ONLINE APPENDIX

Equilibrium Provider Networks: Bargaining and Exclusion in Health Care Markets

Kate Ho Robin S. Lee*

July 2018

A Proofs

Let $\boldsymbol{p}_{(ij=0)} \equiv \{0, \boldsymbol{p}_{-ij}\}$: i.e., $\boldsymbol{p}_{(ij=0)}$ replaces element ij with 0 in the vector of prices $\boldsymbol{p}$. Recall that for any network G and prices $\boldsymbol{p}$, the payment made between MCO j and hospital i does not affect their total bilateral gains-from-trade; hence, $[\Delta_{ij}\Pi_{ij}(G, \boldsymbol{p})] = [\Delta_{ij}\Pi_{ij}(G, \boldsymbol{p}_{(ij=0)})]\ \forall i \in G$.

Our proofs rely on the following Lemma:

Lemma A.1. *For all G, $i \in G$, and $\{\boldsymbol{p} : p_{hj} = 0\ if\ h \notin G\}$:*

$$p_{ij}^{Nash}(G, \boldsymbol{p}_{-ij}) \le p_{ij}^{OO}(G, \boldsymbol{p}_{-ij}) \quad \textit{if and only if} \quad \tau[\Delta_{ij}\Pi_{ij}(G, \boldsymbol{p}_{(ij=0)})] \ge \max_{h \notin G}[\Delta_{hj}\Pi_{hj}((G \setminus i) \cup h, \boldsymbol{p}_{-ij})]\ .$$

Lemma A.1 implies that determining whether the NNTR price for a given hospital $i \in G$ is given by the outside-option price $p_{ij}^{OO}(\cdot)$ or the Nash-in-Nash price $p_{ij}^{Nash}(\cdot)$ is equivalent to determining whether there exists some excluded hospital not contained in G that generates bilateral gains-from-trade with MCO j that exceeds τ share of the bilateral gains-from-trade generated between hospital i and MCO j.

Proof. First, Nash-in-Nash payments are given by the solution to (2):

$$p_{ij}^{Nash}(G, \boldsymbol{p}_{-ij}) \times D_{ij}^{H}(G) = (1-\tau)[\Delta_{ij}\pi_j^M(G, \boldsymbol{p}_{(ij=0)})] - \tau[\Delta_{ij}\pi_i^H(G, \boldsymbol{p}_{(ij=0)})]\ \forall i \in G. \tag{A.1}$$

Next, we derive outside option payments. Reservation prices for any hospital $h \notin G$ can be derived using (4) and our parameterization of firm profits: $p_{hj}^{res}(G \setminus i, \boldsymbol{p}_{-ij}) \times D_{hj}^{H}(G \setminus i) = -[\Delta_{hj}\pi_h^H((G \setminus i) \cup h, \boldsymbol{p}_{-ij})]$. Using this result, the object maximized on the right hand side of (3) can be re-expressed as: $\pi_j^M((G \setminus i) \cup h, \{p_{hj}^{res}(G \setminus i, \boldsymbol{p}_{-ij}), \boldsymbol{p}_{-ij}\}) = [\Delta_{hj}\Pi_{hj}((G \setminus i) \cup h, \boldsymbol{p}_{-ij})] - \pi_j^M((G \setminus i), \boldsymbol{p}_{-ij})$. This implies that the hospital k which maximizes the total bilateral gains-from-trade with MCO j over hospitals $h \notin G$ is also the same hospital k which maximizes the right-hand-side of (3). Thus, re-arranging (3), given $k \equiv \arg\max_{h \notin G}[\Delta_{hj}\Pi_{hj}((G \setminus i) \cup h, \boldsymbol{p}_{-ij})]$, yields:

$$\begin{aligned} p_{ij}^{OO}(G) \times D_{ij}^{H}(G) &= \pi_j^M(G, \boldsymbol{p}_{(ij=0)}) - \pi_j^M((G \setminus i) \cup k, \boldsymbol{p}_{-ij}) - [\Delta_{kj}\pi_k^H((G \setminus i) \cup k, \boldsymbol{p}_{-ij})] \\ &= [\Delta_{ij}\pi_j^M(G, \boldsymbol{p}_{(ij=0)})] - [\Delta_{kj}\pi_j^M((G \setminus i) \cup k, \boldsymbol{p}_{-ij})] - [\Delta_{kj}\pi_k^H((G \setminus i) \cup k, \boldsymbol{p}_{-ij})] \\ &= [\Delta_{ij}\pi_j^M(G, \boldsymbol{p}_{(ij=0)})] - [\Delta_{kj}\Pi_{kj}((G \setminus i) \cup k, \boldsymbol{p}_{-ij})]\ . \end{aligned} \tag{A.2}$$

Using these results, it follows that:

$$\begin{aligned} & \tau[\Delta_{ij}\Pi_{ij}(G, \boldsymbol{p}_{(ij=0)})] \ge [\Delta_{kj}\Pi_{kj}((G \setminus i) \cup k, \boldsymbol{p}_{-ij})] \\ (\iff)\ & -[\Delta_{kj}\Pi_{kj}((G \setminus i) \cup k, \boldsymbol{p}_{-ij})] \ge -\tau[\Delta_{ij}\Pi_{ij}(G, \boldsymbol{p}_{(ij=0)})] \\ (\iff)\ & [\Delta_{ij}\pi_j^M(G, \boldsymbol{p}_{(ij=0)})] - [\Delta_{kj}\Pi_{kj}((G \setminus i) \cup k, \boldsymbol{p}_{-ij})] \ge (1-\tau)[\Delta_{ij}\pi_j^M(G, \boldsymbol{p}_{(ij=0)})] - \tau[\Delta_{ij}\pi_i^H(G, \boldsymbol{p}_{(ij=0)})] \\ (\iff)\ & p_{ij}^{OO}(G, \boldsymbol{p}_{-ij}) \ge p_{ij}^{Nash}(G, \boldsymbol{p}_{-ij}) \end{aligned}$$

*Ho: Department of Economics, Princeton University, Princeton, NJ 08544, and NBER (e-mail: kate.ho@princeton.edu). Lee: Department of Economics, Harvard University, Cambridge, MA 02138, and NBER (e-mail: robinlee@fas.harvard.edu).

where the last line follows from substituting in the expressions from (A.1) and (A.2), and dividing through by $D^H_{ij}(G)$. □

A.1 Proof of Proposition III.1

Fix G and prices for other MCOs $\boldsymbol{p}_{-j}$, and omit them as arguments in subsequent notation. Let H denote the number of hospitals that MCO j contracts with in G. Define the mapping $\rho : [-\bar{p}, \bar{p}]^H \to [-\bar{p}, \bar{p}]^H$ where, for each $i \in G$:

$$\rho_i(\{p_{hj}\}_{h\in G\setminus i}) = \max\Big\{ -\bar{p}, \min\{\rho_i^{Nash}(\{p_{hj}\}_{h\in G\setminus i}), \rho_i^{OO}(\{p_{hj}\}_{h\in G\setminus i}), \bar{p}\}\Big\} , \tag{A.3}$$

$$\rho_i^{Nash}(\{p_{hj}\}_{h\in G\setminus i}) = \Big((1-\tau)[\Delta_{ij}\pi_j^M(\boldsymbol{p}_{(ij=0)})] - \tau[\Delta_{ij}\pi_i^H(\boldsymbol{p}_{(ij=0)})]\Big)/D^H_{ij} , \tag{A.4}$$

$$\rho_i^{OO}(\{p_{hj}\}_{h\in G\setminus i}) = \Big([\Delta_{ij}\pi_j^M(\boldsymbol{p}_{(ij=0)})] - \max_{k\in\mathcal{H}\setminus G}[\Delta_{kj}\Pi_{kj}((G\setminus i)\cup k, \{p_{hj}\}_{h\in G\setminus i})]\Big)/D^H_{ij} . \tag{A.5}$$

Given our assumptions on firm profit functions (which are linear in prices), (A.4) and (A.5) are continuous in $\{p_{hj}\}_{h\in G\setminus i}$ for all $i \in G$, and thus $\rho_i(\cdot)$ is a continuous mapping from a compact convex set into itself. By Brouwer's fixed-point theorem, there exists a fixed point of $\rho(\cdot)$. It is straightforward to show that any fixed point of $\rho(\cdot)$ satisfies (2)-(6) (as (A.4) follows from (A.1) and (A.5) from (A.2)), and thus represents a vector of NNTR prices.

A.2 Proof of Proposition III.2

Assume first G is stable, and omit it as an argument of NNTR prices $\boldsymbol{p}^*$. It must be that $[\Delta_{ij}\Pi_{ij}(G, \boldsymbol{p}^*)] \geq 0\ \forall i \in G$, else G would be unstable. Next, proceed by contradiction, and assume that $[\Delta_{ij}\Pi_{ij}(G, \boldsymbol{p}^*)] < [\Delta_{kj}\Pi_{kj}((G\setminus i)\cup h, \boldsymbol{p}^*_{-ij})]$ for some $i \in G$, $k = \arg\max_{h\in\mathcal{H}\setminus G}[\Delta_{hj}\Pi_{hj}((G\setminus i)\cup h, \boldsymbol{p}^*_{-ij})]$. By Lemma A.1, this implies that the NNTR price $p^*_{ij} = p^{OO}_{ij}$. At this price, hospital i receives:

$$\begin{aligned}
\pi_i^H(G, \boldsymbol{p}^*_{(ij=0)}) + p^*_{ij} \times D^H_{ij}(G) &= \pi_i^H(G, \boldsymbol{p}^*_{(ij=0)}) + \underbrace{[\Delta_{ij}\pi_j^M(G, \boldsymbol{p}^*_{(ij=0)})] - [\Delta_{kj}\Pi_{kj}((G\setminus i)\cup k, \boldsymbol{p}^*_{(ij=kj=0)})]}_{\text{From (A.2)}} \\
&= \pi_i^H(G\setminus i, \boldsymbol{p}^*_{(ij=0)})) + \underbrace{[\Delta_{ij}\Pi_{ij}(G, \boldsymbol{p}^*_{(ij=0)})] - [\Delta_{kj}\Pi_{kj}((G\setminus i)\cup k, \boldsymbol{p}^*_{-ij})]}_{<0 \text{ by assumption (as } [\Delta_{ij}\Pi_{ij}(G,\boldsymbol{p}^*)] = [\Delta_{ij}\Pi_{ij}(G,\boldsymbol{p}^*_{(ij=0)})])} \\
&< \pi_i^H(G\setminus i, \boldsymbol{p}^*_{(ij=0)}))
\end{aligned} \tag{A.6}$$

and hospital i would prefer rejecting the payment $p^*_{ij}(G)$; contradiction. Thus, if G is stable, it must be that $[\Delta_{ij}\Pi_{ij}(G, \boldsymbol{p}^*)] \geq [\Delta_{kj}\Pi_{kj}((G\setminus i)\cup k, \boldsymbol{p}^*_{-ij})]$.

Next, assume that $[\Delta_{ij}\Pi_{ij}(G, \boldsymbol{p}^*)] \geq \max\{0, [\Delta_{kj}\Pi_{kj}((G\setminus i)\cup k, \boldsymbol{p}^*_{-ij})]\}\ \forall i \in G$, $k = \arg\max_{h\in\mathcal{H}\setminus G}[\Delta_{hj}\Pi_{hj}((G\setminus i)\cup h, \boldsymbol{p}^*_{-ij})]$. We now prove that this implies G is stable. Assume by contradiction that some agreement $i \in G$ is not stable at $\boldsymbol{p}^*$. If $p^*_{ij} = p^{Nash}_{ij}$, then agreement i is unstable only if $[\Delta_{ij}\Pi_{ij}(G, \boldsymbol{p}^*)] < 0$; contradiction. If $p^*_{ij} = p^{OO}_{ij}$, by the second line of (A.6), such an agreement will be rejected by i and unstable only if $[\Delta_{ij}\Pi_{ij}(G, \boldsymbol{p}^*_{(ij=0)})] < [\Delta_{kj}\Pi_{kj}((G\setminus i)\cup k, \boldsymbol{p}^*_{-ij})]$; contradiction. Thus, G is stable at $\boldsymbol{p}^*$.

A.3 Proof of Propositions III.3-III.4

In the proofs for these propositions and for Proposition III.5, we restrict attention (unless otherwise specified) to lump-sum payments negotiated between MCO j and each hospital that are made when an agreement is formed.[1] The equivalent lump-sum NNTR payments are defined to be $P^*_{ij}(G) \equiv \min\{P^{Nash}_{ij}(\cdot), P^{OO}_{ij}\}$ for $i \in G$, where (using (A.1) and (A.2)):

$$P^{Nash}_{ij}(G) = (1-\tau)[\Delta_{ij}\pi_j^M(G)] - \tau[\Delta_{ij}\pi_i^H(G)], \tag{A.7}$$

$$P^{OO}_{ij}(G) = [\Delta_{ij}\pi_j^M(G)] - [\Delta_{kj}\Pi_{kj}((G\setminus i)\cup k)] , \tag{A.8}$$

for $k = \arg\max_{h\in\mathcal{H}\setminus G}[\Delta_{hj}\Pi_{hj}((G\setminus i)\cup h]$ (where all bilateral surpluses can now be expressed as a function of the network only, as lump-sum transfers cancel out and do not affect total bilateral gains-from-trade). Note that these prices for each pair $ij \in G$ depend only on profit terms, which are assumed to be primitives; thus, $P^*_{ij}(G)\ \forall i \in G$ exists and is unique. This proves Proposition III.3.

[1] We restrict attention to lump-sum transfers for analytic tractability. Using linear fees may imply that flow payoffs that accrue to each firm depend on the set of prices that have previously been agreed upon, which significantly complicates analysis.

Next, Lemma A.1 can be extended to the case of lump-sum transfers so that:

$$\tau[\Delta_{ij}\Pi_{ij}(G)] \geq \max_{h\in\mathcal{H}\setminus G}[\Delta_{hj}\Pi_{hj}((G\setminus i)\cup h)] \text{ if and only if } P_{ij}^{Nash}(G) \leq P_{ij}^{OO}(G)$$

for any G and $i \in G$. Proposition III.2 also applies in this setting, and implies that if G is stable, then:

$$[\Delta_{ij}\Pi_{ij}(G)] \geq \max\{0, \max_{h\in\mathcal{H}\setminus G}[\Delta_{hj}\Pi_{hj}((G\setminus i)\cup h)]\} .$$

For the remainder of the proof, the following notation is useful. Fix $i \in G$. Let $v_h^i(G) \equiv [\Delta_{hj}\Pi_{hj}((G\setminus i)\cup h)]$ denote the bilateral gains-from-trade created by MCO j and hospital $h \in ((\mathcal{H}\setminus G)\cup i)$ if i is replaced by h in network G. Let $v_{(1)}^i(\cdot)$ and $v_{(2)}^i(\cdot)$ represent the first and second-highest values in the set $\boldsymbol{v}^i(G) \equiv \{v_h^i(\cdot)\}_{h\in(\mathcal{H}\setminus G)\cup i}$, and $k_{(1)}^i(\cdot)$ and $k_{(2)}^i(\cdot)$ their respective indices. For our analysis, we assume that for any network G all values $\{v_h^i(\cdot)\}$ are distinct, implying that $k_{(1)}^i(\cdot) \neq k_{(2)}^i(\cdot)$.

Single hospital announced at period-0. We first prove the conditions of Proposition III.4 hold for subgames where the network announced in period 0 is a single hospital. Consider any subgame where stable network G is announced in period 0 by MCO j, $G \equiv \{i\}$ (i.e., G contains a single hospital i), and no agreement has yet been formed by MCO j. Any agreement with hospital i results in an increase in total discounted profits of $(1-\delta)([\Delta_{ij}\pi_j^M(G)]+[\Delta_{ij}\pi^H(G)])/(1-\delta) = [\Delta_{ij}\Pi_{ij}(G)]$ for MCO j and hospital i (relative to no agreement). Thus, this subgame corresponds exactly to the single seller and multiple buyer case analyzed in Manea (2018), where the MCO j can transact with any hospital $h \in \mathcal{H}$ and generate surplus $v_h^i(\{i\}) = [\Delta_{hj}\Pi_{hj}(\{h\})]$.[2] By Proposition III.2, it must be that $i = k_{(1)}^i(G)$, else G is not stable. Let $k = k_{(2)}^i(G)$, which implies that $[\Delta_{ij}\Pi_{ij}(G)] > [\Delta_{kj}\Pi_{kj}((G\setminus i)\cup k)]$. A direct application of Proposition 1 of Manea (2018) implies that all MPE of this subgame are outcome equivalent, and for any family of MPE (i.e., a collection of MPE for different values of δ), expected payoffs for MCO j (above its disagreement point) converge as $\delta \to 1$ to $\max(\tau[\Delta_{ij}\Pi_{ij}(G)], [\Delta_{kj}\Pi_{kj}((G\setminus i)\cup k)])$. Furthermore, there exists $\underline{\delta}$ such that for $\delta > \underline{\delta}$, if $\tau[\Delta_{ij}\Pi_{ij}(G)] > [\Delta_{kj}\Pi_{kj}((G\setminus i)\cup k)]$, trade occurs only with hospital i; otherwise, the MCO engages with positive probability with either i or k, but the probability that the MCO comes to agreement with hospital i converges to 1 as $\delta \to 1$.

To show that this result implies that negotiated payments converge to NNTR payments, consider the following two cases:

1. $\tau[\Delta_{ij}\Pi_{ij}(G,\boldsymbol{p})] > [\Delta_{kj}\Pi_{kj}((G\setminus i)\cup k)]$. MPE expected payoffs (above its disagreement point) for the MCO then converge to:

$$\begin{aligned}\tau[\Delta_{ij}\Pi_{ij}(G)] &= \tau[\Delta_{ij}\pi_j^M(G,\boldsymbol{p})] + \tau[\Delta_{ij}\pi_i^H(G)] \\ &= [\Delta_{ij}\pi_j^M(G)] - \Big((1-\tau)[\Delta_{ij}\pi_j^M(G)] - \tau[\Delta_{ij}\pi_i^H(G)]\Big) \\ &= [\Delta_{ij}\pi_j^M(G)] - P_{ij}^{Nash}(G)\end{aligned}$$

   where the last line follows from (A.7). By Lemma A.1, $P_{ij}^*(\cdot) = P_{ij}^{Nash}(\cdot)$.

2. $\tau[\Delta_{ij}\Pi_{ij}(G)] \leq [\Delta_{kj}\Pi_{kj}((G\setminus i)\cup k)]$. MPE expected payoffs for the MCO then converge to:

$$[\Delta_{kj}\Pi_{kj}((G\setminus i)\cup k)] = [\Delta_{ij}\pi_j^M(G)] - P_{ij}^{OO}(G)$$

   where the equality follows from (A.8). By Lemma A.1, $P_{ij}^*(\cdot) = P_{ij}^{OO}(\cdot)$.

Thus, for the payoffs for MCO j to converge to $\max(\tau[\Delta_{ij}\Pi_{ij}(G)], [\Delta_{kj}\Pi_{kj}((G\setminus i)\cup k)])$, equilibrium payments must converge to P_{ij}^*.

We now discuss MPE outcomes and strategies of the subgame where network $G = \{i\}$ is announced. Since G is stable, $v_{(1)}^i(G) > 0$. For sufficiently high δ, arguments used in Proposition 1 of Manea (2018) show that any MPE of this subgame results in immediate agreement with any hospital with which the MCO engages with probability

[2] Consistent with the setting detailed in Manea (2018), we assume that excluded hospitals' profits are not affected by the MCO's contracting decisions. This ensures that disagreement profits do not depend on the MCO's network (which may differ from the announced network when $\delta < 1$); it also circumvents the possibility that an MCO may attempt to extract surplus from non-contracting parties (as in Jehiel, Moldovanu and Stacchetti (1996)).

greater than 0; and that all MPE are characterized by the following conditions:

$$u_0 = \tau(v^i_{(1)}(G) - \delta u_i) + (1-\tau)\delta u_0$$
$$u_h = \Lambda_h(\tau\delta u_h + (1-\tau)(v^i_h(G) - \delta u_0))\ \forall h \in \mathcal{H}$$
$$\Lambda_h = \begin{cases} \frac{1-\delta+\delta\tau}{\delta\tau} - \frac{(1-\delta)(1-\tau)v^i_h(G)}{\delta\tau(v^i_h(G)-u_0)} & \text{if } u_0 < v^i_h(G)\frac{\tau}{1-\delta+\delta\tau} \\ 0 & \text{otherwise} \end{cases} \quad \forall h \in \mathcal{H}$$

where u_0 and u_h are the expected payoffs for MCO j and hospital h, and Λ_h is the probability that the MCO engages with h at the beginning of each period where agreement has not yet occurred. Furthermore, Manea proves that in any MPE with sufficiently high δ, only the two highest surplus creating hospitals, i and k, have positive probabilities of being engaged with in any period; and that there exists a unique value of u_0 such that $\sum_h \Lambda_h = 1$. This pins down all equilibrium outcomes, and MPE strategies that generate these payoffs and probabilities are easily constructed. Furthermore, $\Lambda_i \to 1$ as $\delta \to 1$, and if $\tau v^i_i \geq v^i_k$, then $\Lambda_i = 1$ for sufficiently high δ.

Multiple hospitals announced at period-0. We next examine subgames where stable network G is announced in period 0 by MCO j, G contains more than one hospital, and no agreements have yet been formed by MCO j.

Consider the bargain being conducted by MCO representative r_i, $i \in G$, holding fixed its beliefs over the outcomes of other negotiations. Let $\mathbf{\Lambda}^h \equiv \{\Lambda^h_k\}_{k\in(\mathcal{H}\setminus i)}$ represent the perceived probabilities held by r_i and all hospitals representatives contained in $N_i \equiv (\mathcal{H} \setminus G) \cup i$ over whether another MCO representative $r_h, h \in G \setminus i$, forms an agreement with some other hospital $k \in (\mathcal{H} \setminus i)$. Denote by $\mathbf{\Lambda}^{-i} \equiv \{\mathbf{\Lambda}^h\}_{h\in G\setminus i}$ the set of such beliefs over the agreements formed by all MCO representatives $h \in G \setminus i$; these beliefs imply a probability $f(\tilde{G}|\mathbf{\Lambda}^{-i})$ of any other network $\tilde{G} \subseteq \mathcal{H} \setminus i$ not involving i that may form. Let $\tilde{v}^i_h(\mathbf{\Lambda}^{-i}) \equiv \sum_{\tilde{G}\subseteq\mathcal{H}\setminus i}[\Delta_{hj}\Pi_{hj}(\tilde{G}\cup h)] \times f(\tilde{G}|\mathbf{\Lambda}^{-i})$ represent the expected bilateral gains-from-trade created when r_i and h come to an agreement given beliefs $\mathbf{\Lambda}^{-i}$.[3] We establish the following result:

Lemma A.2. *For any $\varepsilon_1, \varepsilon_2 > 0$, there exists $\underline{\Lambda} < 1$ and $\underline{\delta} > 0$ such that if $\Lambda^h_h > \underline{\Lambda}$ $\forall h \in G \setminus i$ and $\delta > \underline{\delta}$, any MPE involves r_i coming to agreement with hospital i with probability greater than $1 - \varepsilon_1$ and payoffs are within ε_2 of $\max(\tau v^i_i(G), v^i_k(G))$, where $k = k^i_{(2)}(G)$.*

Proof. In this setting, any representative r_i is engaged in the same bargaining protocol with hospitals $h \in N_i$ as before, but now expects to generates surplus $\tilde{v}^i_h(\cdot)$ upon agreement with any hospital. For sufficiently high $\underline{\Lambda}$ (so that the probability of all agreements in $G \setminus i$ forming, given by $f(G \setminus i|\mathbf{\Lambda}^{-i}) > (\underline{\Lambda})^{|G|-1}$ where $|G|$ represents the number of agreements in G, is close to 1), $\tilde{v}^i_h(\cdot)$ can be made to be arbitrarily close to $v^i_h(G)$, and the indices for the first and second-highest values in $\{\tilde{v}^i_h(\cdot)\}_{h\in(\mathcal{H}\setminus G)\cup i}$ coincide with the indices for the first and second-highest values in $\{v^i_h(G)\}$.[4] As before, applying the results from Proposition 1 of Manea (2018), shows that payoffs in any MPE must converge to $\max(\tau\tilde{v}^i_{(1)}(\cdot), \tilde{v}^i_{(2)}(\cdot))$ and the probability that r_i engages and comes to agreement with $k^i_{(1)}(G)$, given by $\Lambda^i_{(1)}$, converges to 1 as $\delta \to 1$. Furthermore, for large enough $\underline{\Lambda}$, payoffs converge to be within ε_2 of $\max(\tau v^i_{(1)}(G), v^i_{(2)}(G))$; by the arguments of the single-hospital case, this also ensures that payments are within ε_2 of NNTR prices. Finally, since G is assumed to be stable, by Proposition III.2, $i = k^i_{(1)}(G)$ and the result follows. □

We now prove that there exists an MPE of our game for sufficiently high δ. We adapt the proof of Proposition 4 of Manea (2018); following his arguments, MPE payoffs and probabilities of engagement for each representative r_i, $i \in G$, and its bargaining partners must satisfy:

$$u^i_0 = \sum_{h\in N_i} \Lambda^i_h \left(\tau(\tilde{v}^i_h(\mathbf{\Lambda}^{-i}) - \delta u^i_h) + (1-\tau)\delta u^i_0\right) \tag{A.9}$$

$$u^i_h = \Lambda^i_h \left(\tau\delta u^i_h + (1-\tau)(\tilde{v}^i_h(\mathbf{\Lambda}^{-i}) - \delta u^i_0)\right) \qquad \forall h \in N_i \tag{A.10}$$

[3] Implicit in this construction is the possibility that r_i may negotiate with some hospital $k \in \tilde{G}, k \notin G$, and that the representative from k may have some expectation that an agreement may form between a different representative for k and another representative for MCO j $(r_h, h \neq i)$. This can occur if, as discussed in footnote 37, both r_i and r_h negotiate with k that neither representative was initially assigned to engage with $(k \neq i, h)$. Our analysis is consistent with our assumption that such a hospital k also employs separate agents to engage with each separate MCO representative, and must act without knowledge of other agents' actions.

[4] This follows since profits are assumed to be finite for any potential network.

where u_0^i is the expected payoff created for the MCO by representative r_i, u_h^i is the expected payoff for the hospital h, and Λ_h^i is the probability that representative i engages with hospital h in the beginning of a period. Again, all expected payoffs are greater than what would occur if no agreement between r_i and any hospital in N_i were reached.

For any arbitrary vector $\mathbf{\Lambda}^i = \{\Lambda_h^i\}_{h \in N_i}$ describing a probability distribution over which hospital in $h \in N_i$ that r_i engages with at the beginning of each period (and immediately forms an agreement with), Manea shows that the system of equations given by (A.9) and (A.10), given $\mathbf{\Lambda}^{-i}$, satisfies the conditions of the contracting mapping theorem and has a unique fixed point $\tilde{\boldsymbol{u}}^i(\mathbf{\Lambda}^i|\mathbf{\Lambda}^{-i}) = \{\tilde{u}_h^i(\cdot)\}_{h\in(N_i\cup 0)}$; furthermore, he shows that this solution, expressible as the determinants of this system of linear equations using Cramer's rule, varies continuously in $\mathbf{\Lambda}^i$. Given the construction of $\tilde{v}_h^i$ and similar arguments, it is straightforward to show that $\tilde{\boldsymbol{u}}(\mathbf{\Lambda}) = \{\tilde{\boldsymbol{u}}^i(\mathbf{\Lambda}^i|\mathbf{\Lambda}^{-i})\}_{i\in G}$ also varies continuously in $\mathbf{\Lambda} \equiv \{\mathbf{\Lambda}^h\}_{h\in G}$.

Following Lemma A.2, for any given $i \in \mathcal{G}$, we can find $\underline{\Lambda}$ such that if $\Lambda_h^h > \underline{\Lambda} \forall h \in G \setminus i$ (i.e., all other MCO representatives form agreements with hospitals to whom they were assigned with probability greater than $\underline{\Lambda}$), the indices for the first and second highest values over $\tilde{v}_h^i(\cdot)$ coincide with those of the first and second-highest values over $v_h^i(G)$ (and that these values can be made arbitrarily close to one another). Choose $\underline{\Lambda} < 1$ such that this condition holds for all $i \in G$. Then there exists $\underline{\delta}$ such that for all $\delta > \underline{\delta}$ and $i \in G$, any MPE where $\Lambda_h^h > \underline{\Lambda} \forall h \in G \setminus i$ implies that $\Lambda_i^i > \underline{\Lambda}$.

Let $\mathcal{L}(\underline{\Lambda}) \equiv \{\mathbf{\Lambda} : \Lambda_h^h \geq \underline{\Lambda}\ \forall h \in G\}$ denote the set of probability distributions over the agreements formed by all representatives such that each representative r_h, $h \in G$, engages and forms an agreement with his assigned hospital with probability greater than $\underline{\Lambda}$. For any vector $\boldsymbol{u} \equiv \{u_h^i\}_{i\in G, h\in N_i}$ and set of probabilities $\mathbf{\Lambda}$, let $\tilde{\mathbf{\Lambda}}(\boldsymbol{u}; \mathbf{\Lambda}) \equiv \{\tilde{\Lambda}_h^i(\boldsymbol{u}^i; \mathbf{\Lambda}^{-i})\}_{i\in G, h\in N_i}$ denote the set of probabilities in $\mathcal{L}(\underline{\Lambda})$ consistent with optimization by each representative r_i, $i \in G$: i.e., $\tilde{\Lambda}_i^i \geq \underline{\Lambda}$, and $\tilde{\Lambda}_h^i(\cdot) > 0$ only if $h \in \arg\max_{h\in N_i} \tilde{v}_h^i(\mathbf{\Lambda}^{-i}) - \delta u_h^i$. Consider the correspondence $\tilde{\mathbf{\Lambda}}(\tilde{\boldsymbol{u}}(\mathbf{\Lambda}); \mathbf{\Lambda}) \rightrightarrows \mathbf{\Lambda}$ restricted to the domain $\mathcal{L}(\underline{\Lambda})$. By construction, the correspondence is non-empty valued: by the previous claim, a best response for each r_i given that $G \setminus i$ forms with sufficiently high probability (guaranteed for values in $\mathcal{L}(\underline{\Lambda})$) is to engage with i with positive probability (since $i \in \arg\max \tilde{v}_i^i(\cdot) - \delta\tilde{u}_i^i(\cdot)$ for $\delta > \underline{\delta}$). Such a correspondence also has a closed graph and is convex valued, and since $\mathcal{L}(\underline{\Lambda})$ is compact and convex, an application of Kakutani's fixed point theorem ensures the existence of a fixed point $\mathbf{\Lambda}^*$. This fixed point ensures that expected payoffs $\tilde{\boldsymbol{u}}(\mathbf{\Lambda}^*)$ and expected bilateral gains-from-trade $\tilde{\boldsymbol{v}}(\mathbf{\Lambda}^*)$ are consistent with the probabilities implied by $\mathbf{\Lambda}^*$ that certain networks form, and probabilities $\mathbf{\Lambda}^*$ are consistent with the optimal actions given expected payoffs. Following the arguments of Manea, construction of strategies that yield the desired payoffs, verification that they comprise an MPE, and verification that payoffs to all agents are non-negative is straightforward. Furthermore, for sufficiently high δ, the constructed MPE results in G forming at prices arbitrarily close to NNTR payments.

Linear Prices. The conditions of Proposition III.4 also hold, for subgames where the announced period-0 network is a single hospital i, when contracts specify linear prices. In this case, recall that when hospital i is paid a linear price p_{ij}, total payments to i are equal to $D_{ij}^H(G) \times p_{ij}$ where $D_{ij}^H(G)$ is constant. Hence, the same arguments used above in the single-hospital case also establish that negotiated linear prices converge to NNTR prices, $p_{ij}^*(\cdot) = P_{ij}^*(G)/D_{ij}^H(G)$, in any family of MPEs as $\delta \to 1$. Furthermore, as noted in the main text, if G contained more than one hospital but only a single hospital $i \in G$ bargained with the MCO while all other hospitals contained in $G \setminus i$ had formed agreements with the MCO at NNTR prices $\boldsymbol{p}_{-ij}^*$, then the probability of agreement with i converges to 1 and the linear price negotiated with hospital i converges to the NNTR price $p_{ij}^*(G, \boldsymbol{p}_{-ij}^*)$ in any family of MPEs as $\delta \to 1$.

A.4 Proof of Proposition III.5

The proof of Proposition III.4 establishes that for $\underline{\Lambda}$ and $\underline{\delta}$ sufficiently high, if $\delta > \underline{\delta}$, any MPE outcome in any subgame with stable network G being announced has network G being formed with probability $\Lambda > \underline{\Lambda}$ at prices arbitrarily close to NNTR prices. Consequently, for sufficiently high δ, the unique best response for MCO j at period 0 is to announce the insurer optimal stable network G^* at period-0 in any MPE where the announced network forms with probability $\Lambda > \underline{\Lambda}$.

B Empirical Application: Additional Details

B.1 Hospital and Insurer Demand, and Premium Bargaining

Stage 3: Hospital Demand. In stage 3 of our model, we assume that an individual of type κ (representing one of 10 age-sex categories) requires admission to a hospital with probability γ_κ^a. Conditional on admission, the individual receives one of six diagnoses l with probability $\gamma_{\kappa,l}$. Individual k of type $\kappa(k)$ with diagnosis l derives the following utility from hospital i in market m:

$$u^H_{k,i,l,m} = \delta_i + z_i \upsilon_{k,l}\beta^z + d_{i,k}\beta^d_m + \varepsilon^H_{k,i,l,m} \ , \tag{B.11}$$

where z_i are observed hospital characteristics (e.g. teaching status, and services provided by the hospital), $\upsilon_{k,l}$ are characteristics of the consumer (including diagnosis), $d_{i,k}$ represents the distance between hospital i and individual k's zip code of residence (and has a market-specific coefficient), and $\varepsilon^H_{k,i,l,m}$ is an idiosyncratic error term assumed to be i.i.d. Type 1 extreme value (demeaned).

Stage 2: Insurer Demand Stage 2 of our model assumes that the utility a household or family f receives from choosing insurance plan j in market m is

$$u^M_{f,j,m} = \delta_{j,m} + \alpha^\phi_f \phi_j + \sum_{\forall\kappa} \alpha^W_\kappa \sum_{k\in f,\kappa(k)=\kappa} WTP_{k,j,m} + \varepsilon^M_{f,j,m} \ , \tag{B.12}$$

where $\delta_{j,m}$ is an estimated insurer-market fixed effect, ϕ_j is the premium, and $WTP_{k,j,m}$ represents individual k's ex-ante expected utility (or "willingness-to-pay") for insurer j's hospital network in market m (cf. Town and Vistnes (2001), Capps, Dranove and Satterthwaite (2003)). Given our assumption on the distribution of $\boldsymbol{\epsilon}^H$, this object is given by

$$WTP_{k,j,m}(G_{j,m}) = \gamma^a_{\kappa(k)} \sum_{l\in\mathcal{L}} \gamma_{\kappa(k),l} \log\left(\sum_{h\in G_{jm}} \exp(\delta_h + z_h\upsilon_{k,l}\beta^z + d_{h,k}\beta^d)\right) .$$

Since WTP varies explicitly by age and gender, the model accounts for differential responses by particular types of patients—i.e., selection—across insurers (as well as hospitals) when an insurer's hospital network changes.

The premium coefficient, α^ϕ_f, varies with the (observed) income of the primary household member. The third term sums over the value of $WTP_{k,j,m}$ for each member of the household multiplied by an age-sex-category specific coefficient, α^W_κ. Finally $\varepsilon^M_{f,j,m}$ is a Type 1 extreme value error term. This specification is consistent with households choosing an insurance product prior to the realization of their health shocks and aggregating the preferences of members when making the plan decision.

The utility equations provided in (B.11) and (B.12) are used to predict choice probabilities, which in turn are integrated over (using the population of families and individuals across markets in our sample) to predict insurance enrollment $\{\boldsymbol{D}_{jm}(\cdot), D^E_{jm}(\cdot)\}$ and hospital utilization $D^H_{hj}(\cdot)$ across MCOs and hospitals for any set of hospital networks and insurance premiums.

Stage 1b: Premium Bargaining. We assume that negotiated premiums ϕ_j for each MCO j satisfy

$$\phi_j = \arg\max_{\phi} \Bigg[\underbrace{\pi^M_j(G, \boldsymbol{p}, \{\phi, \boldsymbol{\phi}_{-j}\})}_{GFT^M_j}\Bigg]^{\tau^\phi} \times \Bigg[\underbrace{W(\mathcal{M}, \{\phi, \boldsymbol{\phi}_{-j}\}) - W(\mathcal{M}\setminus j, \boldsymbol{\phi}_{-j})}_{GFT^E_j}\Bigg]^{(1-\tau^\phi)} \quad \forall j \in \mathcal{M} \ , \tag{B.13}$$

(where $\boldsymbol{\phi}_{-j} \equiv \{\boldsymbol{\phi} \setminus \phi_j\}$) subject to the constraints that the terms $GFT^M_j \geq 0$ and $GFT^E_j \geq 0$. These terms represent MCO j's and the employer's gains-from-trade from coming to agreement, i.e., from MCO j being included in the choice set that is offered to employees. The MCO's gains-from-trade are given by its profits from being part of the employer's choice set (where its outside option from disagreement is assumed to be 0). The employer's gains-from-trade are represented by the difference between its "objective" $W(\cdot)$—defined as the employer's total employee welfare net of its premium payments to insurers and derived in Ho and Lee (2017)—when MCO j is and is not offered. The "premium Nash bargaining parameter" is represented by $\tau^\phi \in [0, 1]$.

B.2 Data

The primary dataset includes 2004 enrollment, claims, and admissions information for CalPERS enrollees. The markets that we consider are the health service areas (HSAs) defined by the California Office of Statewide Health Planning and Development (OSHPD). For enrollees in Blue Shield and Blue Cross (BC) we observe hospital choice, diagnosis, and total prices paid by each insurer to a given medical provider for the admission.

The claims data are aggregated into hospital admissions and assigned a Medicare diagnosis-related group (DRG) code which we use as a measure of individual sickness level or costliness to the insurer. We categorize individuals into 10 different age-gender groups. For each we compute the average DRG weight for an admission from our admissions data, and compute the probability of admission to a hospital, and of particular diagnoses, using Census data and information on the universe of admissions to California hospitals. We use enrollment data for state employee households in 2004; for each we observe the age, gender and zip code of each household member and salary information for the primary household member. We also use hospital characteristics, including location, from the American Hospital Association (AHA) survey. Hospital costs are taken from the OSHPD Hospital Annual Financial Data for 2004.

Our measure of hospital costs is the average cost associated with the reported "daily hospital services per admission" divided by the the computed average DRG weight of admissions at that hospital (computed using our data). The prices paid to hospitals are constructed as the total amount paid to the hospital across all admissions, divided by the sum of the 2004 Medicare DRG weights associated with these admissions. We assume each hospital system and insurer pair negotiates a single price index that is approximated by this DRG-adjusted average. Both this price, and the hospital's cost per admission, are scaled up by the predicted DRG severity of the relevant admission given age and gender. Finally, we use 2004 financial reports for each of our three insurers from the California Department of Managed Health Care to compute medical loss ratios for each insurer by dividing total medical and hospital costs by total revenues.

We provide summary statistics of our data in Appendix Tables 2 and 3. Annual premiums for single households across BS, BC, and Kaiser were \$3,782, \$4,193, and \$3,665; premiums for 2-party and families across all plans were a strict 2x or 2.6x multiple of single household premiums. There was no variation in premiums across markets within California or across demographic groups. State employees received approximately an 80 percent contribution by their employer. We use total annual premiums received by insurers when computing firm profits, and household annual contributions (20 percent of premiums) when analyzing household demand for insurers.

B.3 Estimation

The parameters of the hospital demand equation detailed in Section IV.B (Stage 3) are estimated via maximum likelihood using admissions data under the assumption that individuals, when sick, can go to any in-network hospital in the HSA that is within 100 miles of their zip code. The insurer demand model (Stage 2) is also estimated via maximum likelihood, using household-level data on plan choices, location and family composition, and conditioning on the set of plans available in each zip code. Insurer non-inpatient hospital costs $\{\eta_j\}$ and Nash bargaining weights $\{\tau^{\phi}, \{\tau_j\}\}$ for premiums and reimbursement rates are estimated using our data and the first-order conditions implied by the model of Nash bargaining between insurers and the employer over premiums, and Nash-in-Nash bargaining between insurers and hospitals over hospital prices. A third set of moments is generated from the difference between each insurer's medical loss ratio (obtained from the 2004 financial reports) and the model's prediction for this value.

B.4 Simulations

For every market, we examine *all* possible Blue Shield (BS) networks $G \in \mathcal{G}_{BS}$, and compute the set of NNTR prices $\boldsymbol{p}^*(G, \boldsymbol{\phi}^*(\cdot))$ and premiums $\boldsymbol{\phi}^*(G, \boldsymbol{p}^*(\cdot))$ such that (the hospital system equivalent of) equations (2)-(4) hold for all hospital systems negotiating with BS, and premiums for all MCOs satisfy (B.13).[5] Given the set of premiums, prices, and implied insurance enrollment and hospital utilization decisions of consumers, we evaluate whether each network G is stable by testing if $[\Delta_{ij}\pi_j^M(G, \boldsymbol{p}^*, \boldsymbol{\phi}^*)] > 0$ and $[\Delta_{ij}\pi_i^H(G, \boldsymbol{p}^*, \boldsymbol{\phi}^*) > 0$ for all $i \in G$, $j \in \{BS\}$. Finally, once the set of stable networks $\mathcal{G}_{BS}^S$ for BS is determined, we select the stable network that maximizes the appropriate objective (i.e., social welfare, consumer surplus, or BS profits). A similar procedure is used when we solve for Nash-in-Nash as opposed to NNTR prices.

To determine NNTR prices and premiums for a given G, we employ the following algorithm:

1. Initalize $\boldsymbol{p}^0$ and $\boldsymbol{\phi}^0$ to observed prices and premiums.
2. At each iteration t, for a given $\boldsymbol{\phi}^{t-1}$ and $\boldsymbol{p}^{t-1}$:
    (a) Update premiums and demand terms so that $\boldsymbol{\phi}^t$ satisfy (B.13) for all MCOs given reimbursement prices $\boldsymbol{p}^{t-1}$ (see Ho and Lee, 2017, for further details).
    (b) Update NNTR prices via the following procedure. Initialize $\tilde{\boldsymbol{p}}^0 = \boldsymbol{p}^{t-1}$. Iterate on the following until $\tilde{\boldsymbol{p}}$ converges (sup-norm of \$1), where at each iteration l:
        i. Compute $p_{ij}^{Nash}(G, \tilde{\boldsymbol{p}}^{l-1})$ for all $i \in G$ using the hospital system equivalent of the first-order condition for (2) (see Ho and Lee, 2017).

[5]In our main specifications which examine the contracting decisions between BS and five major hospital systems in each market, there are $2^5 = 32$ potential networks that BS is able to form in each market.

ii. For all $i \in G$, compute $p_{ij}^{OO}(G, \tilde{\boldsymbol{p}}^{l-1})$ as the solution to:

$$\pi^M(G, \{p_{ij}^{OO}(\cdot), \tilde{\boldsymbol{p}}_{-ij}^{l-1}, \boldsymbol{\phi}^t\}) = \max_{k \in \mathcal{H} \setminus G} \left[\pi^M((G \setminus i) \cup k, \{p_{kj}^{res}(G \setminus i, \tilde{\boldsymbol{p}}^{l-1}), \tilde{\boldsymbol{p}}_{-ij}^{l-1}, \boldsymbol{\phi}^t\}) \right],$$

(which requires searching over all $k \in \mathcal{H} \setminus G$ and computing $p_{kj}^{res}(\cdot)$).

iii. Update $\tilde{p}_{ij}^l = min(p_{ij}^{Nash}, p_{ij}^{OO})$ for all $i \in G$.

Set $\boldsymbol{p}^t = \tilde{\boldsymbol{p}}$.

3. Repeat step 2 until premiums converge (sup-norm of $1).

C Additional Tables

Table C1: Hospitals Proposed to Be Removed from Blue Shield in 2005

Market Name	Hospital Name	System Name	Decision
Central California	Selma Community Hospital		Approved
	Sierra View District Hospital		Denied
	Delano Regional Medical Center		Withdrawn
	Madera Community Hospital		Withdrawn
East Bay	Eden Hospital Medical Center	Sutter	Approved
	Sutter Delta Medical Center	Sutter	Approved
	Washington Hospital		Approved
Inland Counties	Desert Regional Medical Center	Tenet	Approved
Los Angeles	Cedars Sinai Medical Center		Approved
	St. Mary Medical Center	Dignity	Approved
	USC University Hospital	Tenet	Approved
	West Hills Hospital Medical Center		Approved
	Presbyterian Intercommunity Hospital		Denied
	City of Hope National Medical Center		Withdrawn
	St. Francis Memorial Hospital	Verity	Withdrawn
	St. Vincent Medical Center	Verity	Withdrawn
North Bay	Sutter Medical Center of Santa Rosa	Sutter	Approved
	Sutter Warrack Hospital	Sutter	Approved
North San Joaquin	Memorial Hospital Medical Center - Modesto	Sutter	Approved
	Memorial Hospital of Los Banos	Sutter	Approved
	St. Dominics Hospital	Dignity	Approved
	Sutter Tracy Community Hospital	Sutter	Approved
Orange	Hoag Memorial Hospital Presbyterian		Approved
Sacramento	Sutter Davis Hospital	Sutter	Approved
	Sutter General Hospital	Sutter	Approved
	Sutter Memorial Hospital	Sutter	Approved
	Sutter Roseville Medical Center	Sutter	Approved
San Diego	Sharp Chula Vista Medical Center	Sharp	Withdrawn
	Sharp Coronado Hospital and Healthcare Center	Sharp	Withdrawn
	Sharp Grossmont Hospital	Sharp	Withdrawn
	Sharp Mary Birch Hospital for Women	Sharp	Withdrawn
	Sharp Memorial Hospital	Sharp	Withdrawn
Santa Barbara/Ventura	St John's Pleasant Valley Hosp	Dignity	Denied
	St John's Regional Med Center	Dignity	Denied
Santa Clara	OConnor Hospital	Verity	Approved
West Bay	California Pacific Medical Center Campus Hospital	Sutter	Approved
	Seton Medical Center	Verity	Approved
	St. Lukes Hospital	Sutter	Approved

Notes: List of hospitals that Blue Shield proposed to exclude in its filing to the California Department of Managed Health Care (DMHC) for the 2005 year. Source: DMHC "Report on the Analysis of the CalPERS/Blue Shield Narrow Network" (Zaretsky and pmpm Consulting Group Inc. (2005)). "Market name" denotes the Health Service Area of the relevant hospital; the two HSAs in California that are not listed here did not contain hospitals that Blue Shield proposed to exclude. "Decision" is the eventual outcome of the proposal for the relevant hospital.

Table C2: Summary Statistics and Parameter Estimates

		Blue Shield	Blue Cross	Kaiser
Premiums (per year)	Single	3782.64	4192.92	3665.04
	2 party	7565.28	8385.84	7330.08
	Family	9834.84	10901.64	9529.08
Hospital	# Hospitals in network	189	223	27
Network	# Hospital systems in network	119	149	-
	Avg. hospital price per admission	6624.08 (3801.24)	5869.26 (2321.57)	-
	Avg. hospital cost per admission	1693.47 (552.17)	1731.44 (621.33)	-
Household	Single	19313	8254	20319
Enrollment	2 party	16376	7199	15903
	Family	35058	11170	29127
	Avg # individuals per family	3.97	3.99	3.94
Parameter	η (Non-inpatient cost per enrollee)	1691.50 (10.41)	1948.61 (8.14)	2535.14 (0.62)
Estimates	τ^H (Hospital bargaining weight)	0.31 (0.05)	0.38 (0.03)	-
(Ho and Lee, 2017)	τ^ϕ (Premium bargaining weight)		0.47 (0.00)	

Notes: The first three panels report summary statistics by insurer. The number of hospitals and hospital systems for Blue Shield and Blue Cross are determined by the number of in-network hospitals or systems with at least 10 admissions observed in the data. Hospital prices and costs per admission are averages of unit-DRG amounts, unweighted across hospitals (with standard deviations reported in parentheses). The fourth panel reports estimates from Ho and Lee (2017) of marginal costs for each insurer (which do not include hospital payments for Blue Shield and Blue Cross), and (insurer-specific) hospital price and (non-insurer specific) premium Nash bargaining weights; standard errors are reported in parentheses. For Blue Shield and Blue Cross, as we are explicitly controlling for prices paid to hospitals, the estimated cost parameters $\{\eta_j\}_{j\in\{BS,BC\}}$ represent non-inpatient hospital marginal costs per enrollee, which may include physician, pharmaceutical, and other fees. Since we do not observe hospital prices for Kaiser, η_{Kaiser} also include Kaiser's inpatient hospital costs.

Table C3: Admission Probabilties and DRG Weights

	Admission Probabilities		DRG Weights		
Age/Sex	BS	BC	BS	BC	All
0-19 Male	1.78%	2.08%	1.78	1.49	1.70
20-34 Male	1.66%	2.07%	1.99	1.77	1.92
35-44 Male	2.79%	3.21%	1.95	1.89	1.93
45-54 Male	5.29%	5.32%	2.07	2.05	2.07
55-64 Male	10.13%	9.70%	2.25	2.25	2.25
0-19 Female	1.95%	2.04%	1.31	1.39	1.32
20-34 Female	11.75%	10.22%	0.84	0.87	0.85
35-44 Female	7.31%	7.73%	1.32	1.33	1.32
45-54 Female	6.16%	6.82%	1.90	1.83	1.87
55-64 Female	9.01%	9.26%	2.03	2.02	2.03

Notes: Average admission probabilities and DRG weights per admission by age-sex category.

Table C4: Simulation Results for All Markets (Averages), No Blue Cross

Objective		Social	Consumer	Blue Shield		Complete
		(NNTR)	(NNTR)	(NNTR)	(NN)	(NNTR/NN)
Surplus	BS Profits	1.1%	3.2%	3.5%	0.0%	365.8
($ per capita)		[0.4%,3.0%]	[1.9%,8.5%]	[2.3%,8.9%]	[0.0%,0.0%]	[344.9,375.9]
	Hospital Profits	-6.7%	-32.6%	-27.2%	0.1%	118.6
		[-13.6%,-1.6%]	[-50.9%,-27.1%]	[-48.4%,-20.0%]	[-0.3%,0.1%]	[107.9,158.5]
	Total Hosp Costs	-0.2%	-0.1%	0.0%	-0.1%	89.3
		[-0.4%,0.4%]	[-0.6%,0.3%]	[-0.3%,0.4%]	[-0.1%,0.0%]	[88.0,89.9]
	Total Ins Costs	0.0%	0.0%	0.0%	0.0%	2005.6
		[-0.2%,0.0%]	[0.0%,0.2%]	[-0.1%,0.1%]	[0.0%,0.0%]	[1988.8,2023.9]
Transfer / Cost	BS Premiums	-0.3%	-1.5%	-1.1%	0.0%	2603.1
($ per enrollee)		[-0.8%,-0.1%]	[-3.1%,-1.1%]	[-2.9%,-0.8%]	[0.0%,0.0%]	[2584.3,2643.2]
	BS Hosp Pmts	-3.6%	-17.4%	-15.0%	0.0%	336.4
		[-8.4%,-1.3%]	[-31.8%,-13.8%]	[-30.3%,-10.9%]	[-0.2%,0.0%]	[318.1,404.4]
	BS Hosp Costs	-0.4%	0.3%	-0.1%	-0.1%	146.5
		[-0.5%,-0.3%]	[0.2%,0.4%]	[-0.2%,0.1%]	[-0.1%,0.0%]	[146.5,146.6]
BS Market Share		0.2%	-0.3%	0.0%	0.0%	0.63
		[0.1%,0.7%]	[-0.8%,0.1%]	[-0.4%,0.5%]	[0.0%,0.0%]	[0.62,0.63]
Welfare Δ	Consumer	5.4	20.7	15.8	0.0	
($ per capita)		[1.9,14.7]	[14.1,47.8]	[10.3,45.3]	[-0.3,0.0]	
	Total	0.6	-7.5	-6.8	0.1	
		[0.4,1.9]	[-14.7,-7.3]	[-9.9,-5.1]	[-0.6,0.1]	
# Complete Network Markets		7	2	2	11	
(out of 12)		[6,9]	[0,3]	[0,4]	[11,12]	
# Sys Excluded		0.4	1.7	1.7	0.1	
		[0.3,0.7]	[1.6,2.4]	[1.3,2.3]	[0.0,0.1]	
# Sys Excluded Cond'l on Exclusion		1.0	2.0	2.0	1.0	
		[1.0,1.3]	[2.0,2.4]	[1.9,2.3]	[0.0,1.0]	

Notes: Unweighted averages across markets when Blue Cross is unavailable. See Table 1 for details.

Table C5: Simulation Results for All Markets (Averages), Fixed Premiums

Objective		Social	Consumer	Blue Shield		Complete
		(NNTR)	(NNTR)	(NNTR)	(NN)	(NNTR/NN)
Surplus	BS Profits	0.0%	0.0%	8.8%	0.0%	304.7
($ per capita)		[0.0%,0.1%]	[0.0%,0.0%]	[5.0%,18.2%]	[0.0%,0.0%]	[287.5,312.1]
	Hospital Profits	0.0%	0.0%	-23.1%	0.0%	170.0
		[-0.1%,0.0%]	[0.0%,0.0%]	[-34.0%,-16.5%]	[0.0%,0.0%]	[159.4,209.4]
	Total Hosp Costs	-0.1%	0.0%	-1.1%	0.0%	95.6
		[-0.1%,-0.1%]	[0.0%,0.0%]	[-1.7%,-1.0%]	[0.0%,0.0%]	[94.1,96.3]
	Total Ins Costs	0.0%	0.0%	0.6%	0.0%	2008.5
		[0.0%,0.0%]	[0.0%,0.0%]	[0.5%,0.8%]	[0.0%,0.0%]	[1990.4,2025.7]
Transfer / Cost	BS Premiums	0.0%	0.0%	0.3%	0.0%	2640.1
($ per enrollee)		[0.0%,0.0%]	[0.0%,0.0%]	[0.3%,0.4%]	[0.0%,0.0%]	[2615.8,2695.1]
	BS Hosp Pmts	0.0%	0.0%	-18.8%	0.0%	369.3
		[-0.1%,0.0%]	[0.0%,0.0%]	[-29.4%,-13.2%]	[0.0%,0.0%]	[347.5,449.3]
	BS Hosp Costs	-0.1%	0.0%	1.3%	0.0%	146.2
		[-0.1%,-0.1%]	[0.0%,0.0%]	[1.1%,1.4%]	[0.0%,0.0%]	[146.1,146.3]
BS Market Share		0.0%	0.0%	-3.7%	0.0%	0.52
		[0.0%,0.0%]	[0.0%,0.0%]	[-5.4%,-3.7%]	[0.0%,0.0%]	[0.51,0.53]
Welfare Δ	Consumer	-0.1	0.0	-8.7	0.0	
($ per capita)		[-0.1,-0.1]	[0.0,0.0]	[-12.1,-8.6]	[0.0,0.0]	
	Total	0.0	0.0	-16.2	0.0	
		[0.0,0.0]	[0.0,0.0]	[-23.4,-16.0]	[0.0,0.0]	
# Complete Network Markets		11	12	0	12	
(out of 12)		[11,11]	[12,12]	[0,2]	[12,12]	
# Sys Excluded		0.1	0.0	1.9	0.0	
		[0.1,0.1]	[0.0,0.0]	[1.8,2.5]	[0.0,0.0]	
# Sys Excluded Cond'l on Exclusion		1.0	0.0	1.9	0.0	
		[1.0,1.0]	[0.0,0.0]	[1.9,2.5]	[0.0,0.0]	

Notes: Unweighted averages across markets when premiums are fixed to be the same as when Blue Shield's network is complete. See Table 1 for details.

References

Capps, Cory, David Dranove, and Mark Satterthwaite. 2003. "Competiton and Market Power in Option Demand Markets." *RAND Journal of Economics*, 34(4): 737–763.

Ho, Kate, and Robin S. Lee. 2017. "Insurer Competition in Health Care Markets." *Econometrica*, 85(2): 379–417.

Jehiel, Philippe, Benny Moldovanu, and Ennio Stacchetti. 1996. "How (Not) to Sell Nuclear Weapons." *American Economic Review*, 86(4): 814–829.

Manea, Mihai. 2018. "Intermediation and Resale in Networks." *Journal of Political Economy*, 126(3): 1250–1301.

Town, Robert J., and Gregory Vistnes. 2001. "Hospital Competition in HMO Networks." *Journal of Health Economics*, 20: 733–753.

Zaretsky, H., and pmpm Consulting Group Inc. 2005. "Report of the Analysis of the CalPERS/Blue Shield Narrow Network." California Department of Managed Health Care.

Corrigendum for *Equilibrium Insurer-Provider Networks: Bargaining and Exclusion in Health Care Markets*, AER 2019

There is an error in the expression for hospital i's profits on page 492 of the published version of the article. It should be $\pi_i^H(G, \boldsymbol{p}) \equiv \tilde{\pi}_i^H(G) + \sum_n (D_{in}^H(G) \times p_{in})$, and not $\pi_i^H(G, \boldsymbol{p}) \equiv \tilde{\pi}_i^H(G) + \sum_{n \neq j} (D_{in}^H(G) \times p_{in})$.