: *Parameters in value* v_{ij}		Bargaining		TIOLI	
Same-region-produced	β_1^o	0.023	(0.004)	0.015	(0.003)
Within-100km-produced	β_2^o	0.040	(0.004)	0.018	(0.003)
North × red	β_3^o	0.046	(0.006)	0.041	(0.005)
North × wirecut	β_4^o	0.127	(0.007)	0.114	(0.006)
Absorption × rainfall	β_5^o	-0.049	(0.045)	0.014	(0.039)
Strength × frost	β_6^o	0.264	(0.129)	0.102	(0.112)
Scaling term (red)	σ_{red}	0.027	(0.039)	0.022	(0.036)
Scaling term (wirecut)	$\sigma_{wirecut}$	0.001	(0.036)	0.006	(0.043)
GEV nesting	σ_J	0.619	(0.023)	0.771	(0.019)
GEV scaling	σ_ε	0.207	(0.008)	0.145	(0.003)
Product effect ($\bar{\delta}$ is mean δ_j)†	$\bar{\boldsymbol{\delta}}$	0.847	(0.015)	0.542	(0.014)
C: *Parameters in cost* c_{ij}					
Gas price index	γ_g	0.881	(0.030)	0.917	(0.023)
Wages (£10k/year)	γ_w	0.410	(0.047)	0.195	(0.035)
LOW (1/0)‡	γ_{lq}	-0.038	(0.007)	-0.038	(0.007)
Plant effect ($\bar{\gamma}$ is median)	$\bar{\gamma}$	0.751	(0.057)	1.080	(0.042)
Fixed per-transaction cost	γ_f	0.151	(0.029)	0.138	(0.029)
Scaling term for cost shock	σ_ν	0.071	(0.001)	0.068	(0.001)
D: *Bargaining parameters*					
Seller dummy $1[l \in \mathcal{F}]$	η_1	1.189	(0.020)	-	-
Agent l size y_l	η_2	0.262	(0.024)	-	-
Log likelihood		-46303.929		-446480.675	
LR test statistic $\backsim \chi^2(2)$		353.492		–	

E: *Seller relative bargaining skill* $b_{if(j)} \in [0, 1]$

	Bargaining	TIOLI
Mean	0.542	1
SD	0.062	0
Min	0.403	1
Max	0.704	1

Notes. Panel A: dep. var. is transport costs; #observations: 11,855. Panels B-D: estimates by maximum likelihood; #observations: $I = |\mathcal{I}_J| + \Sigma_m I_{0m} = 18,477$. We do not report regional dummies, buyer-seller dummies in utility and plant dummies in cost. †This row reports the sample mean and sample standard error of the mean utilities $(\delta_j)_{j \in \mathcal{J}_J}$ that are concentrated out in the sense of Berry (1994). ‡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 (see text for definition). The 0.1% significance level for the χ^2 distribution with 2 d.f. is 13.82. Statistics in Panel E for $b_{if(i,1)}$ are for unit of observation $i \in \mathcal{I}_J$. Units for transport costs and surplus estimates is £100 per 1000 bricks. Standard errors in parentheses; those in panels B-D are adjusted to account for error in transport cost parameters $\boldsymbol{\alpha}$ estimated in a first step.

Table 4: Estimated parameters

transport cost (across projects $i \in \mathcal{I}_J$) is £23.74 per 1000 bricks, which is a substantial fraction (13%) of average unit prices (£182.26 per 1000) reported in Table 1. The 1st and 99th percentiles (for $i \in \mathcal{I}_J$) are £9.30 and £50.11 per 1000 bricks respectively, consistent with executive testimony in CC (2007).[32] The negative coefficient on the square of distance is consistent with the simple choice model in section 2.

The parameters in Panels B-D are estimated by maximum likelihood for two specifications: the baseline bargaining model and the TIOLI specification (nested within the baseline model) which restricts the bargaining parameters.[33]

The remaining value parameters are in panel B. The parameter σ_ϵ scales the GEV term ε_{ij} to money-metric units (surplus is scaled in units of £100 per 1000 bricks). The utility parameters $\boldsymbol{\beta}$ in Panel B have as expected a positive home-region taste effect for each of the two home-region variables used. Projects in the north have positive effects for red bricks and wire-cut bricks.[34] Rainfall has a negative effect on taste for water absorption and frost has a positive effect on taste for brick strength. These signs are as expected. Scaling terms on random effects are small and insignificant. The GEV nesting parameter σ_J is less than one, which implies that the εs for inside goods are positively correlated. There are three further groups of unreported utility parameters: mean utility effects $\boldsymbol{\delta}$, NUTS1-region dummies, and buyer-seller taste effects.[35]

Cost parameters are in Panel C. Parameters on gas price, wages, and the low-quality product indicator have the expected sign. The effects for each of the 36 plants are not reported. The per-transaction fixed cost parameter γ_f is small, about £15 per transaction or 9% of the average unit cost of 1000 bricks, which has a negligible effect on unit costs except in the smallest transactions. The spread parameter σ_ν on project-specific costs implies a standard deviation of about 4% of average unit costs.

The bargaining skill coefficients in Panel D comprise a seller effect η_1 and an effect for relative agent size η_2. The positive sign for η_2 indicates that larger agents have better negotiating skills. Panel E reports the implications for the seller's relative bargaining

[32] 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 D, Table 5) is about £167 for 1000 bricks. The 99th percentile transport cost, $\pounds 50.11$, is 23% of the cost of delivered bricks, $\pounds 50.11 + \pounds 167.00 = \pounds 217.11$.

[33] We adjust standard errors as in Murphy and Topel (1985) to account for two-step estimation.

[34] For parsimony we use two large regions, north and south, to interact with aesthetic characteristics. 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 in the next section are consistent with this pattern.

[35] If a buyer never trades with a seller we drop it from the choice set; equivalent to setting its buyer-seller effect to a large negative number. As noted in footnote 12 in section 2, this happens only in a few cases: 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.

skill $b_{ij} = \mathrm{a}_{f(j)}/(\mathrm{a}_{f(j)} + \mathrm{a}_{h(i)})$. The mean of $\{b_{ij(i,1)}\}_{i\in\mathcal{I}_J}$ is 0.542 which indicates similar bargaining skill on average for sellers and buyers. The table shows the variation around this mean because of relative agent size.

Likelihood ratio test of TIOLI pricing The TIOLI model is obtained by imposing the constraint $b_{ij} = 1$. Thus, we can test the hypothesis that $b_{ij} = 1, \forall(i,j)$ using the likelihood ratio test statistic

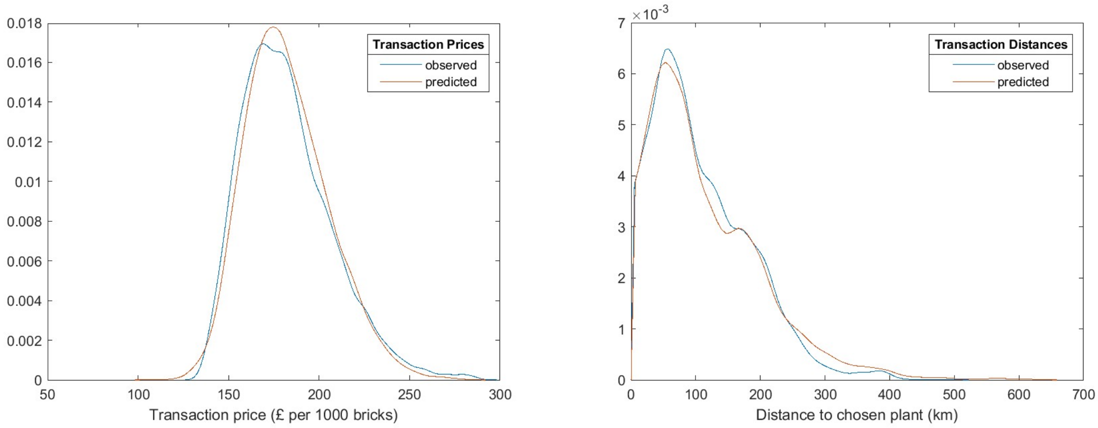
$$\lambda_{LR} = -2[\max_{\boldsymbol{\theta}} l(\boldsymbol{\theta}, \boldsymbol{\delta}(\boldsymbol{\theta}, \boldsymbol{s}_M), \boldsymbol{Y} | b_{ij} = 1, \forall(i, j(i,1))) - \max_{\boldsymbol{\theta}} l(\boldsymbol{\theta}, \boldsymbol{\delta}(\boldsymbol{\theta}, \boldsymbol{s}_M), \boldsymbol{Y})]$$

which has a $\chi^2(2)$ distribution since the restriction eliminates two bargaining parameters. The test statistic in Table 4 exceeds the critical value at a significance level 0.1% (13.82) so we reject the restriction. See section 4.3 for a discussion of identification of the bargaining parameter.

Simulating outcomes and model fit To consider the fit of the bargaining model we compare the outcomes of the model, particularly the dispersion of prices and distances, with those in the transactions data. To do this, we simulate a price and product choice for each project in the transactions data, conditioning on observed project characteristics $(\boldsymbol{z}_i, [y_{ij}]_{j\in\mathcal{J}_j})$. The transactions data record projects if the buyer chooses an inside good, so we condition on this in the simulation. For each project i in the transactions data we proceed in three steps (see Appendix E for details). First, we draw a realization $\boldsymbol{\nu}_i$ of the cost effect from its density $g_{\boldsymbol{\nu}|J}(z_i)$ conditional on $\boldsymbol{z}_i$ and choice of an inside good. Second, we simulate a choice $j \in \mathcal{J}_J$ using product choice probabilities $[s_{j|J}(\mathbf{z}_i, \boldsymbol{\nu}_i)]_{j\in\mathcal{J}_J}$ that condition on $\boldsymbol{\nu}_i$ and choice of an inside good. And, third, we draw a price from the density of price conditional on choice of product j and cost effect $\boldsymbol{\nu}_i$, given by $f^*(p|j, \mathbf{z}_i, y_{ij}, \boldsymbol{\nu}_i) = f_j^*(p|\mathbf{z}_i, y_{ij}, \boldsymbol{\nu}_i)/s_j(\mathbf{z}_i, \boldsymbol{\nu}_i)$.

We compare the overall distribution of simulated distances and prices with their observed counterparts in Figure 2. In Panels A-C of Table 5 we consider the fit of simulated prices from a number of angles, including 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. Overall, we regard the prices and distances simulated from the model as fitting the data well.

External cost validation We perform an external validation exercise for the model's cost predictions. We are fortunate to have external cost data provided by the sellers which was not used in estimation. These data consist of operating costs C_n for each



Notes: The observed data are per-unit prices and distances for $i \in \mathcal{I}_J$ in the full sample period. A predicted outcome is simulated from the model for each project, conditional on choice of an inside good and the project's observable type, as described in section 5.

Figure 2: Distance and price densities

plant-month n for the plant-months covered by the transactions data. 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 the set of plant-months. Given that some plants produce a wider set of products than the type of brick we study (facing bricks), we limit $\mathcal{N}$ to plants that specialize in facing bricks. Table 6 compares the model predictions with the external data. Definitions (a) and (b) use plants in which facing bricks are 90% and 99% of output respectively ($|\mathcal{N}|$ being 182 and 106). The model's unit cost prediction is calculated as $\Sigma_{i \in \mathcal{I}_J}(c_i q_i)/\Sigma_{i \in \mathcal{I}_J} q_i$, where c_i is the simulated cost for transaction i. We do not expect a particularly close match with the cost data, as the predicted and observed objects do not exactly correspond conceptually because of differences between accounting and economic costs. Subject to this caveat, the match between the model's prediction and the external cost data is a reasonably good validation of the model.

6 Market power, pricing policy and concentration

In this section we analyze market power and mergers with negotiated pricing. We calculate equilibrium markups under actual and counterfactual pricing policies and concentration levels. To avoid inter-year cost variation we consider a single year, 2005; in this section the results, and set notation $\mathcal{I}$ and $\mathcal{I}_J$, include only projects for 2005.

Elasticities, diversion ratios and surplus advantage In the standard uniform-pricing case, buyers are price-takers, and choice elasticities are calculated by changing prices. In our model, every buyer negotiates a different price. Thus, we compute choice elasticities with respect to cost rather than price. To do so we adjust the component

	Observed	Predicted
A: Price (£/1000 bricks)		
Mean	182.26	182.81
Standard deviation	24.84	23.17
Pooled standard deviation (product groups)	14.74	15.00
B: Mean price, transaction quantity		
Smallest 25% (of transactions)	179.21	181.27
Largest 25%	186.48	184.89
C: Mean price, buyer/seller size ratio		
Smallest 25% (of transactions)	190.64	191.55
Larges 25%	177.77	178.22
D: Distance (km) DST_{ij}		
Lower quartile	51.42	50.34
Median	91.62	91.83
Upper quartile	157.91	167.59

Notes: The simulated values are calculated as described in section 5. Statistics are for $i \in \mathcal{I}_J$ in the full sample period.

Table 5: Fit: prices and distances

	External (a)	External (b)	Predicted
Unit cost c in £/1000 bricks	167.75	170.00	167.37

Notes: The predicted unit cost is $\Sigma_{i \in \mathcal{I}_J} c_i / \Sigma_{i \in \mathcal{I}_J} q_i$ where costs c_i are simulated as in text as described in section 5. The external cost measures are averages of plant-month level unit costs. Measures (a) and (b) are for plants for which respectively 90% and 99% of volume is facing bricks.

Table 6: External validation: comparison with external cost data

of unit cost, which, for any j, is uniform across i for a given year. In equation (16) this component is $\bar{c}_j = \boldsymbol{\gamma} \mathbf{w}_{tj}$ where year t is 2005. The own-product cost elasticities in Panel A of Table 7 are on average -12.77. To show the impact of spatial differentiation, Panel A compares the cross-elasticities of product pairs with low and high inter-plant distances; as expected, a greater distance between the products' plants is associated with a lower cross-elasticity.

To measure the importance of multi-product ownership, we calculate the diversion ratio from product j (given an increase in $\bar{c}_j$) to other products of seller $f(j)$. This is 0.42 on average across products. It varies across products, because sellers vary in portfolio size. The mean diversion ratio to inside products as a group, including those of seller $f(j)$, is 0.88. This exceeds the joint market share of inside products (0.728 on average across region-years, see section 2), which indicates that inside goods tend to be closer substitutes for each other than for the outside good.

A: Elasticities and diversion ratios wrt cost of product $j \in \mathcal{J}_J$			
		Mean	SD
Own-elasticity		-12.77	1.37
Cross-product elasticity	bottom 10% of product pairs by inter-plant distance	0.29	-
	top 10% of product pairs by inter-plant distance	0.07	-
Diversion ratio	to other seller $f(j)$'s products	0.42	0.18
	to other inside products	0.88	0.03
B: Surplus advantage Δw_i of first-best for $i \in \mathcal{I}_J$			
£/1000 bricks		Mean	SD
With portfolio effects	$\Delta w_i = [w_{ij(i,1)} - w_{ij(i,2)}]$	19.61	16.98
Without portfolio effects	$\Delta w_i = [w_{ij(i,1)} - \max_{j \in \mathcal{J} \setminus j(i,1)} w_{ij}]$	13.33	12.91

Notes In Panel A the unit of observation is the product ($j \in \mathcal{J}_J$). Elasticities are with respect to $\bar{c}_j = \boldsymbol{\gamma}^c \mathbf{w}^c_{tj}$ where t is year 2005. Cross elasticities are for top and bottom 10% of product pairs by distance between products' plants. The two diversion ratios are defined as follows, respectively: $1 - (\partial s_{f(j)}/\partial \bar{c}_j)/(\partial s_j/\partial \bar{c}_j)$ and $1 - (\partial s_J/\partial \bar{c}_j)/(\partial s_j/\partial \bar{c}_j)$ where $s_{f(j)}$ is the market share of seller f and s_J is the market share of all inside goods. In Panel B the unit of observation the project ($i \in \mathcal{I}_J$). To simulate elasticities and diversion ratios we use 100 iid draws per project of ν_i from G_ν. For surplus advantage we simulate a markup for each project setting b=1, conditioning on z_i and choice of an inside good, as described in section 5.

Table 7: Demand elasticities, diversion ratios, and surplus advantage

We now take a look at the first-best surplus advantages $\{w_{ij(i,1)} - w_{ij(i,2)}\}_{i \in \mathcal{I}_J}$ implied by the model. These are a key determinant of markups and can be decomposed into a value and a cost difference

$$w_{ij(i,1)} - w_{ij(i,2)} = [v_{ij(i,1)} - v_{ij(i,2)}] - [c_{ij(i,1)} - c_{ij(i,2)}] \tag{35}$$

where the value difference includes spatial and non-spatial differentiation.

An important factor that affects the surplus advantage is the first-best seller's product portfolio $\mathcal{J}_{f(i,1)}$, which determines the residual set $\mathcal{J} \setminus \mathcal{J}_{f(i,1)}$ that are candidates to be the runner-up. A "portfolio effect" arises if the first-best seller owns the product that would otherwise have been runner-up, thus increasing the surplus difference relative to the case of single-product sellers.

Panel B presents statistics for the simulated sample $\{\Delta w_i\}_{i \in \mathcal{I}_J}$.[36] There is substantial cross-project variation. To evaluate the importance of portfolio effects in the mean and variation of the surplus advantage, we report a measure of surplus advantage, $w_{ij(i,1)} - \max_{j \in \mathcal{J} \setminus j(i,1)} w_{ij}$, where the difference is with the next-best product in $\mathcal{J} \setminus j(i,1)$ rather than $\mathcal{J} \setminus \mathcal{J}_{f(i,1)}$. The table shows that portfolio effects substantially increase the surplus advantage. They also increase the variance, indicating that their

[36]For each i we calculate Δw_i by simulating price, cost, and $j(i,1)$ as in section 5, setting $b_{ij} = 1$ (as in TIOLI) and using the TIOLI result that $p_{ij(i,1)} - c_{ij(i,1)} = w_{ij(i,1)} - w_{ij(i,2)}$.

	Simulated PCMs $\{M_i\}_{i\in\mathcal{I}_J}$	Expected PCMs given locations $\{E[M\|l_i]\}_{i\in\mathcal{I}_J}$	Mean distance minus expected distance of choice $\{\widehat{DST}_i - E[DST_{ij(i,1)}\|l_i]\}_{i\in\mathcal{I}_J}$
	(1)	(2)	(3)
Mean, $i \in \mathcal{I}_J$	0.076	0.083	80.199
CV, $i \in \mathcal{I}_J$	0.779	0.237	–
Mean, bottom 10%	0.006	0.056	69.682
Mean, top 10%	0.201	0.124	152.877

Notes: PCM defined as $(p-c)/p$.CV is coefficient of variation. Expectation operator E is with respect to observed and unobserved project type. Top and bottom deciles refer to the top and bottom 10% of projects: in column (3) projects are sorted by the margin measure in column (2) and in columns (1) and (2) by the margin measure in the same column. $\widehat{DST}_i = (1/|\mathcal{J}_J|) \times \Sigma_{j\in\mathcal{J}_J} DST_{ij}$ is mean distance from i to inside products. Column (1) uses a single draw of the random terms per project as described in section 5. Column (2) uses 1000 draws from distribution for observed and unobserved heterogeneity up to project location l_i to capture variation in markups from location.

Table 8: Market power: PCMs M_i.

relevance varies across transactions.

Market power To measure market power we simulate a price-cost margin (PCM), $(p-c)/p$, denoted M_i, for each $i \in \mathcal{I}_J$, conditioning on observed characteristics and choice of an inside good. We simulate prices and costs using the method in section 5. The resulting sample $\{M_i\}_{i\in\mathcal{I}_J}$ is described in column (1) of Table 8. PCMs have a mean of 7.6%. This is consistent with CC (2007)'s assessment that, despite its high concentration, the industry is characterized by average or below-average profit levels, for industries with similar risk profiles.

PCMs vary a lot across projects, with a coefficient of variation 0.779. Project location l_i is one factor driving this variation. To isolate its role we obtain the expected PCM conditional on location $E(M|l_i)$ for each $i \in \mathcal{I}_J$. To do this, we integrate out, for each $i \in \mathcal{I}_J$, observed and unobserved project type other than location l_i. We follow the steps in section 5 repeatedly for each project i, where, in each of 1000 repetitions, we also draw a random value of $\boldsymbol{z}$ (with replacement) from the transactions dataset while holding one component of $\boldsymbol{z}$, namely project location l_i, at its observed level. Comparing the CV between columns (1) and (2), about a quarter of the variation of PCMs can be attributed to observed location.[37] To characterize locations of high- and low-PCM transactions we sort the projects by $E(M|l_i)$. In column (3) for each i we subtract the expected distance to the chosen plant from the mean distance to all plants—a measure of the first-best seller's geographic advantage for project i—and we note that projects that have the

[37]This is a conservative estimate of the effect of location, i.e. it could be higher, since it does not account for the part of transport cost that is unobserved and included in ε (see section 3.3).

greatest markups tend to have the highest values for this measure, consistent with the seller leveraging its transport cost advantage, a pattern known as "freight absorption" in the spatial pricing literature.

Counterfactual pricing policies To study the impact of negotiated pricing on market power we calculate a uniform pricing counterfactual. In the uniform-pricing case, prices are set by sellers before $(\boldsymbol{\nu}, \boldsymbol{\varepsilon})$ is known so that the model has the standard supply side model in Berry et al. (1995). To analyze uniform prices we write the model in a more general form, in which either pricing policy can apply, depending on the indicator variable $\Lambda \in \{0, 1\}$, which is defined such that $\Lambda = 0$ for negotiated pricing or $\Lambda = 1$ for uniform pricing. For each project i, we condition on the observed characteristics i.e. $(\boldsymbol{z}_i, [y_{ij}]_{j \in \mathcal{J}_J})$ and suppress them from notation. Then the choice indicator function for product j and pricing policy Λ is

$$1_{ij\Lambda}(\boldsymbol{\nu}_i, \boldsymbol{\varepsilon}_i) = 1[u_{ij\Lambda}(\boldsymbol{\nu}_i, p_j) + \varepsilon_{ij} > \max(\{u_{ij\Lambda}(\boldsymbol{\nu}_i, p_j) + \varepsilon_{ij'}\}_{j' \in \mathcal{J}_J \setminus \{j\}}, \varepsilon_{i0})] \tag{36}$$

where for project i, product j, and and pricing policy Λ, the function

$$u_{ij\Lambda}(\boldsymbol{\nu}_i, p_j) + \varepsilon_{ij} = \omega_{ij}(\boldsymbol{\nu}_i) - \Lambda(p_j - c_{ij}(\nu_{ic})) + \varepsilon_{ij}$$

gives either surplus or utility depending on the pricing policy Λ, and $[p_j]_{j \in \mathcal{J}_J}$ is an arbitrary set of uniform prices set by sellers when $\Lambda = 1$. Product j's market share, seller f's profit, and total buyer surplus U, are

$$\begin{aligned}
s_j &= \tfrac{1}{|\mathcal{I}|}\textstyle\sum_{i \in \mathcal{I}} \int_{(\boldsymbol{\nu}, \boldsymbol{\varepsilon})} 1_{ij\Lambda}(\boldsymbol{\nu}, \boldsymbol{\varepsilon}) \mathrm{d}G_{(\boldsymbol{\nu}, \boldsymbol{\varepsilon})} \\
\Pi_f &= \textstyle\sum_{j \in \mathcal{J}_f} \sum_{i \in \mathcal{I}} q_i \int_{(\boldsymbol{\nu}, \boldsymbol{\varepsilon})} 1_{ij\Lambda}(\boldsymbol{\nu}, \boldsymbol{\varepsilon}) \{\Lambda(p_j - c_{ij}(\nu_{ic})) + (1 - \Lambda)\rho_{ij}(\boldsymbol{\nu}, \boldsymbol{\varepsilon})\} \mathrm{d}G_{(\boldsymbol{\nu}, \boldsymbol{\varepsilon})} \\
U &= \textstyle\sum_{i \in \mathcal{I}} q_i \int_{\boldsymbol{\nu}} \sigma_\varepsilon \mathbb{E}_{\boldsymbol{\varepsilon}}(\max[\{u_{ij\Lambda}(\boldsymbol{\nu}, p_j) + \boldsymbol{\varepsilon}_{ij'}\}_{j' \in \mathcal{J}_J}, \boldsymbol{\varepsilon}_{i0}]) \mathrm{d}G_{\boldsymbol{\nu}} - (1 - \Lambda) \sum_{f \in \mathcal{F}} \Pi_f
\end{aligned} \tag{37}$$

where in the second line $\rho_{ij}(\boldsymbol{\nu}_i, \boldsymbol{\varepsilon}_i)$ is the markup given by equation (19). The expression in the third line for U in the uniform pricing case ($\Lambda = 1$) comprises only the first term which is the standard expression for buyer surplus in uniform pricing analysis. In the negotiated pricing case ($\Lambda = 0$) the first term is total joint surplus (with the highest-surplus alternative in each project) so we subtract total profit $\sum_{f \in \mathcal{F}} \Pi_f$ to get buyer surplus.[38]

[38] In the negotiated pricing case $\Lambda = 0$ we simulate outcomes as in section 5 with one draw of $\boldsymbol{\nu}_i$ per project, the only difference is that now we no longer condition on choice of an inside good when drawing $\boldsymbol{\nu}_i$. For each $\boldsymbol{\nu}_i$ draw from G_ν we simulate a choice (including $j = 0$) using the probabilities $\int_\varepsilon s_j(\boldsymbol{z}_i, \boldsymbol{\nu}_i) \mathrm{d}G_{\boldsymbol{\varepsilon}}$, $\forall j$, where $s_j(\boldsymbol{z}_i, \boldsymbol{\nu}_i)$, is defined in (31), and we simulate a negotiated price using the

In the uniform pricing case ($\Lambda = 1$) we assume multi-product Nash equilibrium so that prices solve

$$\boldsymbol{p}_f(\boldsymbol{p}_{-f}) = \arg\max_{\boldsymbol{p}_f} \Pi_f(\boldsymbol{p}_f, \boldsymbol{p}_{-f}) \quad \forall f \in \mathcal{F} \tag{38}$$

where $\boldsymbol{p}_f = [p_j]_{j \in \mathcal{J}_f}$ is the vector of prices for seller f and $\boldsymbol{p}_{-f} = [p_j]_{j \in \mathcal{J} \setminus \mathcal{J}_f}$ is the vector for the other sellers and $\Pi_f(\boldsymbol{p}_f, \boldsymbol{p}_{-f})$ is the function for f's profits (37) expressed in terms of prices.[39] With equilibrium prices in hand, equilibrium markups for the uniform pricing case are given by $\boldsymbol{\rho}_i = (p_j - c_{ij})_{j \in \mathcal{J}_J}$.

Panel A of Table 9 reports that uniform pricing increases average markups by 31% (from 15.67 to 20.49 in £/1000) relative to baseline markups. The table decomposes this change into a component for the change from negotiated to TIOLI pricing and a further component for the change from TIOLI to uniform pricing, showing an important effect from the loss of bargaining ability. Uniform pricing reduces the variation of markups across projects (see columns 2 and 3) as we would expect. Column 4 shows that a substantial minority (29%) of projects benefit. Column 5 shows that there is a loss of welfare: the market share for inside goods s_J falls from its (efficient) level under negotiated pricing because some mutually-beneficial trades of inside goods do not take place. Buyer surplus U falls and seller surplus Π falls marginally.

Panel B shows that some sellers benefit but others lose. Sellers are labeled such that if seller f is larger (in terms of total number of transactions y_f) than seller f' then $f > f'$. We find that the smaller sellers ($f \in \{1, 2, 3\}$) benefit and one of the large sellers ($f = 4$) does not benefit from uniform pricing. This is in part because larger sellers have greater bargaining skill and in part because portfolio effects that they enjoy protect them from the pro-competitive effects of negotiated pricing.[40]

Panel C considers how price changes are distributed across projects. The median price change is 4.65% but there is considerable variation across projects: the bottom and top deciles of the price increase are -6.93% and 14.04% respectively.

density of price conditional on choice of product j and cost effect ν_i, given by $f^*(p|j, \boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i) = f_j^*(p|\boldsymbol{z}_i, y_{ij}, \boldsymbol{\nu}_i)/s_j(\boldsymbol{z}_i, \boldsymbol{\nu}_i)$. In the uniform pricing case $\Lambda = 1$ integrals for ν are simulated (using 300 random draws) as in standard uniform pricing models e.g. Berry et al. (1995). See Appendix E.

[39] The system (38) is solved by iteration on the best reply functions where in each step of the iteration we update only one of the sellers prices and we work through each seller in turn. In practice this always achieves convergence in counterfactuals.

[40] A further question we do not consider is whether a seller has a unilateral incentive to choose uniform pricing. This is studied theoretically in the case of TIOLI model in Thisse and Vives (1988) and in a bargaining context in Desai and Purohit (2004). Thisse and Vives (1988) find there is a dominant strategy of negotiated pricing. Desai and Purohit (2004) finds it can be a dominant strategy to set uniform prices depending on parameter values. In our model there is an extra element, namely the bargaining power of the seller (which does not vary across sellers in Thisse and Vives (1988) or Desai and Purohit (2004)): the lower a seller's bargaining parameter the more likely it is to prefer a unilateral switch to uniform pricing.

Panel D delves deeper to understand the types of projects where price increases the least and greatest from a shift to uniform pricing. We classify projects by their level of local competition using two measures. The first is a count of the number of rival sellers less than 50km from the project (a sign of competition) and the second is the model's choice probability for the chosen seller (a sign of a lack of competition). We see that projects with the greatest price increase from uniform pricing tend to have the greatest local competition and vice versa, consistent with the idea that negotiated pricing allows sellers to respond to local competition.

We now compare these results with the literature. The finding that uniform pricing in oligopoly markets increases average markups relative to price discrimination is consistent with empirical results for medical stents (Grennan (2013)) and coffee markets (Villas-Boas (2009)). The finding contrasts with Miller and Osborne (2014) for cement deliveries and Marshall (2020) for wholesale food supplies, which find lower average markups under uniform prices.[41] The finding that a substantial part of the average increase in markups is a result of loss of bargaining ability is consistent with the empirical results in Grennan (2013). The finding that some projects win and some lose from uniform pricing, on the other hand, is consistent with both Miller and Osborne (2014) and Marshall (2020), and our finding that projects in locations with the most competition also lose most from uniform pricing is consistent with Miller and Osborne (2014).[42]

Counterfactual ownership concentration: demerger and merger We now analyze demergers and mergers that reallocate product ownership, holding fixed the set of inside products $\mathcal{J}_J$. Unless otherwise stated, we assume that bargaining parameters b_{ij} are held fixed for each (i, j) pair before and after ownership change, which allows us to focus on other sources of changes to markups. We also compare the merger effects under uniform and negotiated pricing, to assess whether negotiated pricing tends to abate merger effects, as is sometimes claimed.

Under negotiated pricing, the mechanism by which a merger affects prices is different from the uniform pricing case. Suppose marginal costs are unaffected by merger. Then 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 is therefore limited only to those projects

[41] This contrast is likely to be a consequence of the different models employed in these papers: in Miller and Osborne (2014) price discrimination is third-degree (rather than negotiated) and there is no price negotiation between the parties, and in Marshall (2020) the buyers have search costs and price discrimination softens competition because it tends to reduce the intensity of search.

[42] The finding that uniform pricing increases average markups is consistent with the theoretical literature for some specifications of product differentiation (see Corts (1998)). The finding that some projects win and others lose differs from the theoretical result in Thisse and Vives (1988) (in which all buyers lose) which is derived for the simple Hotelling model.

A: Alternative pricing policies	Mean markups ($\bar{p}$) in £/1000			Mean	Market-level outcomes		
	All	Min 10%	Max 10%	$1_{[p<p_b]}$	s_J	U/U_b	Π/Π_b
[Mean p_b = £187.03]	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Negotiated (bargaining, b)	15.67	1.13	45.53	—	0.75	—	—
Negotiated (TIOLI)	19.44	1.36	56.49	0.00	0.75	0.87	1.24
Uniform pricing	20.49	15.72	25.01	0.29	0.56	0.89	0.98
B: Effect of Uniform Pricing by seller				$f=1$	$f=2$	$f=3$	$f=4$
$\Pi_f/\Pi_{f,b}$				1.63	1.99	1.13	0.80
C: Percentiles of distribution of % price changes for $i \in \mathcal{I}_J$.							
	P_5	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	P_{95}
Bargaining to uniform pricing	-10.45	-6.93	-1.24	4.65	9.66	14.04	16.97
D: Characteristics of projects with least and greatest price increases from change to uniform pricing							
					All projects	Least 5%	Greatest 5%
# Competing sellers within 50km of i					1.58	1.49	1.76
Choice probability of i's chosen seller					0.50	0.57	0.49

Notes In Panel A, b denotes outcomes (prices p_b, buyer utility U_b and seller profit Π_b) using the bargaining model. Statistics in columns 1-4 are based on all projects where an inside good is bought. Column 4 is the proportion of projects $i \in \mathcal{I}_J$ enjoying a lower price for the first-best good than the bargaining price. Column 5 is the market share of inside goods (s_J). Columns 6 and 7 report ratios of buyer and seller surplus to the bargaining case. In Panel B, seller f is larger than seller f' if $f > f'$. Panel C gives the percentiles for projects $i \in \mathcal{I}_J$. In panel D "least 5%" and "greatest 5%" are the bottom and top 5% of projects sorted by price change.

Table 9: Counterfactual pricing policies

whose first-best *and* (pre-merger) runner-up products are insiders to the merger. It follows that not all projects i that buy from the insiders are affected by the merger, and none of those that buy from outsiders are. In contrast, with uniform pricing, all buyers are affected to some extent, since in general all uniform prices change.

In our first ownership counterfactual, we demerge to single-product sellers. This exercise measures the market power that derives from multi-product ownership (i.e. portfolio effects). Comparing the single-product seller market structure with the baseline, mean markups (in £/1000) fall by 3.78 (Panel A of Table 10). This is a drop of about 24%. Panel B shows that the drop in price (in £/1000) varies across projects: the bottom decile has a minor fall of 0.16 while the top decile has a fall of 4.54, about 30 times greater. This highlights that the relevance of multi-product ownership varies greatly across projects, i.e. the harm to buyers from the high level of ownership concentration that characterizes the industry is unequally distributed.

Second, we consider two counterfactual mergers: a merger of the two smallest $f \in \{1, 2\}$ and the two largest sellers $f \in \{3, 4\}$ respectively. The former has a very

A: Market-level effects	Mean markups ($\bar{\rho}$) in £/1000 bricks						Market-level outcomes		
	mean	$\bar{\rho} - \bar{\rho}_a$	$f=1$	$f=2$	$f=3$	$f=4$	$\bar{p}$	s_J	Π/Π_a
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Negotiated pricing									
Baseline structure (a)	15.67	—	11.48	12.35	14.21	17.19	187.42	0.75	–
Single-product sellers	11.89	-3.78	10.82	11.46	11.90	12.04	183.64	0.75	0.75
Merger1 $f \in \{1,2\}$	15.69	0.03	11.71	12.49	14.21	17.19	187.45	0.75	1.00
insiders get $b_2 = \max[b_1, b_2]$	15.71	0.04	12.10	12.49	14.21	17.19	187.47	0.75	1.00
Merger2 $f \in \{3,4\}$	18.77	3.11	11.48	12.35	19.55	20.20	190.53	0.75	1.19
insiders get $b_4 = \max[b_3, b_4]$	19.05	3.39	11.48	12.35	20.68	20.20	190.81	0.75	1.21
Uniform pricing									
Baseline structure (a)	20.49	—	15.53	17.12	19.05	23.22	193.37	0.56	—
Single-product sellers	13.50	-6.99	13.21	13.53	13.44	13.56	186.59	0.63	0.73
Merger1 $f \in \{1,2\}$	20.77	0.27	16.57	17.66	19.12	23.33	193.92	0.56	0.98
Merger2 $f \in \{3,4\}$	24.85	4.36	16.32	18.41	28.02	28.00	197.79	0.51	1.08

B: Percentiles of the distribution of transaction-specific markup changes $\bar{\rho} - \bar{\rho}_a$							
Negotiated pricing	P_5	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	P_{95}
Merger1 $f \in \{1,2\}$	0	0	0	0	0	0	0.32
Merger2 $f \in \{3,4\}$	0	0	0	1.02	2.38	4.24	9.27
Single-product sellers	0	-0.16	-0.50	-1.38	-2.93	-4.54	-8.31

C: Reduction in marginal cost in £/1000 (applied to insider sellers) to leave average brick prices unchanged	
Merger1 $f \in \{1,2\}$	0.15
Merger2 $f \in \{3,4\}$	6.34

Notes: Mean negotiated price in the actual structure is £187.03 (per 1000 bricks). Cost and markup units in £/1000 bricks. $\bar{\rho}_a$ denotes unit markup in the actual market structure. Seller f is larger than seller f' if $f > f'$. In Panel A, column (2) indicates the change in markup relative to the actual structure. Columns (3-8) show average markups by seller. Column (7) is the average price across projects in £/1000 bricks. Panel B gives the percentile markup changes for projects $i \in \mathcal{I}_J$.

Table 10: Counterfactual market structure

small average effect on markups, which supports the CC's decision not to block this merger. The latter has a much larger average effect. Under negotiated pricing (unlike the standard uniform pricing setting), it is relevant to analyze not just the mean but also the distribution of markup changes across projects in $\mathcal{I}_J$. In Panel B we see that the markup effects of the second merger are unequally distributed, and are highly concentrated on the worst-affected decile.

So far the analysis has assumed that bargaining parameters $b_{if(j)}$ are held fixed for each (i, j) pair before and after the merger. Panel A also reports results for an alternative in which the merged seller gets the higher bargaining skill $b_{if(j)}$ between the two sellers that merge; this is the larger seller i.e. $f = 2$ and $f = 4$ respectively. We find that the same results go through qualitatively, though there is a larger effect on markups for products that belong (pre-merger) to the insider sellers with the lower level of bargaining skill ($f = 1$ and $f = 3$ respectively).

To compare merger effects under different pricing policies, we include results for uniform pricing in Panel A. The comparison can be summarized in four points. First, as we see in column (1), for *each* of the market structures, average markups are always higher under uniform pricing (and not just at the observed market structure). Second, average markups increase only for transactions with insider sellers under negotiated pricing, but increase for *all* sellers under uniform pricing; we see this from the reported seller-wise impacts in Panel A. Third, negotiated pricing abates the average markup-increasing effects of a concentration-increasing merger—the average markup change in the table for any given concentration increase is always lower under negotiated than uniform pricing. Fourth, under negotiated pricing the distribution of effects from merger is much more unequal across transactions, such that large adverse competitive effects can arise, and for some of these the harm can be greater than under uniform pricing.[43]

Panel C computes the minimum cost reduction for merging parties such that the average transaction price does not increase. With negotiated pricing, the transaction price is often determined by the runner-up's cost rather than the first-best's cost.[44] Consequently, an efficiency gain for an insider seller may leave prices unchanged for its own customers while reducing prices for customers of outsiders sellers to which it is a runner-up. For this reason, we calculate the cost reduction needed to keep average prices constant, not just the prices of the merging parties. We see that for both mergers the required cost reduction is greater than the average markup increase from the merger. Hence, a cost reduction that exactly offsets the markup increase is not enough.

Robustness In a robustness exercise we estimate the alternative bargaining model (see section 3) which assumes that the disagreement point in negotiations with the first-best is to buy from the runner-up at a zero markup. The estimated parameters are reported in Appendix G. Table 11 shows that marginal costs, equilibrium markups and counterfactual results are similar to baseline model. Columns 1 and 2 give costs and markups at the observed market structure. Columns 3 and 4 give the mean change in markups, and the proportion of transactions in which prices fall, under the uniform-pricing counterfactual. The last four columns give percentiles of changes to markups in

[43] Comparing with the (relatively small) literature, the finding that negotiated pricing abates average merger effects is consistent with the theoretical results in (Cooper et al. (2005)) which are derived in a spatial context and the results from a calibrated model in Sweeting et al. (2020) developed for a merger of private-label breakfast cereal sellers.

[44] To see this, the bargaining solution, in equation (10), is $\rho_{j(1)} = \min\ [b_{ij(1)}(w_{j(1)} - w_0), w_{j(1)} - w_{j(2)}]$. Where $w_{j(1)} - w_{j(2)}$ is the minimum this implies $p_{j(1)} = c_{j(1)} + w_{j(1)} - w_{j(2)}$ which can be rewritten $p_{j(1)} = c_{j(2)} + (v_{j(1)} - v_{j(2)})$. See Appendix F for further discussion.

Buyer's disagreement point			Counterfactual pricing policy/market structure					
			Uniform pricing		Demerger, $\Delta\bar{p}$ (%)		Merger 2, $\Delta\bar{p}$ (%)	
	c	ρ	$\rho_u - \rho$	$1_{[\rho_u < \rho]}$	P_{50}	P_{90}	P_{50}	P_{90}
Baseline (w_{i0})	171.76	15.67	4.83	0.29	-1.38	-4.54	1.02	4.24
Alternative ($w_{ij(i,2)}$)	172.12	15.05	4.14	0.30	-1.51	-4.97	1.26	5.05

Notes: Cost and markup units in £/1000 bricks. Year 2005. The first four columns are averages of $i \in \mathcal{I}_J$ and the last four are percentiles of $i \in \mathcal{I}_J$. ρ_u denotes markup in a uniform pricing policy. P_n denotes the nth percentile of change in markup $\Delta\bar{\rho}_i$ from counterfactual product ownership. Table 6 reports lower unit costs because (unlike here) it uses years 2003-2005 and weights by q_i.

Table 11: Robustness to alternative disagreement point in bargaining model

the demerger counterfactual and the second merger counterfactual.

7 Conclusions

We develop an empirical model of discrete choice and negotiated prices, in which the runner-up good plays a key role, which is well-founded in non-cooperative models of multi-seller bargaining. The model is suited to a decentralized market setting in which search costs are minimal and a complete-information bargaining-theoretic approach is appropriate. Our results have implications in at least two public policy areas. First, they provide empirical support for the view that a switch from uniform to negotiated pricing can bring lower markups for most if not all buyers. Second, the results provide empirical support for the view that negotiated pricing should be accounted for in merger policy: relative to uniform pricing it can abate the average markup-increasing effect of mergers, but it can have adverse impacts for some buyers. While our focus is on negotiations between national home builders and brick sellers, we believe our framework can be applied in other settings with negotiated pricing.

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.

Allen, J., R. Clark, and J.-F. Houde (2014, October). The effect of mergers in search markets: Evidence from the canadian mortgage industry. *American Economic Review 104*(10), 3365–96.

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.

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

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

Berry, S. T. (1994). Estimating discrete-choice models of product differentiation. *The RAND Journal of Economics 25*(2), 242–262.

Berry, S. T. and P. A. Haile (2024). Nonparametric identification of differentiated products demand using micro data. *Econometrica 92*(4), 1135–1162.

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

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.

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.

Desai, P. S. and D. Purohit (2004). Let me talk to my manager: Haggling in a competitive environment. *Marketing Science 23*(2), 219–233.

D'Haultfœuille, X., I. Durrmeyer, and P. Février (2018, 10). Automobile prices in market equilibrium with unobserved price discrimination. *The Review of Economic Studies 86*(5), 1973–1998.

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. (2022). Network formation and bargaining in vertical markets: The case of narrow networks in health insurance. *Marketing Science 41*(3), 501–527.

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.

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.

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

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

Marshall, G. (2020). Search and wholesale price discrimination. *The RAND Journal of Economics 51*(2), 346–374.

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. (2014). Modeling the effects of mergers in procurement. *International Journal of Industrial Organization 37*, 201–208.

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. (2009). Bundling: Ge-honeywell (2001). In J. Kwoka and L. White (Eds.), *The Antitrust Revolution, 5th edition*. Oxford University Press, New York.

Nevo, A. (2001). Measuring market power in the ready-to-eat cereal industry. *Econometrica 69*(2), 307–342.

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

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

Salz, T. (2022). Intermediation and competition in search markets: An empirical case study. *Journal of Political Economy 130*(2), 310–345.

Sweeting, A., D. J. Balan, N. Kreisle, M. T. Panhans, and D. Raval (2020, December). Economics at the FTC: Fertilizer, Consumer Complaints, and Private Label Cereal. *Review of Industrial Organization 57*(4), 751–781.

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

Villas-Boas, S. B. (2009). An empirical investigation of the welfare effects of banning wholesale price discrimination. *The RAND Journal of Economics 40*(1), 20–46.

A Online appendix: Derivations for Sections 3 and 4

A.1 Section 3

We condition on a single buyer and suppress i subscripts in the proofs.

Proposition 1

Proof. [i] *Equilibrium* and *uniqueness.* Let $j(n)$ and $f(n)$ be the nth-best product and nth-best seller as defined in section 3.1. Under this definition $j(n)$ is $f(n)$'s highest-surplus product. Let $\bar{N}$ be defined as the number of sellers whose highest-surplus product's surplus is weakly greater than the surplus w_0 from the outside good ($j = 0$), i.e.

$$\bar{N} \equiv \max\{n | w_{j(n)} \geq w_0\}.$$

We assume $w_{j(2)} \geq w_0$, which implies $\bar{N} \geq 2$. Without loss of generality we adopt a labelling convention for inside goods such that $j(n) = n$ for $1 \leq n \leq \bar{N}$ (and outside good $j = 0$). We do not explicitly label the remaining inside goods $j \in \mathcal{J} \setminus \{0, 1, \ldots, \bar{N}\}$. The buyer negotiates markups $\{\rho_1, \ldots, \rho_N\}$ for products $\{1, 2, \ldots, N\}$ where $N \in \{2, \ldots, \bar{N}\}$. The labeling convention implies

$$w_1 \geq \cdots \geq w_N \geq w_0. \tag{39}$$

Equilibrium markups. We need to show that the markups

$$\rho_j^* = \begin{cases} \min\ [b_1(w_1 - w_0), (w_1 - w_2)] & \text{for } j = 1 \\ 0 & \text{for } j \in \{2, \ldots, N\}, \end{cases} \tag{40}$$

are the unique set of non-negative markups that solve the system of equations

$$\rho_j = \rho_j^A(\boldsymbol{\rho}_{-j}) \text{ for } j = \{1, \ldots, N\} \tag{41}$$

where $\boldsymbol{\rho}_{-j} = \{\rho_1, \ldots, \rho_N\} \setminus \{j\}$. Equation (41) for product j is

$$\rho_j^A(\boldsymbol{\rho}_{-j}) = \min[\rho_j^B,\ \rho_j^C(\boldsymbol{\rho}_{-j})] \tag{42}$$

where ρ_j^B is the Nash bargaining solution and $\rho_j^C(\boldsymbol{\rho}_{-j})$ is the TIOLI best reply function which are defined as follows:

$$\rho_j^B = b_j(w_j - w_0) \geq 0, \tag{43}$$

$$\rho_j^C(\boldsymbol{\rho}_{-j}) = \max[0, w_j - \max_{j' \in \{1,\ldots,N\} \setminus \{j\}}(w_{j'} - \rho_{j'}) - \iota_j]. \tag{44}$$

where $\iota_j > 0$ if $j \in \{2, \ldots, N\}$ and $\iota_j = 0$ if $j = 1$. We assume $0 \leq b_j \leq 1, \forall j$. The proof of equilibrium shows that the markups in (40) solve the system (41) and is in three steps.

Step 1. First, we confirm that $\rho_j^* = \rho_j^A(\boldsymbol{\rho}^*_{-j})$ for $j = 1$. To do this note that $\boldsymbol{\rho}^*_{-1} = \mathbf{0}$ which implies that

$$\max_{j' \in \{1,\ldots,N\} \setminus \{1\}}(w_{j'} - \rho_{j'}^*) = \max_{j' \in \{1,\ldots,N\} \setminus \{1\}}(w_{j'}) = w_2. \tag{45}$$

Substituting from (45) into (44) gives

$$\rho_1^C(\boldsymbol{\rho}^*_{-1}) = \max[0, w_1 - w_2] \tag{46}$$

$$= w_1 - w_2 \tag{47}$$

where the second line follows since $w_1 - w_2 > 0$. Substituting from (43) and (47) into (42) for the case of $j = 1$ we have

$$\begin{aligned} \rho_1^A(\boldsymbol{\rho}^*_{-1}) &= \min[b_1(w_1 - w_0), (w_1 - w_2)] \qquad (48) \\ &= \rho_1^* \end{aligned}$$

as required, where the second line uses (40).

Step 2. Second, we confirm that $\rho_j^A(\boldsymbol{\rho}'_{-j}) = 0$ for all $j \in \{2, \ldots, N\}$ and when $\rho_1 = \rho_1^*$ and the markups for products $\{2, \ldots, N\} \setminus \{j\}$ are non-negative. Formally, for all $j \in \{2, \ldots, N\}$, define

$$\boldsymbol{\rho}'_{-j} \equiv \{\rho'_1, \rho'_2, \ldots, \rho'_N\} \setminus \{\rho'_j\} \text{such that}$$

$$\rho'_1 = \rho_1^* \quad \text{and} \quad \rho'_{j'} \geq 0 \quad \text{for } j' \in \{2, \ldots, N\} \setminus \{j\}. \tag{49}$$

Note that an implication of (40), is that

$$w_1 - w_2 \geq \rho_1^* = \rho'_1 \tag{50}$$

where the equality $\rho'_1 = \rho_1^*$ follows from (49). Recall from (39) that we have labeled products such that

$$w_2 \geq w_j \quad \forall j \in \{3, \ldots, N\}. \tag{51}$$

Rearranging (50) we obtain

$$w_1 - \rho_1' \geq w_2 \tag{52}$$
$$w_1 - \rho_1' \geq w_j \quad \forall j \in \{2, \ldots, N\}, \tag{53}$$

where the second line follows from (51). It follows from (53) that the markups $\boldsymbol{\rho}'_{-j} \equiv \{\rho_1', \rho_2', \ldots, \rho_N'\} \setminus \{\rho_j'\}$ defined in (49) satisfy

$$w_1 - \rho_1' \geq (w_{j'} - \rho_{j'}') \quad \forall j' \in \{2, \ldots, N\} \setminus \{j\}. \tag{54}$$

And, trivially with equality for $j' = 1$, it follows from (54) that

$$(w_1 - \rho_1') = \max_{j' \in \{1,\ldots,N\} \setminus \{j\}} (w_{j'} - \rho_{j'}') \quad \forall j \in \{2, \ldots, N\}. \tag{55}$$

This implies that

$$\rho_j^C(\boldsymbol{\rho}'_{-j}) = \max[0, w_j - \max_{j' \in \{1,\ldots,N\} \setminus \{j\}} (w_{j'} - \rho_{j'}') - \iota_j] \tag{56}$$
$$= \max[0, w_j - (w_1 - \rho_1') - \iota_j] \tag{57}$$
$$= 0 \tag{58}$$

for $j \in \{2, \ldots, N\}$ where the first line is the TIOLI best reply function defined in (44), the second line substitutes in from equation (55) and the third line follows from (53) given that $\iota_j > 0$ for $j > 1$. We now have the required reuslt

$$\begin{aligned} \rho_j^A(\boldsymbol{\rho}'_{-j}) &= \min[\rho_j^B,\ \rho_j^C(\boldsymbol{\rho}_{-j})] \\ &= \min[b_j(w_j - w_0), 0] \\ &= 0 \quad \forall j \in \{2, \ldots, N\} \end{aligned} \tag{59}$$

where the first line is the definition $\rho_j^A(\cdot)$ given in (42), the second line substitutes from (58) for ρ_j^B and from (43) for $\rho_j^C(\boldsymbol{\rho}_{-j})$, and, since $b_j > 0$, the third line follows from (39). We have now established Step 2 as required.

Step 3: Note that $\boldsymbol{\rho}^*_{-j} = \{\rho_1^*, \rho_2^*, \ldots, \rho_N^*\} \setminus \{\rho_j^*\}$ as defined in (40) is consistent with the definition of $\boldsymbol{\rho}'_{-j}$ given in (49) for all $j \in \{2, \ldots, N\}$. It follows from Step 2 that

$$\rho_j^A(\boldsymbol{\rho}^*_{-j}) = 0 \quad \forall j \in \{2, \ldots, N\}. \tag{60}$$

Combining (60) with (48) from Step 1 we have

$$\rho_j^A(\boldsymbol{\rho}_{-j}^*) = \begin{cases} \min[b_1(w_1 - w_0), (w_1 - w_2)] & \text{if } j = 1 \\ 0 & \text{if } j = \{2, \ldots, N\} \end{cases}$$

Since the right hand side coincides with the definition ρ_j^* in (40) we have

$$\rho_j^A(\boldsymbol{\rho}_{-j}^*) = \rho_j^* \quad \forall j \tag{61}$$

which establishes the existence of equilibrium.

Uniqueness. To prove $\boldsymbol{\rho}^*$ is the unique equilibrium of non-negative markups we show there is no solution for the system (41) for any alternative vector of markups $\boldsymbol{\rho}' = \{\rho_1', \ldots, \rho_N'\} \neq \boldsymbol{\rho}^*$ such that $\rho_j' \geq 0 \quad \forall j \in \{1, \ldots, N\}$. First, note that in the existence part of this proof, above, we established that $\rho_1^* = \rho_1^A(\boldsymbol{\rho}_{-1})$ when $\boldsymbol{\rho}_{-1} = \mathbf{0}$ which implies there are no other equilibria at $\boldsymbol{\rho}_{-1} = \mathbf{0}$. It follows that it is sufficient for uniqueness to show that there is no other equilibrium candidate $\boldsymbol{\rho}' = \{\rho_1', \boldsymbol{\rho}_{-1}'\}$ such that $\boldsymbol{\rho}_{-1}' = \{\rho_2', \ldots, \rho_N'\}$ has positive elements. Suppose there is at least one positive element in $\boldsymbol{\rho}_{-1}'$. Then it follows from (39) that

$$w_1 - \max_{j' \in \{2,\ldots,N\}}(w_{j'} - \rho_{j'}') \geq 0 \tag{62}$$

which implies the best response function (44) for $j = 1$ is

$$\rho_1^C(\boldsymbol{\rho}_{-1}') = w_1 - \max_{j' \in \{2,\ldots,N\}}(w_{j'} - \rho_{j'}'). \tag{63}$$

Now, if $\boldsymbol{\rho}' = \{\rho_1', \boldsymbol{\rho}_{-1}'\}$ is an equilibrium, ρ_1' must satisfy the condition (41), $\rho_1' = \min[\rho_1^B,\ \rho_1^C(\boldsymbol{\rho}_{-1}')]$,which implies

$$\rho_1' \leq \rho_1^C(\boldsymbol{\rho}_{-1}') = w_1 - \max_{j \in \{2,\ldots,N\}}(w_j - \rho_j') \tag{64}$$

where the equation follows by substitution from (63). The inequality in (64) rearranges to give the following two equilibrium conditions, which are equivalent to each other:

$$w_1 - \rho_1' \geq \max_{j \in \{2,\ldots,N\}}(w_j - \rho_j') \tag{65}$$

$$w_1 - \rho_1' \geq w_j - \rho_j' \quad \forall j \in \{2, \ldots, N\}. \tag{66}$$

We now show that if the vector $\boldsymbol{\rho}_{-1}'$ has positive elements it cannot satisfy the bargaining function (41) without contradicting equilibrium condition (66), which implies $\boldsymbol{\rho}_{-1}'$ is not an equilibrium. Consider any $j \in \{2, \dots, N\}$. For $\boldsymbol{\rho}' = \{\rho'_j, \boldsymbol{\rho}'_{-j}\}$ to be an equilibrium it must be the case that it satisfies condition (41), $\rho'_j = \min[\rho^B_j,\ \rho^C_j(\boldsymbol{\rho}'_{-j})]$, which implies the following two equivalent conditions

$$\rho'_j \leq\ \rho^C_j(\boldsymbol{\rho}'_{-j}) = \max[0, w_j - \max_{j' \in \{1,\dots,N\} \setminus \{j\}}(w_{j'} - \rho'_{j'}) - \iota_j] \tag{67}$$

$$\rho'_j \leq \max[0, w_j - (w_1 - \rho'_1) - \iota_j] \tag{68}$$

where $\iota_j > 0$ given that $j \in \{2, \dots, N\}$. The second line, (68), is implied by the inequality in (66). Note that (68) returns a zero unless $w_j - (w_1 - \rho'_1) - \iota_j > 0$ so that if $\rho'_j > 0$ then (68) implies $\rho'_j < w_j - (w_1 - \rho'_1)$ given that $\iota_j > 0$. But the inequality $\rho'_j < w_j - (w_1 - \rho'_1)$ contradicts the equilibrium condition in equation (66). This implies there is no equilibrium vector $\boldsymbol{\rho}' = \{\rho'_1, \boldsymbol{\rho}'_{-1}\}$ such that $\boldsymbol{\rho}'_{-1} = \{\rho'_2, \dots, \rho'_N\}$ has positive elements as required.

[ii] *Efficient choice.* In this proof we wish to show that, at equilibrium markups given by $\boldsymbol{\rho}^* = \{\rho^*_1, \rho^*_2, \dots, \rho^*_N\}$, and for all $\boldsymbol{w} \in \mathcal{W}_1 \equiv \{\boldsymbol{w} \in \mathbb{R}^{J+1} | w_0 \leq w_2\}$, the following choice condition holds:

$$D_j(\boldsymbol{\rho}^*) = 1 \iff (w_j > w_{j'}, \forall j' \in \mathcal{J} \setminus \{j\}), \quad \forall \boldsymbol{w} \in \mathcal{W}_1. \tag{69}$$

Note that rearranging (**??**) we obtain

$$w_1 - \rho^*_1 \geq w_2 \tag{70}$$

$$w_1 - \rho^*_1 \geq w_j \quad \forall j \in \{2, \dots, N\}. \tag{71}$$

Step 1. We first show that the following equivalence statement holds

$$(w_j > w_{j'}, \forall j' \in \mathcal{J} \setminus \{j\}) \iff j = 1, \quad \forall \boldsymbol{w} \in \mathcal{W}_1. \tag{72}$$

This is the case by definition because $\mathcal{J} \equiv \mathcal{J}_J \cup \{0\}$, $j = 1$ is defined in section 3.1 as the highest surplus product in $\mathcal{J}_J$ (i.e. $1 \equiv \operatorname{argmax}_{j \in \mathcal{J}_J} w_j$), and $\mathcal{W}_1$ is defined such that $w_2 \geq w_0$ for all $\boldsymbol{w} \in \mathcal{W}_1$. Thus, for all $\boldsymbol{w} \in \mathcal{W}_1$, product j is the highest-surplus alternative in $\mathcal{J}$ if and only if it is first-best ($j = 1$). Thus we have shown that the equivalency in (72) is true which implies that we can restate (69) as follows:

$$D_j(\boldsymbol{\rho}^*) = 1 \iff j = 1 \quad \forall \boldsymbol{w} \in \mathcal{W}_1 \tag{73}$$

so that if we show that (73) it follows that we have shown that (69) is true.

Step 2. We now prove the "if" part of the "if and only if" statement in (73):

$$j = 1 \implies D_j(\boldsymbol{\rho}^*) = 1 \quad \forall \boldsymbol{w} \in \mathcal{W}_1. \tag{74}$$

To show this we show that $D_j(\boldsymbol{\rho}^*) = 1$ if $j = 1$. From (4) at markups $\boldsymbol{\rho}^* = \{\rho_1^*, \rho_2^*, \ldots, \rho_N^*\}$ the function $D_j(\boldsymbol{\rho}^*)$ at $j = 1$ is given by

$$\begin{aligned} D_1(\boldsymbol{\rho}^*) &= 1[w_1 - \rho_1^* \geq \max\{w_0, \max_{j' \in \{1,\ldots,N\}\setminus\{1\}}(w_{j'} - \rho_{j'}^*)\}] && (75)\\ &= 1[w_1 - \rho_1^* \geq w_2] && (76)\\ &= 1 && (77)\end{aligned}$$

where we use a weak inequality because we assume that in the case of a tie with the first-best the buyer selects first-best. The second line follows because $\rho_j^* = 0$ for $j \in \{1, \ldots, N\} \setminus \{1\}$ and the fact that $w_2 \geq w_0$ for all $\boldsymbol{w} \in \mathcal{W}_1$. The third line follows from the property of the equilibrium first-best markup ρ_1^* in (71). We have now shown (74) as required.

Step 3. We now show the "only if" part of the statement in (73):

$$D_j(\boldsymbol{\rho}^*) = 1 \implies j = 1 \quad \forall \boldsymbol{w} \in \mathcal{W}_1. \tag{78}$$

To do this we show that $D_j(\boldsymbol{\rho}^*) = 1$ is not possible for $j \in \{0, \ldots, N\} \setminus \{1\}$ which leaves $j = 1$ as the only possibility. We start with $j = 0$. If $j = 0$ then from equation (4):

$$\begin{aligned} D_0(\boldsymbol{\rho}^*) &= 1[w_0 > \max_{j' \in \{1,\ldots,N\}}(w_{j'} - \rho_{j'}^*)\}] && (79)\\ &= 1[w_0 > w_1 - \rho_1^*] && (80)\\ &= 0 && (81)\end{aligned}$$

where the second line follows because (i) $\rho_j^* = 0$, and therefore $(w_j - \rho_j^*) = w_{j;}$, for $j \in \{1, \ldots, N\} \setminus \{1\}$ and (ii) it is a property of equilibrium markups (see (71) above) that

$$w_1 - \rho_1^* \geq w_j \; \forall j \in \{2, \ldots, N\}. \tag{82}$$

The third line follows because $w_0 \leq w_2$ for all $\boldsymbol{w} \in \mathcal{W}_1$ and (82) implies equilibrium markups satisfy $w_2 \leq w_1 - \rho_1^*$ whether together imply $w_0 \leq w_1 - \rho_1^*$ so that the indicator function returns a zero since its argument is false. Having ruled out $j = 0$ we now consider $j \in \{2, \ldots, N\}$. If $j = \{2, \ldots, N\}$ then from equation (4):

$$
\begin{aligned}
D_{j\in\{2,\ldots,N\}}(\boldsymbol{\rho}^*) &= 1[w_j - \rho_j^* > \max\{w_0, \max_{j'\in\{1,\ldots,N\}\setminus\{j\}}(w_{j'} - \rho_{j'}^*)\}] && (83)\\
&= 1[w_j > w_1 - \rho_1^*] && (84)\\
&= 0 && (85)
\end{aligned}
$$

where the second line follows because (i) $\rho_j^* = 0$, and thus $(w_j - \rho_j^*) = w_{j;}$, for $j \in \{1, \ldots, N\} \setminus \{1\}$ and (ii) it is a property of equilibrium markups that (82) holds. The third line follows since (82) is a property of equilibrium markups. We have now shown (78) as required.

Summary. *Step 2* and *Step 3* establish the statement in (73), which *Step 1* shows is equivalent to the statement in (69).

[iii] *Irrelevance of N being greater than two.* This follows because parts [i-ii] of this proof hold for all $N \in \{2, \ldots \bar{N}\}$. The markups (40) and the choice condition (69) hold for any value of N such that $N \in \{2, \ldots \bar{N}\}$. We did not specify any value for N in these proofs other than that $N \in \{2, \ldots \bar{N}\}$. □

Proposition 2

Proof. We assume that the number of sellers for negotiation is $N \in \{0, \ldots, \bar{N}\}$ where $\bar{N} = \max\{n | w_n \geq w_0\}$ such that $N = \bar{N}$ if $\bar{N} < 2$ and $N \in \{2, \ldots, \bar{N}\}$ if $\bar{N} \geq 2$. We assume that the N sellers in the negotiations are the top-N sellers by surplus (i.e. first-best, runner-up, 3rd best, etc., as defined in section 3.1). To keep the notation simple in the proof let us label the top-N inside products (as defined in section 3.1) such that $j(n) = n$ for $n = \{1, \ldots, N\}$ so that the buyer negotiates markups $\{\rho_1, \ldots, \rho_N\}$ for products $\{1, 2, \ldots, N\}$. We label the outside good $j = 0$. We do not label the remaining goods $j \in \mathcal{J} \setminus \{0, 1, \ldots, N\}$. Let $\boldsymbol{w} = (w_0, \ldots, w_J)$. Proposition 2 states that for projects with surpluses in the set $\mathcal{W} = \{\boldsymbol{w} \in \mathbb{R}^{J+1}\}$ the buyer chooses j at equilibrium markups if and only if it is the highest-surplus alternative:

$$D_j(\boldsymbol{\rho}^*) = 1 \quad \iff \quad w_j > w_{j'} \quad \forall j' \in \mathcal{J} \setminus \{j\} \tag{86}$$

and, if this is an inside good, its markup is

$$\rho_j = \min\ [b_j(w_j - w_0), (w_j - w_j)]. \tag{87}$$

This statement is demonstrated in Proposition 1 for the set $\mathcal{W}_1 = \{\boldsymbol{w} \in \mathbb{R}^{J+1} : w_0 \leq w_2\}$. Therefore in this proof we need to show that the statement holds for the complementary set $\mathcal{W}_2 = \mathcal{W} \setminus \mathcal{W}_1 = \{\boldsymbol{w} \in \mathbb{R}^{J+1} | w_0 > w_2\}$. We partition $\mathcal{W}_2$ into two subsets

$$\mathcal{W}_{2a} = \{w \in \mathbb{R}^{J+1} | w_1 \geq w_0 > w_2\} \quad \mathcal{W}_{2b} = \{w \in \mathbb{R}^{J+1} | w_0 > w_1\}$$

where $\mathcal{W}_2 = \mathcal{W}_{2a} \cup \mathcal{W}_{2b}$ and $\mathcal{W}_{2a} \cap \mathcal{W}_{2b} = \emptyset$. Note that $\mathcal{W}_{2a}$ contains all $\boldsymbol{w} \in \mathcal{W}_2$ such that $j = 1$ is highest-surplus (or tied-highest-surplus) because $w_1 \geq w_0$ and $\mathcal{W}_{2b}$ contains all $\boldsymbol{w} \in \mathcal{W}_2$ such that $j = 0$ is highest-surplus because $w_0 > w_1$. The proof is in three steps.

Step 1. Consider $w \in \mathcal{W}_{2b}$. By definition $w_0 > w_1$ for all $w \in \mathcal{W}_{2b}$. By definition $j = 1$ is the highest-surplus inside product. It follows that for $w \in \mathcal{W}_{2b}$ the outside good has the highest surplus:

$$w \in \mathcal{W}_{2b} \iff w_0 > w_{j'}, \forall j' \in \mathcal{J} \backslash \{0\}. \tag{88}$$

It follows from (88) that $\bar{N} = \max\{n | w_n \geq w_0\} = 0$ so that $N = 0$, i.e. the buyer does not negotiate with an inside seller. (This assumption is reasonable because no seller can offer the buyer more utility than w_0 without making a loss). The buyer selects $j = 0$ and receives utility w_0. Thus we have at equilibrium markups

$$w_j > w_{j'}, \forall j' \in \mathcal{J} \backslash \{j\} \implies D_j(\boldsymbol{\rho}^*) = 1 \quad \forall \boldsymbol{w} \in \mathcal{W}_{2b}. \tag{89}$$

Step 2. Consider set $\mathcal{W}_{2a}$. By definition $w_1 \geq w_0 \geq w_2$ for $w \in \mathcal{W}_{2a}$. By definition $j = 1$ is the highest-surplus inside product. It follows that for $w \in \mathcal{W}_{2a}$ the first-best product has the highest surplus among all options:

$$w \in \mathcal{W}_{2a} \iff w_1 > w_{j'}, \forall j' \in \mathcal{J} \setminus \{1\}. \tag{90}$$

The unconstrained NBS (6) with the first-best is:

$$\rho_1^B = b_1(w_1 - w_0). \tag{91}$$

It follows from (88) that $\bar{N} = \max\{n | w_n \geq w_0\} = 0$ so that $N = 1$, i.e. the buyer only negotiates with the first-best. (This assumption is reasonable because the runner-up $j = 2$ cannot constrain the NBS with $j = 1$ because we can write

$$w_1 - \rho_1^B = w_1 - b_1(w_1 - w_0) \geq w_0 \geq w_2 \tag{92}$$

for $b_1 \leq 1$ and $w_0 \geq w_2$, i.e. $(w_1 - \rho_1^B) \geq w_2$. In words, the utility $(w_1 - \rho_1^B)$ from the first-best good at the unconstrained NBS markup is greater than the utility w_2 from the runner up at a zero markup). Since NBS is unconstrained, $\rho_1^* = \rho_1^B$. Note that, since $w_0 \geq w_2$ and $b_1 \leq 1$, we can write

$$\rho_1^* = b_1(w_1 - w_0) = \min\ [b_1(w_1 - w_0), (w_1 - w_2)] \tag{93}$$

which is identical to (87) as required. From (92) we have $w_1 - \rho_1^* \geq w_0$ which implies the buyer chooses the first-best good $j = 1$. Thus we have that at equilibrium markups

$$w_j > w_{j'}, \forall j' \in \mathcal{J} \setminus \{j\} \implies D_j(\boldsymbol{\rho}^*) = 1 \quad \forall \boldsymbol{w} \in \mathcal{W}_{2a}. \tag{94}$$

Step 3. The statements (89) and (94) say that the highest-surplus alternative is chosen for surplus vectors $\boldsymbol{w} \in \mathcal{W}_{2a}$ and $\boldsymbol{w} \in \mathcal{W}_{2b}$. Therefore since $\mathcal{W}_{2a}$ and $\mathcal{W}_{2b}$ are only two partitions of $\mathcal{W}_2$ it follows that at equilibrium markups the highest-surplus alternative is chosen for surplus vectors $\boldsymbol{w} \in \mathcal{W}_2$, i.e.

$$w_j > w_{j'}, \forall j' \in \mathcal{J} \setminus \{j\} \implies D_j(\boldsymbol{\rho}^*) = 1 \quad \forall \boldsymbol{w} \in \mathcal{W}_2. \tag{95}$$

The two sets $\mathcal{W}_{2a}$ and $\mathcal{W}_{2b}$ differ in which alternative in the set has the highest-surplus and hence which alternative is chosen at equilibrium markups:

$$w_1 \geq w_{j'}, \forall j' \in \mathcal{J} \setminus \{1\} \iff \boldsymbol{w} \in \mathcal{W}_{2a} \implies D_1(\boldsymbol{\rho}^*) = 1 \tag{96}$$

$$w_0 > w_{j'}, \forall j' \in \mathcal{J} \setminus \{0\} \iff \boldsymbol{w} \in \mathcal{W}_{2b} \implies D_0(\boldsymbol{\rho}^*) = 1. \tag{97}$$

Since these two sets are complements i.e. $\mathcal{W}_{2a} = \mathcal{W}_2 \setminus \mathcal{W}_{2b}$ it follows that at equilibrium markups i chooses $j = 0$ only if $w \in \mathcal{W}_{2b}$ and $j = 1$ only if $w \in \mathcal{W}_{2a}$ i.e.

$$\begin{aligned} D_1(\boldsymbol{\rho}^*) = 1 &\implies \boldsymbol{w} \in \mathcal{W}_{2a} \quad \forall \boldsymbol{w} \in \mathcal{W}_2 \\ D_0(\boldsymbol{\rho}^*) = 1 &\implies \boldsymbol{w} \in \mathcal{W}_{2b} \quad \forall \boldsymbol{w} \in \mathcal{W}_2 \end{aligned}$$

so that, at equilibrium markups,

$$D_j(\boldsymbol{\rho}^*) = 1 \iff w_j \geq w_{j'}, \forall j' \in \mathcal{J} \setminus \{j\} \quad \forall \boldsymbol{w} \in \mathcal{W}_2. \tag{98}$$

Summary. We have established that the claims of the proposition hold for all $\boldsymbol{w} \in \mathcal{W}_2$ as required. In Step 3, we established that at equilibrium markups the buyer chooses j iff it is the highest-surplus option, i.e. choice condition (86), for all $\boldsymbol{w} \in \mathcal{W}_2$ as required. Second, in Step 2, we have established that when an inside good is chosen (which is the case iff $\boldsymbol{w} \in \mathcal{W}_{2a}$) that the markup is given by (93) as required. □

A.2 Alternative bargaining model

Let $N = 2$ so the buyer negotiates markups for the first-best and the runner-up products. Label products $j(n) = n$ so that $j(1) = 1$ and $j(2) = 2$. First, let $w_2 \geq w_0$. The negotiated markup for product $j \in \{1, 2\}$ solves the Nash bargaining problem in which $(w_{j'} - \rho_{j'}, 0)$ are the disagreement payoffs to the buyer and seller respectively, where $j' \in \{0, 1, 2\} \setminus \{j\}$ is the highest-utility alternative to j given the markups anticipated in the other negotiation and the outside good.

$$(w_{j'} - \rho_{j'}) = \max[w_2 - \rho_2, w_0]$$

The buyers gain from trade with j is then

$$GFT_j = (w_j - \rho) - (w_{j'} - \rho_{j'})$$

and the sellers GFT is ρ and the bargaining problem is

$$\rho_j = \arg\max_{\rho > 0}[(w_j - \rho) - (w_{j'} - \rho_{j'})]^a \times [\rho]^{a_j} \tag{99}$$

$$= b_j(w_j - (w_{j'} - \rho_{j'})). \tag{100}$$

Consider the negotiation for $j = 1$. Since $b_1 \leq 1$ and $(w_{j'} - \rho_{j'}) = \max[w_2 - \rho_2, w_0]$ it follows that the NBS in (99) implies

$$(w_1 - \rho_1) \geq \max[w_2 - \rho_2, w_0] \geq (w_2 - \rho_2) \tag{101}$$

so that for any anticipated runner-up markup $\rho_2 \geq 0$ the negotiation with the first-best $(j = 1)$ always induces choice of the first-best product. Now consider the negotiation for $j = 2$. The GFT in this negotiation is

$$GFT_2 = (w_2 - \rho) - \max[w_1 - \rho_1, w_0].$$

Since (101) implies that $\max[w_1 - \rho_1, w_0] = w_1 - \rho_1 \geq (w_2 - \rho_2)$ it follows that in equilibrium GFT_2 is always negative at equilibrium markups. A well-defined Nash bargaining problem requires a positive GFT for the buyer. Therefore when bargaining condition (99) is satisfied there is not a well-defined Nash Bargaining problem in the negotiation for $j = 2$. The negative GFT_2 is a consequence of the result in (101) that the negotiation with the first-best $(j = 1)$ always induces choice of the first-best product. Since the buyer and runner-up seller know that there is no positive markup for ρ_2 which will induce demand of $j = 2$ in equilibrium, we assume that they agree a zero runner-up markup i.e. $\rho_2 = 0$: this does not induce trade for $j = 2$ but results in the most advantageous possible outcome for the buyer in the negotiation for $j = 1$. When $\rho_2 = 0$ the first-best markup is $\rho_1 = b_1(w_1 - w_2)$. Therefore the outcome of the model is the following markups

$$\rho^*_{j(n)} = \begin{cases} b_{j(1)}(w_{j(1)} - w_{j(2)}) & \text{for } n = 1 \\ 0 & \text{for } n = 2. \end{cases} \tag{102}$$

At these markups the buyer buys the first-best good since $w_1 - \rho^*_1 \geq w_2 \geq w_0$.We now relax the assumption that $w_2 \geq w_0$. When we do this we obtain identical outcomes as we found for the baseline bargaining model for this case, which are discussed below Proposition 1. Suppose the outside good has a higher surplus than either inside good so that $w_0 \geq w_1$. Here, there cannot be a positive GFT for the buyer relative to the disagreement point of the outside good (even for the case of zero markups for the first-best good), so we assume that the buyer buys the outside good an engages in no negotiations. Now suppose the outside good has a surplus that falls between the first-best and runner up so that $w_1 \geq w_0 \geq w_2$. Here, the highest-utility alternative to the first-best (and hence the disagreement point in negotiations with the first best) will always be the outside good, so that there is no gain to the buyer in negotiating with the runner-up and the NBS for the first-best markup is

$$\rho^*_1 = \ \arg\max_{\rho>0}[(w_1 - \rho) - w_0]^a \times [\rho]^{a_j} = b_1(w_1 - w_0) \tag{103}$$

and the buyer buys the first-best product.

A.3 Contract equilibrium

We show that the equilibrium markups for the (baseline) bargaining model (which nests TIOLI) and the alternative bargaining models (10 and 14 respectively), are contract equilibria (Cremer and Riordan (1987)) as we claim in footnote 20. We restrict the proof to the case where the buyer negotiates for the first-best and runner-up goods since Proposition 1 shows that the outcomes are the same if the buyer also negotiates for third-best and lower-ranked products. To keep the notation simple let us label the products such that $j(n) = n$ for $n = \{1, 2\}$. In a contract equilibrium the agents in each bilateral problem maximize their joint surplus given the markup agreed in the other problem, i.e. for each negotiation $n \in \{1, 2\}$ markup ρ_n is in the set

$$\rho_n(\rho_{n'}) \in \arg\max_{\rho^*\geq 0} \{ \ D_n(\rho^*, \rho_{n'}) \times w_n + D_{n'}(\rho^*, \rho_{n'}) \times [w_{n'} - \rho_{n'}]\}$$

where $n' = \{1,2\}\backslash\{n\}$. To see that the maximand is the bilateral surplus of buyer-seller pair $(i, f(n))$ note that when $D_n = 1$ the maximand is surplus w_n but when $D_{n'} = 1$, because $f(n)$ makes no sales, it is limited to net utility $w_{n'} - \rho_{n'}$. Negotiation $n = 1$ is bilaterally efficient iff $D_1 = 1$. This follows because $w_1 \geq [w_2 - \rho_2]$, $\forall \rho_2 \geq 0$. Therefore contract equilibrium requires both $D_1 = 1$ and bilateral efficiency in negotiation $n = 2$ and the latter obtains iff $w_2 \leq [w_1 - \rho_1]$ (i.e. $\rho_1 \leq [w_1 - w_2]$). The equilibrium prices in the TIOLI, baseline bargaining, and alternative bargaining models satisfy both conditions.

A.4 Section 4

Inequality conditions for alternative model In the alternative model the markup equation can be written $\rho_{ij} = \min\{[b_{ij}(w_{ij} - w_{ij'})]_{j' \in \mathcal{J}\backslash\mathcal{J}_{f(j)}.}\}$ so that for $\rho \geq 0$

$$\rho_{ij} \geq \rho \iff w_{ij} \geq w_{ij'} + \rho \times (b_{ij}^{-1} 1_{[j'>0]} + b_{ij}^{-1} 1_{[j'=0]}) \quad \forall j' \in \mathcal{J}\backslash\mathcal{J}_{f(j)}. \tag{104}$$

Pooling the conditions in (17) and (104), and redefining $\chi_{jj'} = 1_{[j' \in \mathcal{J}\backslash\mathcal{J}_{f(j)}]} b_{ij}^{-1}$,

$$(i \text{ chooses } j \text{ and } \rho_{ij} \geq \rho) \iff w_{ij} \geq w_{ij'} + \rho(\chi_{jj'} 1_{[j'>0]} + b_{ij}^{-1} 1_{[j'=0]}) \quad j' \in \mathcal{J}. \tag{105}$$

Using the new definition of $\chi_{jj'}$ the expressions (24) and (26) follow, which in turn give the corresponding likelihood using the case of $S = 1$ in the following proof of Proposition 3.

Proposition 3

Proof. Let $S = 0$ and $S = 1$ for the baseline and alternative model. Suppress i subscripts. Let $\omega_j = \omega(\boldsymbol{z}_j, \boldsymbol{\nu})$ and let $r_{-f|J} = \Sigma_{j' \in \mathcal{J}_J \backslash \mathcal{J}_f} r_{j'|J}$. Then, since $\partial(\omega_{j'} + \rho\chi_{jj'})/\partial\rho = 1_{[j' \in \mathcal{J}\backslash\mathcal{J}_{f(j)}]} \times b_j^{-S}$ when j' is an inside product, definitions in (26), and standard results of differentiation for nested logit functional forms, imply

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

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

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

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

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

□

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.

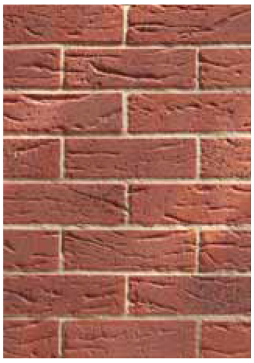
B.2 Geo-coding deliveries and classification of buyer type

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 misrepresenting 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.

Blue Velvet

Blueberry Multi

Brampton Blend



	TYPE	LOCATION	SIZE TOLERANCE		DURABILITY	ACTIVE SOLUBLE SALTS	COMPRESSIVE STRENGTH (N/mm²)	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

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.[45] 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 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

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

	Color	Shaping	Strength	Absorption	Plant
			N/m^2	percent	
			(100s)	(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 12: Classification of varieties into products by observable characteristics

reasons. However plant location also affects visual appearance of the product. This is lower than the total number of brick plants in Great Britain because we count co-located plants of the same firm as a single plant and 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 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 soft mud 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.[46] There are 416 distinct varieties in the transaction data set and we classify these into 75 groups, referred to as *products*, using these five characteristics. The product classification is illustrated in Table 12. The table gives three example products, lists some illustrative varieties in each product, and gives their observable characteristics.

The role of brick plant in this definition of products is based on information from conversations with the Brick Association, which represents UK brick manufacturing firms, and from published evidence about the brick industry. These sources indicated that a brick's plant is an important determinant of its color. Although we include two broadly-defined colors in the product definition, namely red and yellow, there are many different types of reds and yellows, and the plant affects the type of red or yellow. This is because brick plants use local clay, each local clay's mineral content is different, and the mineral content affects the color of the brick. Therefore, two differently-located plants producing red (or yellow) bricks will produce different types of red (or yellow). For a discussion of this point see the document *The Clay Brick Making Process*, published by the Brick Association. It points out that most brick plants "are located in close proximity to a [clay] quarry," that there is "a wide variety of clay deposits in the UK" which "contributes to the extensive range of brick types and colors seen across the British Isles" (page 5), and that a brick's "body color is largely dependent on the clay type" (page 10). Another authority, the Competition Commission (CC), makes the same points: that "nearly all plants are built on or adjacent to clay reserves due to the high cost of transporting clay in comparison with its value," that "brick-making clay is composed of quartz and clay minerals, the type of clay depending on the locality of the brickworks" and that "mineral compounds within the clay are responsible for the brick's color, e.g., iron compounds give rise to red and blue coloration" (see paragraph 4.9, CC (2007)).

Table 13 presents information on the number of brick products that would be obtained under alternative definitions. Row (i) shows that there are 15 unique combinations of manufacturer and aesthetic characteristics, row (ii) shows that there are 42 combinations of manufacturer and technical characteristics, and row (iii) shows that there are 54 unique combinations of manufacturer, aesthetic characteristics, and technical characteristics. As row (iv) shows, there are 75 unique combinations of these

[46]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*.

		# unique combinations
(i)	manufacturer & aesthetic characteristics only	15
(ii)	manufacturer & technical characteristics only	42
(iii)	manufacturer & all non-plant characteristics	54
(iv)	all characteristics including plant	75

Table 13: Number of Products under alternative definitions

characteristics including brick plant. Therefore, there are multiple cases where a brick of the same observable characteristics (to the econometrician) are produced in different plants.

B.4 Determination of transaction dataset

[check this] 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.

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 14 presents information on the

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 14: Aggregation: deliveries to transactions

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). 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. 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). 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. Given lumpiness in the data on completions relative values across regions are assumed 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 by region 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 B.8.

B.8 Characteristics of projects using the outside good

As explained in section 2 we have the total number of projects I_m in each NUTS1-year market m. We use official data on new housing completions from the Office for National Statistics *House Price Statistics for Small Areas* (HPSSA). As explained in Appendix B.7 these data are presented by dwelling size class so we standardize the figures 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. For the same reasons as explained in Appendix B.7 we aggregate these data over the four years to calculate time-invariant proportions $\varpi_{\tilde{\kappa}}$ of projects in each NUTS2 region $\tilde{\kappa}$ conditional on the NUTS1 region κ. Then multiply the weight $\varpi_{\tilde{\kappa}}$ and total number of projects I_m the to obtain the total number of projects $I_{\tilde{m}} = \varpi_{\tilde{\kappa}} I_m$ in NUTS2-year $\tilde{m} = (\tilde{\kappa}, t)$ region. Since from the transactions data we know a figure for the number $I_{J\tilde{m}}$ of these projects using the inside good we have $I_{0\tilde{m}} = I_{\tilde{m}} - I_{J\tilde{m}}$.

C Online appendix: Alternative non-cooperative bargaining protocols

The outcome of the bargaining model (10) is supported in a number of alternative non-cooperative bargaining models where the buyer negotiates with multiple sellers (and the buyer must select no more than one). We mention this to establish the robustness of our specification given that non cooperative bargaining models are often sensitive to differences in the protocol and because it is part of the "Nash Program" tradition to identify whether an axiomatic bargaining model such as ours can be supported by non-cooperative bargaining theory. In the literature referenced in this paragraph, some papers present the problem with a single seller negotiating with multiple buyers and others with a single buyer negotiating with multiple sellers. The strategic problem is formally equivalent in these two alternative cases. We summarize all papers as though they were for a single buyer and multiple sellers, consistent with our setting. In these (multiple-seller) models the outcomes are obtained as the limiting equilibrium when time discounting goes to zero in the non-cooperative framework that dates back to Rubinstein (1982). All the models assume single-sourcing buyers, all have sellers that differ in terms of how much surplus they generate in trade with that buyer, and all have the desirable feature that they allow information flow between the negotiations for the two alternative goods. In the literature referenced in this paragraph, some papers present the problem with a single seller negotiating with multiple buyers and others with a single buyer negotiating with multiple sellers. The strategic problem is formally equivalent in these two alternative cases. We summarize all papers as though they were for a single buyer and multiple sellers in order to make them consistent with our setting. The first model is the seminal one-buyer two-seller "auctioning model" which is sketched in Binmore (1985) (and derived formally in Chapter 9.3 of Osborne and Rubenstein (1990)). This has an alternating-offer protocol in which the buyer begins by announcing a number, which represents the net utility she requires if agreement is to be reached, which both sellers hear. If the first-best seller accepts then there is trade but if he rejects then the runner-up 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. A closely related model which gives the same equilibrium outcome but with a slightly different sequence of moves is the "non-integration" case in Bolton and Whinston (1993). Another is the (no-intermediary version of the) model in Manea (2018) which differs from the others in this paragraph by adopting a "random-proposer" protocol, in which the buyer selects in any period an upstream seller $f \in \mathcal{F}$ and with probability $\varpi \in (0,1)$ the buyer proposes a price and seller f decides whether to accept and roles are reversed with probability $(1-\varpi)$. In either event if the offer is rejected the game proceeds to the next period and the process is repeated, and so on.[47] Finally, the Appendix in Ghili (2022) presents a further model which generates the outcomes in our model. This has an alternating-offer protocol where the timing of moves between the buyer and sellers is as described in Collard-Wexler et al. (2019) but in a set-up where the payoffs (unlike those in Nash-in-Nash) are such that buyer prefers single-sourcing.

D Online appendix: Importance sampling

In the integral for $f_j^*(p|\boldsymbol{z}_i, y_i)$ in (32) we use importance sampling to avoid drawing cost shocks ν_{ic} that are uninformative because they imply negative markups at price p, which have zero probability. Let $\bar{\nu}_{ic}$ be the highest value of the cost shock consistent with non-negative markups, which is given by inverting the monotonic equation $p = c_{ij}(\nu_{ic})$. Each of the individual shocks in $\boldsymbol{\nu}_i = ([\nu_{ik}]_{k\in\mathcal{K}}, \nu_{ic}) \equiv (\boldsymbol{\nu}_{iu}, \nu_{ic})$ is iid standard normal we can write $G_{\boldsymbol{\nu}}(\boldsymbol{\nu}_i) = G(\nu_{ic})G_u(\boldsymbol{\nu}_{iu})$, where $G_u(\boldsymbol{\nu}_{iu}) = \Pi_{k\in\mathcal{K}} G(\nu_{ik})$ and G is a standard normal (univariate) cumulative distribution function. The corresponding probability density functions are $g_{\boldsymbol{\nu}}(\boldsymbol{\nu}_i) = g(\nu_{ic})g_u(\boldsymbol{\nu}_{iu})$, where $g_u(\boldsymbol{\nu}_{iu}) = \Pi_{k\in\mathcal{K}} g(\nu_{ik})$ and g is a

[47]This protocol is adapted by Ho and Lee (2019) to allow for situations where the buyer benefits from trading with multiple sellers in equilibrium; this is a generalization which we do not require given that in our framework the buyer single-sources.

standard normal (univariate) probability density function. Then

$$f_j^*(p|\boldsymbol{z}_i, y_{ij}) = \int_{\boldsymbol{\nu}_{iu}} \int_{-\infty}^{\bar{\nu}_{ic}} f_j^*(p|\boldsymbol{z}_i, y_{ij}, \nu_{ic}, \boldsymbol{\nu}_{iu}) g(\nu_{ic}) g_u(\boldsymbol{\nu}_{iu}) \mathrm{d}\nu_{ic} \mathrm{d}\boldsymbol{\nu}_{iu} \tag{106}$$

$$= G(\bar{\nu}_{ic}) \int_{\boldsymbol{\nu}_{iu}} \int_{-\infty}^{\bar{\nu}_i^c} f_j^*(p|\boldsymbol{z}_i, y_{ij}, \nu_{ic}, \boldsymbol{\nu}_{iu}) \tilde{g}(\nu_{ic}, \bar{\nu}_{ic}) g_u(\boldsymbol{\nu}_{iu}) \mathrm{d}\nu_{ic} \mathrm{d}\boldsymbol{\nu}_{iu}. \tag{107}$$

The first equation follows because the likelihood is zero above the upper limit of integration for the cost shock ν_{ic}. In the second equation $\tilde{g}(\nu_{ic}, \bar{\nu}_{ic}) = g(\nu_{ic})/G(\bar{\nu}_{ic})$ is the density for a standard normal distribution upper-truncated at $\bar{\nu}_{ic}$. In estimation we use 100 independent draws per i.

E Online appendix: Simulating outcomes

In section 5 we compare simulated and observed outcomes for the set of projects in the transactions data, $\mathcal{I}_J$. For each project $i \in \mathcal{I}_J$, we simulate a price p_i and a distance DST_i, conditioning on the choice of an inside good, i.e. the same conditioning as in the data. For the set of projects in the transactions data $\mathcal{I}_{\mathcal{J}}$ we obtain as follows the simulated distances and prices $\{DST_i, p_i\}_{i \in \mathcal{I}_{\mathcal{J}}}$ which we compare to the observed counterparts in the transactions data.

1. We simulate a random effect $\boldsymbol{\nu}_i$ for project i using $g_{\boldsymbol{v}|J}(\boldsymbol{v}|\boldsymbol{z}_i)$, i.e. the probability density for $\boldsymbol{v}$ given choice of an inside good. From Bayes' rule $g_{\boldsymbol{v}|J}(\boldsymbol{v}|\boldsymbol{z}_i) = s_J(\boldsymbol{z}_i, \boldsymbol{v}) g_{\boldsymbol{v}}(\boldsymbol{v})/s_J(\boldsymbol{z}_i)$, where $s_J(\boldsymbol{z}_i, \boldsymbol{v})$ is the probability of choosing an inside good given the cost effect $\boldsymbol{v}$, $g_{\boldsymbol{v}}(\boldsymbol{v})$ is the distribution of $\boldsymbol{v}$ in the population, and $s_J(\boldsymbol{z}_i) = \int s_J(\boldsymbol{z}_i, \boldsymbol{v}) g_{\boldsymbol{v}}(\boldsymbol{v}) d\boldsymbol{v}$ is the marginal probability of project i choosing an inside good. To draw from $g_{\boldsymbol{v}|J}(\boldsymbol{v}|\boldsymbol{z}_i)$ we draw a large number S (we use $S = 200$) of realizations $\{\boldsymbol{v}^1, \ldots, \boldsymbol{v}^S\}$ from the unconditional density $g_{\boldsymbol{v}}$ and then pick one at random such that the probability of picking $\boldsymbol{v}^s$, for $s \in \{1, \ldots, S\}$ is proportional to $s_J(\boldsymbol{z}_i, \boldsymbol{v}^s)$.

2. We simulate a chosen inside good using the conditional choice probabilities $s_{j|J}(\boldsymbol{z}_i, \boldsymbol{\nu}_i)$ given in (31). Let the simulated choice indicators be $D_{ij} \in \{0, 1\}$ for each product $j \in \mathcal{J}_J$ such that $\sum_{j \in \mathcal{J}_J} D_{ij} = 1$. The simulated distance is $DST_i = \sum_{j \in \mathcal{J}_J} \{DST_{ij} \times D_{ij}\}$.

3. To simulate price p_{ij} for project i given choice of product j we simulate a price-cost markup from the cumulative distribution function for the markup for project i conditional on choice of product j and the taste shock $\boldsymbol{v}_i$ from step 1 which is

given as follows

$$\mathcal{F}(\rho|\boldsymbol{z}_i, y_{ij}, \boldsymbol{v}_i, i \text{ chooses } j) = 1 - \Pr(\rho_{ij} \geq \rho|\boldsymbol{z}_i, y_{ij}, \boldsymbol{v}_i, i \text{ chooses } j) \tag{108}$$

$$= 1 - r_j(\rho|\boldsymbol{z}_i, y_{ij}, \boldsymbol{v}_i)/s_j(\boldsymbol{z}_i, \boldsymbol{v}_i) \tag{109}$$

where the second line uses (25) and (31). We simulate the markup ρ_{ij} by putting a random draw $\zeta \in [0,1]$ from a standard uniform distribution into the inverse of $\mathcal{F}_{i|j}(\rho)$. Given the simulated shock $\boldsymbol{v}_i = (\boldsymbol{\nu}_{iu}, \nu_{ic})$ from step 1 we have the simulated cost $c_j(\nu_{ic})$. The price, given choice j, is then given by $p_{ij} = \rho_{ij} + c_j(\nu_{ic})$. Using the simulated choice from step 2 the transaction price for the project is $p_i = \sum_{j \in \mathcal{J}_J} \{p_{ij} \times D_{ij}\}$.

For the negotiated pricing case in the counterfactual exercise in section 6 we use the same method except that in steps 1 and 2 we do not condition on choice of an inside good (see footnote 38).

F Online appendix: Efficiency change in merger analysis

To illustrate the mechanism linking efficiency gains to prices when prices are negotiated we note that an efficiency gain for a first-best seller does not necessarily translate into the seller setting lower negotiated prices. To see this consider the pricing equation from our baseline specification:

$$p_{j(1)} = c_{j(1)} + \min\ [b_{j(1)}(w_{j(1)} - w_0), (w_{j(1)} - w_{j(2)})]. \tag{110}$$

Suppose the first term $b_{j(1)}(w_{j(1)} - w_0)$ is returned by the minimum operator in (110). In this case the first-best price is

$$\begin{aligned} p_{j(1)} &= c_{j(1)} + b_{j(1)}(w_{j(1)} - w_0) \\ &= c_{j(1)} + b_{j(1)}(v_{j(1)} - c_{j(1)} - w_0) \\ &= (1 - b_{j(1)})c_{j(1)} + b_{j(1)}(v_{j(1)} - w_0) \end{aligned}$$

where in the second line we have substituted $w_{j(1)} = v_{j(1)} - c_{j(1)}$. Here, an efficiency gain *does* pass through to the price, but the extent of pass-through depends on the first-best seller's bargaining power: if it is positive ($b_{j(1)} > 0$) then pass-through is less than one-for-one and the extent pass-through is lower if the seller's bargaining power is greater.

Now suppose the second term, $(w_{j(1)} - w_{j(2)})$, is returned by the minimum operator in (110). In this case the first best price is

$$\begin{aligned} p_{j(1)} &= c_{j(1)} + w_{j(1)} - w_{j(2)} \\ &= c_{j(1)} + (v_{j(1)} - c_{j(1)}) - (v_{j(2)} - c_{j(2)}) \\ &= c_{j(2)} + (v_{j(1)} - v_{j(2)}). \end{aligned} \tag{111}$$

and we see that the first-best firm's cost $c_{j(1)}$ has no role in determining the price for the transaction, so that efficiency effects from the merger have no impact on insider prices. An implication of equation (111) is that a runner-up firm's cost can affect first-best prices. Hence an efficiency gain for a merging seller could reduce prices for non-merging firms in transactions where the merging seller is runner-up.

G Online appendix: robustness to disagreement point

A: *Parameters in valuation* v_{ij}			
Same-region-produced	β_1^o	0.023	(0.004)
Within-100km-produced	β_2^o	0.043	(0.005)
North × red	β_3^o	0.047	(0.006)
North × wirecut	β_4^o	0.132	(0.007)
Absorption × rainfall	β_5^o	-0.035	(0.046)
Strength × frost	β_6^o	0.190	(0.129)
sd red	σ_{red}	0.024	(0.039)
sd wirecut	σ_{wire}	0.007	(0.049)
GEV nesting	σ_J	0.846	(0.023)
GEV scaling	σ_ε	0.154	(0.004)
Product effect ($\bar{\delta}$ is mean δ_j)	$\bar{\delta}$	0.513	(0.015)
B: *Parameters in cost* c_{ij}			
Gas price index	γ_1	0.919	(0.024)
Wages (£10k/year)	γ_2	0.228	(0.037)
Low-quality product (1/0)‡	γ_3	-0.036	(0.007)
Fixed per-transaction cost	γ_f	0.149	(0.029)
Scaling term for cost shock	σ_ν	0.072	(0.001)
Plant effect ($\bar{\gamma}$ is median)	$\bar{\gamma}$	1.038	(0.046)
C: *Bargaining parameters*			
Seller dummy $1[l \in \{]$	η_1	-0.110	(0.019)
Agent l size y_l	η_2	0.226	(0.018)
Log likelihood			-46435.493
LR test statistic $\backsim \chi^2(2)$			90.36340906
D: seller *relative bargaining skill* $b_{ij} \in [0,1]$			
Mean			0.816
SD			0.043
Min			0.703
Max			0.911

Notes. These estimates use the alternative bargaining specification detailed in Appendix A. See notes for Table 4

Table 15: Estimated parameters: alternative bargaining specification

The estimates in Table 15 use the alternative bargaining specification detailed in Appendix A. The LR test statistic rejects the hypothesis of price-taking buyers at standard significance levels (as with the baseline specification). The parameters are similar to those found for the baseline model except for η_1 which implies a higher mean value across $i \in \mathcal{I}_J$ for the seller's bargaining power b_{ij} (0.810 compared to 0.540). The difference is a consequence of the different magnitudes of bargained-over surplus: in the baseline the bargained-over surplus is $w_{ij(i,1)} - w_{i0}$, and in the alternative model it is

$w_{ij(i,1)} - w_{ij(i,2)}$ which by definition is smaller. Since the markup represents the seller's share of bargained-over surplus, a given markup for the seller corresponds to a smaller surplus share in the baseline than in the alternative model.

H Online appendix: continuing locations

Parameter	Estimate	Std. Err.
Constant	5.146	0.005
2004	0.038	0.002
2005	0.083	0.002
2005	0.135	0.002
I	-0.006	0.001
Buyer Dummies	Yes	
Variety Dummies	Yes	
R^2	0.7945	

Notes. Dependent variable: log of unit price. Observations: 13,788. Variety and buyer dummies are included in the regression.

Table 16: Repeats and negotiated prices

In the data most transactions (63.2%) are for deliveries to new buyer-destinations rather than destinations that continue from the previous year. On average (across buyer-destinations) 86% of volumes delivered are for the modal year and 98% the top two years. In two exercises we find no evidence of incumbency effects in continuing buyer-destinations: (i) prices for continuing buyer-destinations are very similar to other prices controlling for variety, buyer, and year and (ii) the results of the structural model change minimally when observations for continuing buyer-destinations are dropped.

In this Appendix to look for evidence of incumbency effects for continuing buyer-destinations. We first look at patterns in prices in continuing buyer-destinations. If lock-in effects are present, we might expect that prices are substantially higher, controlling for product variety, year and buyer, when buyers buy at a continuing destination from a seller with incumbency status. We create a variable $I_i \in \{0, 1\}$ which indicates whether the buyer continues to buy the same variety for a project at the same destination as the previous year, i.e. the seller thus has an incumbency status when $I_i = 1$. Table 16 presents the results from a regression of the log of transaction price on I_i and other controls. The other controls are a full set of product variety dummies, buyer dummies and year dummies. The parameter on I_i although statistically significant is very small in magnitude and negative in sign which is contrary to what we would expect if lock-in was important.

In a second unreported exercise we estimate the full bargaining model (and the TIOLI model that is nested within it) on a restricted data set that drops observations at continuing buyer-destinations, i.e. for which $I_i = 1$. If lock-in effects were important then we would expect the implied markups and counterfactual results from the estimated results to be different from those in the full data. We find that there is little change in the parameters relative to those reported in the paper, that the LR test statistic rejects the hypothesis of price-taking buyers at standard significance levels (as with the baseline specification), and that the marginal costs, markups, and counterfactual results show little difference.