Price Discrimination and Bargaining: Empirical Evidence from Medical Devices

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A

1 Introduction

rectly to the theory of price discrimination with oligopoly.[1] If hospitals are more vertically differentiated from one another in their preferences for stents (what the literature would call best-response symmetry among manufacturers), then competition will tend to intensify with more uniform prices (Holmes 1989). If hospitals are instead more horizontally differentiated (best-response symmetry), then competition will tend to soften with more uniform pricing, as manufacturers price to their captive markets (Corts 1998). Thus understanding if different prices are good or bad for hospitals requires knowing first how much variation in price is due to variation in demand, and then whether this demand variation is vertical or horizontal. A complete analysis requires going further and accounting for the fact that prices are not “set by suppliers as they are in the price discrimination literature—stent prices are negotiated.

When buyers and suppliers negotiate prices, supplier costs, buyer willingness-to-pay, and competition determine only a range of potential prices (versus a single price) for empirical and theoretical research by quantifying several mechanisms previously illustrated in theory and demonstrating new interactions between price discrimination and bargaining in a context where both are important.

Central to this study is an unusually detailed panel data set, providing the quantities purchased and prices paid for all coronary stents sold to 9 U.S. hospitals from January 00 through June 00 , at the stent-hospital-month level. The stent market is a business-to-business market in which hospitals generate revenue by implanting stents during angioplasty procedures, and the stent is a necessary input that the hospital must purchase from a device manufacturer. Contracts are negotiated, stipulating the price at which the hospital can purchase a given stent over a specified period of time, and different hospitals negotiate different prices for the same stent. This price variation has significant implications for profits. Moving from the th to th percentile in price would result in a change of about $ 00,000 annually (about four nurses' salaries) at the average-sized hospital. Section of the paper provides more details regarding the industry and data.

Even with these detailed data, several important variables—cost, willingness-to-pay, and bargaining ability—are unobserved. Further, separating the impact of demand and competition on the range of potential prices from the impact of bargaining abilities within that range requires an explicit model of how competition and bargaining determine prices. In Sections and , I address these challenges with a structural e

This model relates to the theoretical literature on bargaining with externalities (Horn & Wolinsky 1988), and Crawford & Yurukoglu (010) use a close varian

doctor, regardless of the type of stent used; and for hospitals, $10,   for a BMS and $11,81   for a DES.[6] Reimbursements do not depend on the manufacturer of the stent.

Out of this revenue comes the hospital's costs, including the cost of any stents used. Thus the hospitals keep in profit any price savings they can achieve on the cost of stents. While in many markets there might be some interaction between the costs negotiated with suppliers and the revenues negotiated from buyers, that is not the case here. For Medicare patients, who receive over 0% of all stenting procedures, the reimbursement levels are fixed; and the reimbursements from private insurers are generally negotiated as a markup on Medicare rates across all procedures performed at the hospital. Thus reimbursement levels at each hospital are fixed with respect to the cost of stents.

2.2 Data Overview

The data set used in this paper is from Millennium Research Group's   survey of catheter labs, the source that major device manufacturers subscribe to for detailed market research. The goal of the survey is to provide an acc8 (r)-1. (e)]TJ cu8 (p)0.9 098(
m.9 119 098(p)0.9 11(t)-1. ht u to119 0 8 (u)0.9 098 9(te)ntp8e9(iisn. 8d [(1(a)- .8 8 (n)-

[illegible] The quantity graph shows the total number of stents implanted, also broken down into DES and BMS. The price graph shows median prices of BMS and DES (the thin lines are the first and third quartiles).

( ) Quantities

These per-unit price differences translate into significant dollar amounts. A $ 1 change in price results in a difference in cost of over $ 00,000 per year in the mean-volume hospital, or nearly $1 billion per year across the three million stents implanted worldwide. This is about 0% of the annual revenue of the global stent market.

There are many potential explanations for this price variation across hospitals. Revenue for stenting procedures varies across hospitals. The relative strength of the interventional cardiologists versus substitute treatments and the distribution of patient types will vary across hospitals as well. Also, stents are differentiated products, and doctors vary in their preferences over which stent is best to treat a given patient. These variations induce different competitive environments in different hospitals. The variation in the market shares of each stent, the number of diagnostic procedures per hospital, and the frequency with which diagnostic procedures lead to stenting, displayed in Table and Figure , all provide a sense of this demand heterogeneity.

[illegible] The table reports summary statistics for the distribution of market share (% of all stents used) across hospitals. (Average shares do not add up to 100% because not all stents are used by all hospitals, as documented in the last column of the table.) The sample is restricted to September 2005 (middle of the sample in time) to isolate cross-sectional variation. There are N=54 hospitals sampled in this month, and BMS1-3 have exited the market.

brand	mean (%)	std. dev. (%)	std.dev./mean	min (%)	max (%)	N
BMS4	5	3	0.7	1	14	25
BMS5	3	2	0.6	1	7	23
BMS6	6	6	1.0	1	25	26
BMS7	4	5	1.1	1	25	39
BMS8	4	4	1.1	1	14	11
BMS9	8	8	1.0	1	32	47
DES1	43	30	0.7	1	88	54
DES2	41	30	0.7	2	93	54

Taking a closer look at the market share data also provides some preliminary evidence regarding the amount of vertical versus horizontal variation in demand across hospitals, which theory suggests will play an important role in determining the effects of competition under price discrimination versus uniform pricing. Regressing the September 00 (to isolate cross-hospital variation) market shares (percent of diagnostic procedures that are treated with each stent) on stent dummy variables, and then on stent and hospital dummy variables, reveals that hospital effects explain only 1 % of th

interaction dummy variables starting in January 00 to account for the scare over DES safety during this time; and $_{jht}$ are unobservable time fluctuations in hospital preferences for each stent model.

Including the $_{jh}$ fixed effects is important, as doing so controls for persistent unobserved heterogeneity at the product-hospital level (and thus also at the product level and hospital level). This heterogeneity across hospitals comes from different average preferences of doctors due to different opinions regarding the clinical data for each product, different mixes of patients, and different reimbursement levels for stenting procedures.

However, because $_{jht}$ is an average across different doctors with different preferences and different patients with different characteristics, monthly variation occurs when the sample of patients varies, when the month's patients are allocated differently among the hospital's doctors, or eseasria

DES and BMS.

$_{ijht}$ and $_{ijht}$ are random components specific to stent , modeling the fact that some doctors may have very strong preferences for a particular stent for a particular patient. $_{ijht}$ is the standard "logit error term (extreme value type I normalized with mean zero and scale 1). The random mean shifter, $_{ijht}$

time according to some imperfectly persistent process. Both demand and bargaining ability should do so in this application. Monthly variation in demand occurs due to changes in doctor preferences (as new studies are released and device salespeople spread the word) or doctor turnover within a hospital over time. Imperfectly persistent variation in bargaining abilities would result from changes over time in the individuals involved in bargaining for a given stent at a given hospital, changes in the incentives faced by the same individuals, or learning by the same individuals over time. Appendix C confirms that these instruments are strongly correlated with price.

The nonlinear parameters in the demand function—the mixture para though, is not an obvious step and warrants further discussion. The motivation behind this step—which implicitly says that doctors and administrators behave according to the same utility function in assessing the value of a given stent—can be best captured by a quote from an article on physician preference items in the Journal of Healthcare Contracting (November/December 009, p.1). It reads, “In many cases, physicians—when given good data to work with—will work out supply chain issues amongst themselves in a way that pleases both the clinical and administrative sides of the house. The intuition behind this comes from the fact that, despite their different roles within the organization, in the end doctors and administrators care about many of the same things: patient health, doctor satisfaction, and hospital profitability.

What if the surplus function for administrators who negotiate prices is different than that of doctors who choose which stents to use (e.g. more price sensitive)? To the extent this is the case, it will be captured in the bargaining ability parameters in the pricing model presented in the next section. This introduces a slightly different interpretation for a high hospital bargaining ability. A high bargaining ability may result from the ability to drive a better deal with device manufacturers, or it may result from an administrators power to maintain and act upon a more price-sensitive view of the available stents than the doctors at that hospital.

3.2 Modeling Pricing with Competition and Bargaining

Prices are set in a model of bargaining in the presence of competition where each hospital negotiates with each manufacturer separately and simultaneously manufacturing are not affected by inclusion or exclusion from a single hospital. Here I write the model with each product negotiated separately, though it is possible to allow for multi-product manufacturers, as discussed in Appendix B. .1.

A variation of this model has been used in prior empirical work by Crawford and Yurukoglu (010), and many related models have been developed in theoretical work on bilateral negotiations with externalities (e.g. Stole & Zwiebel (199); de Fontenay and Gans (00)). This prior work includes detailed discussions on how this model “nests the solutions to many other pricing models of interest. Of particular interest here are: when the hospital has zero bargaining ability ($b_{ht}(\ ) = 0\ \forall\ \ \in \mathcal{J}_{ht}$), manufacturers set prices in a Bertrand-Nash price equilibrium; and when a manufacturer has zero bargaining ability ($b_{jt}(\ ) = 0$), that manufacturer prices at cost. Also, different assumptions on the threat points, d_{jht}

Competition between substitutes enters this model in two ways: (1) via the hospital's disagreement point of not contracting with a given product; and ( ) via the elasticities. The constraint of the hospital's disagreement point is reminiscent of solutions such as the Core, whereas the elasticities are directly related to standard models of price competition with differentiated products.[14] Via these two effects, more "competition, such as lower prices or greater substitutability among products, decreases both the added value and NTU adjustment terms, leaving a smaller piece of the pie for product to capture. However, conditional on competition, the amount of value captured depends on bargaining via $\frac{b_j(h)}{b_j(h)+b_h(j)}$.

3.2.1 Pricing: Identification and Estimation

This section shows how costs and relative bargaining ability can be estimated at the buyer-supplier transaction (and thus firm) level using the demand estimates and the assumed model of bargaining and competition. The quantities to be estimated in the pricing equation (8) are costs, c_{jht}, and the relative bargaining ability ratio $\frac{b_{ht}(j)}{b_{jt}(h)}$. A full statistical model requires specifications for costs and bargaining in terms of data, parameters, and unobservables. Because the distributions of c_{jht} and $\frac{b_{ht}(j)}{b_{jt}(h)}$ are not separately identified, one of thecramon be entireinTf .9 0 term of dat

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For relative bargaining ability, I specify

$$\frac{b_{jt}(\ )}{b_{ht}(\ )} = \beta_{jh\ \ jht}, \tag{10}$$

where β_{jh} measures the average relative bargaining ability of stent   to hospital   , capturing firm-specific features (such as hospital size) as well as allowing for different bargaining abilities for the same hospital across manufacturers and vice-versa. $_{jht}$ is the econometric unobservable term that measures the extent to which bargaining outcomes in the data deviate from the outcomes suggested by the pair-specific bargaining abilities. $_{jht}$ could represent the evolution of bargaining abilities over time (due to learning, changes in personnel, or changes in organizational incentives) or the possibility that bargaining outcomes are simply random (due to idiosyncratic events that might affect a particular negotiation). To the extent that bargaining outcomes vary a great deal over time, this specification will set $\beta_{jh} = 1$, and all variation will be due to the random unobservable term $_{jht}$.

3.2.2 Estimation of costs and bargaining abilities

The only potential problem is that added value can change in response to supply shifts as well as demand shifts because in this NTU game added value is a function of price (and thus bargaining abilities and costs). Higher bargaining ability can lead to a higher price and lower added value, biasing β_{jh} downwards. This is the supply side of the simultaneity problem.

While this is a potentially large problem in theory, I expect it to be small in this context for two reasons: First, allowing for stent-hospital specific bargaining parameters controls for fixed stent-hospital differences, meaning that the variation in unobserved bargaining ability is within stent-hospital and thus likely to be less of a problem than if variation across hospitals were used. Second, industry knowledge predicts (and demand estimates in the next section confirm) that prices play a relatively small role in driving section discusses those quantities directly for the preferred demand model. Appendix C presents the utility parameter estimates themselves across several specifications used to determine the robustness and appropriateness of the one used here.

4.1.1 Demand elasticities

Table shows the distributions of the elasticities for each type of stent across stents, hospitals, and months.[15] The own-elasticity estimates vary across particular stents and hospitals, but in all cases they are quite low, with means -0. for BMS and -0. for DES. The small elasticities do not appear to be due to a failure of the demand identification strategy. As detailed in Appendix C, the stent-hospital fixed effects, AR(1) disturbance, and instruments do an effective job of increasing the estimated price sensitivity compared to more naive approaches. Additionally, these small elasticities are consistent with two prominent facts in the stent market: (1) doctors are not very price-sensitive, and ( ) prices are negotiated.

[illegible] $\frac{\partial q_j}{\partial p_k}\frac{p_k}{q_j}$ distributions across hospitals, months, and stents of that type. Own-elasticities less than -1 are consistent with negotiated prices and inconsistent with suppliers setting prices to price-taking buyers.

price elasticity of q_j:	with respect to p_k:	mean	std. dev.	min	max
BMS	own	-0.32	0.07	-.70	-.09
		[illegible]	[illegible]	[illegible]	[illegible]
	other BMS	0.02	0.02	0.00	0.47
		[illegible]	[illegible]	[illegible]	[illegible]
	DES	0.12	0.14	0.00	1.70
		[illegible]	[illegible]	[illegible]	[illegible]
DES	own	-0.52	0.11	-.99	-.09
		[illegible]	[illegible]	[illegible]	[illegible]
	BMS	0.01	0.01	0.00	0.24

The small elasticity estimates show that price does matter in treatment choice, but relatively little. This is consistent with how industry participants describe doctor behavior, especially for physician preference items like coronary stents. It is also consistent with the limited evidence from previous studies that also suggest physicia [illegible] A [illegible] $\frac{\pi_h - d_{jh}}{q_{jh}} + p_{jh}$ across hospitals for each stent. The sample is restricted to September 2005 (middle of the sample in time) to isolate cross-sectional variation. There are N=54 hospitals sampled in this month; BMS1-3 have exited the market.

	mean ($)	std. dev. ($)	min ($)	max ($)	N
BMS4	3916	265	3410	4345	25
	[illegible]	[illegible]	[illegible]	[illegible]	
BMS5	3681	232	3385	4325	23
	[illegible]	[illegible]	[illegible]	[illegible]	
BMS6	3874	323	3312	4770	26
	[illegible]	[illegible]	[illegible]	[illegible]	
BMS7	3872	286	3372	4798	39
	[illegible]	[illegible]	[illegible]	[illegible]	
BMS8	3811	461	3272	4860	11
	[illegible]	[illegible]	[illegible]	[illegible]	
BMS9	4163	441	3539	5840	47
	[illegible]	[illegible]	[illegible]	[illegible]	

are fairly imprecisely estimated. This is because the stent-hospital-month added value terms range from three to seven thousand dollars, and prices for added values near zero are the ideal data to identify the cost parameters. Without such observations, the cost parameters are identified by extrapolations far from the region of the data, and small changes in the bargaining ability (slope) estimates can lead to larger changes in the cost (intercept) estimates.

C o n o on The first column reports marginal cost estimates for the bargaining model used in this paper. Column two reports industry expert estimates for per-unit costs. The ranges reflect di erent experts' assumptions about what should enter "cost". Column three reports marginal cost estimates (mean and std. dev. across stent-hospital-months) implied by the model if manufacturers were assumed to set prices.

	bargaining model estimates, γ	industry expert estimates	assuming Bertrand, $b_h = 0$	
			mean	std. dev.
cost of BMS in $	34	100-400	-2211	547
	(9)		(4 1)	(5)
cost of DES in $	1103	400-1600	-2481	1325
	(286)		(660)	(1 4)

The third column in Table gives the cost estimates implied by assuming that manufacturers set prices in a Bertrand-Nash Equilibrium, and these results point out two ways in which that model falls short. First, the mean cost estimates are unrealistically small because prices are negotiated, and to assume that manufacturers set price is equivalent to assuming that hospitals have zero bargaining ability, $b_h = 0$, which is not the case on average. Second, the variation in cost estimates across hospitals is unrealistically large because the Bertrand model fails to allow for variation in relative bargaining abilities, forcing the variation that cannot be explained by willingness-to-pay and competition into costs. Any model with fixed bargaining abilities will produce similarly unreasonable variation in costs.

Thus the model estimated in this paper, which allows for bargaining and heterogeneity in bargaining abilities, yields more reasonable cost estimates. Unfortunately, the cost estimates are imprecise because the observed added value measures are large. The "positive aspect of this cost imprecision is that cost changes have only a small impact on subsequent estimates. Thus, as illustrated in Appendix C, the bargaining distribution and counterfactual estimates to come are robust to a variety of assumptions regarding costs. Any unobserved cost variation would have to be unrealistically large to materially affect the results.

4.3 Bargaining Distribution Estimates

Given demand and cost estimates, the estimated distribution of relative bargaining abilities, $\beta_{jh \quad jht}$, is given by Equation 1 . This distribution is easiest to interpret when

5 The Welfare Effects of More Uniform Pricing

The results in the previous Section indicate that the observed price variation across hospitals for a given stent comes from variation in both demand and bargaining abilities. Both of these sources of heterogeneity also play an important role in this Section, which examines several counterfactual scenarios with more uniform pricing, including: uniform prices set by manufacturers (a potential outcome of transparency reforms), centrally negotiated pricing for all hospitals (via GPOs or government purchasing), and negotiated prices at the level of merged hospital systems. The analysis makes clear that the details of how more uniform prices are implemented matter a great deal for whether or not prices for stents would rise or fall. Two particularly important forces that play a role in all cases are the effect of a move to more uniform prices on: (1) the intensity of competition, and (2) whether buyers are able to negotiate, and if so, at what bargaining ability.

The effect of imposing uniform pricing on the intensity of competition is closely related to what the price discrimination literature calls "best-response symmetry/asymmetry (Corts 1998). If demand across hospitals for the different stents is symmetric in the sense that all stents prefer to set a higher price to the same hospitals (e.g., because compared to alternative treatments, these hospitals value [illegible] stents more than other hospitals), then a move to uniform pricing will tend to intensify competition (Holmes 1989; Stole 2007). On the other hand, if demand across hospitals is asymmetric in the sense that some hospitals prefer one stent while other hospitals prefer another (and thus different stents want to set high prices in different hospitals), then a move to uniform pricing will tend to soften competition as stent suppliers retreat to their more captive markets (Corts 1998). The results in this Section suggest that the market for coronary stents exhibits more asymmetry that symmetry in demand across hospitals, leading to competition to soften and—holding all else equal—making hospitals worse off under any policy that imposes more uniform pricing.

softened competition, but has the opportunity to make up for this through increased bargaining ability. Mergers introduce an interesting complementarity between bargaining ability and symmetry of demand—while the competitive effect encou [illegible] Equilibrium outcomes under the current negotiated price regime compared to those under uniform pricing for September 2005. Column 2 sets $\mathbf{b}_{\mathcal{H}}$ to zero, the case where hospitals do not bargain collectively and manufacturers set prices. Column 3 sets bargaining ability of the group of hospitals, $\mathbf{b}_{\mathcal{H}}$, to the mean of individual hospitals, $\overline{\boldsymbol{\beta}_{\mathbf{h}}}$, in order to isolate the change to competition. Column 4 sets $\mathbf{b}_{\mathcal{H}}$ to the maximum estimated bargaining ability of any individual hospital.

	Current Regime	% change with Uniform Prices		
		$\mathbf{b}_{\mathcal{H}} = 0$	$\mathbf{b}_{\mathcal{H}} = \overline{\boldsymbol{\beta}_{\mathbf{h}}}$	$\mathbf{b}_{\mathcal{H}} = \max(\boldsymbol{\beta}_{\mathbf{h}})$
manufacturer profits ($M/hospital/year)	1.24	81	8	-15
		(2)	(1)	(3)
hospital surplus ($M/hospital/year)	4.32	-48	-1.4	7.2
	(0.58)	(2)	(0.3)	(0.5)
total surplus ($M/hospital/year)	5.56	-19	0.7	2.2
	(0. 5)	(1)	(0.1)	(0.2)
total stentings (stents/hospital/year)	977	-43	-1.1	5.9
		(2)	(0.3)	(0.4)
mean BMS price ($/stent)				

changes in stent prices, the effects on the total number of stentings and total welfare are small. As a result, the interesting changes are in the way the surplus such a high bargaining ability speaks to how difficult it might be to obtain.

[illegible] The vertical axis is the percent change in hospital profits, and the horizontal axis is the bargaining ability of the hospital ation of 0.1 and a lower mean of $1 9 for the same stent in the same month. While this evidence is not systematic, it does show that more centralization in purchasing is not necessarily accompanied by enough bargaining ability to drive down prices relative to a decentralized system. Similar evidence exists for the U.S. in the fact that hospital group purchasing organizations (GPOs) play little to no meaningful role in the markets for coronary stents and other "physician preference items (Burns and Lee 008). The analysis here offers an explanation for this: GPOs are unable to achieve enough of an increase in bargaining ability to overcome the competitive disadvantage created by aggregating demand across hospitals with asymmetric demand. Thus GPOs are not able to provide value when it comes to physician preference items, where different doctors have brand loyalties to different manufacturers.

5.2 Hospital Mergers: Quantifying The Role of (A)symmetry

The results thus far are consistent with theory that predicts more asymmetry softens competition under uniform pricing because manufacturers to retreat to their captive markets. However, in real-world empirical settings, there is no such thing as complete symmetry or asymmetry, only some measure of the extent of one versus the other. Better understanding and quantifying this effect becomes especially important for thinking about hospital mergers because mergers may vary in the extent to which the merging hospitals exhibit (a)symmetry in their demand. This section develops a measure of demand symmetry among a group of buyers and quantifies the role of more or less symmetry in the context of hospital mergers into multi-hospital systems.

Of the ,008 registered U.S. community hospitals, ,9 1 are part of a multi-hospital system, with an average of seven hospitals per system.[20] The argument in favor of hospital mergers into systems often includes arguments for reducing costs, but the evidence hospitals by taking the across-hospital, within-stent variation in stent own-elasticities (${}_{jh} := \frac{\partial q_{jh}}{\partial p_{jh}} \frac{p_{jh}}{q_{jh}}$) explained by hospital dummy variables divided by the total stent-hospital variation, $y \quad etry := \frac{Var(\hat{\eta}_{jh}(jFE,hFE)) - Var(\hat{\eta}_{jh}(jFE))}{Var(\eta_{jh}) - Var(\hat{\eta}_{jh}(jFE))}$. This measure is equal to 1 when hospitals are perfectly symmetric (purely vertically differentiated in their demand for the different stents), and equal to 0 when hospitals are perfectly asymmetric (purely horizontally differentiated). I simulate the new equilibrium prices and w predicts that a merger between hospitals with perfect asymmetry in demand would result in a 8.9% decrease in hospital profits. Hospital profits increase with symmetry at a slope of . , predicting that a merger between hospitals with perfect symmetry would still result in a decrease of 1. % in hospital profits. With an ^{2} of 0.0 , the fitted line provides a noisy prediction of merger outcomes, so for very high levels of symmetry, the competitive effect is will often flip and work in favor of uniform pricing. Despite this somewhat encouraging extrapolation, the data suggest that high levels of symmetry are rare—across the 100 simulated hospital groups, the maximum symmetry measure is 0. 9 (mean 0. 1 and minimum 0.09). Thus for the highest symmetry actually observed, the competitive effect still softens competition substantially, with a predicted decrease of . % in hospital profits.

Turning to Panel (b)—the case where the merged hospitals have the maximum bar-

First, under individually negotiated prices, what matters is the prod

Taken together, these results suggest that moving towards more uniform pricing may be a difficult and indirect route towards lowering the prices hospitals pay for physician preference items such as coronary stents. This could be one reason why GPOs play such a small role in contracting for physician preference items and why hospital mergers often don't seem to reduce costs. If the goal is to lower the costs of medical technologies, a more fruitful approach might be to embrace the increased competition that comes

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Duggan, Mark and Fiona Scott Morton

Nevo, Aviv, "A Practitioner's Guide to Estimating Random Coe cients Logit Models of Demand," *n n n n*, 000, , 1 – 8.

Pauly, Mark V. and Lawton R. Burns, "Price Transparency for Medical Devices," *A*, 008, , 1 –1 .

Stole, Lars, *nd nd n n* 00 .

Sweeting, Andrew, "Dynamic Product Repositioning in Di erentiated Product Industries: The Case of Format Switching in the Commercial Radio Industry," 00 . NBER working paper.

Villas-Boas, Sofia B., "An Empirical Investigation of the Welfare E ects of Banning Wholesale Price Discrimination," *A n n*, 009, , 0– .

A Data Set Construction

The data set used in this paper is from Millennium Research Group's survey of catheter labs, the source that major device manufacturers subscribe to for detailed market research. The goal of the survey is to provide an accurate picture of market shares and prices by U.S. region (Northeast, Midwest, South, West).[21]

in column two. Despite the fact that observations are missing whenever $q_{jht} = 0$, there

A.1 Potential Sole-Sourcing and Exclusivity

Because the data is recorded for stents d by a given hospital in a given month, it does not contain data on the set of stents available but not used. Further, the price data does not include any information besides price, such as exclusivity arrangements. Despite the fact that exclusive arrangements which impact prices paid are common in business-to-business markets, including many medical supplies, my understanding from talking with industry participants is that "exclusivity did not play a major role in coronary stent pricing during the time of this study (00 -0). However, because the model used in this paper does not explicitly allow for strategic choices regarding "who contracts with whom , it is important to verify this omission empirically.

The analysis in this Section looks at the e ects of exclusive (100% market share among similar type stents) and near-exclusive (over 80%) situations on prices paid for two stents: DES and BMS8.[22] The results indicate that neither exclusive nor nearly exclusive contracts seem to play a role in driving the observed price variation across hospitals.

Tables 9 and 10 show the results of several regressions of price on dummy variables for exclusivity for DES and BMS8. In each case, the first four colu

[illegible]

parameter	E1	E2	E3	E4	NE1	NE2	NE3	NE4
Exclusive, $s_{jht}\|_{g_j} = 1$	-42	-11	-94	28				
	[illegible]	[illegible]	[illegible]	[illegible]				
Nearly-exclusive, $s_{jht}\|_{g_j} > 0.8$					43	4	65	5
					[illegible]	[illegible]	[illegible]	[illegible]
Month Fixed Effects	-	Y	-	Y	-	Y	-	Y
Hospital Fixed Effects	-	-	Y	Y	-	-	Y	Y
N	2805	2805	742	742	1960	1960	1184	1184
# "Sole-source"	451	451	451	451	624	624	517	517
$N_{Hospitals}$	101	101	24	24	94	94	52	52
R^2	0.005	0.26	0.32	0.65	0.008	0.26	0.59	0.79

Standard errors clustered at the hospital level.

and the ^{2} suggest that exclusivity does little to explain the price variation observed in the data. Relatedly, beyond the regression results regarding the two sample means, there is no discernible difference in the sample standard deviations either, at $ 1 for sole-sourcers and $ for non. Combined with the further evidence that these sole-sourcing cases comprise only 1 % of the hospital-month observations for DES (and this is the largest percentage observed for any stent), it seems difficult to make a case for an important role of full exclusivity. Results for near exclusivity are similar in every way except for the fact that the sample mean differences for the specifications without time dummy variables suggest that those with high market shares pay about $ - on average than others, which is more consistent with the standard problem of a positive correlation between price and market share as a result of unobserved quality than a story of exclusivity.

[illegible]

parameter	E1	E2	E3	E4	NE1	NE2	NE3	NE4
Exclusive, $s_{jht}\|_{g_j} = 1$	15	52	-23	10				
	[illegible]	[illegible]	[illegible]	[illegible]				
Nearly-exclusive, $s_{jht}\|_{g_j} > 0.8$					-37	-8	-40	-0.8
					[illegible]	[illegible]	[illegible]	[illegible]
Month Fixed Effects	-	Y	-	Y	-	Y	-	Y
Hospital Fixed Effects	-	-	Y	Y	-	-	Y	Y
N	2260	2260	516	516	1597	1597	925	925
# "Sole-source"	168	168	130	130	173	173	173	173
$N_{Hospitals}$	89	89	21	21	82	82	39	39
R^2	0.0003	0.11	0.68	0.75	0.003	0.07	0.65	0.71

Standard errors clustered at the hospital level.

Looking to BMS8 and Table 10 shows similar small and noisy point estimates comparing sample means, little in sample standard deviation ($19 for sole and $ 1 for non), and infrequency of sole-sourcing in general (8% of observations).

estimation relative to cases when they must be simulated (e.g. normally distributed random coefficients). The elasticities are given by $\frac{\partial q_{jht}}{\partial p_{kht}}\frac{p_{kht}}{q_{jht}} = \sum_{l=1}^{L} \lambda^{l}_{ht}\frac{\partial q^{l}_{jht}}{\partial p_{kht}}\frac{p_{kht}}{q_{jht}}$ where (suppressing the hospital and time subscripts):

$$\frac{\partial q_j^l}{\partial p_k} = -\alpha^p q_j \left(s_k + s_k|_{stent}\frac{\sigma_{stent}\mathbf{1}_{\{j,k\in stent\}}}{1-\sigma_{stent}} + s_k|_{des}\right.$$

for more flexibility in the demand curve with the nested logit random coefficients and the mixture terms which allow for brand loyalty. C.1. checks the robustness of the demand estimates to estimating from a subsample of the data and including time dummy variables. C. checks robustness of the paper's results to various assumptions on stent marginal costs.

C.1 Demand Estimation Specification and Robustness

C.1.1 Identifying the Effect of Price on Demand

Table 11 illustrates how the stent-hospital fixed effects, AR(1) error process, and instrumental variables identify the price sensitivity coefficient in the context of a simple logit model of demand: $\ln(s_{jht}\ s_{0ht}) = {}^{p}p_{jht} + X_{jht}{}^{x} + {}_{jht}$. Though the logit restricts the shape of the demand curve and thus does a poor job of estimating own and cross-elasticities, it will consistently estimate the average price effect, and it provides a simple context that focuses on this effect in order to see the identification strategy at work.

[illegible] Logit demand estimates from: $\ln(s_{jht}/s_{0ht}) = \theta^p p_{jht} + X_{jht}\theta^x + \xi_{jht}$ for different specifications to illustrate how the fixed effects, AR(1) term, and instrumental variables identify the effect of price on demand.

parameter	OLS	stent-hospital FE	FE & AR(1)	IV
ρ ([illegible])	-	-	0.26	0.26
			[illegible]	[illegible]
θ^p ([illegible] $\frac{utils}{\$1000}$)	0.98	-0.63	-0.67	-0.73

instruments increases the magnitude of the price coefficient by approximately 9%. The results of the first-stage regression of price on these instruments and the other regressors shown below in Table 1 indicate that both are strongly correlated with price; and under the timing assumption discussed in the paper—that price does not incorporate known changes in future demand that are not already captured in current demand—the instruments are also uncorrelated with the unobservable innovation in demand (ξ_{jht}).

on Price (p_{jht}) regressed on instrumental variables of lagged own price (p_{jht-1}

[illegible]

parameter	Logit	Nested Logit	Mixture of NL (Paper)
ρ (p rs st n n n no s r	0.26	0.10	0.08
	(	(	(
θ^{p} (pr s ns t t n $\frac{utils}{\$1000}$	-0.73	-0.29	-0.27
	(	(	(
σ_{stent} (orr t on n n or st nts	-	0.56	0.38
		(	(
σ_{des} (orr t on n n or DE	-	0.31	0.29
		(	(
λ_{des} (s t or s r o DE	-	-	3.3
			(
λ_{bms} (s t or s r o B	-	-	2.0
			(
mean BMS own-elasticity	-0.61	-0.56	-0.32
mean DES own-elasticity	-1.38	-2.05	-0.52
mean outside option cross-elasticity	0.08	0.04	0.03
GMM criterion	161.2	16.25	15.19

Table 1 shows the results of robustness checks that (1) estimate the same model on the subset of the data before the DES safety scare, and ( ) estimate the same model with month fixed effects added.

n o n

parameter	Paper	2004-06	Month FE
ρ (p rs st n n n no s r	0.08	0.09	0.08
	(	(	(
θ^p (pr s ns t t n $\frac{utils}{\$1000}$	-0.27	-0.31	-0.15
	(	(	(
σ_{stent} (orr t on n n or st nts	0.38	0.26	0.46
	(	(	(
σ_{des} (orr t on n n or DE	0.29	0.23	0.41
	(	(	(
λ_{des} (s t or s r o DE	3.3	3.95	3.25
	(	(	(
λ_{bms} (s t or s r o B	2.0	0.0	2.0
	(	(	(
mean BMS own-elasticity	-0.32	-0.41	-0.17
mean DES own-elasticity	-0.52	-0.62	-0.28
mean outside option cross-elasticity	0.03	0.07	0.03
A s st r osp t ($N_{Hospitals}$			

The results across the robustness checks are all qualitatively similar. In particular, demand is relatively inelastic, consistent with the institutional facts about doctor price-sensitivity and negotiated prices. Quantitatively, the results of the two robustness checks are close to those of the main specification from the paper, though they differ in some ways that make sense.

The results from running the model on the period before the DES safety scare (Jan. 00 - Feb. 00) show slightly more elastic demand estimates, and in particular less brand loyalty among BMS. This makes sense because the DES safety scare provided