12-2014

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Keywords

economics, game theory, bargaining theory, healthcare, industrial organization, market structure, firm strategy, market performance, microeconomics, market pricing

Disciplines

Business Administration, Management, and Operations | Business Analytics | Business Intelligence | Equipment and Supplies | Health and Medical Administration | Health Information Technology | Management Sciences and Quantitative Methods | Operations and Supply Chain Management | Organizational Behavior and Theory

Bargaining Ability and Competitive Advantage: Empirical Evidence from Medical Devices

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September 24, 2013

Abstract

In markets where buyers and suppliers negotiate, supplier costs, buyer willingness-to-pay, and competition determine only a range of potential prices, leaving the final price dependent on other factors (e.g. negotiating skill), which I call *bargaining ability*. I use a model of buyer demand and buyer-supplier bargaining, combined with detailed data on prices and quantities at the buyer-supplier relationship level, to estimate firm bargaining abilities in the context of the coronary stent industry where different hospitals (buyers) pay different prices for the exact same product from the same supplier. I estimate that: (1) variation in bargaining abilities explains 79% of this price variation, (2) bargaining ability has a large firm-specific component, and (3) changes in the distribution of bargaining abilities over time suggest learning as an important channel influencing bargaining ability.

*Data for this research was provided by Millennium Research Group (www.mrg.net). Special thanks for the guidance and encouragement throughout the many phases of this research project go to my dissertation committee: John Asker, Adam Brandenburger, Allan Collard-Wexler, Michael Katz, and Bernie Yeung. I also benefited from discussions with Heski Bar-Isaac, Luís Cabral, Catherine de Fontenay, JP Eggers, Robin Lee, PT Leger, Hong Luo, Gabriel Natividad, Joanne Oxley, Ariel Pakes, Mike Ryall, Rob Salomon, Gus Stuart, Ali Yurukoglu, and seminar audiences at Analysis Group, Arizona, Columbia, Georgia, LSE, NYU, Toronto, Wharton, and Yale. Andy Cron, John Brumleve, Mark Bly, Rob Tumarkin, and many others have been helpful in teaching me about medical device manufacturing and sales. Physicians and administrators at NYU Medical Center and CGH, Sterling, IL were especially generous with their time and knowledge regarding hospital purchasing and the inner workings of a cardiac catheterization lab. Some industry background research was conducted while attending the Transcatheter Cardiovascular Therapeutics 2008 conference, which was made possible by the Cardiovascular Research Foundation.

1 Introduction

"In business, as in life, you don't get what you deserve, you get what you negotiate." reads the ubiquitous airline magazine advertisement of Chester L. Karrass, whose company runs seminars on negotiation skills. These ads are at least partially correct, as many business outcomes are negotiated, and different buyers often negotiate substantially different prices for the exact same product from the same supplier. The "value-based strategy" literature (Brandenburger and Stuart 1996, 2007; Chatain and Zemsky 2007; and MacDonald and Ryall 2004) offers two explanations for this type of variation: (1) that buyers vary in the added value they get from the same supplier, or (2) that buyers vary in their ability to negotiate. This paper empirically separates these two explanations, identifies firm-specific variation in ability to negotiate as an important force, and estimates the dollar value of this bargaining ability to a firm in the context of the market for coronary stents, a $30 billion medical device market.

Markets where prices are negotiated are different from markets where buyers are price-takers in that supplier costs, buyer willingness-to-pay, and competition (forces Porter (1980) refers to as sources of *bargaining power*) determine only a range of potential prices (versus a single price) for each buyer and supplier. The endpoints of this range are determined by the total value each buyer and supplier can create together as well as each firm's disagreement point (Nash 1950) or best-alternative-to-negotiated-agreement (BATNA) (Fisher, Ury, and Patton 1991). Strategies that move these endpoints can have important implications for firm profits and social welfare. This fact has been explored by theoretical research in competitive strategy cited above and empirical research in industrial organization (Ho 2009).

However, the final negotiated price depends not only on the range of prices over which negotiation occurs, but also on where firms end up within this range. This latter aspect has received less attention, despite the fact that it can be important, especially in cases where the range over which negotiations occur is large and firms vary in their *bargaining abilities*—the ability to reach a more favorable point within the range determined by costs, willingness-to-pay, and competition.

The primary goal of this paper is to empirically analyze the role of costs, willingness-to-pay, and competition (which determine a minimum and maximum price a buyer "deserves" according to market forces) versus the role of bargaining ability (which determines the final price a buyer "negotiates" within this range). I do this by combining a formal model of demand and price negotiations with an unusually detailed panel data set that provides the quantities purchased and prices paid for all coronary stents sold to 96 U.S. hospitals from January 2004 through June 2007, at the stent-hospital-month level of observation.

Measuring bargaining ability and its role in determining prices is important for several reasons. First, bargaining ability directly affects firm profitability because it determines the split of the surplus created when buyers and suppliers transact. In the coronary stent market, I estimate that heterogeneity in bargaining ability—variation within the negotiation range—is responsible for 79% of the variation in prices across hospitals. I also estimate that this heterogeneity in bargaining ability has a large firm-specific component. Thus firms seeking a competitive advantage may want to look beyond strategies that increase their added value to strategies that help them capture a larger portion of that value in negotiations.

Second, measuring bargaining ability from market data is a step towards bridging market outcomes with organizational structure and individual behavior. A large literature of negotiations research in psychology (see Bazerman et al. 2000) has studied extensively the determinants of negotiated outcomes. In-depth case studies in strategic management have pointed to features of the "pricing process" as important firm capabilities (Dutta, Zbaracki, and Bergen 2003). A few recent studies in marketing (Draganska, Klapper, and Villas-Boas 2009; Meza and Sudhir 2010; Scott-Morton, Silva-Rosso, and Zettelmeyer 2011) and strategy (Bennett 2013) have begun to match data on negotiated prices with firm characteristics such as organizational structure. This paper contributes to these lines of research by using a rare multi-dimensional panel data set on prices and quantities for many buyer-supplier pairs in a business-to-business market over time, developing a modeling framework to separately identify bargaining power and bargaining ability, and providing new evidence on the degree of firm-specificity of bargaining ability and how it changes over time.

The model is an important part of this study because even with the detailed price and quantity data, several important variables—cost, willingness-to-pay, and bargaining ability—are unobserved. Further, separating the impact of 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. I address these challenges using a structural empirical approach—combining the data with a formal theoretical model. The theoretical model builds on the value-based strategy literature, is motivated by institutional details of the market being studied, and can be thought of as a way to combine qualitative facts about these institutions with the large-sample data on prices and quantities. Structural econometrics has become a standard tool in the marketing and industrial organization economics literatures because, in addition to addressing the challenges just mentioned, estimating a structural model has the benefit of providing a "laboratory" in which the researcher can then use the model and estimated parameters to make predictions regarding counterfactual scenarios.[1] A companion paper, Grennan (2013), uses the same data and model to answer policy questions regarding the impact of price discrimination (versus more uniform pricing) on the prices hospitals pay for medical devices.

The paper proceeds as follows: Section 2 builds on the value-based strategy literature, developing a model of how prices emerge from competition and bargaining. Section 3 presents the data and industry details, illustrating the large variation in prices negotiated for the same product and offering some preliminary evidence regarding the potential sources of this variation that will need to be separately identified in the analysis. Section 4 completes the pricing model introduced Section 2 and summarizes the model and estimation approach. The model has two parts: (1) a model of doctor demand for coronary stents uses the price and quantity data to estimate willingness-to-pay for each stent in each hospital in each month; and (2) the pricing

[1]See Reiss and Wolak (2007) for an excellent discussion and overview of the pros and cons of structural econometric modeling for analyzing competitive environments.

model that uses willingness-to-pay estimates along with the price and quantity data to estimate costs and relative bargaining abilities for each stent in each hospital in each month. The pricing model also specifies exactly how costs, willingness-to-pay, competition, and bargaining abilities combine to determine prices, allowing me to decompose the price variation into variation in these different variables in Section 5.1, revealing the large role played by bargaining ability. Section 6 takes a closer look at bargaining ability, using the panel structure of the data to estimate firm and pair-specific bargaining abilities, and then examining how the distribution of bargaining abilities evolves over time.

2 Theory: Negotiated Prices and Value-Based Strategy

The value-based strategy literature has built on the insight that cooperative game theory—in particular the transferable utility (TU) games using the Core solution concept—relates closely to verbal concepts in business strategy such as the importance of differentiation (Brandenburger and Stuart 1996), and these ideas can be used to characterize how primitives such as willingness-to-pay and opportunity cost affect the total value created in a market as well as the minimum and maximum payoffs a firm can hope to capture (MacDonald and Ryall 2004). Brandenburger and Stuart (2007) introduced the notion of a confidence index, reflecting a firm's expected value capture between these minimum and maximum payoffs, and subsequent research (Chatain and Zemsky 2007) has often interpreted these confidence indices as capturing the expected outcome of a negotiation (bargaining ability) over the portion of the surplus left indeterminate from willingness-to-pay, cost, and competition (bargaining power).

This division of value capture into parts determined by bargaining power and bargaining ability makes the value-based strategy paradigm well-suited for the present study. However, institutional details of the research setting require a slightly different model than the TU Core traditionally used in the literature. In this Section, I will lay out this alternative model, discuss why it fits the current setting well, and provide a proof for a set of conditions under which the two models are equivalent (thus providing a class of situations for which the model used in this paper is a generalization of the standard TU Core model).

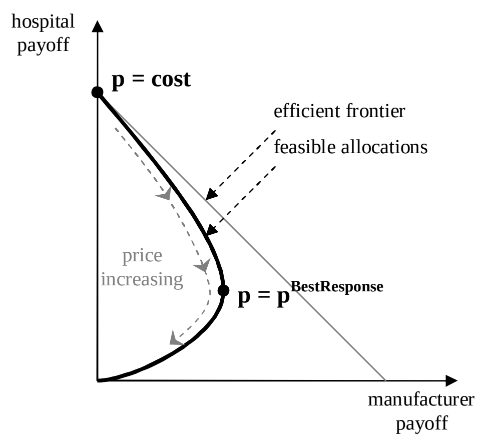
I consider a model of bargaining and competition similar to that of Horn and Wolinsky (1988) with a single buyer and a finite number of suppliers of differentiated substitute products. The buyer negotiates with each supplier separately and simultaneously, with the outcome of each negotiation satisfying the bilateral Nash Bargaining solution. Consistency across the bilateral bargaining problems requires that the outcomes form a Nash Equilibrium in the sense that no party wants to renegotiate. Formally, prices are determined as a Nash Equilibrium of bilateral Nash Bargaining problems (NENB). Each bilateral price maximizes the Nash Product of supplier j and buyer h surplus, taking the other prices as given, solving

$$\max_{p_{jh}} \quad [\pi_j(\vec{p}_h) - d_j(h)]^{\beta_j(h)} \, [\pi_h(\vec{p}_h) - d_h(j)]^{\beta_h(j)} \qquad \forall j \in \mathcal{J}_h, \tag{1}$$

where the parameters $\beta_j(h), \beta_h(j) \geq 0$ represent the bargaining ability of the supplier and buyer vis-a-vis each other, respectively, and similarly $d_j(h)$ and $d_h(j)$ represent the disagreement payoffs when no contract is signed. π_j and π_h are the profits to suppliers and the buyer as a function of the equilibrium price vector $\vec{p}_h$.

The main departure from the standard TU Core model here is that the size of the total surplus created is allowed to be a function of the split of the surplus—that is, the NENB model allows for non-transferable utility (NTU).[2] Figure 1 shows the feasible set of surpluses for a manufacturer-hospital pair and how the NTU surplus deviates from the efficient TU surplus. For simplicity of the graphical representation, there are only a single hospital (buyer) and a single manufacturer (supplier) in the graph. This could be thought of as a case of bilateral monopoly, or the residual curve faced between the pair, holding the prices of all other available products fixed.

Figure 1: Surplus size and split depend on price. The vertical axis measures hospital surplus and the horizontal axis measures manufacturer profit. The dotted line is the efficient frontier. The curved line maps the allocations that the hospital and manufacturer can achieve for different prices. Note that a two-dimensional graph allows only one manufacturer. This could be thought of as a case of bilateral monopoly, or the residual curve faced between the pair, holding the prices of all other available products fixed.



Another way to see the connection with the TU Core is to solve for the equilibrium profit equations of the NENB model:

$$\pi_j = \underbrace{d_j(h)}_{\pi_j^{min}} + \underbrace{\frac{\beta_j(h)}{\beta_j(h) + \beta_h(j)}}_{\text{Confidence Index weight}} \underbrace{\left[\left(\frac{\partial \pi_j / \partial p_{jh}}{\partial \pi_h / \partial p_{jh}} \right) \right.}_{\text{NTU adjustment}} \underbrace{\pi_h - d_h(j) + \pi_j}_{\pi_j^{max}} - \underbrace{\left. d_j(h) \right]}_{\pi_j^{min}}, \tag{2}$$

where the terms under braces demonstrate how this equation maps into the value-based strategy modeling. The NTU adjustment term accounts for the possibility that the transfer of dollars

[2]There are many reasons that real world markets can deviate from the TU ideal in the way just demonstrated. The TU Core assumes both "no externalities" in the sense that the price one buyer-supplier pair agrees to does not affect the value-added for another buyer-supplier pair, and also "perfect price discrimination" in the sense that a supplier can set a different price to each and every product user (or more precisely user "type"). Both of these assumptions are violated in the medical device sales context because prices affect doctor choice and because price discrimination is at the hospital rather than patient level.

may destroy or create surplus, and the special case where $\frac{\partial \pi_j / \partial p_{jh}}{\partial \pi_h / \partial p_{jh}} = 1$ corresponds to TU. In the TU case it turns out that the NENB model is a generalization of the Core solution concept for this game.

Theorem 1. *In the TU version of the game described above, given the appropriate choice of disagreement points in the NENB model, the range of outcomes possible in the NENB model is equivalent to the Core.*

The complete proof is in Appendix A. A sketch follows here. Transferability utility implies that $\frac{\partial \pi_j / \partial p_{jh}}{\partial \pi_h / \partial p_{jh}} = 1$, so it remains to find the disagreement points such that the NENB set (the set of allocations that can be achieved as one varies the ratio of Nash Bargaining weights in Equation (2) from 0 to 1) is equivalent to the Core of the corresponding cooperative game. The required assumption is that in the case of disagreement over product j, the buyer's disagreement point allows extraction of all of the producer's surplus from the increased sales this yields to the other suppliers: $d_h(j) = \pi_h(p; \mathcal{J} \setminus \{j\}) + \sum_{l \in \mathcal{J} \setminus \{j\}} [\pi_l(p; \mathcal{J} \setminus \{j\}) - \pi_l(p; \mathcal{J})]$. (Intuitively, this could happen if the hospital could negotiate binding contracts with $k \neq j$ specifying that, under the contingency that a contract is not signed with j, the manufacturers would charge only marginal cost for any sale that would have gone to j.) This disagreement point ensures that the NENB set is such that no *single firm* can obtain more than its marginal contribution. In the case where suppliers' products are substitutes selling to a single buyer, these single firm restrictions are enough to ensure that no *coalition* can obtain more than its marginal contribution, and thus NENB=Core in TU games of this type.

This result is only established for the particular model (monopsonist buyer, substitute suppliers, an no capacity constraints) studied empirically in this paper. It is not necessarily the case that NENB nests the TU Core for all modeling situations. As always, modeling choices will depend on the features of the market which are most relevant for the given theoretical or empirical setting.

One feature highlighted by the NENB model that will vary with institutional details is the correct characterization of disagreement points. As shown in the proof of Theorem 1, the Core corresponds to a setting with contingent contracts that allow the buyer to play the sellers off one another in a strong way. At the other extreme, Stole and Zwiebel (1995) show that disagreement points that involve a commitment to never reengage negotiations after a breakdown, combined with costless renegotiation for the remaining firms, result in a generalization of the Shapley Value, giving sellers more market power. As neither of these assumptions seem to match the institutional details in coronary stents, I take a middle ground and follow the Horn and Wolinsky (1988) and subsequent literature "passive beliefs" assumption that in equilibrium the players expect that the breakdown of any given negotiation would leave the prices agreed upon in other negotiations unaffected.

The next Section goes into more detail regarding the institutional details of the coronary stent industry as well as the data and descriptive statistics. Section 4 then shows how the NENB model described thus far is combined with a model of demand and the data to disentangle cost, willingness-to-pay, competition, and bargaining ability as determinants of value creation and capture in this industry.

3 Coronary Stents: Industry Description and Data

The coronary stent is a medical device used in angioplasty, an important treatment for coronary artery disease, the leading cause of death in the United States.[3] Angioplasty is a minimally invasive technique in which the doctor threads a balloon-tipped catheter from a peripheral access point to the heart. Using imaging devices, the doctor positions the balloon tip across the blockage, and expands the balloon, compressing the blockage to the artery walls. A stent is a small metal tube that is then placed via catheter where the blockage was cleared and left in the body as structural support for the damaged artery wall. The three million stents implanted worldwide each year generate annual revenues of more than $5 billion to stent manufacturers and $30 billion to hospitals and doctors for the stenting procedures.

Hospitals and doctors generate revenue from each angioplasty procedure, usually via reimbursement from a patient's insurer. Importantly, 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 typically the case here. For Medicare patients, 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 (though in some cases these markups can vary across diagnostic categories). Thus—to a first approximation, over the short run—reimbursement levels at each hospital are fixed with respect to the cost of stents.

The data set used in this paper is from Millennium Research Group's *Marketrack* 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).[4] The U.S. market is dominated by four large multinational firms: the Abbott Vascular (formerly Guidant) division of Abbott Laboratories, Boston Scientific, Johnson & Johnson's Cordis division, and Medtronic, which together make up over 99% of U.S. coronary stent sales.[5] These manufacturers offered a total of nine BMS (the older, established technology) and two DES (the new, superior, and more expensive technology) during the sample period.

The key variables in the data are the price paid and quantity used for each stent in each hospital in each month. In addition, the hospitals report monthly totals for different procedures performed, such as diagnostic angiographies, and prices and quantities for other products used in the catheter lab, such as balloon catheters and guiding catheters. After removing hospitals

[3] U.S. Department of Health & Human Services, National Heart Lung and Blood Institute Diseases and Conditions Index. www.nhlbi.nih.gov/health/dci/Diseases/Cad/CAD_WhatIs.html (June 2008)

[4] See www.mrg.net for more details on the survey. Because the data is sold as market research to device makers, hospitals are anonymous, preventing linking the data with other sources.

[5] iData Research, Inc. "US Markets for Interventional Cardiology" (2006).

with incomplete reporting (usually failure to report price data), the data set I use for analysis is an unbalanced panel of 10,098 stent-hospital-month observations at 96 U.S. hospitals over 42 months from January 2004 through June 2007.[6]

3.1 Price and Market Share Variation Across Hospitals

Table 1 provides price and market share summary statistics for each stent in the market. The most striking pattern is the significant variation in pricing and usage patterns across hospitals.

Table 1: Price and market share variation 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.

	Price Data		Share Data		N
	mean ($)	s.d. ($)	mean (%)	s.d. (%)	
BMS4	1006	175	5	3	25
BMS5	926	191	3	2	23
BMS6	952	156	6	6	26
BMS7	1035	174	4	5	39
BMS8	1063	338	4	4	11
BMS9	1088	224	8	8	47
DES1	2508	317	43	30	54
DES2	2530	206	41	30	54

The variation in market shares for the same stent across different hospitals provides preliminary empirical support for the anecdotal claims that different doctors vary in their preferences for which stent would be best to treat a given patient. However, there are other potential explanations for this usage variation: patient mix, the relative strength of interventional cardiology versus substitute treatments, reimbursement rates, and price all can vary across hospitals as well.

The price variation across hospitals also has several potential explanations. First, the variations in demand discussed above induce different competitive environments in different hospitals. Second, prices are usually negotiated directly between each manufacturer and each hospital. Who is involved in the negotiation and the incentives they face differ across hospitals and manufacturers, and anecdotal evidence suggests that this could also be an important source of variation in the final price. The goal of the rest of this paper is to use this data, institutional detail, and a formal theoretical model to determine the relative importance of demand and competition versus bargaining in explaining the observed price variation while allowing/controlling for these confounding explanations.

[6]Summary statistics and data set construction details beyond those provided here are available in the text and online appendix of Grennan (2013).

4 Combining Theory, Institutions, and Data: A Structural Model of Pricing and Demand

This Section summarizes the model and estimation approach used–in combination with the data–to tease apart and estimate costs, willingness-to-pay, and bargaining abilities.[7] The model is informed by the institutional details, and predicts the quantities of each stent used by each hospital and the prices negotiated for each stent by each manufacturer-hospital pair. The parameters in the model correspond to the unobserved variables to be estimated: costs, willingness-to-pay, and bargaining abilities. The estimation procedure then finds the parameter values that fit the predictions of the model to the prices and quantities in the data.

The agents in the model are the device manufacturers who supply the products, the doctors whose decisions determine demand for those products, and the hospitals that negotiate prices with manufacturers. The model is a two-stage game with no information asymmetries, proceeding as follows:

Stage 1: Pricing Device manufacturers and hospitals contract on prices, taking expected future quantities into account.

Stage 2: Demand Given prices and choice sets, doctors decide on stent purchases as patients arrive at the hospital.

As in the pricing model introduced in Section 2, I consider the problem of multiple device manufacturers selling to a single hospital. Under the maintained assumptions that hospitals are monopsonists of their own flow of patients and that manufacturer profits are separable across hospitals, this immediately extends to the empirical context, where each product is sold to multiple hospitals. Because the first stage pricing equilibrium depends on expected demand, I begin with how the demand model is used to estimate willingness-to-pay, and then return to the pricing model and how it is used along with the demand estimates to estimate costs and bargaining abilities.

4.1 Modeling Demand and Estimating Willingness-to-pay for Coronary Stents

I model demand using a discrete choice random utility model of how doctors choose which stent to use for each patient. This approach has the benefit of intuitively matching the discrete nature of the doctor decision process, and it accommodates the empirical fact that the choice sets of available stents vary across hospitals and over time. It also allows for a very flexible specification that allows willingness-to-pay for each stent to vary across hospitals and patients/doctors within a hospital (Berry, Levinsohn, and Pakes 1995; Nevo 2001).

Each hospital h has contracted with a set of stent manufacturers for the set of stent models $j \in \mathcal{J}_{ht}$. Over the course of a month t, patients $i = 1, ..., Q_{ht}$ arrive at the hospital to receive a

[7] The discussion here provides a summary, with special attention paid to the way in which the model relates to the value-based strategy literature. The interested reader can find more details regarding the model and estimation procedure in the text and appendices of the companion paper, Grennan (2013).

diagnostic procedure. The doctor chooses a treatment for the patient to maximize the following indirect utility function:

$$u_{ijht} = \theta_{jh} - \theta^p p_{jht} + X_{jt}\theta^x + \xi_{jht} + \epsilon_{ijht}^{stent} + (1-\sigma_{stent})\epsilon_{ijht}^{des} + (1-\sigma_{stent})(1-\sigma_{des})\epsilon_{ijht} + \lambda_{ijht}. \quad (3)$$

where θ_{jh} is a stent-hospital fixed effect, capturing the mean quality of product j across all patients at hospital h; θ^p is the marginal disutility of price p_{jht} (in utils per dollar); $X_{jt}\theta^x$ are a set of DES-time dummy variables and coefficients starting in March 2006 to account for the DES safety scare; ξ_{jht} are the econometric unobservable "error" terms; and $\epsilon_{ijht}^{stent} + (1 - \sigma_{stent})\epsilon_{ijht}^{des} + (1 - \sigma_{stent})(1 - \sigma_{des})\epsilon_{ijht} + \lambda_{ijht}$ is a stochastic quality component, representing characteristics of the specific patient/doctor combination i that make the patient an especially good candidate for a specific stent. The ϵ components as written here correspond to a two-level nested logit (allowing different substitution patterns between stent and no stent, DES and BMS, and the stents within each category), and λ allows for doctors to be loyal customers of a specific stent, making this component a mixture of nested logits (the mixing probabilities can change over time to accommodate the flow of information and experience). This utility function can be thought of as a reduced form for how a doctor incorporates his own preferences, patient welfare, and hospital profitability into the treatment decision (similar to the role of physicians in Blomqvist (1991)).

The set $\mathcal{J}_{ht}$ also includes a choice $j = 0$ for a treatment other than stenting, and I normalize $\theta_0 - \theta^p p_0 = 0$ so that the utility for each stent is the utility relative to the next best non-stent treatment. The most common alternative treatment would be no direct intervention (and typically a suggested diet and exercise regimen). The next most common would be coronary artery bypass graft surgery.[8]

4.1.1 Elasticities, Quantities, and Surplus Measures

The demand parameters enter the pricing model through expected quantities, elasticities, and hospital surplus measures. At the time of contracting, the exact set of patients that will show up at the hospital is uncertain. So expected quantities for any given price vector $\vec{p}_{ht} = \{p_{jht}\}_{j\in\mathcal{J}_{ht}}$ are anticipated via expected market shares by $q_{jht}(\vec{p}_{ht}) = s_{jht}(\vec{p}_{ht})Q_{ht}$. Price elasticities, $\frac{\partial q_{jht}}{\partial p_{kht}}\frac{p_{kht}}{q_{jht}}$ and hospital surplus, $\pi_{ht} = \sum_{j\in\mathcal{J}_{ht}}\int_{\mathcal{A}_{jht}}\frac{u_{ijht}}{\theta^p}d\varepsilon$ are similarly considered in expectation. The explicit equations for all three come from the distributional assumption on ε, and are thus a linear combination of the well-known equations for the nested logit.

4.1.2 Demand Identification and Estimation

The demand model estimation proceeds by integrating out the doctor/patient specific unobservables, ε, to obtain the predicted market shares from the model, matching those predicted shares to the actual market shares in the data, and inverting the resulting system of equations

[8]According to the Dartmouth Health Atlas, angioplasty procedures outnumbered bypass by approximately 3 to 1 in the U.S. in 2007, suggesting approximately 90% of the outside option is no intervention.

(using the contraction mapping in Berry, Levinsohn, and Pakes (1995)) to obtain the mean utility for each stent as a function of market shares and the nonlinear parameters, $\delta_j(s_{ht}; \sigma, \lambda, \phi)$, which can then be set equal the the mean utility parameters in the following linear regression:

$$\delta_j(s_{ht}; \sigma, \lambda, \phi) = \theta_{jh} - \theta^p p_{jht} + X_{jt}\theta^x + \xi_{jht}. \tag{4}$$

The challenge in obtaining consistent estimates from this regression is the potential for price to be correlated with the unobservable, ξ_{jht}. The inclusion of the stent-hospital fixed effects, θ_{jh}, subsumes any time invariant stent- or hospital-specific unobservables such as quality or procedure revenue, and so identification comes from variation over time within each stent-hospital pair. In this case, demand identification relies on a *timing assumption*: that price negotiations do not anticipate and take into account future changes in demand that are not already incorporated in current demand. This assumption seems reasonable in this context because any future development that is certain enough to be taken into account in pricing negotiations seems likely to already be incorporated into current demand. Failure of this assumption would require a situation where a device salesperson knows about a forthcoming study regarding a stent, convinces the hospital purchasing negotiator that this future study will increase future demand, but keeps this information from doctors so that it does not increase current demand.

Under this identifying assumption, if new prices are always negotiated at the beginning of a month, then realized demand is a response to this new price and any subsequent changes in demand, and there is no simultaneity problem in using contemporaneous price as its own instrument. However, I take a more conservative approach and construct a set of instrumental variables using one month lags to ensure that the instruments are uncorrelated with unobservable changes in demand over time. I use two different instruments, both leveraging the fact that the economics of negotiated prices in long-term contracts introduce two new sources of identification for demand: (1) When prices are negotiated, bargaining ability becomes available as an additional supply shifter. Thus I use the lagged average price of *other* stents at the same hospital, which captures supply side variation over time in hospital bargaining ability (and also in competition as demand for other stents changes, similar in spirit to the Berry, Levinsohn, and Pakes (1995) instruments). (2) When prices are fixed in long-term contracts and demand shifts over time, the observed prices and quantities will be "out of equilibrium" until price is renegotiated. I use this source of variation by adding lagged own price as a second instrument. The first-stage F-statistic of 664 (with standard errors clustered at the hospital level) confirms that the instruments have a great deal of predictive power.

The nonlinear parameters in the demand function—the mixture parameters $(\lambda_{bms}, \lambda_{des})$ and nested logit parameters $(\sigma_{stent}, \sigma_{des})$—are identified by nonlinearities in the demand curve and variations in the market share responses within stent type and versus the outside good. To capture the nonlinearities, I use a semi-parametric basis of the squares of the price instruments, lagged market shares, and their interaction. To capture the substitution patterns across groups, I use lagged logarithms of the within-stent and within-DES market shares (the standard nested logit instruments). Estimation of the demand parameters proceeds using a method-of-moments algorithm based on the conditions $E[(\xi_{jht} - \rho\xi_{jht-1})|Z^d_{jht}] = 0$, where the vector of instruments, Z^d_{jht}, includes the instruments discussed above for price and the nonlinear parameters, and other regressors serve as their own instruments.

4.2 Estimating Costs and Bargaining Abilities from the Bargaining Model

The bargaining model introduced in Section 2 predicts equilibrium total surplus and split of that surplus as a function of costs, bargaining abilities, and willingness-to-pay. The willingness-to-pay estimates and price and quantity data can then be combined with the model to estimate cost and bargaining ability parameters via a nonlinear regression model.

Dividing the equilibrium profit equation (2) by quantity and collecting the linear cost terms yields the equilibrium pricing equation:

$$p_{jht} = c_{jht} + \frac{b_{jt}(h)}{b_{ht}(j)} \left[\left(1 + \frac{\partial q_{jht}}{\partial p_{jht}} \frac{p_{jht} - c_j}{q_{jht}} \right) \frac{\pi_{ht} - d_{jht}}{q_{jht}} \right] \tag{5}$$

which can be turned into a fully specified regression model by parameterizing costs

$$c_{jht} = \gamma_j = \gamma_{bms} \mathbf{1}_{\{j=bms\}} + \gamma_{des} \mathbf{1}_{\{j=des\}} \tag{6}$$

and relative bargaining abilities

$$\frac{b_{jt}(h)}{b_{ht}(j)} = \beta_{jh} \nu_{jht}. \tag{7}$$

In this specification, cost is determined entirely by whether the stent is a BMS or DES. Ideally, marginal costs would be stent-specific, but the data in this study is not able to identify a more flexible specification. I further assume that there are no unobservable determinants of costs. This assumption seems reasonable in this context because marginal costs of production and distribution are thought to be quite low and to vary little (if at all) for a given product across hospitals and time. Both of these issues, and the robustness of the paper's results to cost estimates, are discussed at length in the results.

Assuming costs have no unobservable component allows me to estimate the full distribution of relative bargaining abilities, with β_{jh} measuring the average relative bargaining ability of stent j to hospital h, 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. ν_{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. ν_{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 ν_{jht}.

The resulting specification is the following nonlinear regression model:

$$p_{jht} = \gamma_{bms}\mathbf{1}_{\{j=bms\}} + \gamma_{des}\mathbf{1}_{\{j=des\}} + \beta_{jh}\nu_{jht}\left[\left(1 + \frac{\partial q_{jht}}{\partial p_{jht}}\frac{p_{jht} - c_j}{q_{jht}}\right)\frac{\pi_{ht} - d_{jht}}{q_{jht}}\right] \quad (8)$$

where the elasticities, $\frac{\partial q_{jht}}{\partial p_{jht}}\frac{p_{jht}}{q_{jht}}$, and hospital surplus measures with stent j, π_{ht}, and without stent j, d_{jht}, are all "data" in the sense that they can be computed from the demand model, using the demand parameter estimates and the price and quantity data. This equation clearly shows how the cost and bargaining ability parameters are separately identified by the fact that cost enters price as a constant term, while the relative bargaining abilities of the manufacturer-hospital pair are identified by the extent to which price changes as the added value of the stent changes. Then the cost and bargaining parameters can be estimated by solving for the unobservable, ν, taking logarithms so that the bargaining parameters enter linearly, and then forming a GMM algorithm based on the assumption $E[\ln(\nu)|Z^s] = 0$, where the IV are the standard first derivatives of the moments with respect to the parameters, lagged by one month for the same timing reasons as discussed in the demand estimation.

5 Estimated Sources of Price Variation

The estimated parameters of the demand and pricing models provide estimates for the costs (c_j), bargaining ability ratios $\left(\frac{b_{jt}(h)}{b_{jt}(h)+b_{ht}(j)}\right)$, and added value terms $\left(\left(1 + \frac{\partial q_{jht}}{\partial p_{jht}}\frac{p_{jht}-c_j}{q_{jht}}\right)\frac{\pi_{ht}-d_{jht}}{q_{jht}} + p_{jht} - c_j\right)$ that enter the pricing equation. Table 2 summarizes the cross-sectional variation in these estimates and prices across hospitals in September 2005.

Table 2: Important sources of price variation across hospitals for each stent, from the supply and demand parameter estimates. 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.

	Price Data		Cost Est.	Barg. Ratio Est.		Added Value Est.	
	mean ($)	s.d. ($)	mean ($)	mean	s.d.	mean ($)	s.d. ($)
BMS4	1006	175	34	0.33	0.07	2980	254
			(79)	(0.04)	(0.004)	(327)	(25)
BMS5	926	191	34	0.32	0.07	2807	155
			(79)	(0.10)	(0.006)	(313)	(13)
BMS6	952	156	34	0.31	0.05	2993	291
			(79)	(0.06)	(0.004)	(321)	(28)
BMS7	1035	174	34	0.35	0.07	2899	248
			(79)	(0.02)	(0.004)	(314)	(21)
BMS8	1063	338	34	0.36	0.10	2809	222
			(79)	(0.04)	(0.01)	(310)	(18)
BMS9	1088	224	34	0.34	0.08	3171	403
			(79)	(0.01)	(0.005)	(341)	(31)
DES1	2508	317	1103	0.35	0.08	4298	463
			(286)	(0.02)	(0.004)	(389)	(26)
DES2	2530	206	1103	0.36	0.06	4317	472
			(286)	(0.02)	(0.002)	(390)	(30)

(Standard errors clustered at hospital level.)

The added value estimates from the demand model are large—almost \$2000 more than prices. This is consistent with the facts that: (1) doctors are brand-loyal and relatively insensitive to price and (2) prices are negotiated. Added values also vary substantially across hospitals, indicating that some of the observed price variation is due to variation in demand.

The type-specific cost parameters—\$34 for BMS and \$1103 for DES—are close to the range that industry experts report, but imprecisely estimated. Section 6.3.2 demonstrates how realistic changes to the level or variation in costs have little impact on the main results of this paper.

The bargaining ability ratio estimates indicate that on average, each stent captures 31-36% of its added value in negotiations. While this results in large margins of \$1000 or more for the device manufacturers, an even larger portion of the surplus goes to hospitals/doctors/patients. Of special interest here is the large variation in bargaining ability ratios across hospitals for each stent, indicating that some of the observed price variation across hospitals is due to variation in bargaining abilities (in addition to variation in demand). The rest of this paper further investigates the relative importance of this bargaining ability variation, the extent to which this variation is firm-specific, and the dollar value of bargaining ability to firms.

5.1 How Much Does Bargaining Ability Matter?

The structure of the pricing equation, $p_{jht} = c_j + \frac{b_{jt}(h)}{b_{jt}(h)+b_{ht}(j)} AV_{jht}$, allows a precise breakdown of the extent to which variation in added value and bargaining abilities influence the observed price variation across hospitals. Moving cost to the left-hand side and taking logarithms gives[9]

$$\ln(p_{jht} - c_{jht}) = \ln\left(\frac{b_{jt}(h)}{b_{jt}(h) + b_{ht}(j)}\right) + \ln\left(AV_{jht}\right). \tag{9}$$

Comparing the variance of each term across hospitals in September 2005 indicates that heterogeneity in bargaining ability is a major driver of the observed price variation. On average, the variation in bargaining abilities, $V\left(\ln\left(\frac{b_{jt}(h)}{b_{jt}(h)+b_{ht}(j)}\right)\right)$, represents 79% of the total variation in bargaining abilities and added values, $V\left(\ln\left(\frac{b_{jt}(h)}{b_{jt}(h)+b_{ht}(j)}\right)\right) + V\left(\ln\left(AV_{jht}\right)\right)$ across hospitals for a given stent. Table 3 shows the variation in each term for each stent.

How should one interpret this fact that variation in bargaining abilities is four times larger than variation in demand? Because the model is constructed such that bargaining ability must explain all of the residual variation in price that is unexplained by variation in demand, there is a sense in which bargaining ability could simply be "a measure of our ignorance" in modeling the determinants of price variation in this market. While this explanation cannot be completely ruled out, there are several pieces of evidence that suggest bargaining ability is indeed measuring an economically and strategically important construct.

The first reason to believe that bargaining ability captures a meaningful construct is that it

[9] An alternative to using logarithms to separate the product of bargaining abilities and added value is to use the formulas for the variance of a product. The results are qualitatively similar, though a bit more cumbersome to explain due to the complexity of the formulas.

Table 3: Variation in price due to bargaining abilities. The first three columns correspond to the within-product variation in each component of the equation $\ln(p_{jht} - c_{jht}) = \ln\left(\frac{b_{jt}(h)}{b_{jt}(h)+b_{ht}(j)}\right) + \ln\left(AV_{jht}\right)$. The last column measures the variation in bargaining abilities relative to the variation in added values, $\frac{V(\ln(\frac{b_{jt}(h)}{b_{jt}(h)+b_{ht}(j)}))}{V(\ln(\frac{b_{jt}(h)}{b_{jt}(h)+b_{ht}(j)}))+V(\ln(AV_{jht}))}$.

	$V(\ln(p_{jht} - c_j))$	$V(\ln(AV_{jht}))$	$V(\ln(\frac{b_{jt}(h)}{b_{jt}(h)+b_{ht}(j)}))$	% Variation due to bargaining abilities
BMS4	0.029	0.007	0.040	85%
BMS5	0.034	0.003	0.037	93%
BMS6	0.023	0.009	0.026	75%
BMS7	0.026	0.006	0.032	83%
BMS8	0.077	0.006	0.060	91%
BMS9	0.037	0.015	0.042	74%
DES1	0.047	0.009	0.052	85%
DES2	0.020	0.010	0.025	72%

is not the only "residual" in the model. The demand model also contains a residual term, and due to the rich panel data, the demand model here is able to incorporate stent-hospital-specific heterogeneity across hospitals. This minimizes the concern that bargaining ability might simply be capturing demand heterogeneity that the demand model does not. Further supporting this point is the interesting fact that the total variation in bargaining abilities and added values is greater than the total variation in margins, $V(\ln(p_{jht} - c_j))$, indicating that relative bargaining ability and added value are positively correlated.[10] Because of this potential for covariation, 79% is not an upper bound for the amount of variation due to bargaining abilities. Instead, this percentage should be interpreted as the best approximation provided by fitting the assumed model to the price and quantity data available.

The analysis in the next Section offers yet another reason to believe that bargaining ability estimates are meaningful—variation in bargaining ability estimates is largely firm-specific and the distribution of bargaining abilities varies systematically over time. Robustness checks in Section 6.3.2 reinforce this finding by demonstrating that even if all variation in the residual ν_{jht} were attributed to costs, bargaining ability remains an important explanation for price variation.

6 Determinants of Bargaining Ability

The finding from Section 5.1—that in the coronary stent market, differences in bargaining abilities are an important source of price variation—has implications for how to think about prices in markets where they are negotiated and the value-based strategy paradigm. However, these implications depend critically on whether these differences in bargaining abilities are simply noise from the many idiosyncracies of the negotiation process or firm-specific differences that point to bargaining ability as a potential source of competitive advantage.

[10] The analysis here follows previous theory in assuming that this covariation is exogenous. An interesting question for future theory would be to analyze models (and develop underlying theoretical mechanisms) where bargaining ability is potentially endogenous to the added value being negotiated over.

This Section takes a closer look at the sources of bargaining ability. After examining the impact of basic firm and buyer-supplier pair characteristics, I exploit the panel data to decompose the variation into firm, pair, and time components. I then document changes in the distribution of bargaining abilities over time.

Table 4: Determinants of bargaining ability across hospitals and over time. Regressions of the form $-\ln(\beta_{jh}\nu_{jht}) = X_{jht}\alpha - \ln(\nu_{jht})$, so that coefficients can be interpreted as percent changes in relative bargaining abilities, with positive numbers indicating changes in favor of hospitals. Standard errors, clustered by hospital, in parentheses.

	(1)	(2)	(3)	(4)	(5)
Midwest	0.016	0.011			
	(0.06)	(0.06)			
Northeast	-0.006	-0.005			
	(0.04)	(0.04)			
South	-0.004	-0.004			
	(0.05)	(0.05)			
Teaching	-0.038	-0.037			
	(0.03)	(0.034)			
Public	-0.031	-0.041			
	(0.04)	(0.036)			
Diagnostic Angiographies (100's)	0.013	0.012			
	(0.010)	(0.012)			
Share, s_{jht} (1%)	0.013	0.038	0.044	0.047	0.048
	(0.002)	(0.012)	(0.011)	(0.007)	(0.008)
DES_j * Share, s_{jht} (1%)		-0.027	-0.032	-0.032	-0.033
		(0.013)	(0.012)	(0.008)	(0.008)
Quantity, q_{jht}	0.0018	0.0070	0.0051	0.0025	0.0014
	(0.0007)	(0.0038)	(0.0031)	(0.0024)	(0.0026)
DES_j * Quantity, q_{jht}		-0.0053	-0.0040	-0.0024	-0.0014
		(0.0038)	(0.0031)	(0.0023)	(0.0026)
Product FE	Y	Y	Y		
Hospital FE			Y		
Product-Hospital FE				Y	Y
2005					0.09
					(0.02)
2006					0.15
					(0.02)
2007					0.19
					(0.02)
R^2	0.24	0.28	0.47	0.73	0.75
N	9,269	9,269	10,098	10,098	10,098

Table 4 builds a series of specifications to uncover the determinants of bargaining ability. The first specification shows that none of the available hospital characteristics (census region, teaching/non-teaching, public/private, and size in terms of number of diagnostics procedures performed) have economically or statistically meaningful explanatory power. However, there is economically modest but statistically significant evidence of share and quantity discounting. This is in contrast to the raw price data which shows no such effects—the model rationalizes this by the offsetting effects of higher shares being correlated with higher willingness-to-pay (and thus higher prices) as well as discounting.

Share discounts should only exist if administrators are able to move market shares via their influence with doctors (Sorenson 2003). To explore this idea further, the second specification allows the share variable to differ for BMS (which are an older and potentially more commoditized technology with many options where physicians may be open to switching) versus DES (where physicians may have stronger opinions on their preferred one of the two products available). The results are stark: all share discounting comes from BMS, and quantity discounting is no longer statistically significant for BMS or DES. One might be skeptical of the cross-sectional nature of the variation in the first two specifications, but the share and quantity discounting results remain similar as hospital fixed effects (specification 3), product-hospital fixed effects (specification 4), and year fixed effects (specification 5) are added. In the most restrictive specification, a one percent increase in market share for a BMS is associated with a five percent increase in hospital bargaining ability relative to the manufacturer of that stent. To put this result in context, both the average and standard deviation for BMS market share are five percent, suggesting that share discounts could explain a significant part of the variation in BMS prices.

Looking at the model fit across specifications in Table 4 suggests some interesting patterns in the panel data regarding the sources of bargaining ability: the R^2 jumps dramatically with the addition of firm fixed effects, and again with the addition of product-hospital fixed effects. The next section examines this decomposition of the bargaining ability variation more precisely and in light of related literature. The other interesting result in Table 4 regards the year fixed effects in the final specification which suggest that hospital bargaining ability has increased steadily relative to manufacturers over the sample period. This result is examined in more detail in Section 6.2.

6.1 Firm-specific Bargaining Abilities

A large psychology literature in negotiations has studied the determinants of negotiated outcomes via experimental methods (for a review, see Bazerman et al. (2000)). This research suggests that bargaining ability will be determined by: (1) structural features of the negotiation environment, such as the organizational incentive structures; (2) characteristics of the individuals engaged in negotiation, such as bargaining skill; and (3) idiosyncratic features of the actual instance of negotiation, such as emotions. Experiments allow these studies to examine the micro-level determinants of bargaining success in detail, but this advantage comes with all the limitations of experimental studies as well. The current paper comes from the opposite direction, using a large data set on prices paid and quantities used in a business-to-business setting where both competition and bargaining play a role.

Despite the lack of detailed firm and individual characteristics that might explain the prices observed in the data, the panel data here has the advantage of observing each manufacturer negotiating with multiple hospitals, each hospital negotiating with multiple manufacturers, and several such negotiations for each pair over time during the sample period. I use this variation to quantify the extent to which bargaining outcomes are random or whether a firm tends to extract a consistent amount of value via bargaining across partners and time.

The pricing model estimates consist of the *relative* bargaining ability of each hospital to each manufacturer in each month, $\frac{b_{jt}(h)}{b_{ht}(j)} = \beta_{jh}\nu_{jht}$. Regressing the logarithm of these ratios on firm (hospital and manufacturer) dummy variables:

$$\ln\left(\frac{b_{jt}(h)}{b_{ht}(j)}\right) = \ln(\beta_{jh}\nu_{jht}) = \ln\left(\frac{\beta_j}{\beta_h}\Delta\beta_{jh}\nu_{jht}\right) = \ln(\beta_j) - \ln(\beta_h) + \ln\left(\Delta\beta_{jh}\nu_{jht}\right), \qquad (10)$$

generates estimates for the average bargaining ability of each manufacturer (stent β_j) and hospital (β_h) across bargaining partners and over time. The R-squared of this regression is 0.29, indicating that 29% of the variation in relative bargaining abilities is firm-specific.

This analysis can be extended to examine the extent to which bargaining outcomes are pair-specific by regressing the logarithm of bargaining ability ratios on manufacturer-hospital pair dummy variables:

$$\ln(\frac{b_{jt}(h)}{b_{ht}(j)}) = \ln(\beta_{jh}\nu_{jht}) = \ln(\beta_{jh}) + \ln(\nu_{jht}). \qquad (11)$$

The R-squared of this regression is 0.65, indicating that 65% of the variation in relative bargaining abilities over the entire sample can be explained by knowing the manufacturer-hospital pair. Because this specification subsumes the firm-specific variation, another way to look at this result is to say that 29% of the variation in relative bargaining abilities is firm-specific, and an additional 36% is pair-specific.

The fact that a significant portion of the variation in bargaining ability is explained by variation across firms is consistent with the idea that bargaining ability may be influenced by firm-specific incentive structures or routines (Nelson and Winter 1982; Kogut and Zander 1992) and recent results in Bennett (2013) suggesting that the prices negotiated at auto dealerships depend on the dealership's organizational structure. The fact that bargaining ability varies across partners and over time points to the possibility that there may be issues of "fit" between different bargaining approaches, and that the determinants of bargaining ability might evolve over time. This provides large-sample evidence consistent with the results of the in-depth case study of Dutta et. al. (2003).

The remaining 35% of the variation in relative bargaining abilities is within-pair variation over time and is analyzed further in Section 6.2. First, though, I use the estimated firm fixed effects to examine the distributions of bargaining abilities across manufacturers and hospitals.

6.1.1 Distribution of bargaining abilities across firms

The fact that firm dummy variables explain 29% of the variation in bargaining outcomes across partners and time indicates that bargaining ability is something that is indeed a firm-specific capability. It also shows that firms are heterogeneous in their bargaining abilities. This subsection looks at the distribution of heterogeneity in bargaining abilities across firms, using the firm-specific estimates of β_j and β_h from the regression in Equation (10) above.

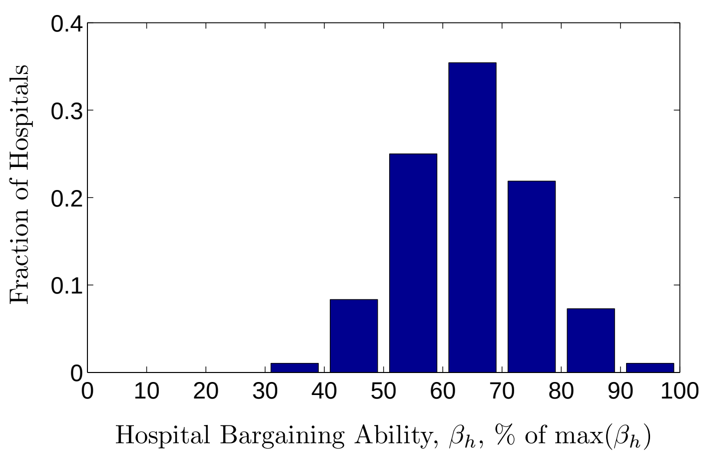
Table 5 presents the manufacturers' bargaining ability estimates for each stent, where the

Table 5: Manufacturer bargaining ability estimates across products. Coefficient estimates from bargaining specification $\frac{b_{jt}(h)}{b_{ht}(j)} = \beta_{jh}\nu_{jht}$ via the linear regression $\ln(\beta_{jh}\nu_{jht}) = \hat{\beta}_j - \hat{\beta}_h + \hat{\nu}_{jht}$, recovering the original parameters using $\beta_j = e^{\hat{\beta}_j}$. Standard errors are in parentheses and clustered at the hospital level.

	BMS1	BMS2	BMS3	BMS4	BMS5	BMS6	BMS7	BMS8	BMS9	DES1	DES2
β_j	28	24	24	30	30	28	32	34	31	35	34
	(3.8)	(3.5)	(3.4)	(4.0)	(3.9)	(3.6)	(4.3)	(4.5)	(4.0)	(9.1)	(8.8)
Across products: mean=30 , std.dev.=3.8 , std.dev/mean=0.13											

scale is given by normalizing the highest bargaining ability among hospitals to 100, so the numbers represent "percent of the bargaining ability of the highest bargaining ability hospital".[11] The point estimates suggest that there is some variation in bargaining abilities across manufacturers, with a mean of 30 and a standard deviation of 3.8. However, there is enough noise in the estimates that one cannot reject the hypothesis that all manufacturer bargaining abilities are equal to one another.

Figure 2: Estimated distribution of bargaining abilities across hospitals. Coefficient estimates from bargaining specification $\frac{b_{jt}(h)}{b_{ht}(j)} = \beta_{jh}\nu_{jht}$ via the linear regression $\ln(\beta_{jh}\nu_{jht}) = \hat{\beta}_j - \hat{\beta}_h + \hat{\nu}_{jht}$, recovering the original parameters using $\beta_h = e^{\hat{\beta}_h}$. Standard errors are in parentheses and clustered at the hospital level.



	mean	std. dev.	std. dev. / mean	min	median	max	N
β_h	65	11	0.17	40	64	100	96
	(2.3)	(0.4)	(0.4)	(0.01)	(2.5)	(2.1)	

Figure 2 presents the estimated distribution of bargaining abilities across hospitals, where the scale is again given by normalizing the highest bargaining ability among hospitals to 100. Interestingly, the hospitals' bargaining abilities are uniformly larger than those for the stents, with the lowest at 40. The mean across hospitals is 65, over double that of the average

[11] Note that it is *relative* bargaining ability that drives negotiated outcomes; thus bargaining ability itself has no natural scale. Multiplying all firm bargaining abilities by the same number results in the same relative bargaining abilities.

stent. There is also substantial variation with a standard deviation of 11, and this variation is statistically significant.

Thus the firm-specific variation in negotiated outcomes appears to be driven by the fact that some hospitals consistently negotiate better prices (conditional on costs, willingness-to-pay, and competition) than other hospitals across manufacturers and over time. Interestingly, the distribution of hospital bargaining abilities relative to manufacturers evolved fairly substantially over the sample period. This phenomenon is explored in detail in the next section.

6.2 Changes in Bargaining Abilities over Time

The fact that 35 percent of the variation in bargaining abilities is over time could be due to the randomness inherent in any particular negotiation, or it could represent a variety of more systematic factors: learning, evolving relationships, introduction of new people to the negotiation, or introduction of new incentives or processes at either the buyer or supplier. While the increasing year fixed effects in Table 4 suggest something systematic is happening over time, it is difficult to tell if those changes in the means are due to decreases in manufacturer bargaining ability or increases in hospital bargaining ability—and perhaps more importantly, how these changes are shared across the heterogeneous distribution of firms revealed thus far.

Table 6: Changes in the distribution of hospital bargaining ability over time. Quantile regressions of the form $-\ln(\beta_{jh}\nu_{jht}) = -\ln(\beta_j) + \alpha_{2005}1_{\{t\in 2005\}} + \alpha_{2006}1_{\{t\in 2006\}} + \alpha_{2007}1_{\{t\in 2007\}} - \ln(\nu_{jht})$. Positive coefficients are favorable to hospitals. Standard errors in parentheses.

	0.10	0.25	0.50	0.75	0.90
2005	0.10	0.11	0.08	0.05	0.04
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
2006	0.22	0.19	0.16	0.11	0.08
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
2007	0.32	0.25	0.21	0.14	0.11
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
Product FE	Y	Y	Y	Y	Y

Table 6 uses quantile regressions to examine the sources of the increase in hospital bargaining abilities relative to manufacturers over the sample period. While all quantiles examined (0.10, 0.25, 0.50, 0.75, 0.90) are increasing over time, the gains are also monotonically larger as one moves from higher to lower quantiles. Whereas the 0.90 quantile increased by an average of four percent per year, the 0.10 quantile increased by an average of 11 percent per year. Thus in addition to changing in favor of hospitals, the distribution has become more compressed from the bottom, with fewer hospitals getting "bad deals" over time.

These changes in the location and shape of the relative bargaining ability distribution over time provide some suggestive clues regarding the sources of firm bargaining ability. First, the systematic increase in favor of hospitals over time suggest that not all of this variation can be due to randomness in negotiated outcomes or random introduction of new people, incentives, or processes. Second, the compression from the bottom of the distribution provides suggestive evidence of learning mechanisms across hospitals, leading to more similar outcomes over time. Finally, this compression also suggests that changes are on the hospital side, as it is difficult to imagine what changes on the manufacturer side would lead to such asymmetric improvements for hospitals over time.

6.3 Robustness and Interpretation of Bargaining Ability Estimates

6.3.1 Robustness to Cost Parameter Levels and Variation

While bargaining ability parameters are separately identified from cost parameters through covariation in prices and added values, they are also closely linked as the two potential theoretical explanations for variation in prices beyond the variation explained by demand and competition. This Section explores the robustness of the fundamental results of this paper regarding variation in bargaining abilities to the levels and variation in cost parameters. The first robustness check explores the implications of varying the level of cost parameters within the widest possible reasonable range. The second explores the implications of allowing portions of the residual variation ν_{jht} to be due to costs.

Cost parameters are not tightly identified in this application because the large amount of product differentiation leads to added values that are always much larger than marginal costs. The flip side of this situation is that even large changes to the cost numbers induce relatively small changes in bargaining ability and counterfactual estimates. Table 7 shows the results of these estimates for costs fixed at zero, the estimated costs in the paper ($c_{bms} = 34, c_{des} = 1103$), and costs fixed at the minimum observed prices in the data ($c_{bms} = 240, c_{des} = 1540$).

Table 7: Robustness to Changing Cost Levels

	$c_{bms} = 0$ $c_{des} = 0$	PAPER $c_{bms} = 34$ $c_{des} = 1103$	$c_{bms} = 240$ $c_{des} = 1540$
mean bargaining split, $\frac{b_j(h)}{b_j(h)+b_h(j)}$, (0, 1)	0.43	0.33	0.25
std. dev. bargaining split, $\frac{b_j(h)}{b_j(h)+b_h(j)}$, (0, 1)	0.15	0.07	0.07
bargaining variation explained by firms, β_j, β_h, %	76	29	28
bargaining variation explained by pairs, β_{jh}, %	87	65	64

All of the results show the same qualitative and nearly the same quantitative patterns. The largest quantitative difference is for the case when all costs are set to zero, forcing bargaining abilities to be higher, especially for DES. It is this bargaining ability difference between BMS and DES which results in firm effects explaining a great deal of the variation in bargaining abilities for this case.

Table 8 shows the results of these estimates for the estimated costs in the paper ($c_{bms} = 34, c_{des} = 1103$) with zero variation across hospitals or time, but also for cases where 10% and 90% of the residual variation, ν_{jht}, is allocated to costs instead of bargaining ability. The results indicate how the main results of the paper are left nearly unaffected by whether the residual is allocated to bargaining ability or costs. Even in the case where almost all (90%) of the residual variation is allocated to costs, the only implications are that: costs start to vary an unrealistic amount across hospitals, the standard deviation of bargaining splits decreases from 0.7 to 0.6, and the amount of bargaining variation explained by firm and pairs increases (which is mechanical due to assuming that the residual variation is not due to bargaining abilities).

Table 8: Robustness to Changing Cost Variation

	PAPER $StdDev_{ht}(c_{jht})$ $= 0$	$StdDev_{ht}(c_{jht})$ $= 0.1 * StdDev_{ht}(\nu_{jht})$	$StdDev_{ht}(c_{jht})$ $= 0.9 * StdDev_{ht}(\nu_{jht})$
mean costs \$	$bms = 34, des = 1103$	$bms = 34, des = 1103$	$bms = 34, des = 1103$
std. dev. costs \$	$bms = 0, des = 0$	$bms = 12, des = 20$	$bms = 112, des = 180$
mean bargaining split, $\frac{b_j(h)}{b_j(h)+b_h(j)}$, (0, 1)	0.33	0.34	0.33
std. dev. bargaining split, $\frac{b_j(h)}{b_j(h)+b_h(j)}$, (0, 1)	0.07	0.07	0.06
bargaining var. explained by firms, β_j, β_h, %	29	31	44
bargaining var. explained by pairs, β_{jh}, %	65	70	99

6.3.2 Interpretation of Bargaining Ability Estimates

The exposition thus far has tended to refer to bargaining ability as something akin to skill or effort in price negotiation, but it is important to point out that the sources of this bargaining ability should be interpreted rather broadly. Here I clarify some of the potential sources more explicitly in the context of the model, data, and institutional context.

Recall that bargaining abilities are inferred from the split of the surplus up for negotiation, and this surplus is estimated from how the demand model rationalizes the price and quantity patterns in the data. In particular, deriving expected quantities and elasticities from the demand model matches the reality in the stent market that the decision about how to treat each patient is made by the physician, and thus represents how that physician weights her own preferences, those of the patient, and those of the hospital. Extending this physician utility function to the hospital surplus measure that will enter pricing negotiations implicitly assumes 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. 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. The ideal data set would have information—perhaps based on administrator surveys—that would help disentangle these two channels, but for the present study the two are bundled together.

Another gap between the data available and the ideal is that while the data is at the hospital level, some hospitals may be part of larger systems that negotiate on their behalf. In these cases, the bargaining ability parameter estimate will aggregate all of the ways in which negotiation at the system level affects the final price relative to the competitive environment at that particular hospital. System membership data and price and quantity data from all hospitals within each system would be required to tease apart these forces.

Thus bargaining ability as estimated here should be interpreted broadly as anything that might explain the gap between demand and competition at each hospital and the final price that hospital pays for a given stent. In this sense, this study complements previous studies such as Dutta et al (2003) and Mayer and Argyres (2004) which have used detailed internal data for a particular firm. As more detailed data on both business-to-business contracts and relevant characteristics about the internal organization of the firms involved (such as the car sales data in Bennett (2013)) become available, future research will be able to make further progress towards understanding how the details of negotiations, organization, and markets interact to determine value creation and capture.

7 Conclusion

This paper contributes to our knowledge regarding the sources of competitive advantage in markets where prices are negotiated, where *bargaining power* (e.g., costs, willingness-to-pay, and competition) determines only a range of potential prices. I show that *bargaining ability*, the set of factors that influence a firm's profitability within this range, can be an important source of firm profitability. Using a unique panel data set on prices and quantities exchanged between medical device manufacturers and hospitals, I show that variation in bargaining ability is the leading source of the different prices that different hospitals pay for the same device. Further, I show that: (1) bargaining ability is a firm-specific capability; (2) there is significant heterogeneity in bargaining ability across hospitals; and (3) changes in the distribution of relative bargaining abilities over time are consistent with learning as a mechanism by which hospital bargaining abilities evolve.

While I document significant heterogeneity in bargaining abilities across firms, the data only allows a limited analysis of the determinants of bargaining ability. Anecdotal evidence suggests that these determinants may involve important links among competitive strategy, organizational structure, and individual behavior. Pursuing this important research topic will require detailed data on firm characteristics related to the price negotiation process in addition to the type of transfer data used here.

If bargaining ability lies within individuals, it is worth pointing out that it is not clear how much of the profits from increased bargaining ability will accrue to the firm versus the worker (Coff 1999). More generally, if there are costs to developing bargaining ability and firms are constrained in their short-term resource allocations (Penrose 1959), then the fact that some firms have less bargaining ability than others need not mean that such a firm is behaving sub-optimally. Thus a full study of bargaining ability would not only uncover its determinants, but also measure the cost of acquiring or developing bargaining ability. Both of these issues are promising topics for future research.

Appendices

A Proof of Theorem 1: Conditions for TU Core and NENB Equivalence

Proof. The proof depends on showing that, given the appropriate choice of disagreement points, the range of outcomes in the NENB model is equivalent to the range of outcomes obtained by applying a subset of the Core restrictions. Then under a restriction on the characteristic function, this subset of restrictions is enough to obtain the Core.

In the transferable utility (TU) case, where $\frac{\partial q_j}{\partial p_j} = 0$, the first-order conditions for an equilibrium of the NENB model require that $\pi_j = d_j(h) + \frac{b_j}{b_j+b_h}\left[\pi_h + \pi_j - d_h(j) - d_j(h)\right]$ for all $j \in \mathcal{J}$. Define the disagreement points as $d_j(h) = v(\{j\})$ and $d_h(j) = \pi_h(p; \mathcal{J} \setminus \{j\}) + \sum_{l \in \mathcal{J} \setminus \{j\}} \left[\pi_l(p; \mathcal{J} \setminus \{j\}) - \pi_l\right]$. Combining this with the fact that $\frac{b_j}{b_j+b_h} \in [0,1]$ gives the inequalities $\pi_j \geq v(\{j\})$ and

$$\begin{aligned} \pi_j &\leq \pi_h + \pi_j - d_h(j) \\ &= \pi_h + \pi_j - \pi_h(p; \mathcal{J} \setminus \{j\}) - \sum_{l \in \mathcal{J} \setminus \{j\}} \left[\pi_l(p; \mathcal{J} \setminus \{j\}) - \pi_l\right] \\ &= v(\mathcal{J}) - v(\mathcal{J} \setminus \{j\}) \quad . \end{aligned} \tag{12}$$

Here I have defined $v(\mathcal{S}) := \pi_h(\mathcal{S}) + \sum_{l \in \mathcal{S}} \pi_l(\mathcal{S})$, which automatically satisfies the *efficiency* requirement of the Core. The *marginal contribution* version of the Core definition further requires that $\pi(\mathcal{S}) \leq v(\mathcal{J}) - v(\mathcal{J} \setminus \mathcal{S})$, for every subset $\mathcal{S}$ of $\mathcal{J}$. Thus it is clear that the Core implies the single-firm restrictions that are equivalent to the NENB model, and so the Core must be a weak subset of the NENB model allocations.

If it turns out that it is enough to consider only taking away the single-firm subsets, $\{j\}$, to satisfy this condition for all coalitional subsets, $\mathcal{S}$, then the Core and NENB sets are equivalent.

The condition needed for the single-firm subsets to be enough is that the characteristic function $v(\cdot)$ is such that the marginal contribution is weakly super-additive, i.e. $\sum_{j \in \mathcal{S}} \left[v(\mathcal{J}) - v(\mathcal{J} \setminus \{j\})\right] \leq v(\mathcal{J}) - v(\mathcal{J} \setminus \mathcal{S})$ for all subsets $\mathcal{S}$ of $\mathcal{J}$. If this is the case, then we have:

$$\begin{aligned} \pi \in NENB &\Rightarrow \pi_j \leq v(\mathcal{J}) - v(\mathcal{J} \setminus \{j\}), \quad \forall j \in \mathcal{J} \\ &\Rightarrow \sum_{j \in \mathcal{S}} \pi_j \leq \sum_{j \in \mathcal{S}} \left[v(\mathcal{J}) - v(\mathcal{J} \setminus \{j\})\right] \leq v(\mathcal{J}) - v(\mathcal{J} \setminus \mathcal{S}), \quad \forall \mathcal{S} \subseteq \mathcal{J} \end{aligned} \tag{13}$$

where the last inequality follows from the super-additivity of the marginal contributions.

□

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