Mergers When Prices Are Negotiated: Evidence from the Hospital Industry[*]

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Abstract

In healthcare and other bilateral oligopoly markets, prices are often negotiated by the contracting parties. Many hospitals have merged in recent years in part to gain bargaining leverage with managed care organizations (MCOs), leading to several antitrust trials. We specify and estimate a bargaining model of competition between hospitals and MCOs using claims and discharge data from Northern Virginia. We find that MCO bargaining restrains hospital prices significantly relative to standard insurance. Increasing patient coinsurance tenfold would reduce prices by 16%. A proposed hospital acquisition that was challenged by the Federal Trade Commission would have significantly raised hospital prices.

The views expressed here are the authors alone and do not necessarily reflect the views of the Federal Trade Commission or any Commissioner.

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JEL Classification: L11, L13, L31, L38, I11, I18

1   Introduction

In many markets prices are negotiated by the relevant parties rather than set by one of the sides or determined by means of an auction. Examples are commonplace and include wholesale prices set between upstream and downstream firms, prices of houses set between buyers and sellers, and car prices negotiated between consumers and dealers. In all these examples, each side has an incentive to improve its bargaining leverage. One of the ways that parties can achieve a better bargaining leverage is by joining forces: firms through a horizontal merger or consumers by negotiating as a group.[1]

In this paper we develop and estimate a model of competition with negotiated prices. We apply our methodology to bargaining between managed care organizations (MCOs) and hospitals. We use the model to investigate the extent to which hospital bargaining and patient coinsurance restrain prices and to analyze the impact of counterfactual hospital mergers and policy remedies. Our approach can be used more generally to understand mergers and competition in industries where prices are determined by negotiation between differentiated sellers and a small numbers of "gatekeeper" buyers who act as intermediaries for end consumers.

It is both important and policy relevant to analyze the impact of hospital mergers. MCOs can obtain lower prices from providers than traditional fee-for-service insurance arrangements because of bargaining leverage, and have been significant in restraining medical care prices (Cutler et al., 2000). One strategic response of hospitals to the rise of managed care is to horizontally merge. Indeed, over the last 25 years hospital markets have become significantly more concentrated due to mergers (Gaynor and Town, 2012), with the hospital industry having the most federal horizontal merger litigation of any industry.[2] Moreover, the hospital industry's large share of GDP (5.3%) implies that understanding its structure and performance has implications for aggregate economic activity.

A standard way to model competition in differentiated product markets is with a Bertrand pricing game. However, this model is problematic as a model of competition between hos-

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[1]For example, Chipty (1995) finds that larger cable providers are able to bargain for better input prices. Similarly, Sorensen (2003) finds that larger health plans are able to secure better prices from hospitals. Finally, Ho (2009) finds that hospitals that are part of a hospital system are able to obtain higher reimbursement rates from healthcare providers.

[2]Since 1989, there have been thirteen federal hospital antitrust trials. Most recently, the Federal Trade Commission successfully challenged mergers in Toledo, OH (*In the Matter of ProMedica Health System Inc.* Docket No. 9346, 2011) and Rockford, IL (*In the Matter of OSF Healthcare System and Rockford Health System*, Docket No. 9349, 2012).

pitals. Consumers pay little out of pocket for hospital stays, implying that demand for any hospital based on patient flows will be inelastic. The only way to rationalize inelastic demand with Bertrand competition is negative marginal costs, a finding that is not credible for the hospital industry. In contrast, a MCO will have different, and probably more elastic, incentives than patients. Following a merger, these incentives will change in different ways from the patient's own incentives. By estimating a bargaining model, we are able to shed light on how MCO/hospital competition works and how it changes following hospital mergers.

Our model of competition between MCOs and hospitals has two stages. In the first stage, MCOs and hospital systems negotiate the base prices that each hospital will be paid by each MCO for hospital care. MCOs act as agents for self-insured employers, seeking to maximize a weighted sum of enrollee welfare and insurer costs. This is consistent with a situation where employers have existing contracts with MCOs to administer healthcare services for their employees in exchange for fixed management fees. Hospitals, which may be not-for-profit, seek to maximize a weighted sum of profits and quantity. We model the outcome of these negotiations using the Horn and Wolinsky (1988a) model. The solution of the model specifies that prices for an MCO/hospital-system pair solve the Nash bargaining problem between the pair, conditioning on the prices for all other MCO/system pairs.[3] The Nash bargaining problem is a function of the value to each party from agreement relative to the values without agreement.

In the second stage, after hospital prices have been negotiated, each MCO enrollee receives a health draw and decides whether to go to a hospital and if so to which hospital. Enrollees choose a hospital to maximize utility, which is a function of out-of-pocket expense, distance to the hospital, hospital-year indicators, the resource intensity of the illness interacted with hospital indicators, and a random hospital-enrollee-specific draw. The out-of-pocket expense is the negotiated base price – as determined in the first stage – multiplied by the coinsurance rate and the resource intensity of the illness. The two stages of our model are linked in that the first-stage Nash bargaining disagreement values are determined by the utilities generated by the expected second-stage choices.

Solving the first-order conditions of the Nash bargaining problem, we show that equilibrium prices can be expressed by a formula that is analogous to the standard Lerner index

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[3]Collard-Wexler et al. (2013) provide conditions under which this solution is the unique perfect Bayesian equilibrium with passive beliefs of a specific simultaneous alternating offers game.

equation one would get from a Bertrand pricing game, but where actual patient price sensitivity is replaced by the *effective price sensitivity* of the MCO. If hospitals have all the bargaining weight, the actual and effective price sensitivities are equal and prices are the same as under Bertrand competition. In the general case, the two will not be equal. While the difference between actual and effective price elasticities depends on a number of factors, in the simple case of identical single-firm hospitals, the effective price sensitivity will be higher than the actual price sensitivity, and hence markups will be lower than under Bertrand competition. The Lerner-index-like equation further allows us to follow a long tradition in empirical industrial organization and use the equilibrium conditions in estimation by inverting the first-order conditions as a linear system to solve for the vector of marginal costs that generates the observed prices.

We estimate the model using discharge data from Virginia Health Information and administrative claims data from payors. The use of claims data is novel and helps in two ways. First, it allows us to construct prices for each hospital-payor-year triple. A longstanding challenge in the analysis of hospital markets is the difficulty of acquiring actual transaction-level prices. Second, it allows us to construct patient-specific coinsurance rates, which are necessary to model patient behavior.

We estimate the multinomial logit patient choice model parameters using maximum likelihood. To estimate the remaining parameters (bargaining weight, hospital cost and MCO objective function parameters) we form moment conditions based on orthogonality restrictions on marginal costs, where marginal costs are calculated by inverting the first-order conditions as explained above. This is the analog for the bargaining model case of the "standard" techniques used to incorporate equilibrium behavior in differentiated products estimation (e.g., Bresnahan, 1987; Goldberg, 1995; Berry et al., 1995).

We find that patients pay an average of 2-3% of the hospital bill out of their own pocket. While patients significantly dislike high prices, the own-price elasticity for systems is relatively low, ranging from 0.07 to 0.15, due to the low coinsurance rates. Without any health insurance, own-price elasticities would range from 3.13 to 6.57. Mean estimated Lerner indices, based on the bargaining model, range from 0.21 to 0.68 across hospital systems. From the inverse elasticity rule, these Lerner indices are equivalent to those implied by Bertrand pricing with own-price elasticities of 4.84 and 1.48, respectively. This implies that bargaining incentives make MCOs act more elastically than individual patients, but less elastically than

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patients without insurance.

Using the estimated parameters of the model, we examine the impact of a proposed acquisition between Inova Health System and Prince William Hospital – a transaction that was challenged by the Federal Trade Commission (FTC) and ultimately abandoned. Our model predicts that the proposed merger would have raised the quantity-weighted average price of the merging hospitals by 3.1%. In terms of the revenue increase at the merged hospitals, this is equivalent to a 30.5% price increase at just Prince William. We also examine a remedy proposed by the FTC in a different hospital merger case, where the newly acquired hospitals were forced to bargain separately, in order to reinject competition into the marketplace. We find that separate bargaining does not eliminate the anticompetitive effects of the merger since bargaining leverage diminishes on both sides of the market. Finally, we find that mean prices would would rise by 3.7% if coinsurance rates were 0 but drop by 16% if coinsurance rates were 10 times as high as at present (found to be the optimal coinsurance rate for hospitalizations (Manning and Marquis, 1996)).

This paper builds on three related literatures. First, a large literature uses pre-merger data to simulate the likely effects of mergers by using differentiated products models with price setting behavior.[4] With a few exceptions (Gaynor and Vogt, 2003), it has been difficult to credibly model the hospital industry within this framework. For instance, as noted above, because consumers typically pay only a small part of the cost of their hospital care, own-price elasticities are low implying either negative marginal costs or infinite prices under Bertrand competition. We find that the equilibrium incentives of an MCO will both be more elastic and also change in different ways following a hospital merger than would the incentives of its patients. More generally, the impact of a merger on prices in the bargaining context will be different in magnitude and potentially even sign than in a Bertrand setting.[5]

Second, an existing literature has focused on bargaining models in which hospitals negotiate with MCOs for inclusion in their network of providers. Capps et al. (2003) and Town and Vistnes (2001) estimate specifications that are consistent with an underlying bargaining model but neither paper fully specifies or estimates a structural bargaining model. We show

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[4]See, for example, Berry and Pakes (1993); Hausman et al. (1994); Werden and Froeb (1994); Nevo (2000).

[5]Horn and Wolinsky (1988a,b) show that total surplus of the integrated party can be lower than the sum of the surplus of the parties bargaining separately. Chipty and Synder (1999) show that a horizontal merger will not improve the bargaining outcome for parties whose contribution to total surplus is greater than the average contribution of the merging parties. O'Brien and Shaffer (2005) find that a merger to monopoly between upstream duopolist may not affect downstream prices if firms can bundle products.

that their specification corresponds to a special case of our model with zero coinsurance rates and lump-sum payments from MCOs to hospitals. Our work also builds upon the more recent work modeling the hospital/MCO bargaining process of Ho (2009, 2006) and Lewis and Pflum (2011). Ho (2009) is of particular interest. She estimates the parameters of MCO choices of provider network focusing on the role of different networks on downstream MCO competition. Our work, in contrast, focuses on the complementary price setting mechanism between MCOs and hospitals, taking as given the network structure.

Finally, our analysis is also closely related to recent work that estimates structural, multi-lateral bargaining models.[6] Relative to this literature, we focus on modeling the consequences of mergers. Our econometric approach is differentiated from these papers in that our unobserved term reflects cost variation – which is closer to standard pricing models – instead of variation in Nash bargaining weights as in Grennan (2013), and by our assumptions on the pass-through from negotiated prices to out-of-pocket prices.

The remainder of this paper is organized as follows. Section 2 presents our model. Section 3 discusses data and econometrics. In Section 4 provides our results. Section 5 provides counterfactuals. Section 6 concludes.

2 Model

This section describes our model of hospital and managed care bargaining, and patient choice of a hospital. In our model, the product that is sold by MCOs is health administration services to self-insured employers.[7] Employers acquire these services and insure their employees as part of a compensation package, so employee and employer incentives are largely aligned.

In self-insured plans, the employer pays the cost of employee health care (less coinsurance, copays and deductibles) plus an administrative fee to the MCO. The central role of the MCO

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[6]Crawford and Yurukoglu (2012) estimate bargaining between content providers and cable companies to study the impact of a la carte pricing of channels. Grennan (2013) studies negotiated prices set between hospitals and suppliers of medical devices. In the marketing literature, Draganska and Villas-Boas (2011) and Meza and Sudhir (2010) estimate the relative bargaining power of manufacturers and retailers in the markets for coffee and breakfast cereals, respectively. Sieg (2000) estimates a bargaining model with asymmetric information of malpractice disputes and Keniston (2011) estimates passengers and auto-rickshaw drivers bargaining in India.

[7]In the U.S., private health insurance is generally acquired through an employer and approximately 60% of employers are self-insured with larger employers significantly more likely to self-insure (Kaiser Family Foundation/Health Research and Educational Trust, 2011).

is to construct provider networks, negotiate prices, provide care and disease management services, and process medical care claims. We assume that employers have ongoing contracts with MCOs, under which the MCO agrees to act in the incentives of the employers that it represents in its negotiation with hospitals, in exchange for fixed management fees that are determined by some earlier market interactions between MCOs and employers. This assumption allows us to focus our attention on the interactions between hospitals and MCOs rather than on imperfect agency between employers and MCOs.[8]

We model a two-stage game that takes as given the employer/MCO contracts. In the first stage, hospital systems and MCOs negotiate the terms of hospitals' inclusion in MCOs' networks. In the second stage, each patient receives a health status draw. Some draws do not require inpatient hospital care, while others do. If a patient needs to receive inpatient hospital care, she must pay a predetermined coinsurance fraction of the negotiated price for each in-network hospital, with the MCO picking up the remainder. Coinsurance rates can vary across patients and diseases. The patient selects a hospital in the MCO's network – or an outside alternative – to maximize her utility.

2.1 Patient choice model

We now exposit the second stage of the game. There is a set of hospitals $j = 1, \ldots, J$, and a set of managed care companies $m = 1, \ldots, M$. We assume that the hospitals are partitioned into $S \leq J$ systems. Let $J_s, s = 1, \ldots, S$, denote the set of hospitals in system s.

Each enrollee has health insurance issued by a particular MCO. Let $i = 1, \ldots I_m$ denote the enrollees of MCO m. Each MCO m has a subset of the hospitals in its network; denote this subset N_m. For each m and each $j \in N_m$, there is a base price p_{mj}, which was negotiated in the first stage. Let $\vec{p_m}$ denote the vector of all negotiated base prices for an MCO.

At the start of the second stage, each patient receives a draw on her health status which determines if she has one of a number of health conditions that require inpatient care. Let f_{mid} denote the probability that patient i at MCO m is stricken by illness $d = 0, 1, \ldots D$, where $d = 0$ implies no illness; and w_d denote the relative intensity of resource use for illness d, with $w_0 = 0$. In our empirical analysis, w_d is observed. We assume that the price paid for treatment is $w_d p_{mj}$, the base price multiplied by the disease weight. Therefore, the base

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[8]Section 2.4 below also examines the implications of imperfectly aligned incentives between MCOs and enrollees by specifying a model where MCOs engage in Bertrand competition for enrollees.

price, which will be negotiated by the MCO and the hospital, can be viewed as a price per unit of w_d. This is essentially how most hospitals are reimbursed by Medicare, and many MCOs incorporate this payment structure into their hospital contracts.

Each patient's contract with her MCO specifies a coinsurance rate for each condition, which we denote c_{mid}. The coinsurance rate specifies the fraction of the billed price $w_d p_{mj}$ that the patient must pay out of pocket. We treat c_{mid} as predetermined in the sense that we do not endogenize its choice in response to counterfactual mergers or other policies.

For each realized illness, $d = 1, \ldots, D$, the patient seeks hospital care at the hospital which gives her the highest utility, including an outside option. The utility that patient i enrolled in health plan m receives from care at hospital $j \in N_m$ is given by

$$u_{mijd} = \beta x_{mijd} - \alpha c_{mid} w_d p_{mj} + e_{mij}. \tag{1}$$

In equation (1), x_{mijd} is a vector of hospital and patient characteristics including travel time, hospital indicators, and interactions between hospital and patient characteristics (e.g., hospital indicators interacted with disease weight w_d), and β is the associated coefficient vector. The out-of-pocket expense to the patient is $c_{mid} w_d p_{mj}$. As we describe below, we observe data that allow us to impute the base price, the disease weight, and coinsurance rate; hence we treat out-of-pocket expense as observable.[9] We let α denote the price sensitivity. Finally, e_{mij} is an *i.i.d.* error term that is distributed type I extreme value.

The outside choice, denoted as choice 0, is treatment at a hospital located outside the market. The utility from this option is given by

$$u_{mi0d} = -\alpha c_{mid} w_d p_{m0} + e_{mi0}. \tag{2}$$

We normalize the quality from the outside option – i.e., the measures x_{mi0d} – to 0 but we allow for a non-zero base price p_{m0}. Specifically, we let p_{m0} be the unweighted mean of the base price vector $\vec{p_m}$.[10] Finally, we will assume that e_{mi0} is also distributed type 1 extreme

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[9]Gaynor and Vogt (2003) also model patient utility as including price but they do not observe coinsurance rate information.

[10]As the empirical analysis includes hospital fixed effects, attributes of the outside option will only rescale the fixed effects and otherwise do not affect choice model coefficient estimates. However, because our bargaining model specifies payments from MCOs, the price of the outside option has real implications as to the bargaining model parameter estimates and counterfactual equilibrium behavior.

value.

Consumers' expected utilities will play an important role in the bargaining game. To exposit expected utility, first define $\delta_{mijd} = \beta x_{mijd} - \alpha c_{mid} w_d p_{mj}$, $j \in \{0, N_m\}$. Given the extreme value distribution, the choice probability for patient i with disease d as a function of prices and network structure is:

$$s_{mijd}(N_m, \vec{p_m}) = \frac{\exp(\delta_{mijd})}{\sum_{k \in 0, N_m} \exp(\delta_{mikd})}. \tag{3}$$

The ex-ante consumer surplus, or dollar value of expected utility, as a function of prices and the network of hospitals in the plan, is given by:[11]

$$W_m(N_m, \vec{p_m}) = \frac{1}{\alpha} \sum_{i=1}^{I_m} \sum_{d=1}^{D} f_{mid} \ln \left(\sum_{j \in 0, N_m} \exp(\delta_{mijd}) \right). \tag{4}$$

Capps et al. (2003) refer to $W_m(N_m, \vec{p_m}) - W_m(N_m \setminus J_s, \vec{p_m})$, as the "willingness-to-pay" (WTP) as it represents the utility gain to the enrollees of MCO m from the system s.

Another important quantity for the bargaining game is the intensity-weighted expected number of plan m patients who are admitted to hospital j, $j \in N_m$, given by

$$q_{mj}(N_m, \vec{p_m}) = \sum_{i=1}^{I_m} \sum_{d=1}^{D} f_{mid} w_d s_{mijd}(N_m, \vec{p_m}). \tag{5}$$

Since prices are per unit of w_d, the intensity-weighted expected number of patients times price will give the expected revenue to the hospitals from MCO m.

2.2 Bargaining model

We now exposit the bargaining model. There are $M \times S$ potential contracts, each specifying the negotiated base prices for one MCO/hospital system pair. We assume that each hospital within a system has a separate base price, and that the actual price paid to a hospital for treatment of a patient with disease d will be its base price multiplied by the disease weight w_d. MCOs and hospitals have complete information about MCO enrollee and hospital attributes, including x_{mijd} and hospital costs.

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[11]We exclude Euler's constant from this expression.

Following Horn and Wolinsky (1988a) we assume that prices for each contract solve the Nash bargaining solution for that contract, conditional on all other prices. The Nash bargaining solution is the price vector that maximizes the exponentiated product of the values to both parties from agreement (as a function of that price) relative to the values without agreement. It is necessary to condition on other prices because the different contracts may be economically interdependent implying that the Nash bargaining solutions are interdependent. For instance, in our model the value to an MCO of reaching an agreement with one hospital system may be lower if it already has an agreement with another geographically proximate system.

Essentially, the Horn and Wolinsky solution nests a Nash bargaining solution (an axiomatic cooperative game theory concept) within a Nash equilibrium (a non-cooperative game) without a complete non-cooperative structure. The results of Rubinstein (1982) and Binmore et al. (1986) show that the Nash bargaining solution in a bilateral setting corresponds to the unique subgame perfect equilibrium of an alternating offers non-cooperative game. Extending these results, Collard-Wexler et al. (2013) provide conditions such that the Horn and Wolinsky solution is the same as the unique perfect Bayesian equilibrium with passive beliefs of a specific simultaneous alternating offers game with multiple parties on both sides.

Starting with MCOs, we now detail the payoff structures and then use them to exposit the Nash bargain for each contract. We assume that each MCO, acting on behalf of its contracted employers, seeks to maximize a weighted sum of the consumer surplus of its enrollees net of the payments to hospitals. Define the ex-ante expected cost to the MCO of a given hospital network and vector of negotiated prices to be $TC_m(N_m, \vec{p_m})$. Note that the MCO must pay the part of the bill that is not paid by the patient, hence

$$TC_m(N_m, \vec{p_m}) = \sum_{i=1}^{I_m} \sum_{d=1}^{D} (1 - c_{mid}) \sum_{j \in 0, N_m} p_{mj} f_{mid} w_d s_{mijd}(N_m, \vec{p_m}). \qquad (6)$$

Then, define the value for the MCO and the employer it represents to be:

$$V_m(N_m, \vec{p_m}) = \tau W_m(N_m, \vec{p_m}) - TC_m(N_m, \vec{p_m}), \qquad (7)$$

where τ is the relative weight on employee welfare. If employer/employee/MCO incentives

were perfectly aligned then $\tau = 1$. Assume that $N_m, m = 1, \ldots, M$, are the equilibrium sets of network hospitals. For any system s for which $J_s \subseteq N_m$, the net value that MCO m receives from including system s in its network is $V_m(N_m, \vec{p_m}) - V_m(N_m \setminus J_s, \vec{p_m})$.

Continuing to hospitals, hospital systems can be either for-profit or not-for-profit (NFP). NFP systems may care about some linear combination of profits and weighted quantity of patients served. Let mc_{mj} denote the "perceived" marginal cost of hospital j for treating a patient from MCO m with disease weight $w_d = 1$. We assume that the costs of treating an illness with weight w_d is $w_d mc_{mj}$. Our model of perceived marginal costs implicitly allows for different NFP objective functions: a NFP system which cares about the weighted quantity of patients it serves will equivalently have a perceived marginal cost equal to its true marginal cost net of this utility amount (Lakadawalla and Philipson, 2006; Gaynor and Vogt, 2003).

We make three additional assumptions regarding the cost structure. First, we assume that marginal costs are constant across patients and proportional to the disease weight. Second, we allow hospitals to have different marginal costs from treating patients at different MCOs, because the approach to care management, the level of paperwork, and ease and promptness of reimbursement may differ across MCOs. Finally, we specify that

$$mc_{mj} = \gamma v_{mj} + \varepsilon_{mj}, \tag{8}$$

where mc_{mj} is the marginal cost for an illness with disease weight $w_d = 1$, v_{mj} are a set of cost shifters (notably hospital, year, and MCO fixed effects), γ are parameters to estimate, and ε is the component of cost that is not observable to the econometrician. The returns that hospital system s expects to earn from a given set of managed care contracts are then:

$$\pi_s(M_s, \{\vec{p_m}\}_{m \in M_s}, \{N_m\}_{m \in M_s}) = \sum_{m \in M_s} \sum_{j \in J_s} q_{mj}(N_m, \vec{p_m})[p_{mj} - mc_{mj}] \tag{9}$$

where M_s is the set of MCOs that include system s in their network. From (9), the net value that system s receives from including MCO m in its network is $\sum_{j \in J_s} q_{mj}(N_m, \vec{p_m})[p_{mj} - mc_{mj}]$.

Having specified objective functions, we now define the Nash bargaining problem for MCO

m and system s as the exponentiated product of the net values from agreement:

$$NB^{m,s}(p_{mj_{j\in J_s}}|\vec{p_{m,-s}}) = \left(\sum_{j\in J_s} q_{mj}(N_m, \vec{p_m})[p_{mj} - mc_{mj}]\right)^{b_{s(m)}}$$

$$\left(V_m(N_m, \vec{p_m}) - V_m(N_m \setminus J_s, \vec{p_m})\right)^{b_{m(s)}}, \quad (10)$$

where $b_{s(m)}$ is the bargaining weight of system s when facing MCO m, $b_{m(s)}$ is the bargaining weight of MCO m when facing system s, and $\vec{p_{m,-s}}$ is the vector of prices for MCO m and hospitals in systems other than s. Without loss of generality, we normalize $b_{s(m)} + b_{m(s)} = 1$.[12]

The Nash bargaining solution is the vector of prices $p_{mj_{j\in J_s}}$ that maximizes (10). Let $\vec{p_m^*}$ denote the Horn and Wolinsky (1988a) price vector for MCO m. It must satisfy the Nash bargain for each contract, conditioning on the outcomes for each other contract. Thus, $\vec{p_m^*}$ will satisfy:

$$p_{mj}^* = \max_{p_{mj}} NB^{m,s}(p_{mj}, \vec{p_{m,-j}^*}|\vec{p_{m,-s}^*}), \quad (11)$$

where $\vec{p_{-m,j}^*}$ is the equilibrium price vector for other hospitals in the same system as j.

To understand more about the equilibrium properties of our model, we solve the FOC $\partial \log NB^{m,s}/\partial p_{mj} = 0$. For ease of notation, we omit the '*' from now on, even though all prices are evaluated at the optimum, and obtain:

$$b_{s(m)} \frac{q_{mj} + \sum_{k\in J_s} \frac{\partial q_{mk}}{\partial p_{mj}}[p_{mk} - mc_{mk}]}{\sum_{k\in J_s} q_{mk}[p_{mk} - mc_{mk}]} = -b_{m(s)} \underbrace{\frac{\overbrace{\frac{\partial V_m}{\partial p_{mj}}}^{A}}{V_m(N_m, \vec{p_m}) - V_m(N_m \setminus J_s, \vec{p_m})}}_{B}. \quad (12)$$

Note that our assumption of constant marginal costs results in the FOCs (12) being separable across MCOs.

We can rearrange the joint system of $\#(J_s)$ first order conditions from (12) to write

$$\vec{q} + \Omega(\vec{p} - \vec{mc}) = -\Lambda(\vec{p} - \vec{mc}) \quad (13)$$

where Ω and Λ are both $\#(J_s) \times \#(J_s)$ size matrices, with elements $\Omega(j,k) = \frac{\partial q_{mk}}{\partial p_{mj}}$ and

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[12]In both Rubinstein (1982) and Collard-Wexler et al. (2013), the Nash bargaining weights have the non-cooperative interpretation as relative discount factors.

$\Lambda(j, k) = \frac{b_{m(s)}}{b_{s(m)}} \frac{A}{B} q_{mk}$. Solving for the equilibrium prices yields

$$\vec{p} = \vec{mc} - (\Omega + \Lambda)^{-1}\vec{q}, \qquad (14)$$

where $\vec{p}$, $\vec{mc}$ and $\vec{q}$ denote the price, marginal cost and adjusted quantity vectors respectively for hospital system s and MCO m. Equation (14), which characterizes the equilibrium prices, would have a form identical to standard pricing games were it not for the inclusion of Λ. One case where $\Lambda = 0$ – and hence there is differentiated products Bertrand pricing with individual prices for each MCO – is where hospitals have all the bargaining weight, $b_{m(s)} = 0, \forall s$.

Importantly, (14) shows that, as with Bertrand competition models, we can back out implied marginal costs for the bargaining model as a linear function of prices, quantities and derivatives, given MCO and patient incentives. Using this insight, (8) and (14) together form the basis of our estimation.

2.3   Implications of model

In general, the comparative statics of the model are complicated and depend on many factors including, for example, the coinsurance rates and the degree of asymmetry between hospitals. Section 4 below demonstrates the working of the model in the context of the application. This subsection provides theoretical intuition for some of the forces at work. In particular, we show (1) the impact of prices on MCO surplus; (2) the impact of bargaining on prices; (3) the impact of mergers on equilibrium prices; and (4) the impact of zero coinsurance rates and the relation to Capps et al. (2003).

The impact of price on MCO surplus.   In order to understand how equilibrium prices are impacted by various factors, we need to develop the A expression from equation (12). We provide this derivation in Appendix A. We focus here on the case where $\tau = 1$ (so that MCOs value consumer surplus equally to dollar costs), in which case A is

$$\frac{\partial V_m}{\partial p_{mj}} = -q_{mj} - \alpha \sum_{i=1}^{I_m} \sum_{d=1}^{D} (1 - c_{mid}) c_{mid} w_{id}^2 f_{mid} s_{mijd} \left(\sum_{k \in N_m} p_{mk} s_{mikd} - p_{mj} \right). \qquad (15)$$

The first term, $-q_{mj}$, captures the standard effect: higher prices reduce patients' expected utility. The second term accounts for the effect of consumer choices on payments from MCOs

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to hospitals. As the price of hospital j rises, consumers will switch to cheaper hospitals. This term can be either positive or negative, depending on whether hospital j is cheaper or more expensive than the share-weighted price of other hospitals; the difference is reflected in the expression in the large parentheses.

In our model, as long as coinsurance rates are strictly between zero and one, MCOs use prices to steer patients towards cheaper hospitals, and this fact will influence equilibrium pricing. To see this, consider a hospital system with two hospitals, one low cost and one high cost, that are otherwise equal. The MCO/hospital system pair will maximize joint surplus by having a higher relative price on the high-cost hospital, as this will steer patients to the low-cost hospital. At coinsurance rates near one, i.e., no insurance, this effect disappears, because patients bear most of the cost and hence the MCO has no incentive to steer to low cost hospitals beyond patients' preferences. Interestingly, at coinsurance rates near zero (full insurance) this effect also disappears but for a different reason: since the patient bears no expense, the MCO cannot use price to impact hospital choice. In both extreme cases, low-cost hospitals will see prices increase relative to high-cost hospitals.

The effect of bargaining on equilibrium prices. Note from equation (14) that price-cost margins from our model have an identical formula to those that would arise if hospitals set prices to patients, and patients choose hospitals using our choice model, but with $\Omega + \Lambda$ instead of Ω. Since Ω is the matrix of actual price sensitivities, we define the *effective price sensitivity* to be $\Omega + \Lambda$. For the special case of a single-hospital system, we can write

$$p_{mj} - mc_{mj} = -q_{mj} \left(\frac{\partial q_{mj}}{\partial p_{mj}} + q_{mj} \frac{b_{m(j)}}{b_{j(m)}} \frac{A}{B} \right)^{-1} \tag{16}$$

so that (the scalar) Λ is equal to $q_{mj} \frac{b_{m(j)}}{b_{j(m)}} \frac{A}{B}$. The term B must be positive or the MCO would not gain surplus from including hospital j in its network. From equation (15), the first term in A is the negative of quantity, which is negative. If the rest of A were 0, as would happen with identical hospitals, then Λ would be negative. In this case, MCO bargaining would add to the effective price sensitivity, and hence lower prices relative to differentiated products Bertrand competition.

More generally, with asymmetric hospitals and multi-hospital systems, the incentives are more complicated. There may be cases where MCO bargaining may not uniformly lower

prices, notably if cost differences across hospitals are large and hence where it is important to steer patients to low-cost hospitals. However, we still generally expect that MCO bargaining lowers prices relative to differentiated products Bertrand competition.

The impact of mergers on prices. Consider now the impact of mergers on prices. Similarly to Bertrand competition, negotiated prices also result in an upward pricing pressure from mergers. For example, as two separate hospitals merge, by raising the price of one of the hospitals some consumers are diverted to the other hospital. Pre-merger these were considered lost profits, post-merger these are captured. This creates an incentive to raise prices relative to the pre-merger prices. However, the impact of a merger in a bargaining model will be different than under Bertrand competition. To see this, note that with Bertrand competition, a merger only changes the cross-price effects. With bargaining, the term B increases with a merger as B is the joint value of the system. Moreover, since B enters into the effective own-price elasticity in equation (16), with bargaining, the effective own- and cross-price sensitivities both change from a merger. However, the cross-price terms change differently, and potentially less, than with Bertrand competition. Since these effects can be of opposite sign, the net effect of the merger relative to the Bertrand prediction is ambiguous.

Another point to note is that in Bertrand competition, a merger between two hospitals in distinct markets without any patient overlap will not change the pricing incentives and can affect prices only through changes in costs. Yet, if these two distinct markets are served by the same MCO, then this merger will likely change the effective price sensitivity and hence have an impact on price. As an example, an MCO serving two separate markets without overlap and with one hospital each might be willing to trade off a slightly higher price in one market with a slightly lower price in the other. If the hospitals merge into a single system the MCO can negotiate this tradeoff, but cannot do that without a merger. If, for instance, the markets are identical except that one hospital is higher cost, the bargain with the merged system would increase the price for this hospital and decrease it for the lower-cost hospital.

Zero coinsurance rates and the relation to Capps et al. (2003) Now consider the special case of zero coinsurance rates. In this case, prices cannot be used to steer patients, and hence the marginal value to the hospital of a price increase is q_j, while the marginal value to the MCO is $-q_j$. Because a price increase here is effectively just a transfer from the MCO

to the hospital system, individual hospital prices within a system do not matter. The FOC for any price $p_{mj}, j \in J_s$ then reduces to:

$$\sum_{k \in J_s} q_{mk}[p_{mk} - mc_{mk}] = \frac{b_{s(m)}}{b_{m(s)}} \left[V_m(N_m, \vec{p_m}) - V_m(N_m \setminus J_s, \vec{p_m}) \right]. \tag{17}$$

Hence, prices will adjust so that system revenues are proportional to the value that the system brings to the MCO. Because the prices of systems other than s enter into the right hand side of (17) through V_m, (17) still results in an interdependent system of equations. However, these equations form a linear system and hence we can solve for the equilibrium price vector for all systems in closed form with a matrix inverse.[13]

There is also a large similarity between our model with zero coinsurance and Capps et al. (2003)'s empirical specification of hospital system profits. Using our notation, Capps et al. argue that hospital system profits can be expressed as:

$$\sum_{k \in J_s} q_{mk}[p_{mk} - mc_{mk}] = \frac{b_{s(m)}}{b_{m(s)}} \left[W_m(N_m, \vec{p_m}) - W_m(N_m \setminus J_s, \vec{p_m}) \right], \tag{18}$$

which is similar to equation (17) except that the right side has willingness to pay rather than the sum of willingness to pay and MCO costs.[14] The Capps et al. formula in equation (18) would yield the same price as our model with zero coinsurance if hospitals obtained a lump-sum payment for treating patients, with the MCO then paying all the marginal costs of their treatment.

2.4 Robustness to MCO objective function

In our base model, we assume that MCOs earn fixed management fees and act on behalf of the employers that they represent. An alternative model of interactions is that MCOs value profits and compete for enrollees in a differentiated products Bertrand setting. Here we outline such a model and some of its implications.

We model the following four stage game.[15] In Stage 1, each MCO and hospital system

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[13]See Brand (2013) for a derivation of this solution.

[14]See also Lewis and Pflum (2011) for a similar argument.

[15]This game is similar to the model of Crawford and Yurukoglu (2012) adapted to the context of hospitals and MCOs.

negotiate prices with a separate contract for each system. This stage has the same form as in our base model but the incentives are different. In Stage 2, MCOs, with potentially different provider networks and input costs (as determined in the first stage), simultaneously set premiums P_m for health coverage. In Stage 3, enrollees receive *i.i.d.* logit draws ε for each MCO and then select an MCO based on price, quality, provider network and their draws ε. Let the utility to a consumer from a particular plan be given by

$$U_{im} = \gamma_1 \hat{U}_i(N_m, \vec{p_m}) - \gamma_2 P_m + \xi_m + \varepsilon_{im}, \tag{19}$$

where $\gamma_1 \hat{U}_i(N_m, \vec{p_m})$ is the expected consumer surplus from future hospital treatment, γ_2 is the price sensitivity to premiums, and ξ_m is the quality of the MCO regarding attributes other than hospital care (such as customer service for billing). Finally, in Stage 4, each enrollee receives a draw on her health status and seeks medical care in a process that is identical to Stage 2 of our base model.

In this model, MCOs' willingness to act in the interests of their enrollees is more limited than in our base model. By negotiating a low price with hospitals, they essentially lower their factor input prices in Stage 2. However, their ability to transform the lower factor input prices into profits is imperfect, because this model results in double marginalization, which can lead to large incentive problems. It is worth noting that many economists believe that, in the real world, double marginalization problems are often addressed by two-part tariffs, as in our base model.

In order to further evaluate the implications of the model, we compute equilibria of the model for a simple case where coinsurance is zero, there are six MCOs and four hospitals (all identical), and ex-ante identical patients. We examine the implications of a merger between two hospitals for a grid of values of ξ, γ_1, and γ_2, and compare these to our base model with the same set of patient and hospitals as above but with the estimated α from Table 3 and τ from Table 5 Specification 1, both below.

For the merging firms, the mean percentage price increase over the case with no mergers is 5.7%, compared to our base model, which reports an increase of 2.5%. The standard deviation of the percentage price increase from the Bertrand model (across the grid of values) is 12.6%. From the large standard deviation, it appears that the Stage 2 Bertrand competition for patients results in imperfect incentives for the MCO in its Stage 1 bargaining with hospitals.

The Bertrand model of insurer competition may be better suited to studying the market individual health insurance and competition within the new state health insurance exchanges (e.g. Starc (2013)). In the market for large employer insurance, MCOs often negotiate multi-year, multi-part contracts with employers. These contracts plausibly would generate more surplus to divide if they more closely align the incentives of the MCO with employers and employees in their negotiation with hospitals than would be predicted by the Bertrand model. In addition, the Monte Carlo evidence shows that the evaluation of mergers in the Bertrand model depends heavily on having appropriate values of ξ, γ_1, and γ_2, because these parameters significantly affect MCOs' equilibrium incentives. Finally, the evidence indicates that the predictions from our base model will still capture the price-increasing forces of mergers even if the true model of MCO competition is differentiated products Bertrand.

3 Institutional setting, data and estimation

3.1 Inova/Prince William merger

We use the model to study the competitive interactions between hospitals and MCOs in Northern Virginia. In late 2006, Inova Health System, a health care system based in northern Virginia, sought to acquire Prince William Health System, a not-for-profit institution which operated a single general acute care hospital, Prince William Hospital (PWH). PWH had 180 licensed beds and was located in Manassas, Virginia. Inova was a not-for-profit system that operated five general acute care hospitals in northern Virginia with a combined 1,633 beds.[16] The Federal Trade Commission, with the Virginia Office of the Attorney General as co-plaintiff, challenged the acquisition in May, 2008. Subsequently, the parties abandoned the transaction.[17]

The FTC alleged that the relevant geographic market consisted of all hospitals in Virginia Health Planning District 8 (HPD8) and Fauquier County.[18] This geographic area includes

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[16]The hospitals in the Inova system include Fairfax Hospital, a large tertiary facility with 884 licensed beds located in Falls Church, Virginia; Fair Oaks Hospital (182 licensed beds) located in Fairfax, Virginia; Alexandria (334) and Mount Vernon (237) Hospital located in Alexandria, Virginia; and Loudoun Hospital (255) located in Leesburg, Virginia.

[17]PWH was later acquired by the Novant Health, a multi-hospital system based in North Carolina.

[18]HPD8 is defined by the Commonwealth of Virginia as the counties of Arlington, Fairfax, Loudoun and Prince William; the cities of Alexandria, Fairfax, Falls Church, Manassas and Manassas Park; and the towns of Dumfries, Herndon, Leesburg, Purcellville and Vienna.

all five Inova hospitals and PWH, as well as HCA Reston (located in Reston, VA), Fauquier (located in Warrenton, VA), Potomac (located in Woodbridge, VA), and the Virginia Hospital Center (located in Arlington, VA).[19] The product market alleged by the FTC was general acute care inpatient services sold to MCOs.

Figure 1 presents a map of the locations of the hospitals in Northern Virginia. The heavy line defines the boundary of HPD8 and Fauquier County. The two closest hospitals to PWH are members of the Inova system – Fair Oaks and Fairfax – and, according to MapQuest, are 21 and 29 minutes drive times from PWH, respectively.

Figure 1: Hospitals in Northern Virginia
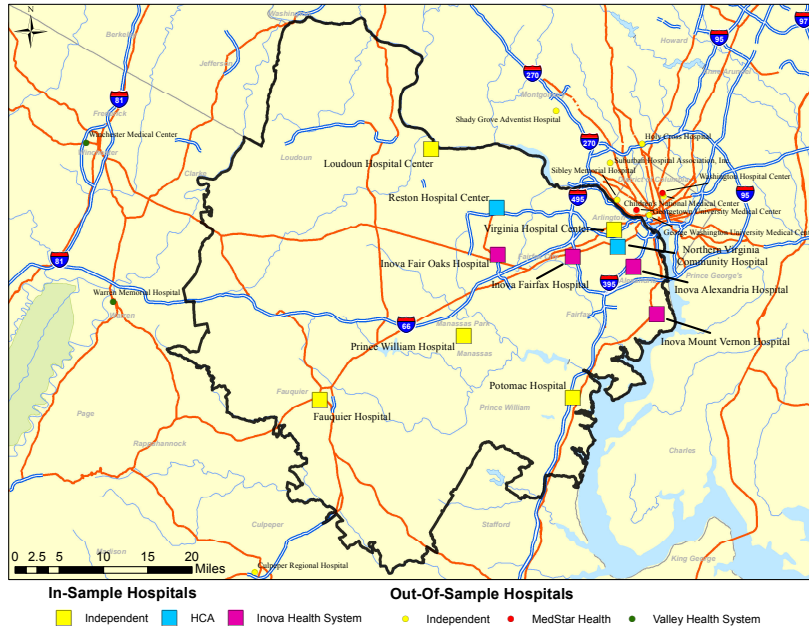
3.2 Data

Our primary data come from two sources: administrative claims data provided by four large MCOs serving Northern Virginia (payor data) and inpatient discharge data from Virginia

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[19]More distant competitors include several hospitals in the District of Columbia and the suburban areas of the District in Maryland and other hospitals in northern and central Virginia including Warren Memorial Hospital located in Warren; and the University of Virginia Medical Center located in Charlottesville.

Health Information. Both datasets span the years 2003 through 2006. These data are supplemented with information on hospital characteristics provided by the *American Hospital Association (AHA) Guide.*

A longstanding challenge in the analysis of hospital markets is the difficulty of acquiring actual transaction-level prices for each hospital-payor pair in the market. The administrative claims data are at the transactions level and contain most of the information that the MCO uses to process the appropriate payment to a hospital for a given patient encounter. In particular, the claims data contain demographic characteristics, diagnosis, procedure performed, diagnosis related group (DRG), and the actual amount paid to the hospital for each claim. There are often multiple claims per inpatient stay and thus the data must be aggregated to the inpatient episode level. We group claims together into a single admission based on the date of service, member ID, and hospital identifier. The claims often have missing DRG information. To address this issue, we use DRG grouper software from 3M to assign the appropriate DRG code to each admission.

Using the claims data, we construct risk-adjusted prices for each hospital-payor-year triple. We do this by first performing regressions of total price divided by DRG weight on gender, age and hospital dummies, separately for each payor and year. We then create the base price as the fitted regression value using all observations in the sample.[20]

An alternative method of constructing prices would be to directly use the contracts between hospitals and MCOs. However, the complexity of these contracts resulted in difficulties in constructing apples-to-apples prices across the MCO and hospitals. As an example, we examined one hospital in our data, which had contracts of four separate types: (1) fixed-rate contracts that specified a fixed payment for each DRG; (2) per-diem contracts with fixed daily rates for medical, surgical and intensive care patients; (3) contracts with a set discount off of charges; and (4) a hybrid of the above, with switching between reimbursement regimes often based on the total charges. To avoid having to deal with a myriad of different and non-comparable contracts, we use the claims data to formulate the price measures as described above.

The claims data also contain information on the amount of the bill the patient paid out-of-pocket. This information allows us to construct patient-specific out-of-pocket coinsur-

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[20]We have also explored alternative approaches to calculating prices including simply dividing the amount paid by the DRG weight. The quantitative implications of our estimates are robust to these different price construction methodologies.

ance rates – a data element we have not seen used in the analysis of hospital competition.[21] Different insurers report coinsurance rates differently on the claims. In order to provide a standardized coinsurance measure across patients and MCOs, we formulate an expected coinsurance rate. We do this by first formulating a coinsurance amount which is the out-of-pocket expenditure net of deductibles and co-payments divided by the allowed amount.[22] The resulting coinsurance variable is censored at zero. Then, separately for each MCO, we estimate a tobit model of coinsurance where the explanatory variables are age, female indicator, age×female, DRG weight, age×DRG weight and female×DRG weight. We then create the expected coinsurance rate for each patient as the predicted values from this regression.

The Virginia discharge data contain much of the same information as the claims data but, in general, the demographic, patient ZIP code, and diagnoses fields are more accurate, and an observation in these data is at the (appropriate) inpatient admission level. The discharge data also contain more demographic information (e.g., race), and the identity of the payor, and are a complete census of all discharges at the hospital.

For these reasons, we use the discharge data to estimate the patient choice model. We limit our sample to general acute care inpatients whose payor is one of the four MCOs in our payor data and who reside in Northern Virginia (defined as Virginia HPD8 plus Fauquier County). We exclude patients transferred to another general acute care hospital (to avoid double counting); patients over 64 years of age (to avoid Medicare Advantage and supplemental insurance patients); and newborn discharges (treating instead the mother and newborn as a single choice observation). We define the choice of an outside hospital to be patients residing within the geographic area who sought care at a hospital outside this area.

We obtain the following hospital characteristics from the *AHA Guide* of the relevant year: staffed beds, residents and interns per bed, indicators for FP ownership, teaching hospital status, and the presence of a cardiac catheterization laboratory, MRI, and neonatal intensive care unit. We compute the driving time from the patient's zip code centroid to the hospital using information from MapQuest. We use DRG weights published and revised by CMS each year, which are a measure of the mean resource acuity of the diagnosis and are the primary

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[21]All hospitals in our sample were in-network providers for all of the MCOs for which we have claims information.

[22]We identify deductibles and copayments by treating expenditures of an even dollar amount (e.g., 25, 30, 50, 60, 70, 80, 90, 100, 125, 135, 140, 150, etc.) as a deductible/copay (implying no variation in out-of-pocket expenditure across the hospitals) and coding the coinsurance amount in that case as 0.

basis for Medicare inpatient payments to hospitals.

3.3 Estimation and identification

We estimate the model in two steps. In the first step we estimate the patient-level hospital choice model using the discharge data augmented with price and coinsurance information from the payor data. The coefficients on characteristics, β, and the price coefficient, α, are estimated by maximum likelihood. The model includes hospital-year fixed effects and interactions of hospital fixed effects with patient disease weight. Note that different coinsurance rates imply different out-of-pocket prices. Thus, our model will identify α from the variation within a hospital-year in choices across coinsurance rates and payors. The identification of the β parameters in this model is relatively standard, e.g., travel time coefficients will be identified by the relative drop in choice probability for a hospital as travel time increases.

The remaining parameters, namely the bargaining weights b, the cost shifters γ, and τ, the weight put on the WTP measure, are estimated by imposing the bargaining model. Our estimation of the bargaining model conditions on the set of in-network hospitals and treats the negotiated prices as the endogenous variable. Combining equations (14) and (8) we define the econometric error as

$$\vec{\varepsilon}(b, \gamma, \tau) = -\gamma \vec{v} + mc(b, \tau) = -\gamma \vec{v} + \vec{p} + (\Omega + \Lambda(b, \tau))^{-1} \vec{q}, \tag{20}$$

where (20) now makes explicit the points at which the structural parameters enter. We estimate the remaining parameters with a GMM estimator based on the moment condition that $E[\varepsilon_{mj}(b, \gamma, \tau)|Z_{mj}] = 0$, where Z_{mj} is a vector of (assumed) exogenous variables. Recall that Ω and Λ are functions of equilibrium price (which depends on ε) and thus are endogenous.

Our estimation depends on exogenous variables Z_{mj}. We include all the cost shifters v_{mj} in Z_{mj}. In specifications that include variation in bargaining weights, we include indicators for the entities covered by each bargaining parameter. Finally, we include four other exogenous variables to the "instrument" set: predicted willingness-to-pay for the hospital, predicted willingness-to-pay for the system, predicted willingness-to-pay per enrollee for each MCO, and predicted total hospital quantity, where these values are predicted using the overall mean price. From our model, price is endogenous in the first-stage bargaining model because it is chosen as part of a bargaining process where the marginal cost shock ε is observed. By

construction, these four exogenous variables will not be correlated with ε but will correlate with price, implying that they will be helpful in identifying the effect of price.

Our bargaining model must identify τ, b, and γ. Essentially, τ is identified by the extent to which MCOs value consumer surplus from hospital choice relative to payments to hospitals, which then is reflected in their negotiated equilibrium prices. The four willingness-to-pay "instruments" are (assumed exogenous) demand shifters that provide variation in enrollees' characteristics (notably location, disease severity, and coinsurance rates) and from this in expected equilibrium prices. The orthogonality condition between them and ε will help identify τ by imposing the implications of the model as to equilibrium prices. The estimation of the γ parameters is essentially a linear regression conditional on recovering marginal costs. We believe that the bargaining weights have somewhat similar equilibrium implications to cost shifters and hence it would be empirically difficult to identify the b and γ parameters at the same level, e.g., MCO fixed costs for bargaining weight and for marginal costs. Hence, when we include MCO fixed effects for bargaining weights we do not include these fixed effects for marginal costs.

4 Results

4.1 Summary Statistics

Table 1 presents the mean base prices for the set of hospitals used in the analysis. There is significant variation in risk-adjusted prices across the hospital prior to the merger. These differences do not reflect differences in case-mix, as our analysis controls for disease complexity with DRG weights. The range between the highest and lowest hospital is 36% of the mean PWH price, which is in the middle of the price distribution. Even within the Inova system there is notable variation in prices with a range of $2,356 between the high (Mount Vernon) and low priced hospital (Alexandria). Inova Alexandria has two competitors located nearby, Virginia Hospital Center and Northern Virginia Community Hospital, although Northern Virginia Community Hospital closed in 2005.

Table 1 also presents other characteristics of the hospitals in HPD8 and Fauquier County. Hospitals are heterogeneous with respect to size, for-profit status and the degree of advanced services they provide. Seven of the eleven hospitals provided some level of neonatal intensive

care services by the end of our sample, and most hospitals have cardiac catheterization laboratories that provide diagnostic and interventional cardiology services.

Table 1: Hospital characteristics

Hospital	Beds	Mean price $	FP	Mean NICU	Cath lab
Prince William Hospital	170	10,273	0	1	0
Alexandria Hospital	318	9,754	0	1	1
Fair Oaks Hospital	182	9,793	0	0.5	1
Fairfax Hospital	833	11,881	0	1	1
Loudoun Hospital	155	11,560	0	0	1
Mount Vernon Hospital	237	12,110	0	0	1
Fauquier Hospital	86	13,269	0	0	0
N. VA Community Hosp.	164	9,545	1	0	1
Potomac Hospital	153	11,420	0	1	1
Reston Hospital Center	187	9,972	1	1	1
Virginia Hospital Center	334	9,545	0	0.5	1

Note: we report (unweighted) mean prices across year and payor. "FP" is an indicator for for-profit status, "Mean NICU" for the presence of a neonatal intensive care unit, and "Cath lab" for the presence of a cardiac catheterization lab that provides diagnostic and interventional cardiology services.

Table 2 presents summary statistics by hospital for the sample of patients we use to estimate the hospital demand parameters. The patient sample is majority white at every hospital. Not surprisingly, there is significant variation in the mean DRG weight across hospitals. PWH's mean DRG weight is 0.82 as reflective of their role as a community hospital. The patient-weighted mean DRG weight across all of Inova's hospitals in 1.09 with its Fairfax and Mt. Vernon hospitals treating patients with the highest resource intensity. About 1.4% of patients choose care in Virginia outside the geographic market. Patients choosing the outside option had a high mean DRG weight of 1.39 suggesting that they are traveling to specialized centers such as the University of Virginia Medical Center.

Table 2 also reveals heterogeneity in travel times. Notably, patients travel the furthest to be admitted at Inova Fairfax hospital, the largest hospital and only tertiary care hospital in our sample. Interestingly, Inova Fairfax also has the lowest mean patient age reflecting the popularity of its obstetrics program. Coinsurance rates potentially play an important

Table 2: Patient sample

Hospital	Mean age	Share white	Mean DRG weight	Mean travel time	Mean coins. rate	Discharges Total	Share
Prince William Hospital	36.1	0.73	0.82	13.06	0.032	9,681	0.066
Alexandria Hospital	39.3	0.62	0.92	12.78	0.025	15,622	0.107
Fair Oaks Hospital	37.7	0.54	0.94	17.75	0.023	17,073	0.117
Fairfax Hospital	35.8	0.58	1.20	18.97	0.023	46,428	0.319
Loudoun Hospital	37.2	0.74	0.81	15.54	0.023	10,441	0.072
Mount Vernon Hospital	50.3	0.66	1.38	16.18	0.022	3,749	0.026
Fauquier Hospital	40.5	0.90	0.92	15.29	0.033	3,111	0.021
N. VA Comm. Hosp.	47.2	0.48	1.43	16.02	0.016	531	0.004
Potomac Hospital	37.5	0.60	0.93	9.62	0.024	8,737	0.060
Reston Hospital Center	36.8	0.69	0.90	15.35	0.021	16,007	0.110
Virginia Hospital Center	40.8	0.59	0.98	15.88	0.017	12,246	0.084
Outside option	39.3	0.82	1.39	0.00	0.029	2,113	0.014
All Inova	37.5	0.59	1.09	17.37	0.024	85,540	0.641
All others	38.1	0.68	0.92	13.74	0.023	60,199	0.359

role in our model, and Table 2 presents mean coinsurance rates by hospital. The average coinsurance rate is low but meaningfully larger than zero. Average coinsurance rates across hospitals range from 1.7 to 3.3% with a mean of 2.4%.

Finally, Table 2 provides the shares by discharges among hospital systems in this area. Within this market, Inova has a dominant share attracting 64% of the patients. PWH is the third largest hospital in the market with a 6.6% share. Using the standard *Horizontal Merger Guidelines* methodology, the 2006 HHI based on the relevant market is 4,428 and the proposed acquisition would have increased the HHI by 977 based on pre-merger shares.

A challenge for our model is explaining the large variation in the mean price that the different MCOs pay hospitals. The highest-paying MCO pays hospitals, on average, over 100% more than the lowest paying MCO. While this variation is high, large variations across hospitals and payors is not uncommon (see Ginsburg, 2010). In our framework, there are two possible reasons for this variation, differences in bargaining weight and differential costs of treating patients across MCOs. We will estimate models that allow for both possibilities.

4.2   Patient choice estimates

We now exposit the results from our model of patient choice of hospital, based on equation (1). In addition to the negotiated price, the explanatory variables include hospital/year fixed effects, hospital indicators interacted with the patient's DRG weight, and a rich set of interactions aimed at capturing the essential dimensions of hospital and patient heterogeneity that affect hospital choice.

Table 3: Multinomial logit demand estimates

Variable	Coefficient	Standard error
Base price × weight × coinsurance	−0.0008**	(0.0001)
Travel time	−0.1150**	(0.0026)
Travel time squared	−0.0002**	(0.0000)
Closest	0.2845**	(0.0114)
Travel time × beds / 100	−0.0118**	(0.0008)
Travel time × age / 100	−0.0441**	(0.0023)
Travel time × FP	0.0157**	(0.0011)
Travel time × teach	0.0280**	(0.0010)
Travel time × residents/beds	0.0006**	(0.0000)
Travel time × income / 1000	0.0002**	(0.0000)
Travel time × male	−0.0151**	(0.0007)
Travel time × age 60+	−0.0017**	(0.0013)
Travel time × weight / 1000	11.4723**	(0.4125)
Cardiac MDC × cath lab	0.2036**	(0.0409)
Obstetric MDC × NICU	0.6187**	(0.0170)
Nerv, circ, musc MDC × MRI	−0.1409**	(0.0460)
N	1,710,801	
Pseudo R^2	0.445	

Note: ** denotes significance at 1% level. Specification also includes hospital-year interactions and hospital dummies interacted with disease weight.

Table 3 presents coefficient estimates from the MNL model of hospital choice. Consistent with the large literature on hospital choice, we find that patients are very sensitive to travel times. The willingness to travel is increasing in the DRG weight and decreasing in age. The sensitivity to travel time is striking. An increase in travel time of 5 minutes reduces each hospital's share between 17 and 41%. The parameter estimates imply that increasing the travel time to all hospitals by one minute reduces consumer surplus by approximately $167.[23]

[23]The patient's price sensitivity to travel likely reflects the fact that they will be visited by members of

Table 4: Mean estimated 2006 demand elasticities for selected hospitals

Hospital	(1) PW	(2) Fairfax	(3) Reston	(4) Loudoun	(5) Fauquier
1. Prince William	−0.125	0.052	0.012	0.004	0.012
2. Inova Fairfax	0.011	−0.141	0.018	0.006	0.004
3. HCA Reston	0.008	0.055	−0.149	0.022	0.002
4. Inova Loudoun	0.004	0.032	0.037	−0.098	0.001
5. Fauquier	0.026	0.041	0.006	0.002	−0.153
6. Outside option	0.025	0.090	0.022	0.023	0.050

Note: Elasticity is $\frac{\partial s_j}{\partial p_k}\frac{p_k}{s_j}$ where j denotes row and k denotes column)

The parameter on out-of-pocket price is negative and significant indicating that, in fact, inpatient prices do play a role in admissions decisions.[24] However, in contrast to travel time, patients are relatively insensitive to the gross price paid from the MCO to the hospital, largely because of the low coinsurance rates that they face. Table 4 presents the estimated price elasticities of demand for selected hospitals. Own-price elasticities range from −0.098 to −0.153 across the five reported hospitals.

The fact that our elasticity estimates are substantially less than 1 imply that under Bertrand competition the observed prices could only be rationalized with negative marginal costs, even for stand-alone hospitals. The effective price sensitivity can of course be larger than the own-price sensitivity, but evaluating the extent to which this is the case requires estimating the bargaining model, to which we now turn.

4.3   Bargaining model estimates

Table 5 presents the coefficient estimates and standard errors from the GMM bargaining model estimation. We estimate two specifications. In Specification 1, we fix the bargaining weights to $b_{m(s)} = 0.5$ (which implies that $b_{s(m)} = 0.5$ also) and allow for marginal cost fixed effects at the hospital, MCO and year level. In Specification 2, we allow the bargaining parameters to vary across MCOs (lumping MCO 2 and 3 together) but omit the MCO cost

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their social support network who may make several trips per day.

[24]Ho and Pakes (2011) using data from California, also find that the patient's choice of hospital is influenced by the prices paid by the MCOs.

fixed effects.[25] We bootstrap all standard errors at the payor/year/system level.

Table 5: Estimates from bargaining model

Parameter	Specification 1 Estimate	S.E.	Specification 2 Estimate	S.E.
MCO Welfare Weight (τ)	2.79	(2.87)	6.69	(5.53)
MCO 1 Bargaining Weight	0.5	–	0.52	(0.09)
MCOs 2 & 3 Bargaining Weight	0.5	–	1.00**	(7.77×10^{-10})
MCO 4 Bargaining Weight	0.5	–	0.76**	(0.09)
Cost parameters				
Inova Fairfax	10,786**	(3,765)	6,133**	(1,211)
Inova Fair Oaks	11,192**	(3,239)	6,970**	(2,352)
Inova Alexandria	10,412*	(4,415)	6,487**	(1,905)
Inova Mount Vernon	10,294*	(5,170)	4,658	(3,412)
Inova Loudoun	12,014**	(3,188)	8,167**	(1,145)
Prince William Hospital	8,635**	(3,009)	5,971**	(1,236)
Fauquier Hospital	14,553**	(3,390)	9,041**	(1,905)
No. VA Community Hosp.	10,086**	(2,413)	5,754**	(2,162)
Potomac Hospital	11,459**	(2,703)	7,653**	(902)
Reston Hospital Center	8,249**	(3,064)	5,756**	(1,607)
Virginia Hospital Center	7,993**	(2,139)	5,303**	(1,226)
MCO 2 Cost	−9,043**	(2,831)	–	–
MCO 3 Cost	−8,910**	(3,128)	–	–
MCO 4 Cost	-4,476	(2,707)	–	–
Year 2004	1,123	(1,303)	1,414	(1,410)
Year 2005	1,808	(1,481)	1,737	(1,264)
Year 2006	1,908	(1,259)	2,459*	(1,077)

Note: ** denotes significance at 1% level and * at 5% level. Significance tests for bargaining parameters test the null of whether the parameter is different than 0.5. We report bootstrapped standard errors with data resampled at the payor/year/system level.

Focusing first on Specification 1, the point estimate on τ indicates that MCOs place over twice as much weight on enrollee welfare as on reimbursed costs, though the coefficient is not statistically significantly different from 0 or 1. A value of τ other than 1 may reflect employers placing a different weight on welfare than enrollees but may also be due to error in measuring coinsurance rates or physician incentives to steer patients to low-price hospitals (see Dickstein, 2011). The hospital cost parameters estimates show a large variation in the

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[25]We lump MCOs 2 and 3 together because they have similar characteristics and negotiated similar prices with the hospitals.

implied costs across the MCOs. This is not surprising as the cost differences will reflect variation in the data on mean hospital prices across the MCOs. There is also an increasing cost trend over time.

Turning to the results from Specification 2, here we estimate three different bargaining weights $b_{m(s)}$. We find significant variation in bargaining weights across MCOs, with all MCOs having more leverage than hospitals. Only MCO 1's bargaining parameter is not significantly different than .5. This variation is driven by the same price variation that generated the estimated cost heterogeneity in Specification 1. The estimates from Specification 2 imply that MCOs 2 and 3 have a bargaining weight of essentially 1, so that hospitals have a bargaining weight of essentially 0. Thus, MCOs 2 and 3 are able to drive hospital surpluses down to their reservation values. Given the interpretation of bargaining weights as relative discount factors (Rubinstein, 1982; Collard-Wexler et al., 2013), we believe that Specification 1 – which effectively sets the discount rates equal across MCOs and systems – is more reasonable and hence we focus on it in the rest of the paper.

Figure 2 plots the predicted mean marginal costs $(v_{mj}\gamma)$ against the actual estimated marginal costs $(v_{mj}\gamma + \varepsilon_{mj})$ using the Specification 1 estimates.[26] It shows that the included cost shifters have a significant predictive effect as the two lines are highly positively correlated. Figure 3 presents a scatterplot of the hospital/MCO base prices and the implied marginal costs. The vast majority of the observations are well above the 45 degree line indicating that most of the hospitals in our sample earn positive margins.

Table 6: Lerner indices, actual and effective price elasticities

System Name	Lerner index	Actual own price elasticity	Effective own price elasticity (Lerner^{-1})	Own price elasticity w/o insurance
Fauquier Hospital	0.21	0.15	4.84	5.66
Inova Health System	0.43	0.07	2.33	3.13
Potomac Hospital	0.48	0.15	2.07	6.60
Prince William Hospital	0.60	0.12	1.67	4.99
HCA – Reston Hospital	0.45	0.15	2.20	7.45
Virginia Hospital Center	0.68	0.13	1.48	6.57

Table 6 lists the estimated (unweighted) mean 2006 Lerner index, $\frac{P-mc}{P}$, by hospital sys-

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[26]We truncate negative actual marginal costs at zero.

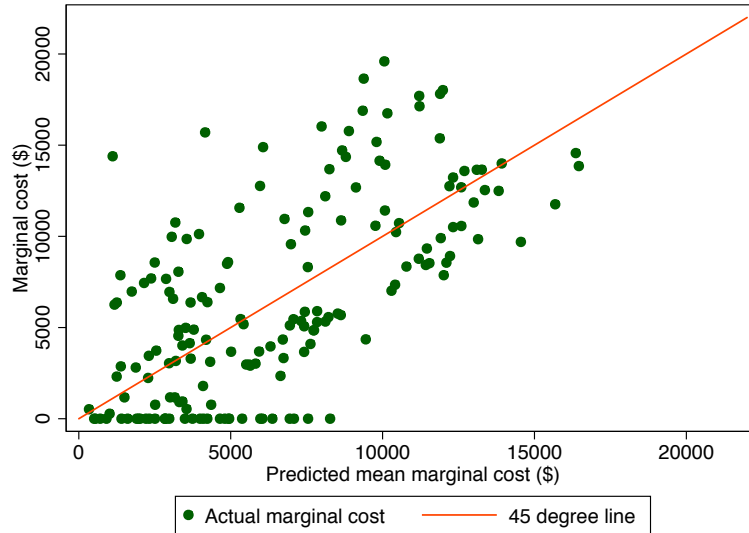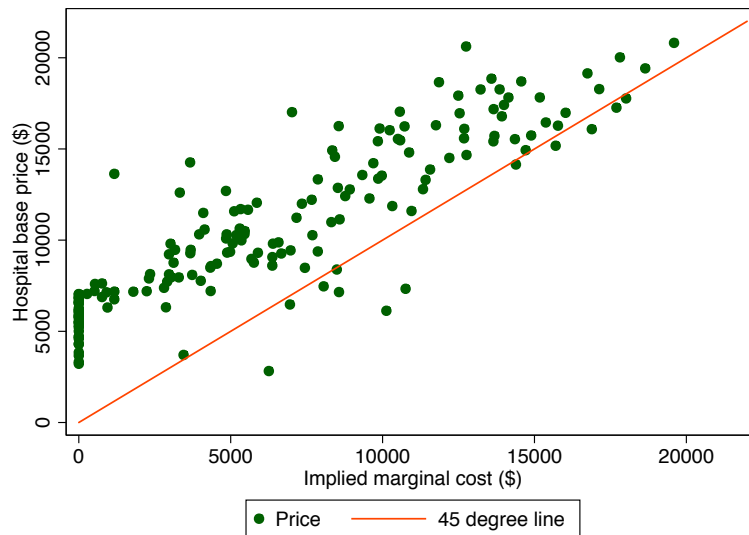Figure 2: Scatterplot of predicted mean and actual estimated marginal cost

Figure 3: Scatterplot of Hospital-MCO base prices on implied marginal cost

tem. The mean Lerner indices range from 0.21 to 0.68, and are relatively high for both Inova and PWH. Importantly, Table 6 also presents the actual (own-price) elasticity,[27] effective price elasticity, and own-price elasticity that would exist without insurance. We calculate effective price elasticities using the inverse elasticity rule $elast_{mj} = -Lerner^{-1}$.

For PWH, the actual price elasticity is 0.12, but the effective price elasticity is much higher, and at 1.67, consistent with positive marginal costs. If patients faced the full cost of their treatment instead of having insurance, our first stage estimates imply that PWH's price elasticity would rise to 4.98. For Inova, the own-price elasticity is even lower than for PWH, at 0.07, because it is a large system, but the effective own-price elasticity is 2.33, slightly higher than for PWH.

Overall, the three elasticities in Table 6 provide a clearer picture of the impact of MCO bargaining. In all cases, the effective price elasticities are in between actual price elasticities and price elasticities without insurance. It is well-understood that the risk-reduction component of insurance dampens consumer price responsiveness relative to having no insurance. In a Bertrand model, this will raise equilibrium prices. However, we find that MCO bargaining leverage serves to partially overcome this insurance moral hazard problem, driving equilibrium prices closer to what they would be in a world without health insurance.

5 Counterfactuals

Having estimated the primitives of the bargaining model, we now perform seven antitrust and health policy counterfactual experiments. Specifically, we focus on the impact of different hospital mergers and previously implemented structural remedies to those mergers. We also study the impact of different coinsurance rates on the bargaining equilibrium. Table 7 presents the results from these experiments.

Counterfactual 1: Inova and Prince William merger. In the first counterfactual we examine the predicted price, quantity, and welfare impacts of the merger that the FTC

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[27]To calculate an actual price elasticity for system s, we first calculate the derivative of system quantity with respect to each of its hospital's prices, $\sum_{k \in J_s} \frac{\partial s_k}{\partial p_j}$, and then approximate the derivative with respect to system price as the mean of these derivatives across member hospitals $j \in J_s$.

successfully blocked.[28] We find that the PWH/Inova merger leads to a significant increase in prices (weighted by hospital/MCO volume) and profits for the new Inova system.[29] The net quantity-weighted price increase is approximately 3.1% and the net increase in profits is 9.3%. Considering the relative size of PWH compared to the Inova system, a 3.1% price increase across the joint systems from this transaction is quite substantial. Holding the pre-merger discharges constant, PWH would account for 10.2% of Inova's discharges. Thus, the price increase relative to PWH size is 30.5%. Patient volume goes down only slightly, by 0.5%, reflecting both the fact that coinsurance rates are low (and hence that patient demand is inelastic) and the equilibrium increase in prices by rival hospitals.[30] Managed care surplus, which is weighted consumer surplus net of payments to hospitals, drops by approximately 27%.

Counterfactual 2: Break-up Loudoun from Inova. In the second counterfactual we examine the impact of Inova divesting Loudoun Hospital. The counterfactual predictions tell a different story for the Inova/Loudoun demerger than the Inova/PHW merger. Forcing a divesture of Loudoun Hospital leads to a more modest net reduction in price of 1.8% for the Inova system and a reduction in profits of 4.7%. It would increase net consumer surplus by 13.5%. The price decrease translates into an approximate 14.7% price decrease relative to Loudoun's discharge share of the Inova system. The smaller price impact is consistent with the FTC challenging Inova's proposed Prince William acquisition but not its Loudoun acquisition, but is nonetheless still substantial.

Counterfactual 3: Separate bargaining merger remedy. In the Evanston Northwestern hospital merger case, the FTC imposed a remedy requiring the Evanston Northwestern system to negotiate separately with MCOs (with firewalls in place) from the newly acquired hospital, Highland Park Hospital.[31] We examine the implications of this type of policy by simulating a world where Inova acquires PWH and the PWH negotiator bargains

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[28]For payors with very low coinsurance rates, we used the no-coinsurance solution from Brand (2013) for this simulation, due to convergence difficulties.

[29]We have also examined the implied impact of the Inova/PWH merger under the assumption that patients are insured and hospital competition is Bertrand. This exercise generates implausibly large post-merger price increases.

[30]However, the quantity decrease relative to PHW size is a more substantial 4.9%.

[31]*In the Matter of Evanston Northwestern Healthcare Corporation, Docket No. 9315, Opinion of the Commissioners*, 2008.

Table 7: Counterfactuals

System	%Δ Price	%Δ Quantity	%Δ Profits
Counterfactual 1: Prince William and Inova merger			
Inova & PWH	3.1	−0.5	9.3
Rival hospitals	3.6	1.2	12.0
Relative to PWH's system discharge share	30.5	−4.9	91.5
%Δ CS - MCO costs		−26.9	
Counterfactual 2: Breakup of Loudoun from Inova			
Inova & Loudoun	−1.8	0.1	−4.7
Rival hospitals	−1.6	−0.2	−4.7
Relative to Loudoun's system discharge share	−14.7	.8	−38.5
%Δ CS − MCO costs		13.5	
Counterfactual 3: PW and Inova merger with separate bargaining			
Inova & PWH	3.3	−0.5	8.8
Rival hospitals	3.5	1.2	11.2
%Δ CS − MCO costs		−27.8	
Counterfactual 4: No multi-hospital systems			
All hospitals	−6.8	.05	−18.9
%Δ CS - MCO costs		54.8	
Counterfactual 5: No coinsurance relative to base			
All hospitals	3.7	0.01	9.8
%Δ CS - MCO costs		5.9	
Counterfactual 6: PW and Inova merger w/ no coinsurance			
Inova & PWH	2.9	0	7.4
Rival hospitals	1.3	0	3.9
%Δ CS - MCO costs		−19.2	
Counterfactual 7: Co-insurance rate is 10 times larger			
All hospitals	−16.1	0.9	−0.4
%Δ CS - MCO costs		−140.1	

Note: price changes are calculated using prices weighted by quantity.

with a firewall from the other Inova hospitals.[32] Following Collard-Wexler et al. (2013), an alternating-offers extensive form representation of this game would have PWH's negotiator unable to observe the offered prices to the rest of the Inova system when deciding whether to accept an MCO's offer. In the Horn and Wolinsky (1988a) framework, the Nash bargaining disagreement point for PWH's negotiation with an MCO now has only PWH eliminated from the network, not the other Inova hospitals.

Even though the negotiations are separate in this way, the PWH bargainer might internalize the incentives of the system, namely that if a high price discouraged patients from seeking care at PWH some of them would still divert instead to other Inova members which is beneficial for the parent organization. Our counterfactual, which assumes that the negotiators recognize these true incentives faced by the system, finds that the conduct remedy performs similarly to the base merger outcomes, with a post-merger price increase of 3.3% and a loss of net consumer surplus of 27.8%.

The FTC in its Evanston decision hoped that this conduct remedy would re-inject competition into the market by reducing the leverage of the hospital that bargains separately; e.g., PWH could only threaten a small harm to the MCO from disagreement. However, this remedy also reduces the leverage of the MCO since if it offers an unacceptable contract to PWH, some of its but-for PWH patients would certainly go to other Inova hospitals. The increase in disagreement values on both sides implies that the impact of this remedy (relative to the outcome under the merger absent the remedy) is theoretically very ambiguous. Empirically, separate negotiations do not appear to solve the problem of bargaining leverage by hospitals.

Counterfactual 4: Breaking up the entire Inova system. The 1990s saw a large wave of hospital mergers that dramatically increased average hospital market concentration in the U.S. We can get a rough sense of consequences of this merger wave by computing the impact of breaking up the entire Inova system into separately-owned hospitals. Breaking up the entire system into stand-alone hospitals leads to a 7% market-wide decline in prices and a 54.8% increase in consumer surplus. While this is only one example of a large hospital system, these estimates suggest that the creation of large hospital systems during the 1990s, in fact, lead to meaningfully higher hospital prices.

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[32]Appendix B provides the first order conditions for this case.

Counterfactual 5: Impact of no coinsurance on bargained prices. The moral hazard effect of health insurance have long been an important area of study. Less studied is the indirect impact of health insurance cost-sharing arrangements on equilibrium provider prices. By covering out-of-pocket expenses, health insurance dampens the incentive of consumers to respond to differential prices in selecting healthcare providers which, as we discussed above, likely affects equilibrium prices. Our model allows us to examine the equilibrium impact of coinsurance on the insurer's cost of hospital care. We first examine the polar case of insurance policies that cover all inpatient care expenses at the margin.

We find that quantity-weighted prices would be 3.7% higher than in the base case if coinsurance rates were zero. The reason for the price increase is straightforward. Patient demand would go from having a moderate elasticity to no elasticity at all. Thus, these results indicate that both patient coinsurance and MCO bargaining leverage play a role in constraining prices in this market.

Counterfactual 6: Merger impact when patients do not pay any coinsurance. It is hypothesized that increasing patient cost sharing can partially undo the price impact of hospital mergers. Theoretically, however, the steering effect of coinsurance can either enhance or mitigate the increase in bargaining leverage from merger. We explore these possibilities in the context of our model by calculating the predicted impact of the Inova/PWH merger when patient cost sharing is zero. We find that here the steering effect enhances the increased bargaining leverage of mergers. The percentage price increase of the merger here is smaller than in the baseline, raising prices at the new Inova system 2.9% relative to the base prices with no coinsurance.

Counterfactual 7: Impact of 10-fold increase in coinsurance on bargained prices. Estimates of the optimal health insurance design in the presence of moral hazard indicate that coinsurance rates should be approximately 25% (see Manning and Marquis, 1996).[33] In this counterfactual, we consider the impact of a tenfold increase in the coinsurance rates on the equilibrium, which yields roughly equivalent coinsurance rates to the Manning and Marquis ones.

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[33]Manning and Marquis (1996)'s optimal insurance contract also includes a $25,000 (in 1995 dollars) stop-loss.

The increase in cost sharing has a large impact, which quantity-weighted prices dropping by 16% and quantity increasing slightly, relative to the base case. This counterfactual suggests that analyses of the optimal benefit design of insurance contracts, which do not consider the additional impact of increasing cost sharing on the price of health care, likely understate the gains from increased coinsurance rates.

6   Conclusion

Many bilateral, business-to-business transactions are between oligopoly firms negotiating prices over a bundle of imperfectly substitutable goods. In this paper we develop a model of the price negotiations game between managed care organizations and hospitals. We show that standard oligopoly models will generally not accurately capture the pricing behavior under these bargaining scenarios. We then develop a GMM estimator of the negotiation process and estimate the parameters of the model using detailed managed care claims and patient discharge data from Northern Virginia.

We find that patient demand is quite inelastic – with own-price elasticities of about 0.12 on average – due to the fact that patients typically only pay out-of-pocket 2 to 3 percent of the cost of their hospital care at the margin. Consistent with our theoretical model, prices are significantly constrained by MCO bargaining leverage. Prices under MCO bargaining are still much higher than they would be in the absence of insurance. We find that the proposed merger between Inova hospital system and Prince William Hospital, which the FTC challenged, would have significantly raised prices. Conduct remedies used by the FTC in other hospital merger cases, with separate, fire-walled negotiating teams, would not help. Finally, we find that a large increase in the coinsurance rate would significantly reduce hospital prices. Patient cost-sharing has recently trended upwards and our model indicates that if this trend continues it could result in a significant reduction in provider prices.

While our focus is on negotiations between hospitals and MCOs, we believe our framework can be applied in a number of alternative settings where there are a small number of "gatekeeper" buyers. Our approach allows us to write the equilibrium pricing in a way that is very similar to the standard Lerner index inverse elasticity rule, by substituting effective demand elasticities for the demand elasticities. This approach further allows us to construct a simple GMM estimator for marginal costs, bargaining weights and underlying incentives.

An interesting extension to explore in future work is formal identification of the bargaining weights. We conjecture that the identification of these weights might be similar to identification of the nature of competition and that some of the results in Haile and Berry (2010) would generalize to our case.

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Appendix A: Derivation of the A term

For on-line publication

We defined the A term as

$$\frac{\partial V_m}{\partial p_{mj}} = \tau \frac{\partial W(N_m, \vec{p_m})}{\partial p_{mj}} - \frac{\partial TC_m(N_m, \vec{p_m})}{\partial p_{mj}} \tag{21}$$

$$W(N_m, \mathbf{p_m}) = \frac{1}{\alpha} \sum_{i=1}^{I_m} \sum_{d=1}^{D} f_{mid} \ln \left(\sum_{j \in N_m} e^{\delta_{mijd}} \right) \tag{22}$$

$$\frac{\partial W(N_m, \vec{p_m})}{\partial p_{mj}} = -\sum_{i=1}^{I_m} \sum_{d=1}^{D} c_{mid} w_{id} f_{mid} \frac{e^{\delta_{mijd}}}{\sum_{k \in N_m} e^{\delta_{mikd}}} = -\sum_{i=1}^{I_m} \sum_{d=1}^{D} c_{mid} w_{id} f_{mid} s_{mijd} \tag{23}$$

$$\frac{\partial TC_m(N_m, \vec{p_m})}{\partial p_{mj}} = \sum_{i=1}^{I_m} \sum_{d=1}^{D} (1 - c_{mid}) f_{mid} w_{id} s_{mijd} + \sum_{i=1}^{I_m} \sum_{d=1}^{D} (1 - c_{mid}) f_{mid} w_{id} \sum_{k \in N_m} p_{km} \frac{\partial s_{mikd}}{\partial p_{mj}} \tag{24}$$

Note that $\frac{\partial s_{mijd}}{\partial p_{mj}} = -\alpha c_{mid} w_{id} s_{mijd} (1 - s_{mijd})$ if $k = j$ and otherwise $\frac{\partial s_{mikd}}{\partial p_{mj}} = \alpha c_{mid} w_{id} s_{mikd} s_{mijd}$.
Putting this all together gives:

$$\frac{\partial V_m}{\partial p_{mj}} = -\tau \sum_{i=1}^{I_m} \sum_{d=1}^{D} c_{mid} w_{id} f_m i d s_{mijd} - \sum_{i=1}^{I_m} \sum_{d=1}^{D} (1 - c_{mid}) w_{id} f_{mid} s_{mijd}$$
$$- \alpha \sum_{i=1}^{I_m} \sum_{d=1}^{D} (1 - c_{mid}) c_{mid} w_{id}^2 f_{mid} s_{mijd} \left(\sum_{k \in N_m} p_{km} s_{mikd} - p_{mj} \right). \tag{25}$$

Appendix B: Derivation of the FOCs for the Prince William separate bargaining

For on-line publication

We start by considering the (notationally simpler) case where each hospital and MCO pair bargain with separate contracts, even if the hospital is part of a system. Consider a system s and a hospital $j \in J_s$. Define $NB^{m,j}(p_{mj}|\vec{p}_{m,-j}, \vec{p}_{m,-s})$ to be the Nash bargaining product for this contract. Analogously to (10), we have:

$$NB^{m,j}(p_{mj}|\vec{p}_{m,-j}, \vec{p}_{m,-s}) =$$
$$\left(q_{mj}(N_m, \vec{p}_m)[p_{mj} - mc_{mj}] + \sum_{k \in J_s, k \neq j} (q_{mk}(N_m, \vec{p}_m) - q_{mk}(N_m \setminus j, \vec{p}_m))[p_{mk} - mc_{mk}] \right)^{b_{s(m)}}$$
$$\left(V_m(N_m, \vec{p}_m) - V_m(N_m \setminus j, \vec{p}_m) \right)^{b_{m(s)}}.$$

(26)

In words, the disagreement value of system s for this contract is now that it withdraws hospital j. In this case, it will lose its profits from hospital j but will gain profits from the additional diversion quantity $\lambda_{mjk} \equiv (q_{mk}(N_m \setminus j, \vec{p}_m) - q_{mk}(N_m, \vec{p}_m))$ from each other hospital $k \neq j$ that it owns. The MCO's disagreement value from failure for this contract is now the difference in value from losing hospital j instead of from losing system s.

Analogously to (12), the FOC for this problem is:

$$b_{s(m)} \frac{q_{mj} + \sum_{k \in S_j} \frac{\partial q_{mk}}{\partial p_{mj}}[p_{mk} - mc_{mk}]}{q_{mj}(N_m, \vec{p}_m)[p_{mj} - mc_{mj}] - \sum_{k \in J_s, k \neq j} \lambda_{mjk}[p_{mk} - mc_{mk}]}$$
$$= -b_{m(s)} \frac{\frac{\partial V_m}{\partial p_{mj}}}{V_m(N_m, \vec{p}_m) - V_m(N_m \setminus j, \vec{p}_m)}. \quad (27)$$

We now consider the case where Inova acquires Prince William but where Prince William bargains separately from the rest of the Inova system. In this case, the FOCs for the Prince William contracts will be exactly as in (27). The FOCs for the other Inova hospitals will now resemble (27) but the disagreement values will reflect removing all Inova legacy hospitals

from the network and having diversion quantities only for Prince William.