Mergers When Prices Are Negotiated: Evidence from the Hospital Industry

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We estimate a bargaining model of competition between hospitals and managed care organizations (MCOs) and use the estimates to evaluate the effects of hospital mergers. We find that MCO bargaining restrains hospital prices significantly. The model demonstrates the potential impact of coinsurance rates, which allow MCOs to partly steer patients towards cheaper hospitals. We show that increasing patient coinsurance tenfold would reduce prices by 16%. We find that a proposed hospital acquisition in Northern Virginia that was challenged by the Federal Trade Commission would have significantly raised hospital prices. Remedies based on separate bargaining do not alleviate the price increases.
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In many markets, prices are determined via bilateral negotiations rather than set by one of the sides or via an auction. Examples include rates negotiated between content providers and cable companies (Crawford and Yurukoglu, 2012), the terms of trade between book publishers and online retailers, such as Amazon,[1] and hospital prices in the health care markets that we study here. A party to negotiations will earn more beneficial terms of trade by improving its bargaining leverage. One of the ways that a firm can achieve better bargaining leverage is by merging with a competitor.[2]

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[1]See http://bits.blogs.nytimes.com/2014/05/30/why-is-amazon-squeezing-hachette-maybe-it-really-needs-the-money/.

[2]Theoretical results in the literature show that joint negotiation can lead to higher or lower prices, with the effect depending on the curvature of the value of the bargaining partner (Horn and Wolinsky, 1988*a*; Chipty and Snyder, 1999). The empirical literature generally, but not unanimously, finds that larger firms are able to negotiate lower prices, all else equal (see Chipty, 1995; Sorensen, 2003; Ho, 2009).

In this paper we estimate a model of competition in which prices are negotiated between managed care organizations (MCOs) and hospitals. We use the estimates 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. It is both important and policy relevant to analyze the impact of hospital competition. 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.[3] Our analysis builds on and brings together three different literatures that (i) structurally estimate multi-party bargaining models; (ii) simulate the likely effect of mergers; and (iii) study competition in health care markets. Our contribution is in modeling the effect of final consumers paying some of the costs (through coinsurance); in our estimates of price-cost margins and policy-relevant counterfactuals; and in the way we estimate the model, which generalizes the equilibrium models commonly used in industrial organization that does not require data on downstream market outcomes. The approach we follow in this paper can be used more generally to understand mergers 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.

A standard way to model competition in differentiated product markets is with a Bertrand pricing game. In this industry, patient demand for hospitals is very inelastic because patients pay little out of pocket for hospital stays, and therefore Bertrand competition between hospitals implies negative marginal costs. In contrast, our estimated bargaining model generates more reasonable marginal costs and (as we show empirically) merger impacts.

Our model of competition between MCOs and hospitals has two stages. In the first stage, MCOs and hospital systems negotiate the base price that each hospital will be paid by each MCO for hospital care. We model the outcome of these negotiations using the Horn and Wolinsky (1988*a*) 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/hospital-system pairs. The Nash bargaining problem is a function of the value to each party from agreement relative to the value without agreement, and hence depends on the objective functions of the parties. We assume that hospitals, which may be not-for-profit, seek to maximize a weighted sum of profits and quantity and that MCOs act as agents for self-insured employers, seeking to maximize a weighted sum of enrollee welfare and insurer costs. To evaluate the robustness of this relatively strong assumption on the MCO objective function, we also report calibrated results from a model where MCOs, whose objective is profit maximization, explicitly post premiums à la Bertrand following the price

[3]Since 1989, 13 hospital mergers have been challenged by the federal antitrust agencies. Recently, the Federal Trade Commission successfully challenged hospital 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).

negotiation stage.[4]

In the second stage, each MCO enrollee receives a health draw. Enrollees who are ill decide where to seek treatment, choosing a hospital to maximize utility. Utility 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 shock. 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 first-stage Nash bargaining disagreement values are then determined by the utilities generated by the expected patient 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 equation, 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 pricing by hospitals with targeted prices to each MCO. In general, the two are not 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 hospital markups will be lower than under Bertrand pricing.

We estimate the model using discharge data from Virginia Health Information and administrative claims data from payors, from Northern Virginia. The use of claims data is novel and helps in two ways. First, the data allow us to construct prices for each hospital-payor-year triple. Second, the data let us construct patient-specific coinsurance rates, which we use to estimate patient behavior.

We estimate the multinomial logit patient choice model by maximum likelihood, and the parameters of the bargaining model by forming moment conditions based on orthogonality restrictions on marginal costs. We calculate marginal costs 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, Levinsohn and Pakes, 1995).

We find that patients pay an average of 2-3% of the hospital bill as coinsurance amounts. While patients significantly dislike high prices, the own-price elasticities for systems are relatively low, ranging from 0.07 to 0.17, due to the low coinsurance rates. Without any health insurance, these own-price elasticities would range from 3.10 to 7.34. Estimated Lerner indices range from 0.22 to 0.58, which are equivalent to those implied by Bertrand pricing by hospitals if own-price elasticities ranged from 4.56 to 1.74. This implies that bargaining incentives make MCOs act more elastically than individual patients, but less elastically than patients without insurance.

[4]We discuss the advantages and disadvantages of both approaches below.

Using the estimated parameters of the model, we examine the impact of a number of counterfactual market structures, focusing on the proposed acquisition by Inova Health System of Prince William Hospital, a transaction that was challenged by the Federal Trade Commission (FTC) and ultimately abandoned. We find that the proposed merger would have raised the quantity-weighted average price of the merging hospitals by 3.1%, equivalent to a 30.5% price increase at just Prince William. We also consider a remedy implemented by the FTC in a different hospital merger case, where the newly acquired hospitals were forced to bargain separately, in order to re-inject competition into the marketplace. We find that separate bargaining does not eliminate the anticompetitive effects of the Prince William acquisition since it changed disagreement values for both hospitals and MCOs. Finally, we examine the impact of different coinsurance rates on restraining prices. We find that mean prices 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 (approximately the optimal coinsurance rate for hospitalizations calculated by Manning and Marquis (1996)).

To evaluate the robustness of our results, we also consider a model where MCOs simultaneously post premiums and then compete for enrollees. Lacking data on premiums and premium elasticities necessary to estimate this model, we instead calibrate it using estimates from other studies and from our base model. We find a larger price increase of 7.2% from the Prince William merger. Unlike our base model, with posted premium competition, a hospital system will recapture some of the patients from the MCO in the event of disagreement through those patients choosing different MCOs. This increase in the disagreement value gives the hospital system more leverage, relative to the base model. On the other hand, the disagreement values of MCOs will also likely be higher in the posted premium competition model as MCOs can optimally adjust premiums in response to disagreement.

Given that we present results from two models, it is worth considering the relative advantages of each approach. Models that are similar to our posted premium competition one have been used in other bargaining contexts, such as Crawford and Yurukoglu (2012)'s model of the cable industry. We believe that posted premium setting is the better model in industries such as television where the downstream firms set posted prices and consumers select products based on those prices. However, for the hospital industry, there are several industry features that are at odds with the assumptions of the posted premium competition model. These include the fact that the majority of employees have only one choice of employer-sponsored health plan;[5] that premiums for large employers are typically determined via negotiated non-linear long-run contracts that allow for price discrimination (Dafny, 2010), and not by take-it-or-leave-it premium

[5] Fifty eight percent of employees offered health insurance through their employer are only given one health insurance option (Agency for Healthcare Research and Quality, Medical Expenditure Panel Survey Insurance Component National-Level Summary Tables, 2012).

offers that follow the price negotiation process (as in the posted premium competition model); and that self-insured employers negotiate administrative fees alone, and not premiums. For these reasons, we believe that employers and MCOs align their incentives more than implied by posted premium setting. This would result in there being less of a tradeoff between capturing employee surplus and creating employee surplus than in the posted premium competition model, though admittedly more than the zero tradeoff that is allowed by the base model. Overall, our view is that the real world is somewhere "in between" the two models in this sense, and that estimation using the base model is the best way to proceed given our available data.

This paper builds on three related literatures. First, our analysis builds on recent work that structurally estimates multilateral bargaining models. Crawford and Yurukoglu (2012) were the first to develop and estimate a full structural bargaining framework based on Horn and Wolinsky (1988*a*); they examined bargaining between television content providers and cable companies.[6] The posted premium competition model is essentially their model (with a slightly different demand model), with the addition of coinsurance and other features unique to the healthcare sector. Our econometric approach is differentiated in that the estimation does not require solving for equilibrium prices and the unobserved term reflects cost variation.

Second, our paper relates to the literature that uses pre-merger data to simulate the likely effects of mergers by using differentiated products models with price setting behavior.[7] 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 hospital pricing. 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 with Bertrand hospital price setting.[8]

Finally, an existing literature has focused on bargaining models in which hospitals negotiate with MCOs for inclusion in their network of providers. Capps, Dranove and Satterthwaite (2003) and Town and Vistnes (2001) estimate specifications that are consistent with an underlying bargaining model but neither paper structurally estimates a bargaining model. We show 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 on Ho (2009,

[6]Other papers that seek to estimate structural bargaining models include Grennan (2013), Allen, Clark and Houde (2014), Draganska and Villas-Boas (2011) and Meza and Sudhir (2010).

[7]See, for example, Berry and Pakes (1993); Hausman, Leonard and Zona (1994); Werden and Froeb (1994); Nevo (2000).

[8]Horn and Wolinsky (1988*a*,*b*), Chipty and Snyder (1999) and O'Brien and Shaffer (2005).

2006), Lewis and Pflum (2014), and Ho and Lee (2013). 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.

The remainder of this paper is organized as follows. Section 2 presents our model. Section 3 discusses econometrics. Section 4 provides our results. Section 5 provides counterfactuals. Section 6 examines the robustness of our results to modeling assumptions. Section 7 concludes.

I. Model

A. *Overview*

We model the interactions between MCOs, hospitals, and patients. The product we consider for MCOs is health administration services sold to self-insured employers.[9] Employers acquire these services and insure their employees as part of a compensation package, so employee and employer incentives are largely aligned.[10] In self-insured plans, the employer pays the cost of employee health care (less coinsurance, copays and deductibles) plus a management fee to the MCO. In this market, the central role of the MCO is to construct provider networks, negotiate prices, provide care and disease management services, and process medical care claims. Our base model assumes that each employer has an ongoing contract with one MCO, under which the MCO agrees to act in the incentives of the employers that it represents in its negotiation with hospitals, in exchange for a fixed management fee that is determined by some long-run market interaction between the MCO and the employer.[11]

We model a two-stage game that takes as given these employer/MCO contracts. In the first stage, MCOs, acting as agents of the employers, negotiate with hospital systems for the terms of hospitals' inclusion in MCOs' networks.[12] 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

[9]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).

[10]Baicker and Chandra (2006) find that increases in medical costs are incompletely passed through to wages but that they also have broader labor market consequences.

[11]According to an industry expert, the most common fee structure that MCOs use for self-insured plans are fixed fees based on the employer size. We thank Leemore Dafny for putting us in contact with this expert.

[12]Section V considers a calibrated model where MCOs explicitly post premiums à la Bertrand to attract enrollees following the hospital-MCO price negotiation process.

selects a hospital in the MCO's network – or an outside alternative – to maximize her utility.

B. Patient hospital choice

We now describe the second stage: patient choice of hospital. There is a set of hospitals indexed by $j = 1, \ldots, J$, and a set of managed care companies indexed by $m = 1, \ldots, M$. The hospitals are partitioned into $S \leq J$ systems. Let $\mathcal{J}_s$ denote the set of hospitals in system s.

There is a set of enrollees be denoted by $i = 1, \ldots, I$. Each enrollee has health insurance issued by a particular MCO. Let $m(i)$ denote the MCO of enrollee i. In our base model, $m(i)$ is fixed, having been chosen via the long-run employer/MCO contracts. Each MCO m has a subset of the hospitals in its network; denote this subset $\mathcal{N}_m$. For each m and each $j \in \mathcal{N}_m$, there is a base price p_{mj}, which was negotiated in the first stage. Let $\mathbf{p}_m$ denote the vector of all negotiated prices for MCO m.

Prior to choosing the hospital, taking as given plan enrollment and the networks, each patient receives a draw of her health status that determines if she has one of a number of health conditions that require inpatient care. Let f_{id} denote the probability that patient i at MCO m is stricken by illness $d = 0, 1, ...D$, where $d = 0$ implies no illness, w_d denotes the relative intensity of resource use for illness d, and $w_0 = 0$. In our empirical analysis, w_d is observed. We assume that the total price paid for treatment at hospital j by MCO m of disease d is $w_d p_{mj}$, which is the base price multiplied by the disease weight. Therefore, the base 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 insurance specifies a coinsurance rate for each condition, which we denote c_{id}. The coinsurance rate indicates the fraction of the billed price $w_d p_{m(i)j}$ that the patient must pay out of pocket.

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 receives from care at hospital $j \in \mathcal{N}_{m(i)}$ is given by

$$u_{ijd} = \boldsymbol{\beta} \mathbf{x}_{ijd} - \alpha c_{id} w_d p_{m(i)j} + e_{ij}. \tag{1}$$

In equation (1), $\mathbf{x}_{ijd}$ 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 $\boldsymbol{\beta}$ is the associated coefficient vector. The out-of-pocket expense to the patient is $c_{id} w_d p_{m(i)j}$. As we describe below, we observe data that allow us to impute the base price, disease weight, and coinsurance rate; hence we treat out-of-pocket expense as observable. We let α denote the price sensitivity. Finally, e_{ij} is an $i.i.d.$ error term that is distributed type 1 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

$$u_{i0d} = -\alpha c_{id} w_d p_{m(i)0} + e_{i0}. \tag{2}$$

We normalize the quality from the outside option, $\mathbf{x}_{i0d}$, to 0 but we allow for a non-zero base price $p_{m(i)0}$.[13] Finally, we assume that e_{i0} is also distributed type 1 extreme value.

Consumers' expected utilities play an important role in the bargaining game. To exposit expected utility, define $\delta_{ijd} = \boldsymbol{\beta}\mathbf{x}_{ijd} - \alpha c_{id} w_d p_{m(i)j}$, $j \in \{0, \mathcal{N}_{m(i)}\}$. The choice probability for patient i with disease d as a function of prices and network structure is:

$$s_{ijd}(\mathcal{N}_{m(i)}, \mathbf{p}_{m(i)}) = \frac{\exp(\delta_{ijd})}{\sum_{k \in 0, \mathcal{N}_{m(i)}} \exp(\delta_{ikd})}. \tag{3}$$

The ex-ante expected utility to patient i, as a function of prices and the network of hospitals in the plan, is given by:[14]

$$W_i(\mathcal{N}_{m(i)}, \mathbf{p}_{m(i)}) = \sum_{d=1}^{D} f_{id} \ln \left(\sum_{j \in 0, \mathcal{N}_{m(i)}} \exp(\delta_{ijd}) \right). \tag{4}$$

Capps, Dranove and Satterthwaite (2003) refer to $W_i(\mathcal{N}_{m(i)}, \mathbf{p}_{m(i)}) - W_i(\mathcal{N}_{m(i)} \setminus \mathcal{J}_s, \mathbf{p}_{m(i)})$, as the "willingness-to-pay" (WTP) as it represents the utility gain to enrollee i from the system s.

C. MCO and hospital bargaining

We now exposit the bargaining stage. 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 price paid to a hospital for treatment of 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 $\mathbf{x}_{ijd}$ and hospital costs.

Following Horn and Wolinsky (1988*a*) 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

[13] 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 implications for the bargaining model parameter estimates and counterfactual equilibrium behavior.

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

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. Our bargaining model makes the relatively strong assumption that each contract remains the same even if negotiation for another contract fails.

Essentially, the Horn and Wolinsky solution nests a Nash bargaining solution (an axiomatic cooperative game theory concept) within a Nash equilibrium (of a non-cooperative game) without a complete non-cooperative structure. The results of Rubinstein (1982) and Binmore, Rubinstein and Wolinsky (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, Gowrisankaran and Lee (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.

Starting with MCOs, we now detail the payoff structures and use them to exposit the Nash bargain for each contract. 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, taking $m(i)$ as fixed. Because $m(i)$ is fixed, a hospital system that does not reach agreement with MCO m will not capture back any of m's patients through plan switches by those patients. Define the ex-ante expected cost to the MCO and the employer that it represents to be $TC_m(\mathcal{N}_m, \mathbf{p}_m)$. The MCO pays the part of the bill that is not paid by the patient, hence

$$TC_m(\mathcal{N}_m, \mathbf{p}_m) = \sum_{i=1}^{I} \sum_{d=1}^{D} 1\{m(i) = m\}(1 - c_{id}) f_{id} w_d \sum_{j \in 0, \mathcal{N}_m} p_{mj} s_{ijd}(\mathcal{N}_m, \mathbf{p}_m). \tag{5}$$

Define the value in dollars for the MCO and the employer it represents to be:

$$V_m(\mathcal{N}_m, \mathbf{p}_m) = \frac{\tau}{\alpha} \sum_{i=1}^{I} 1\{m(i) = m\} W_i(\mathcal{N}_m, \mathbf{p}_m) - TC_m(\mathcal{N}_m, \mathbf{p}_m), \tag{6}$$

where τ is the relative weight on employee welfare. If employer/employee/MCO incentives were perfectly aligned then $\tau = 1$; $\tau < 1$ implies that MCOs/employers value insurer costs more than enrollee welfare; while $\tau > 1$ implies that they value enrollee welfare more than insurer costs. Assume that $\mathcal{N}_m, m = 1, \ldots, M$, are the equilibrium sets of network hospitals. For any system s for which $\mathcal{J}_s \subseteq \mathcal{N}_m$, the net value that MCO m receives from including system s in its network is $V_m(\mathcal{N}_m, \mathbf{p}_m) - V_m(\mathcal{N}_m \setminus \mathcal{J}_s, \mathbf{p}_m)$.

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 $w_d mc_{mj}$. The 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 further assumptions regarding the cost structure. First, we assume that marginal costs are constant in quantity (though 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

$$mc_{mj} = \boldsymbol{\gamma}\mathbf{v}_{mj} + \varepsilon_{mj}, \tag{7}$$

where mc_{mj} is the marginal cost for an illness with disease weight $w_d = 1$, $\mathbf{v}_{mj}$ are a set of cost fixed effects (notably hospital, year, and MCO fixed effects), $\boldsymbol{\gamma}$ are parameters to estimate, and ε_{mj} is the component of cost that is not observable to the econometrician. Note that we are assuming no capacity constraints, and hence in the event of a disagreement between a hospital and an MCO, the patient will always go to her ex-post second choice.

Define the normalized quantity to hospital j, $j \in \mathcal{N}_m$ as

$$q_{mj}(\mathcal{N}_m, \mathbf{p}_m) = \sum_{i=1}^{I} \sum_{d=1}^{D} 1\{m(i) = m\} f_{id} w_d s_{ijd}(\mathcal{N}_m, \mathbf{p}_m). \tag{8}$$

Since prices and costs are per unit of w_d, the returns that hospital system s expects to earn from a given set of managed care contracts are

$$\pi_s(\mathcal{M}_s, \{\mathbf{p}_m\}_{m\in\mathcal{M}_s}, \{\mathcal{N}_m\}_{m\in\mathcal{M}_s}) = \sum_{m\in\mathcal{M}_s} \sum_{j\in\mathcal{J}_s} q_{mj}(\mathcal{N}_m, \mathbf{p}_m)[p_{mj} - mc_{mj}] \tag{9}$$

where $\mathcal{M}_s$ is the set of MCOs that include system s in their network. The net value that system s receives from including MCO m in its network is $\sum_{j\in\mathcal{J}_s} q_{mj}(\mathcal{N}_m, \mathbf{p}_m)[p_{mj} - mc_{mj}]$.

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:

$$(10)\quad NB^{m,s}(p_{mj\,j\in\mathcal{J}_s}|\mathbf{p}_{m,-s}) = \Big(\sum_{j\in\mathcal{J}_s} q_{mj}(\mathcal{N}_m,\mathbf{p}_m)[p_{mj}-mc_{mj}]\Big)^{b_{s(m)}} \Big(V_m(\mathcal{N}_m,\mathbf{p}_m) - V_m(\mathcal{N}_m\setminus\mathcal{J}_s,\mathbf{p}_m)\Big)^{b_{m(s)}},$$

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 $\mathbf{p}_{m,-s}$ is the vector of prices for MCO m and hospitals in systems other than s. Without loss of generality, we normalize $b_{s(m)} + b_{m(s)} = 1$.

The Nash bargaining solution is the vector of prices $p_{mj\,j\in\mathcal{J}_s}$ that maximizes (10). Let $\mathbf{p}^*_m$ denote the Horn and Wolinsky (1988*a*) price vector for MCO m. It must satisfy the Nash bargain for each contract, conditioning on the outcomes of other contracts. Thus, $\mathbf{p}^*_m$ satisfies

$$(11)\qquad p^*_{mj} = \max_{p_{mj}} NB^{m,s}(p_{mj},\mathbf{p}^*_{m,-j}|\mathbf{p}^*_{m,-s}),$$

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

D. Equilibrium properties of the bargaining stage

To understand more about the equilibrium properties of our model, we solve the first order conditions of the Nash bargaining problems, $\partial \log NB^{m,s}/\partial p_{mj} = 0$. For brevity, we omit the '*' from now on, even though all prices are evaluated at the optimum. We obtain:

$$(12)\quad b_{s(m)}\frac{q_{mj} + \sum_{k\in\mathcal{J}_s}\frac{\partial q_{mk}}{\partial p_{mj}}[p_{mk}-mc_{mk}]}{\sum_{k\in\mathcal{J}_s} q_{mk}[p_{mk}-mc_{mk}]} = -b_{m(s)}\frac{\overbrace{\frac{\partial V_m}{\partial p_{mj}}}^{A}}{\underbrace{V_m(\mathcal{N}_m,\mathbf{p}_m) - V_m(\mathcal{N}_m\setminus\mathcal{J}_s,\mathbf{p}_m)}_{B}}.$$

The assumption of constant marginal costs implies that the FOCs (12) are separable across MCOs.

We rearrange the joint system of $\#(\mathcal{J}_s)$ first order conditions from (12) to write

$$(13)\qquad \mathbf{q} + \Omega(\mathbf{p}-\mathbf{mc}) = -\Lambda(\mathbf{p}-\mathbf{mc})$$

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

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

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

where $\mathbf{p}$, $\mathbf{mc}$ and $\mathbf{q}$ 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 closed-form function of prices, quantities and derivatives, given MCO and patient incentives. Using this insight, (7) and (14) together form the basis of our estimation. We now show some intuition for the forces at work.

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 A1. We focus here on the case where $\tau = 1$ (so that MCOs value consumer surplus equally to insurer costs), in which case A is

$$\frac{\partial V_m}{\partial p_{mj}} = - q_{mj} - \alpha \sum_{i=1}^{I} \sum_{d=1}^{D} 1\{m(i) = m\}(1 - c_{id}) c_{id} w_{id}^2 f_{id} s_{ijd} \left(\sum_{k \in \mathcal{N}_m} p_{mk} s_{ikd} - p_{mj} \right). \tag{15}$$

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 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 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.

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 chose 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 j in its network. From (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 increases the effective price sensitivity, and hence lowers prices relative to differentiated products hospital Bertrand pricing.

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 there are large cost differences across hospitals, equilibrium prices will reflect the desire of the MCO to steer patients to low-cost hospitals. However, we still generally expect that MCO bargaining lowers prices relative to differentiated products Bertrand hospital pricing.

The impact of mergers on prices.

Similarly to with Bertrand pricing by hospitals, mergers here can also result in higher equilibrium hospital prices, although the mechanism is slightly different. In bargaining models, the MCO holds down prices by playing hospitals against each other. Post-merger, this competition is lost, causing prices to rise. Formalizing this intuition, Chipty and Snyder (1999) find that a merger of upstream firms (i.e., hospitals) will lead to higher prices if the value to the downstream firm (i.e., MCO) of reaching agreement relative to disagreement is concave.[15] In our model, if consumers view hospitals as substitutes, then the WTPs generated from the

[15] Horn and Wolinsky (1988*a*) also study mergers by upstream firms in a bargaining framework. They show that a merger between the upstream firms will increase negotiated prices if the downstream firms are substitutes even when the upstream firms are not substitutes.

patient choice model will tend to generate a concave value function, resulting in a price rise from a hospital merger.

Note that the magnitude of the merger effect may be different than under hospital Bertrand pricing. With hospital Bertrand pricing, 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 (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 pricing. Since these effects can be of opposite sign, the net effect of the merger under the bargaining model relative to under the Bertrand pricing model is ambiguous.

Note also that non-linearities of the value function can come from sources other than consumer substitution between hospitals. As an example, a merger between hospitals in two distinct markets could result in a price change, which would not happen with hospital Bertrand pricing. To see this, consider an MCO serving two separate markets without overlap and with one hospital in each market. If the two hospitals are identical except that the hospital in the first market is more expensive, then the MCO might be willing to trade off a higher price in the first market for a lower price in the second, in order to steer patients to or away from the outside option appropriately. A merger between the two hospitals would allow the new system to make this tradeoff, and thus it would increase price in the first market and decrease it in the second market. With competition between MCOs (as in our posted premium competition model) there is an additional source of non-linearity: in the case of disagreement some enrollees will switch their insurance plan, and will end up going to the same hospital through a different plan. This additional source will tend to increase prices more than in our base model.

Zero coinsurance rates and the relation to Capps, Dranove and Satterthwaite (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 m and $j, j \in \mathcal{J}_s$ then reduces to:

$$(17) \qquad \sum_{k \in \mathcal{J}_s} q_{mk} [p_{mk} - mc_{mk}] = \frac{b_{s(m)}}{b_{m(s)}} [V_m(\mathcal{N}_m, \mathbf{p}_m) - V_m(\mathcal{N}_m \setminus \mathcal{J}_s, \mathbf{p}_m)] .$$

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 (see Brand, 2013).

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

$$\sum_{k\in\mathcal{J}_s} q_{mk}[p_{mk} - mc_{mk}] = \frac{b_{s(m)}}{b_{m(s)}} \sum_{i=1}^{I} 1\{m(i) = m\} \frac{1}{\alpha} \left[W_i(\mathcal{N}_m, \mathbf{p}_m) - W_i(\mathcal{N}_m \setminus \mathcal{J}_s, \mathbf{p}_m)\right], \tag{18}$$

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.[16] The Capps, Dranove and Satterthwaite formula in (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.

II. Econometrics

A. Data

We use data from Northern Virginia to simulate the effects of a merger that was proposed in this area. 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 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

[16] See also Lewis and Pflum (2014) for a similar argument.

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 base prices, p_{mjt}, for each hospital-payor-year triple. We use the DRG weight, published by the Center for Medicare and Medicaid Services each year, as the disease weight w_{id}. DRG weights are a measure of the mean resource usage by diagnosis and are the primary basis for Medicare inpatient payments to hospitals. Our use here is appropriate if the relative resource utilization for Medicare patients across DRGs is similar to that of commercial patients. We regress the total amount paid divided by DRG weight on gender, age and hospital dummies, separately for each payor and year. We then create the base price for each hospital as the mean of the fitted regression values using all observations for the payor and year.[17] Our price regressions explain a large part of the within payor/year variation in prices: the R^2 values across the 16 regressions have an (unweighted) mean of 0.41. Our model also relies on the prices for the outside option, which is treatment at a Virginia hospital outside our geographic area. For each MCO m, we let the outside option price p_{m0} be the unweighted mean of the base price vector $\mathbf{p}_m$.

An alternative method of constructing prices is 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 MCOs and hospitals.[18] As consistently quantifying the contract terms was impractical, 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 coinsurance rates. 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. The allowed amount is the expected total payment the hospital is receiving for providing services to a given MCO patient.[19] 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.[20] We then create the expected coin-

[17]We have also explored alternative approaches to calculating prices including using amount paid as the dependent variable with the addition of DRG dummy variables as regressors. The quantitative implications of our estimates are robust to these different price construction methodologies.

[18]As an example, we examined one hospital in our data, which had (1) contracts with 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 based on the total charges.

[19]Some MCOs do not distinguish between deductibles and copayments. For these MCOs, we identify 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 (implying no variation in out-of-pocket expenditure across the hospitals) and coding the coinsurance amount in that case as 0.

[20]We allow coinsurance rates to vary by DRG because insurance contracts may have different terms

surance rate for each patient as the predicted values from this regression. In our coinsurance regressions, the percent of observations censored at 0 ranges from 31% to 98% across payors, reflecting variations in coinsurance practices across MCOs. The parameters generally indicate that the coinsurance rate is decreasing in age, higher for women, and decreasing in DRG weight.[21]

The Virginia discharge data contain much of the same information as the claims data but, in general, the demographic, patient ZIP code, and diagnosis 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 Health Planning District (HPD) 8 plus Fauquier County.[22] 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). We restrict our sample to patients discharged at a hospital in Virginia. The outside choice, $j = 0$, consists of people in this area who were treated at a hospital in Virginia other than one in our sample.[23]

We obtain the following hospital characteristics from the *AHA Guide* of the relevant year: staffed beds, residents and interns per bed, and 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.

B. *Estimation and identification of patient choice stage*

We estimate the patient choice model by maximum likelihood using the discharge data augmented with price and coinsurance information from the payor data. The model includes hospital-year fixed effects and interactions of hospital fixed effects with patient disease weight.

Since we include hospital-year fixed effects, all identification comes from variation in choices of a hospital within hospital-year groups. Thus, for instance,

for different inpatient conditions and patients may sort into different insurance contracts based on their conditions.

[21]These parsimonious tobit regressions explain the data reasonably well. The mean of the absolute value of the prediction errors normalized by the mean coinsurance rate range from 0.90 to 1.14.

[22]HPD8 is defined 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.

[23]We do not have data from Virginia residents who sought treatment out of state, for instance in Maryland or Washington, DC, but believe this number is small.

our coefficient on distance is identified by the extent to which patients who live nearer a given hospital choose that hospital relative to patients who live further away in the same year choose that hospital. Note that different coinsurance rates across MCOs imply different out-of-pocket prices. Thus, we identify α from the variation within a hospital-year in choices, based on different coinsurance rates and different negotiated prices across payors.[24]

C. *Estimation and identification of bargaining stage*

We estimate the remaining parameters, namely $\mathbf{b}$, the bargaining weights, $\boldsymbol{\gamma}$, the cost fixed effects, and τ, the weight MCOs put on the WTP measure, by imposing the bargaining model. Our estimation conditions on the set of in-network hospitals and treats the negotiated prices as the endogenous variable. Combining equations (14) and (7) we define the econometric error as

$$\boldsymbol{\varepsilon}(\mathbf{b},\boldsymbol{\gamma},\tau) = -\boldsymbol{\gamma}\mathbf{v} + \mathbf{mc}(\mathbf{b},\tau) = -\boldsymbol{\gamma}\mathbf{v} + \mathbf{p} + (\Omega + \Lambda(\mathbf{b},\tau))^{-1}\mathbf{q}, \tag{19}$$

where (19) 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 $E[\varepsilon_{mj}(\mathbf{b},\boldsymbol{\gamma},\tau)|\mathbf{Z}_{mj}] = 0$, where $\mathbf{Z}_{mj}$ is a vector of (assumed) exogenous variables. Recall that Ω and Λ are functions of equilibrium price (which depends on $\boldsymbol{\varepsilon}$) and thus are endogenous.

Our estimation depends on exogenous variables $\mathbf{Z}_{mj}$. We include all the cost fixed effects $\mathbf{v}_{mj}$ in $\mathbf{Z}_{mj}$. 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 in 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_{mj} is observed. We assume that these four exogenous variables do not correlate with $\boldsymbol{\varepsilon}$ but do correlate with price, implying that they will be helpful in identifying the effect of price.

The moments based on (19) identify τ, $\mathbf{b}$, and $\boldsymbol{\gamma}$. The estimation of the $\boldsymbol{\gamma}$ parameters is essentially a linear instrumental variables regression conditional on recovering marginal costs. We believe that the bargaining weights have somewhat similar equilibrium implications to fixed effects and hence it would be empirically difficult to identify the $\mathbf{b}$ and $\boldsymbol{\gamma}$ parameters at the same level, e.g., MCO fixed effects 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.

[24] Ho and Pakes (2014) estimate fixed effects at a narrower level which they believe are important in avoiding inconsistent estimates on price coefficients.

Because we include MCO, hospital, and year fixed effects, it is variation across hospitals for a given MCO and year that will serve to identify τ. As a concrete example, consider an MCO whose enrollees have a high WTP for a certain hospital, due to their geographic and illness characteristics. (Note that WTP is estimated in the patient choice stage.) That hospital will be able to negotiate a relatively high price with that MCO. The relative importance of WTP, and hence the extent of the price variation relative to other prices that involve the same MCO or hospital, is determined by τ, thus serving to identify this parameter.

III. Results

A. Institutional setting: 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 with hospitals solely in Northern Virginia, sought to acquire a not-for-profit institution that operated a single general acute-care hospital, Prince William Hospital (PWH). Inova operated a large tertiary hospital in Falls Church, Fairfax Hospital, with 884 licensed beds, which offered all major treatments from low acuity ones to high-end ones such as transplants. Inova also operated four, roughly similar community hospitals: Fair Oaks, Alexandria, Mount Vernon, and Loudoun Hospitals. Inova's previous acquisitions included Alexandria Hospital, in 1997 and Loudoun Hospital, in 2005. PWH had 180 licensed beds and was located in Manassas.

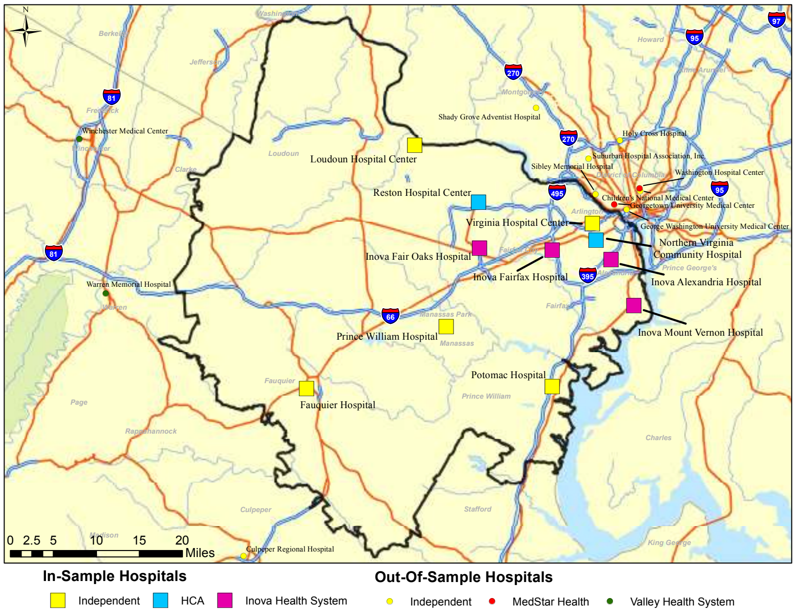
The Federal Trade Commission, with the Virginia Office of the Attorney General as co-plaintiff, challenged the acquisition in May, 2008. Subsequently, the parties abandoned the transaction.[25] The FTC alleged that the relevant geographic market consisted of all hospitals in Virginia Health Planning District 8 (HPD8) and Fauquier County. This geographic area included five other hospitals, although Northern Virginia Community Hospital closed in 2005. Of the remaining four, Fauquier, Potomac, and the Virginia Hospital Center are independent while Reston Hospital Center was owned by the HCA chain. The closest competitor to the Inova system was the Virginia Hospital Center.

The product market alleged by the FTC was general acute care inpatient services sold to MCOs. Given these market definitions, the market is highly concentrated. In its complaint, the FTC calculated a pre-merger HHI (based on MCO revenues) of 5,635 and the post-merger HHI of 6,174. The pre-merger and change in the HHI are well above the thresholds the antitrust agencies use for assessing the presumption of competitive harm from a merger.

Figure 1 presents a map of the locations of the hospitals in Northern Virginia as of 2003, the start of our sample. The heavy line defines the boundary of HPD8 and Fauquier County. The two closest hospitals to PWH are members of the

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

Figure 1. : 2003 Northern Virginia hospital locations



Inova system – Fair Oaks and Fairfax – and, according to MapQuest, are 21 and 29 minutes drive times from PWH, respectively.

All 11 hospitals in the market contracted with the four MCOs in our sample. The four MCOs in our sample represent 56% of private pay discharges in this market. None of these MCOs pay on a capitated basis.

B. *Summary Statistics*

Table 1 presents the mean base prices for the set of hospitals used in the analysis. There is significant variation in base prices across the hospitals prior to the merger. These differences do not reflect variation in the severity of diagnoses across hospitals as our construction of prices controls for disease complexity. The range between the highest and lowest hospital is 36% of the mean PWH price, which is in the middle of the price distribution.

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 2 presents statistics by hospital for the sample of patients we use to

Table 1—: Hospital characteristics

Hospital	Mean beds	Mean price $	Mean FP	Mean NICU	Mean cath lab
Prince William Hospital	170	10,273	0	1	0
Alexandria Hospital	318	9,757	0	1	1
Fair Oaks Hospital	182	9,799	0	0.5	1
Fairfax Hospital	833	11,881	0	1	1
Loudoun Hospital	155	11,565	0	0	1
Mount Vernon Hospital	237	12,112	0	0	1
Fauquier Hospital	86	13,270	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	9,973	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. The Mean NICU values of 0.5 reflect entry. Source: AHA and authors' analysis of MCO claims data.

Table 2—: Patient sample

Hospital	Mean age	Share white	Mean DRG weight	Mean travel time	Mean coins. rate	Discharges Total	Discharges Share
Prince William	36.1	0.73	0.82	13.06	0.032	9,681	0.066
Alexandria Hosp.	39.3	0.62	0.92	12.78	0.025	15,622	0.107
Fair Oaks Hosp.	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
Mt. Vernon Hosp.	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 Community 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 Hosp. Ctr.	36.8	0.69	0.90	15.35	0.021	16,007	0.110
VA Hosp. 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

Note: mean travel time is measured in minutes. Source: Authors' analysis of VHI discharge data and MCO claims data.

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, reflective of its role as a community hospital. The patient-weighted mean DRG weight across all of Inova's hospitals in 1.09 with its Fairfax and Mount Vernon facilities treating patients with the highest resource intensity. About 1.4% of patients in our sample choose care at a Virginia hospital that is not in our sample, a figure that ranges from 0.9% to 2.3% across the four MCOs in our sample. Patients choosing the outside option had a high mean DRG weight of 1.39. Not reported in the table, the five most frequent choices that constitute the outside good are two large tertiary care centers (Valley Health Winchester Medical Center in Winchester and the University of Virginia Health System in Charlottesville) and three psychiatric specialty hospitals.[26]

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 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%, which aligns with national data from three of the largest insurers.[27] There is significant variation across payors in the use of coinsurance which helps in our identification of α, as average coinsurance rates vary between 0.2% and 4.4% across MCOs in our data.

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. There is a large variation in the mean price that the different MCOs pay hospitals which is a challenge for our model to explain. 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 are not uncommon (Ginsburg, 2010). In our framework, there are three possible reasons for this variation, differences in bargaining weight, differential costs of treating patients across MCOs, and differences in enrollee geographic distributions, characteristics, and preferences.

[26] Our sample excludes discharges with a psychiatric major diagnostic category however a small number of psychiatric patients have multiple diagnoses with the primary diagnosis not being psychiatric.

[27] According to analysis based on claims data for over 45 million covered lives from the Health Care Cost Institute (HCCI), the average total out-of-pocket expenditures is approximately 4.8%. HCCI's figure includes deductibles and co-payments which we have removed from our coinsurance variable and thus the two estimates are well aligned. See HCCI 2012 Health Care Cost and Utilization Report available at http://www.healthcostinstitute.org/2012report for details.

C. Patient choice estimates

Table 3 presents coefficient estimates from the model of hospital choice. 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 that capture 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 major diagnostic class × cath lab	0.2036^{**}	(0.0409)
Obstetric major diagnostic class × NICU	0.6187^{**}	(0.0170)
Nerv, circ, musc major diagnostic classes × MRI	-0.1409^{**}	(0.0460)

Note: ** denotes significance at 1% level. Specification also includes hospital-year interactions and hospital dummies interacted with disease weight. Pseudo R^2=0.445, N=1,710,801.

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. 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.[28]

The parameter on out-of-pocket price is negative and significant indicating that, in fact, inpatient prices do play a role in admissions decisions.[29] However, in contrast to travel time, patients are relatively insensitive to the gross price paid from

[28]The patient's price sensitivity to travel likely reflects the fact that they will be visited by members of their social support network who may make several trips per day.

[29]Using data from California, Ho and Pakes (2014) also find that the patient's choice of hospital is influenced by the prices paid by the MCOs.

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 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. Table A1 in Appendix A2 reports a version of Table 4 with bootstrapped standard errors, which we find to be small.

D. *Bargaining model estimates*

Table 5 presents the coefficient estimates and standard errors from the GMM estimation of the bargaining model. We estimate two specifications. In Specification 1, we fix the bargaining weights to $b_{m(s)} = 0.5$ (which implies that $b_{s(m)} = 0.5$) and allow for marginal cost fixed effects at the hospital, MCO, and year levels. In Specification 2, we allow the bargaining parameters to vary across MCOs (lumping MCO 2 and 3 together) but omit the MCO cost fixed effects.[30] We bootstrap all standard errors 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, 95 of the 100 bootstrapped draws of τ are positive. A value of τ other than 1 may reflect employers placing a different weight on welfare than enrollees but may also be due to errors in measuring coinsurance rates or physician incentives to steer patients to low-price hospitals (Dickstein, 2011). We find an increasing cost trend for hospitals over time. We also find large variation in the hospital marginal costs across MCOs. This latter finding reflects the fact that there is large variation across MCOs in the mean prices charged by hospitals.

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

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 0.5. 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 0. Thus, MCOs 2 and 3 drive hospital surpluses down to their reservation values. Table A2 in Appendix A2 reports a specification where the bargaining weight differs across each MCO/hospital-system pair. Very few of the parameters here are significantly different than 0.5.

Table 5—: Bargaining parameter estimates

	Specification 1		Specification 2	
Parameter	Estimate	S.E.	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 $\times 10^{-10}$)
MCO 4 bargaining weight	0.5	–	0.76**	(0.09)
Hospital cost parameters				
Prince William Hospital	8,635**	(3,009)	5,971**	(1,236)
Inova Alexandria	10,412*	(4,415)	6,487**	(1,905)
Inova Fairfax	10,786**	(3,765)	6,133**	(1,211)
Inova Fair Oaks	11,192**	(3,239)	6,970**	(2,352)
Inova Loudoun	12,014**	(3,188)	8,167**	(1,145)
Inova Mount Vernon	10,294*	(5,170)	4,658	(3,412)
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)
Patients from MCO 2	−9,043**	(2,831)	–	–
Patients from MCO 3	−8,910**	(3,128)	–	–
Patients from MCO 4	-4,476	(2,707)	–	–
Year 2004	1,130	(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. "Patients from MCO 1" and "Year 2003" are both excluded indicators.

Our estimation can explain the large cross-MCO price differences in three ways: (1) as differences in hospital costs across MCOs; (2) as differences in the bargaining weights across MCOs; or (3) as differences in WTP across MCOs. Specification 1 focuses on the first explanation, while the Specification 2 focuses on the second. The third alternative could occur if, for example, the geographic or illness severity distribution of enrollees varies across MCOs. Both specifications allow for the third alternative but find that the cost or bargaining weight explanations (respectively) fit the data better. Because we include MCO fixed effects, our estimates of $\boldsymbol{\tau}$ and $\mathbf{b}$ will be largely identified by within-MCO price differences. Despite the large cross-MCO price variation, we believe that the within-MCO variation allows us to perform credible counterfactuals that reflect reasonable estimates of what would happen relative to the baseline.

We consider Specification 1 to be the most salient for three reasons: (1) given one particular interpretation of bargaining weights, which is as relative discount factors (Rubinstein, 1982; Collard-Wexler, Gowrisankaran and Lee, 2013), it is most consistent with standard dynamic industrial organization models that treat discount factors as identical across agents; (2) the results from Specification 2 that all hospital prices for two MCOs are equal to their reservation values implies that hospital mergers (even to monopoly) will have little impact on prices, a finding that is not consistent with the empirical hospital merger literature (Gaynor and Town, 2012); and (3) it aligns with previous estimates from the literature – for example, Crawford and Yurukoglu (2012) finds bargaining parameters that are closer to 0.5 than to 0 or 1.

Table 6—: Lerner indices and actual and effective price elasticities

System name	Lerner index	Actual own price elasticity	Effective own price elasticity	Own price elasticity without insurance
Prince William Hospital	0.52	0.13	1.94	5.16
Inova Health System	0.39	0.07	2.55	3.10
Fauquier Hospital	0.22	0.17	4.56	6.11
HCA (Reston Hospital)	0.35	0.15	2.87	7.34
Potomac Hospital	0.37	0.15	2.74	6.77
Virginia Hospital Center	0.58	0.13	1.74	6.43

Note: reported elasticities and Lerner indices use quantity weights.

Table 6 lists the estimated weighted mean 2006 Lerner index, $\frac{P-mc}{P}$, by hospital system. The mean Lerner indices range from 0.22 to 0.58, and are relatively high for both Inova and PWH. Importantly, Table 6 also presents the actual own-price elasticity, effective price elasticity, and own-price elasticity that would exist without insurance. We calculate effective price elasticities using the inverse elasticity rule $elast = (\frac{p-mc}{p})^{-1}$.

For PWH, the actual price elasticity is 0.13 while the effective price elasticity is much higher and, at 1.94, 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 5.16. 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 2.55, slightly higher than for PWH.

Overall, Table 6 provides 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 model of Bertrand competition between hospitals, this will result in hospital prices far above marginal costs. We find that MCO bargaining leverage serves to partially overcome the equilibrium effects of insurance moral hazard, driving equilibrium prices closer to what they would be in a world without health insurance.

IV. Counterfactuals

We now use the estimates from both models to perform antitrust and health policy counterfactual experiments. All experiments in this section use the estimated parameters from Specification 1 in Table 5, except when noted.

A. *Industry structure and conduct remedies*

This subsection evaluates the impact of counterfactual industry structures, focusing on the proposed Inova/PWH merger that the FTC successfully blocked in 2008. In addition to examining the proposed Inova/PWH merger, we also examine the impact of imposing separate bargaining in this merger; the de-merger of Loudoun Hospital from Inova; and breaking up the Inova system.[31]

Our results are in Table 7. Counterfactual 1 finds that the Inova/PWH merger leads to a significant increase in prices and profits for the new Inova system. 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 to the Inova system, a 3.1% price increase across the joint systems from this transaction is quite substantial, amounting to 30.5% of base PWH revenues. Patient volume at the merged system goes down slightly, by 0.5%, reflecting both low coinsurance rates (and hence that patient demand is inelastic) and the equilibrium price increase by rival hospitals. Not reported in the table, managed care surplus, which is weighted consumer surplus net of payments to hospitals, drops by approximately 27% from this merger.

[31]For payors with very low coinsurance rates, we compute the no-coinsurance solution from Brand (2013) for this table, due to convergence difficulties. For other payors, we find prices that jointly set the vector of FOCs to 0. We have no proof of uniqueness of equilibrium except for the no-coinsurance solution, but we have not found any evidence of multiple equilibria.

Table 7—: Impact of counterfactual industry structures

Counterfactual	System	%Δ Price	%Δ Quantity	%Δ Profits
1. Inova/PWH merger	Inova & PWH	3.1	−0.5	9.3
	Rival hospitals	3.6	1.2	12.0
	Change at Inova+PW relative to PW base	30.5	−4.9	91.5
2. Inova/PWH merger with separate bargaining	Inova & PWH	3.3	−0.5	8.8
	Rival hospitals	3.5	1.2	11.2
3. Loudoun demerger	Inova & Loudoun	−1.8	0.1	−4.7
	Rival hospitals	−1.6	−0.2	−4.7
	Change at Inova relative to Loudoun base	−14.7	0.8	−38.5
4. Breaking up Inova	All hospitals	−6.8	0.05	−18.9

Note: price changes are calculated using quantity weights. The price changes relative to PWH or Loudoun base reflect the total system revenue change divided by the base revenue of this hospital.

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.[32] We examine the implications of this type of policy by simulating a world where Inova acquires PWH and the PWH negotiator bargains with a firewall from the other Inova hospitals. We simulate this counterfactual by assuming that the disagreement values for PWH negotiations reflect the case where only PWH is excluded from the network, and analogously for the 'legacy-Inova' disagreement values.[33]

Even though the negotiations are separate, 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 hospitals which is beneficial for the parent organization. Counterfactual 2 imposes the Evanston Northwestern remedy and assumes that the negotiators recognize these true incentives faced by the system in their bargaining. We find that the conduct remedy performs similarly to the base merger outcomes, with a post-merger price increase of 3.3% and a managed care surplus loss of 27.8%.

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

[33] Appendix A3 provides the first order conditions for this case.

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 ambiguous. Empirically, separate negotiations do not appear to solve the problem of bargaining leverage by hospitals.

Counterfactual 3 examines the impact of Inova divesting Loudoun Hospital, which it acquired in 2005 without antitrust opposition. The counterfactual predictions tell a different story for the Inova/Loudoun demerger than the Inova/PWH merger. A divesture of Loudoun Hospital leads to a net reduction in price of 1.8% for the Inova system a reduction in profits of 4.7%, and an increase in managed care surplus of 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. Finally, Counterfactual 4 simulates the impact of breaking up the entire Inova system into separately-owned hospitals. This breakup leads to a 7% market-wide decline in prices and a 54.8% increase in consumer surplus. This result is consistent with the evidence that points to the creation of large hospital systems during the 1990s as an important driver of higher hospital prices.

We also examine the sensitivity of these results to the bargaining parameter estimates. We first consider the impact of the Inova/PW merger using the estimates from Table 5, Specification 2, instead of Specification 1. For the two MCOs with bargaining weights less than one, we find that our base Specification 1 generates a price increase of 1.7% for Inova and Prince William from the merger for these two payors, while Specification 2 generates a price increase of 4.2% for the same payors.

We also estimate our model and compute the effect of the Inova/PWH merger with different fixed bargaining parameters, focusing on one MCO for ease of computation. The results, which are in Appendix A2 Table A3, show that estimated marginal costs increase monotonically in the bargaining weight $\mathbf{b}$. For $b_{m(s)} = 0, \forall m, s$ (which, as we showed in Section I.D, corresponds to Bertrand competition) we estimate mean marginal costs of $-278,000, which rise to $11,500 – very close to mean price – when $b_{m(s)} = 0.9$. Given the increasing estimated marginal costs, it follows that the effective own price elasticity also increases monotonically in $\mathbf{b}$. Finally, since higher price elasticities generally imply lower markups, it is not surprising that we find that the effects of the predicted Inova/PWH merger are also monotonic in $\mathbf{b}$, ranging from a market-wide 18.3% price increase with $b_{m(s)} = 0$ to 0.05% with $b_{m(s)} = 0.9$. We view the merger impacts at both extremes to be implausible, also lending support to a bargaining weight of $b_{m(s)} = 0.5$.

B. Moral hazard and coinsurance in equilibrium

There is a long tradition in economics of evaluating how the moral hazard from health insurance causes enrollees to over consume medical care relative to the societal optimum (Pauly, 1968). Less studied is the indirect impact of health insurance 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 affects equilibrium prices. We seek to evaluate the extent to which coinsurance serves as a solution to the equilibrium pricing problems resulting from moral hazard.

Table 8—: Impact of counterfactual coinsurance levels

Counterfactual	System	%Δ Price	%Δ Quantity	%Δ Profits
1. No coinsurance	All hospitals	3.7	0.01	9.8
2. Coinsurance 10 times current	All hospitals	−16.1	0.9	−0.4
3. Inova/PWH merger, no coinsurance	Inova & PWH	2.9	0	7.4
	Rival hospitals	1.3	0	3.9

Note: price changes are calculated using quantity weights.

Table 8 examines the equilibrium impact of coinsurance on equilibrium hospital prices. Counterfactual 1 examines the extreme 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.

We also consider higher coinsurance rates in Counterfactual 2. 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).[34] 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. The increase in cost sharing has a large impact, with quantity-weighted prices dropping by 16% and quantity increasing

[34] The Manning and Marquis (1996) optimal insurance contract also includes a $25,000 (in 1995 dollars) total out-of-pocket maximum.

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.

Finally, Counterfactual 3 considers the interaction of no coinsurance and the Inova/PWH merger. 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 by calculating the predicted impact of the Inova/PWH merger when patient cost sharing is zero. We find a lower increase from the merger at Inova/PWH, of 2.9% instead of 3.1%, than when we allow for positive coinsurance rates. In other words, the steering effect from coinsurance increases the equilibrium pricing effect of the merger.

V. Robustness to modeling assumptions

This section considers an alternate model of the bargaining stage.[35] In this model, MCOs maximize their expected profits when negotiating with hospital systems over the terms of hospitals' inclusions in MCO networks. After the networks are set, MCOs simultaneously post premiums. Observing coinsurance rates, posted MCO premiums, and hospital prices, each enrollee chooses an MCO, which determines the assignment of patients to MCOs, $m(i)$. Given this assignment, the second stage is the same as in the base model: patients receive health status draws and then choose hospitals.

The posted premium competition model differs from the base model in that (i) the MCO objective function is to maximize profits, rather than the weighted difference between enrollee surplus and costs; and (ii) enrollee plan choices in the case of disagreement are allowed to vary. Note that both models account for consumer preferences in the formation of the network, they just do it in different ways. The base model assumes that there is agency between employers and MCOs, while in the posted premium competition model, this accounting occurs through the competitive interactions of the health plan marketplace.

We now detail the posted premium competition model, starting with the plan choice decision which occurs at the end of Stage 1. At this point, each individual i is faced with a premium P_m for each plan m. The enrollee does not know her disease realization or her e_{ij} hospital-specific shocks. Each enrollee makes a discrete choice of MCO to maximize the utility

$$U_{im} = \alpha_1 W_i(\mathcal{N}_m, \mathbf{p}_m) - \alpha_2 P_m + \xi_m + E_{im}, \tag{20}$$

where α_1 is the dollar transformation of measured welfare from (4), α_2 is the disutility from premiums, ξ_m is the utility from MCO m from attributes other

[35]This model builds on Crawford and Yurukoglu (2012) and is most similar to Ho and Lee (2013)'s model.

than its patient care and price (e.g., customer service), and E_{im} is an $i.i.d.$ unobservable, distributed type 1 extreme value. The enrollee may choose the outside option, $U_{i0} = E_{i0}$, in which case the enrollee will not be able to use a hospital in the second stage. The market share of MCO m for patient i is:

$$S_{im}(P_m, P_{-m}) = \frac{\alpha_1 W_i(\mathcal{N}_m, \mathbf{p}_m) - \alpha_2 P_m + \xi_m}{1 + \sum_{n=1}^{M} \alpha_1 W_i(\mathcal{N}_n, \mathbf{p}_n) - \alpha_2 P_n + \xi_n},$$

which conditions on the choice of hospital networks and prices.

Moving back in time to the premium-setting phase, we assume that MCOs simultaneously choose premiums, P_m, to maximize expected profits, knowing all input costs $p_{ns}, \forall n, s$. Expected profits from a patient are the market share of the patient times the expected margin from attracting her. Overall, then, we can write profits (gross of fixed costs) to MCO m as:

$$(21) \quad R_m(P_m|P_{-m}) = \sum_{i=1}^{I} \left(\overbrace{(P_m - \sum_{d=1}^{D} (1 - c_{id}) f_{id} w_d \sum_{j=0,\mathcal{N}_m} p_{ms(j)} s_{ijd}(\mathcal{N}_m, \mathbf{p}_m))}^{\text{Expected margin from } i} S_{im}(P_m, P_{-m}) \right),$$

where we are again implicitly conditioning on hospital networks and prices.

Moving now to the start of Stage 1, the bargaining process is similar to the base model, but the threat points are different. In particular, when considering the disagreement point, an MCO takes into account that if it does not reach an agreement with a hospital system it will lose some enrollees and adjust its premiums to reoptimize given its new network. Similarly, when considering a disagreement with an MCO, a hospital system considers that it will recapture some of the patients from that MCO because of the spill of patients to other MCOs. Appendix A4 details the agreement and disagreement values for MCOs and hospital systems.

To compute the equilibrium of the posted premium competition model, we require data on hospital costs, patient illness distributions, and plan quality, as well as values of the parameters α_1 and α_2. We do not use any data on plan premiums, as these are calculated in equilibrium. We now outline the calibration of these data and parameters, with details in Appendix A4.

First, we calibrate the premium sensitivity parameter α_2, which is the disutility of spending an extra dollar on health insurance, using the equivalent parameter reported by Ericson and Starc (2012)'s study of health insurance in Massachusetts. Second, we choose the coefficient on hospital welfare at the premium stage, α_1, that makes the marginal utilities of a dollar equal at the plan choice and hospital choice stages. We use the estimated marginal costs estimates from our base model specification (Table 5, Specification 1) and set $b_{s(m)} = 0.5, \forall s, m$ as in this specification. We calculate ξ_m based on plan market shares and let coinsurance $c_{id} = 0, \forall i, d$ to ease the burden of computation. Finally, we assume that the ex-ante distribution of illness for each patient at the point when the patient chooses a health plan takes on exactly two potential values, no illness or illness.

Note that we are in part using the estimates from our base model to calibrate this model. While this does not provide us with independent estimates of the posted premium competition model, it does provide us evidence on the difference between the equilibrium predictions of the two models when starting with similar values. The results can also be seen (heuristically) as indicating the first-order difference between the two models if we were able to estimate both.

Table 9—: Base simulation results from posted premium competition model

Variable	Mean value in posted premium competition model	Mean value in base model
Hospital prices	\$11,088	\$13,618
Hospital margin per patient	\$4,796	\$4,893
MCO premiums	\$1,706	–
MCO margin per enrollee	\$792	–
Consumer surplus	\$4,398	–
Health insurance take-up (%)	84.5	–

Note: hospital prices are patient-weighted base prices excluding the outside good, hospital margins are patient-weighted, MCO premiums and margins are enrollee-weighted, and consumer surplus is per capita.

Table 9 provides the calibrated baseline outcomes from the posted premium competition model. Overall, the results are broadly similar to the base model, although hospital base prices are somewhat lower while per-patient margins are slightly lower.[36] MCO premiums are estimated at \$1,706 per year for hospitalization insurance, of which \$792 represents a margin over marginal cost. Ex-ante consumer surplus from having health insurance – and hence being able to use hospitals – is an average of \$4,398. The take-up rate of health insurance is 84.5%. Appendix A2 Table A4 presents the Lerner indices and actual and effective price elasticities from this model, analogous to Table 6 for the base model. They are similar to the base model.

Table 10 presents the implications of the proposed Inova/PWH merger for the posted premium competition model and also displays the analogous results from the base model for comparison purposes. The posted premium model generates

[36]The relatively high margins reflect differential insurance take-up, where more severely ill patients disproportionately enroll with an MCO.

Table 10—: Mean Inova/PWH merger effects from posted premium competition model

	Posted premium competition model	Base model – Specification 1
Inova/PWH prices	7.2%	3.1%
Other hospitals prices	2.2%	3.6%
Inova/PWH margin per patient	16.9%	9.8%
Other hospitals margin per patient	6.6%	10.7%
MCO premiums	3.4%	–
MCO margin per enrollee	1.0%	–
Consumer surplus	-4.4%	–
Health insurance take-up	-1.6%	–

Note: hospital prices are patient-weighted base prices excluding the outside good, hospital margins are patient-weighted, MCO premiums are enrollee-weighted, MCO margins are enrollee-weighted, and consumer surplus is per capita.

larger price increases from the Inova/PWH merger for the merging parties than does the base model: 7.2% instead of 3.1%. Premiums rise by 3.4% following the merger. The combined effect leads to significantly lower consumer surplus (4.4%) and a decrease in insurance take-up of 1.6%. The increased price implies that the fact that hospitals can recapture some patients in the case of disagreement with an MCO in this model, which will increase the disagreement value of the hospital system following a merger, appears to be the dominant difference between the models.

VI. 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 – as 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, though still much higher than they would be in the absence of insurance. Moreover, they are similar across two different objective functions for MCOs, one where they act as agents of employers through long-run contracts, and the other where they post premiums and compete for enrollees à la Bertrand.

The proposed merger between Inova hospital system and Prince William Hospital, which the FTC challenged, would have significantly raised prices. The market we study is more concentrated than the average market but not an outlier,[37] implying that hospital mergers in other MSAs may also cause price increases and hence be cause for antitrust concern. 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 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 Berry and Haile (2014) would generalize to our case.

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[37] In 2006, the average MSA concentration was approximately 3,250 with approximately 25% of MSAs having an HHI greater than 5,000 (Gaynor and Town, 2012). The reported HHI of 5,635 for Northern Virginia uses a market definition that is much smaller than the Washington, DC MSA.

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On-line Appendix

Mergers When Prices Are Negotiated: Evidence from the Hospital Industry

Gautam Gowrisankaran and Aviv Nevo and Robert Town

Appendix A1: Derivation of the A term

For ease of notation, define the welfare for all patients at MCO m from the choice stage to be

$$\overline{W_m}(\mathcal{N}_m, \mathbf{p}_m) = \frac{\tau}{\alpha} \sum_{i=1}^{I} 1\{m(i) = m\} W_i(\mathcal{N}_m, \mathbf{p}_m) - TC_m(\mathcal{N}_m, \mathbf{p}_m). \tag{22}$$

In Section I.D, we defined the A term as $\frac{\partial V_m}{\partial p_{mj}}$. Note that

$$\frac{\partial V_m}{\partial p_{mj}} = \frac{\partial \overline{W_m}(\mathcal{N}_m, \mathbf{p}_m)}{\partial p_{mj}} - \frac{\partial TC_m(\mathcal{N}_m, \mathbf{p}_m)}{\partial p_{mj}}. \tag{23}$$

Note that

$$\begin{aligned} \frac{\partial \overline{W_m}(\mathcal{N}_m, \mathbf{p}_m)}{\partial p_{mj}} &= -\tau \sum_{i=1}^{I} \sum_{d=1}^{D} 1\{m(i) = m\} c_{id} w_{id} f_{id} \frac{e^{\delta_{ijd}}}{\sum_{k \in \mathcal{N}_m} e^{\delta_{ikd}}} \\ &= -\tau \sum_{i=1}^{I} \sum_{d=1}^{D} 1\{m(i) = m\} c_{id} w_{id} f_{id} s_{ijd} \end{aligned} \tag{24}$$

and that

$$\begin{aligned} \frac{\partial TC_m(\mathcal{N}_m, \mathbf{p}_m)}{\partial p_{mj}} = &\sum_{i=1}^{I} \sum_{d=1}^{D} 1\{m(i) = m\}(1 - c_{id}) f_{id} w_{id} s_{ijd} \\ &+ \sum_{i=1}^{I} \sum_{d=1}^{D} 1\{m(i) = m\}(1 - c_{id}) f_{id} w_{id} \sum_{k \in \mathcal{N}_m} p_{km} \frac{\partial s_{ikd}}{\partial p_{mj}}. \end{aligned} \tag{25}$$

Further, note that $\frac{\partial s_{ijd}}{\partial p_{mj}} = -\alpha c_{id} w_{id} s_{ijd}(1 - s_{ijd})$ if $k = j$ and otherwise $\frac{\partial s_{ikd}}{\partial p_{mj}} = \alpha c_{id} w_{id} s_{ikd} s_{ijd}$.

Putting this all together gives:

$$(26)\quad \frac{\partial V_m}{\partial p_{mj}} =$$
$$-\tau \sum_{i=1}^{I}\sum_{d=1}^{D} 1\{m(i)=m\} c_{id} w_{id} f_{id} s_{ijd} - \sum_{i=1}^{I_m}\sum_{d=1}^{D} 1\{m(i)=m\}(1-c_{id}) w_{id} f_{id} s_{ijd}$$
$$-\alpha \sum_{i=1}^{I}\sum_{d=1}^{D} 1\{m(i)=m\}(1-c_{id}) c_{id} w_{id}^2 f_{id} s_{ijd} \left(\sum_{k\in\mathcal{N}_m} p_{km} s_{ikd} - p_{mj}\right).$$

Appendix A2: Extra tables

Table A1 replicates Table 4 from the paper and adds bootstrapped standard errors. The key message from this table is that the own- and cross-price elasticity estimates are very precise.

Table A1—: Mean and associated standard errors of 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
	(0.012)	(0.005)	(0.001)	(0.0004)	(0.001)
2. Inova Fairfax	0.011	−0.141	0.018	0.006	0.004
	(0.0008)	(0.013)	(0.0014)	(0.0006)	(0.0003)
3. HCA Reston	0.008	0.055	−0.149	0.022	0.002
	(0.0006)	(0.004)	(0.011)	(0.002)	(0.0001)
4. Inova Loudoun	0.004	0.032	0.037	−0.098	0.001
	(0.0003)	(0.003)	(0.003)	(0.01)	(0.00008)
5. Fauquier	0.026	0.041	0.006	0.002	−0.153
	(0.002)	(0.004)	(0.0006)	(0.0002)	(0.015)
6. Outside option	0.025	0.090	0.022	0.023	0.050
	(0.002)	(0.008)	(0.0017)	(0.002)	(0.004)

Note: Elasticity is $\frac{\partial s_j}{\partial p_k}\frac{p_k}{s_j}$ where j denotes row and k denotes column. Standard error estimates in parentheses are calculated using 100 bootstrap draws.

Table A2 presents the estimates from the bargaining model allowing the bargaining weights to vary by MCO/hospital system pair. There is significant variation in the bargaining parameter estimates across hospitals within a MCO but those estimates tend to be imprecise.

Table A3 presents an additional robustness specification. The table presents the parameter estimates fixing the MCO bargaining weights that span the possible

Table A2—: Bargaining parameter estimates with extra bargaining parameters

Parameter	Estimate	S.E.
MCO welfare weight (τ)	2.75**	(0.51)
MCO 1 bargaining weight Inova Health System	0.33	(0.20)
MCO 1 bargaining weight Loudoun Hospital	0.30	(0.22)
MCO 1 bargaining weight Prince William Hospital	0.29	(0.23)
MCO 1 bargaining weight HCA	0.04*	(0.05)
MCO 1 bargaining weight Potomac Hospital	0.22	(0.20)
MCO 1 bargaining weight Virginia Hospital Center	0.11	(0.13)
MCO 1 bargaining weight Fauquier Hospital	0.23	(0.16)
MCO 2 bargaining weight Inova Health System	0.35	(0.36)
MCO 2 bargaining weight Loudoun Hospital	0.72	(0.69)
MCO 2 bargaining weight Prince William Hospital	1.00**	(0)
MCO 2 bargaining weight HCA	0.04	(0.05)
MCO 2 bargaining weight Potomac Hospital	0.76	(0.75)
MCO 2 bargaining weight Virginia Hospital Center	0.96	(1.03)
MCO 2 bargaining weight Fauquier Hospital	0.57	(0.56)
MCO 3 bargaining weight Inova Health System	0.67	(0.77)
MCO 3 bargaining weight Loudoun Hospital	0.35	(0.33)
MCO 3 bargaining weight Prince William Hospital	0.89	(0.99)
MCO 3 bargaining weight HCA	0.73	(1.07)
MCO 3 bargaining weight Potomac Hospital	0.67	(0.80)
MCO 3 bargaining weight Virginia Hospital Center	1.00	(1.39)
MCO 3 bargaining weight Fauquier Hospital	0.26	(0.27)
MCO 4 bargaining weight Inova Health System	0.51	(0.41)
MCO 4 bargaining weight Loudoun Hospital	0.04	(0.14)
MCO 4 bargaining weight Prince William Hospital	0.08	(0.10)
MCO 4 bargaining weight HCA	0.75	(0.75)
MCO 4 bargaining weight Potomac Hospital	0.14	(0.11)
MCO 4 bargaining weight Virginia Hospital Center	0.47	(0.44)
MCO 4 bargaining weight Fauquier Hospital	0.03	(0.18)
Year 2003	2,360	(9,585)
Year 2004	5,850	(12,051)
Year 2005	5,976	(7,484)
Year 2006	6,409	(11,407)

Note: ** denotes significance at 1% level and * at 5% level. This specification allows for different bargaining weight parameters for each MCO/hospital-system pair. Significance tests for bargaining parameters test the null of whether the parameter is different than 0.5. We report non-bootstrapped standard errors here.

support. Very low bargaining weights generate implied marginal costs that are negative. Very high bargaining weights imply that mergers have little impact on negotiated prices.

Table A3—: Variation in outcomes by bargaining weight

	MCO bargaining weight					
	0	0.1	0.25	0.5	0.75	0.9
Mean effective own price elasticity	0.04	0.22	0.91	2.52	7.34	23.55
Mean estimated MC ($1,000)	−278	−43	−1.26	7.2	10.3	11.5
Estimated MCO welfare weight (τ)	–	5.17	2.7	2.79	2.9	3.0
Mean % Δ price from PW merger for MCO 1	18.3	11.8	6.3	3.1	1.0	0.05

Note: the first three rows of each column reports the results of an estimation similar to Specification 1 from Table 5 but with the MCO bargaining weight fixed to alternate values. When the bargaining weight is set to 0, τ is not identified. The final row reports counterfactuals for each estimation.

Table A4 presents the analog of Table 6 for the alternative, posted premium competition model. In general, the Lerner indices are similar to those in the base model. Consequently, the implications of the posted premium model are very similar to our base model for the counterfactuals we consider.

Table A4—: Lerner indices and actual and effective price elasticities for posted premium competition model

System name	Lerner index	Actual own price elasticity	Effective own price elasticity	Own price elasticity without insurance
Prince William Hosp.	0.48	0.13	2.10	5.16
Inova Health System	0.42	0.07	2.38	3.10
Fauquier Hospital	0.15	0.17	6.85	6.11
HCA (Reston Hosp.)	0.39	0.15	2.56	7.34
Potomac Hospital	0.12	0.15	8.26	6.77
Virginia Hospital Ctr.	0.59	0.13	1.71	6.43

Note: reported elasticities and Lerner indices use quantity weights. These results are from the calibrated posted premium competition model described in Section V.

Appendix A3: Derivation of the FOCs for the Prince William separate bargaining

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

$$(27) \quad NB^{m,j}(p_{mj}|\mathbf{p}_{m,\_j}, \mathbf{p}_{m,\_s}) = \Big(q_{mj}(\mathcal{N}_m, \mathbf{p}_m)[p_{mj} - mc_{mj}] + \sum_{k \in \mathcal{J}_s, k \neq j} (q_{mk}(\mathcal{N}_m, \mathbf{p}_m) - q_{mk}(\mathcal{N}_m \backslash j, \mathbf{p}_m))[p_{mk} - mc_{mk}]\Big)^{b_{s(m)}} \Big(V_m(\mathcal{N}_m, \mathbf{p}_m) - V_m(\mathcal{N}_m \setminus j, \mathbf{p}_m)\Big)^{b_{m(s)}}.$$

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 $\lambda_{mjk} \equiv (q_{mk}(\mathcal{N}_m \setminus j, \mathbf{p}_m) - q_{mk}(\mathcal{N}_m, \mathbf{p}_m)$ 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:

$$(28) \quad b_{s(m)} \frac{q_{mj} + \sum_{k \in S_j} \frac{\partial q_{mk}}{\partial p_{mj}}[p_{mk} - mc_{mk}]}{q_{mj}(\mathcal{N}_m, \mathbf{p}_m)[p_{mj} - mc_{mj}] - \sum_{k \in \mathcal{J}_s, k \neq j} \lambda_{mjk}[p_{mk} - mc_{mk}]} = -b_{m(s)} \frac{\frac{\partial V_m}{\partial p_{mj}}}{V_m(\mathcal{N}_m, \mathbf{p}_m) - V_m(\mathcal{N}_m \setminus j, \mathbf{p}_m)}.$$

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 (28). The FOCs for the other Inova hospitals will now resemble (28) but the disagreement values will reflect removing all Inova legacy hospitals from the network and having diversion quantities only for Prince William.

Appendix A4: Details of the posted premium competition model

This appendix provides more details on the bargaining problem, calibration and computation of the model where MCOs simultaneously post premiums to compete for enrollees, à la Bertrand. We start by expositing the Nash bargaining problem.

First, let $R_m^*(\mathcal{N}_m, \mathcal{N}_{-m}, \mathbf{p}_m, \mathbf{p}_{-m})$ denote the equilibrium profits to MCO m, given all MCOs' networks and prices. The disagreement value from MCO m and hospital system s is $R_m^*(\mathcal{N}_m \setminus \mathcal{J}_s, \mathcal{N}_{-m}, \mathbf{p}_m, \mathbf{p}_{-m})$, noting that the definition of R^* accounts for the equilibrium premium response and for the spill of patients in case of disagreement.

Correspondingly, let $S_{im}^*(\mathcal{N}_m, \mathcal{N}_{-m}, \mathbf{p}_m, \mathbf{p}_{-m}), \forall m = 1, \ldots, M$ denote the equilibrium plan market shares to consumer i, given MCOs' networks and prices. To account for the equilibrium spill of patients following disagreement, we redefine normalized quantities (from its earlier definition in the base model in (8)) as
(29)

$$q_{mj}(\mathcal{N}_m, \mathcal{N}_{-m}, \mathbf{p}_m, \mathbf{p}_{-m}) = \sum_{i=1}^{I} \sum_{d=0}^{D} S_{im}^*(\mathcal{N}_m, \mathcal{N}_{-m}, \mathbf{p}_m, \mathbf{p}_{-m}) f_{id} w_d s_{ijd}(\mathcal{N}_m, \mathbf{p}_m),$$

where (29) substitutes the endogenous plan choice S^* for the fixed plan assignment from (8). Hospital system returns are now

$$\pi_s(\mathcal{N}_1, \ldots, \mathcal{N}_M, \mathbf{p}_1, \ldots, \mathbf{p}_M) = \sum_{m=1}^{M} \sum_{j \in \mathcal{J}_s} q_{mj}(\mathcal{N}_m, \mathcal{N}_{-m}, \mathbf{p}_m, \mathbf{p}_{-m})[p_{mj} - mc_{mj}]. \tag{30}$$

The disagreement value from the hospital system is then $\pi_s(\mathbf{p}_1, \ldots, \mathbf{p}_M, \mathcal{N}_1, \ldots, \mathcal{N}_{m-1}, \mathcal{N}_m \setminus \mathcal{J}_s, \mathcal{N}_{m+1}, \ldots, \mathcal{N}_M)$.

Using these definitions, we rewrite the Nash bargaining problem (analogously to (10)) as:

$$\begin{aligned} NB^{m,s}(p_{mj_{j\in\mathcal{J}_s}} | \mathbf{p}_{m,\_s}) = \Big(\sum_{j \in \mathcal{J}_s} & \pi_s(\mathcal{N}_1, \ldots, \mathcal{N}_M, \mathbf{p}_1, \ldots, \mathbf{p}_M) \\ & - \pi_s(\mathbf{p}_1, \ldots, \mathbf{p}_M, \mathcal{N}_1, \ldots, \mathcal{N}_{m-1}, \mathcal{N}_m \setminus \mathcal{J}_s, \mathcal{N}_{m+1}, \ldots, \mathcal{N}_M) \Big)^{b_{s(m)}} \\ & \Big(R_m^*(\mathcal{N}_m, \mathcal{N}_{-m}, \mathbf{p}_m, \mathbf{p}_{-m}) - R_m^*(\mathcal{N}_m \setminus \mathcal{J}_s, \mathcal{N}_{-m}, \mathbf{p}_m, \mathbf{p}_{-m}) \Big)^{b_{m(s)}}. \end{aligned} \tag{31}$$

The price vector that solves the posted premium competition model is the vector of prices that jointly maximizes the Nash bargaining problems in (31) for each m and s.

We now turn to the details of the calibration of our model, starting with the calibration of the premium sensitivity parameter. Ericson and Starc (2012) report a value of 2.271 for 40-year-olds from the Massachusetts Connector for 2008. We use this number as the mean age in our data is approximately 38. We further divide the Ericson and Starc value by 1,200 to account for the fact that our model is at the annual level and measures premiums in dollars (they use monthly coverage and measure premiums in hundreds of dollars), obtaining $\alpha_2 = 0.0019$.

Turning to the coefficient on hospital welfare at the premium stage, we use $\alpha_1 =$

$\frac{\tau\alpha_2}{\alpha}$ with the estimated τ (Table 5, Specification 1) and α (Table 3). Scaling the utility from the second stage by τ/α expresses the consumer welfare from second stage utility in dollars. The marginal utility of a dollar in equation (20) is α_2, as this is the coefficient on premiums. Multiplying by α_2 turns the welfare dollar value into utility at the plan choice stage. The scaling of the utility functions differs across the different equations because the unobservables are normalized to both be type 1 extreme value, which implicitly means that an equation with more noise will have a smaller marginal utility of money.

One other calibration is required because, unlike in the base model, we need to know the ex-ante distribution of illness for each patient at the point when the patient chooses a health plan.[38] We assume that each patient in our sample would, ex-ante, have obtained either her actual observed illness or illness 0. We take the ex-ante probability of obtaining her actual observed illness as 10.9% per year, which is the weighted average hospital discharge rate for individuals age 25-64.[39]

Next, we need to specify the ξ_m value for each MCO m. We use $\xi_m = \log\left(\frac{\sum_i S_{im}}{\sum_i S_{i0}}\right)$. We take the total number of inpatient observations in our payor data to represent the relative market share of each MCO. We calculate the outside good MCO share as 14.3% based on a survey of employed Virginia residents who report not having health insurance coverage,[40] which allows us to compute the actual (and not relative) share. The calibration of ξ_m here is meant to capture the heterogeneity in enrollment numbers across plans. As in Berry (1994), if the first two terms in (20) summed to 0, the values of ξ_m that we choose would match observed market shares exactly.[41] The first two terms in (20) will not sum to 0 exactly, so our chosen value will approximate shares imperfectly. The most important effect that we aim to capture with this parametrization is the relative attractiveness of different MCOs.

Finally, we discuss the computation of the equilibrium of the posted premium competition model. We solved for the first-order conditions for the price setting game using the implicit function theorem. A full derivation of the equilibrium first-order conditions is available from the authors upon request. Using these first-order conditions, we compute counterfactual equilibria with the C programming language using a Newton-Raphson method. This procedure is very computationally intensive. In order to minimize the computational burden, we compute the equilibrium for 20 enrollee draws chosen at random from the discharge data rather than the full set of enrollees from the discharge data.

[38] In the base model, the estimating equations are unaffected by whether one patient has two illnesses or the two illnesses occur to two different patients, and by the fraction of enrollees having illness 0.

[39] Authors' calculation based on the National Hospital Discharge Survey, 2005, available at http://www.cdc.gov/nchs/data/series/sr_13/sr13_168.pdf.

[40] American Community Survey, 2005, available at https://www.census.gov/acs/www/.

[41] Berry, S. 1994. "Estimating Discrete Choice Models of Product Differentiation." *RAND Journal of Economics*, 25: 242-262.