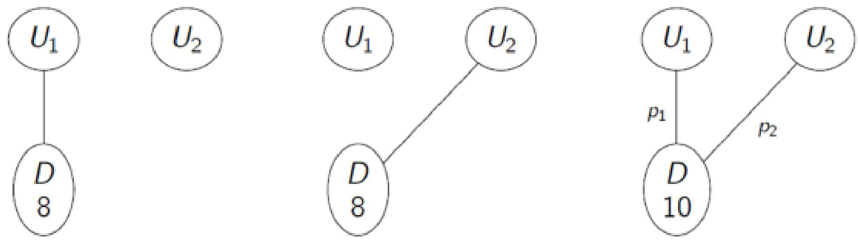
1 Competition with Negotiated Prices

1.1 Introduction to NiN

Nash-in-Nash (Horn Wolinsky 1988): the basic idea is one of a Nash equilibrium governing a number of Nash bargaining games. One way to think about NiN is buyers and sellers sending out uncoordinated representatives to a number of bilateral negotiations: each negotiation is cooperative, but the equilibrium is non-cooperative[1]. The Nash bargaining games are played by buyers and suppliers, who are bilaterally connected and set prices to divide the surplus from the buyer-supplier exchange. The price externalities that multiple sellers connecting to the same buyer impose on each other will drive price towards an equilibrium.

Consider the following structure, where D is the buyer and U the seller:



assume zero marginal cost and zero outside utility for the seller. It is evident that D will buy from both sellers iff their price is equal, and sellers have no reason not to sell at any strictly positive price. D has disagreement payoff 8 and agreement payoff 10 in both Nash bargaining games. Her Nash bargaining solution is as follows:

$$p_1 = p_2 = p \mid \arg\max_p [(10 - p) - 8][p] : 2 - 2p = 0 \to p = 1$$

Instead of assuming a disagreement payoff, one can endogenise it. Suppose for example D knows that she can buy at p_e from U_i if bargaining with U_j fails $(i \neq j)$, and has disagreement payoff $9 - p_e$. The Nash bargaining solution is

$$\underbrace{p_i = p_j = p}_{symmetry} \mid \arg\max_p [(10 - p) - (9 - p_e)][p] : 1 + p_e - 2p = 0$$

and note that in equilibrium $p_e = p$, so that $p_e = p = 1$ and $9 - p_e = 8$. A similar thought exercise can be conducted to estimate the impact of a **merger** between U_1 and U_2, which deprives D of a bargaining outside option, on price and, relatedly, on total welfare.

1.2 Estimation of NiN

Continue with the $\{U_i, U_j, D\}$ example. Set the beliefs as follows: if a bilateral exchange does not take place, agents expect the other trade to take place (*passive beliefs*). Firms have marginal cost mc_i, D

These notes are based on Howard Smith's lectures from the 2018-2019 academic year.
Of course, this is our interpretation of the material Howard presented. Good content is his; mistakes are ours.

[1] The use of a cooperative bargaining solution does not sit well with some researchers, who prefer other models such as Rubinstein's alternating offers model. However, we know that the Rubinstein solution converges to the Nash bargaining solution as the length of periods shrinks to zero, and the result holds for NiN as well (see Collard-Wexler et al., 2018).

pays prices p_i.

D has payoff π_{12} if she can agree with both sellers, π_1 if she can't agree with U_2, and π_2 if she can't agree with U_1. π is a function of prices indicated by the subscript. Demands are denoted by $q_i(p_1, p_2)$.

The following payoff matrix applies for $i, j \in \{1, 2\}, i \neq j$ given passive beliefs:

	U_i	D
U_i and D agree	$q_i(p_1, p_2)(p_i - mc_i)$	π_{12}
U_i and D disagree	0	π_j

The Nash bargaining solution is

$$p_i = \arg\max_{p_i} [\pi_{12} - \pi_j]^{b_D} [q_i(p_i - mc_i) - 0]^{b_{U_i}} \tag{1.1}$$

Given $\ln(\cdot)$ is a strictly increasing function in the price domain, p_i will also maximise

$$p_i = \arg\max_{p_i} b_D \ln[\pi_{12} - \pi_j] + b_{U_i} \ln[q_i(p_i - mc_i) - 0] \tag{1.2}$$

with first order condition

$$b_D \frac{\frac{\partial \pi_{12}}{\partial p_i} - \frac{\partial \pi_j}{\partial p_i}}{\pi_{12} - \pi_j} + b_{U_i} \frac{q_i + (p_i - mc_i)\frac{\partial q_i}{\partial p_i}}{q_i(p_i - mc_i)} = 0$$

which, by using $\frac{\partial \pi_{12}}{\partial p_i} = \frac{\partial \pi_i}{\partial p_i} = -q_i$ (proof in section on Grennan, 2013) and $\frac{\partial \pi_j}{\partial p_i} = 0$, yields

$$b_{U_i} \frac{q_i + (p_i - mc_i)\frac{\partial q_i}{\partial p_i}}{q_i(p_i - mc_i)} = b_D \frac{q_i}{\pi_{12} - \pi_j}$$

$$(p_i - mc_i)\frac{\partial q_i}{\partial p_i} = \frac{b_D}{b_{U_i}} \frac{q_i^2}{\pi_{12} - \pi_j}(p_i - mc_i) - q_i$$

$$p_i = mc_i - q_i \underbrace{\left\{ \frac{\partial q_i}{\partial p_i} - \frac{b_D}{b_{U_i}} \frac{q_i^2}{\pi_{12} - \pi_j} \right\}^{-1}}_{\Omega(b)} \tag{1.3}$$

where note that (1.3) reduces to Nash pricing if the buyer has no bargaining power ($b_D = 0$).

To make progress, we can:

1. Specify a functional form for mc_i:
$$mc_i = w_i \gamma + \nu_i \tag{1.4}$$
with, denoting by z_i an instrument that allows identification of b and assuming all elements of Ω except b are known, $\mathbb{E}(\nu_i | w_i, z_i) \overset{(1.3)(1.4)}{=} \mathbb{E}(p_i + q_i \Omega(b) - w_i \gamma | w_i, z_i) = 0$.

2. Assume a functional form depending on unobserved heterogeneity for the bargaining power ratio and let marginal costs be deterministic:
$$\frac{b_D}{b_{U_i}} = \beta \nu_i \qquad\qquad mc_i = w_i \gamma \tag{1.5}$$
with $\mathbb{E}(\ln \nu_i | w_i, z_i) = 0$. Functional form (1.5) can in particular yield, with some rearranging, an isolated term for the bargaining power ratio[2] (see below).

[2]kids, if you assume everything is nicely multiplicative then you can take logs and isolate stuff!

2 Application: Grennan (2013)

An analysis of price discrimination, bargaining and the effect of merging purchasers in the market for coronary stents. Two types of stent, one than can scar and one that does not.

2.1 Setup

Two-stage game: in the first stage, manufacturers and hospital h negotiate stent prices for time t, p_{ht}; in the second stage, doctors decide which stent to assign to patients given prices and stent choice set. Backwards inducing,

Stage 2: Doctor chooses stent j to maximise patient i's utility with functional form

$$u_{ijht} = \delta_{jht} + \epsilon_{ijht} \equiv \gamma_{jh} + \xi_{jht} - \alpha p_{jht} + \beta x_{jt} + \epsilon_{ijht} \qquad \epsilon_{ijht} \sim \text{EVT-1} \tag{2.1}$$

where γ_{jh} is hospital-specific taste and ξ_{jht} is a time-varying shock.
Non-stent treatment purchases are taken as excluded good. The market share and total demand of good j are

$$s_{jht} = \frac{e^{\delta_{jht}}}{\sum_{k\in J_{ht}} e^{\delta_{jht}}} \qquad q_{jht} \equiv Q_{ht} s_{jht} \tag{2.2}$$

Stage 1: The payoff to the hospital from choice set J_{ht} is (using the standard EVT-1 result)

$$\pi(p_{ht}) = \frac{Q_{ht}}{\alpha}\mathbb{E}_\epsilon[\max_{j\in J_{ht}}(\delta_{jht} + \epsilon_{ijht})] = \frac{Q_{ht}}{\alpha}\ln[\sum_{j\in J_{ht}} e^{\delta_{jht}}] \tag{2.3}$$

and, if choice k is excluded, it is

$$\pi_{-k}(p_{ht}) = \frac{Q_{ht}}{\alpha}\mathbb{E}_\epsilon[\max_{j\in J_{ht}\backslash k}(\delta_{jht} + \epsilon_{ijht})] = \frac{Q_{ht}}{\alpha}\ln[\sum_{j\in J_{ht}\backslash k} e^{\delta_{jht}}] \tag{2.4}$$

$\pi_{-k}(p_{ht})$ is effectively the disagreement payoff each hospital gets if bargaining fails with producers of k: the added value of the additional stent type is $\pi(p_{ht}) - \pi_{-k}(p_{ht})$. Hospitals have passive beliefs. Stent sellers have 0 disagreement utility. Thus the Nash bargaining solution price is

$$p_{jht} \mid \arg\max_{p_{jht}} \ [\pi(p_{ht}) - \pi_{-j}(p_{ht})]^{b_h}[q_{jht}(p_{jht} - mc_{jht})]^{b_j} \tag{2.5}$$

with first order condition

$$p_{jht} \mid \arg\max_{p_{jht}} \ b_h \ln[\pi(p_{ht}) - \pi_{-j}(p_{ht})] + b_j \ln[q_{jht}(p_{jht} - mc_{jht})]$$

$$b_j \frac{\frac{\partial q_{jht}}{\partial p_{jht}}(p_{jht} - mc_{jht}) + q_{jht}}{q_{jht}(p_{jht} - mc_{jht})} = -b_h \frac{\frac{\partial \pi(p_{ht})}{\partial p_{jht}}}{\pi(p_{ht}) - \pi_{-j}(p_{ht})}$$

noting

$$\frac{\partial \pi_{ht}}{\partial p_{jht}} \overset{(2.3)}{\equiv} \frac{Q_{ht}}{\alpha}\frac{\partial \ln[\sum_{j\in J_{ht}} e^{\delta_{jht}}]}{\partial p_{jht}} \equiv \frac{Q_{ht}}{\alpha}\frac{\partial \ln[\sum_{j\in J_{ht}} e^{\delta_{jht}}]}{\partial \sum_{j\in J_{ht}} e^{\delta_{jht}}}\frac{\partial \sum_{j\in J_{ht}} e^{\delta_{jht}}}{\partial p_{jht}} \equiv -Q_{ht}\frac{e^{\delta_{jht}}}{\sum_{j\in J_{ht}} e^{\delta_{jht}}} \overset{(2.2)}{=} -q_{jht}$$

one obtains

$$b_j\left(1 + \frac{\partial q_{jht}}{\partial p_{jht}}\frac{(p_{jht} - mc_{jht})}{q_{jht}}\right) = b_h \frac{q_{jht}(p_{jht} - mc_{jht})}{\pi(p_{ht}) - \pi_{-j}(p_{ht})}$$

$$b_j\left(1+\frac{\partial q_{jht}}{\partial p_{jht}}\frac{(p_{jht}-mc_{jht})}{q_{jht}}\right)\frac{\big(\pi(p_{ht})-\pi_{-j}(p_{ht})\big)}{q_{jht}}=b_h(p_{jht}-mc_{jht})$$

finally add $b_j(p_{jht}-mc_{jht})$ to both sides and rearrange to obtain equation (8) in Grennan,

$$p_{jht}=mc_{jht}+\frac{b_j}{b_j+b_h}\left[\left(1+\frac{\partial q_{jht}}{\partial p_{jht}}\frac{(p_{jht}-mc_{jht})}{q_{jht}}\right)\frac{\big(\pi(p_{ht})-\pi_{-j}(p_{ht})\big)}{q_{jht}}+p_{jht}-mc_{jht}\right] \tag{2.6}$$

Identification: bargaining generates two sources of demand identification: **(i)** negotiated prices depend on exogenous variation in bargaining abilities of players (see (2.6)), i.e. bargaining ability is a supply shifter; **(ii)** if a contract fixes prices for a long period, price renegotiation will induce movement along the demand curve, thus allowing identification. Moreover, Grennan defines a functional form for unobserved time-changing hospital-level preferences ξ_{jht}, which is defined to be AR(1): $\xi_{jht}=\rho\xi_{jht-1}+\bar{\xi}_{jht}$. As a result of the assumed exogeneity in bargaining ability variation and a timing assumption in the error term $\bar{\xi}_{jht}$, assumed to be realised after price setting, the author can then claim that prices in (2.1) are indeed exogenous.[3] To avoid offending IV-heads, the author nonetheless instruments price with lagged price and within-hospital price average of other stents (a measure of hospital bargaining power).

Given the simple logit formulation, (2.1) can then be estimated as

$$\ln s_{jht}-\ln s_{0ht}=\gamma_{jh}+\xi_{jht}-\alpha p_{jht}+\beta x_{jt}+\epsilon_{ijht}$$

As for pricing equation estimation, note that the first order condition of the Nash bargaining problem would not allow to separately identify variation in marginal costs from variation in (the ratio of) bargaining powers. To circumvent the issue, the author assumes that

$$mc_{jht}=mc_j=\mathbb{1}_{\{j=scar\}}mc_{scar}+\mathbb{1}_{\{j=noscar\}}mc_{noscar} \qquad \text{and} \qquad \frac{b_h}{b_j}=\beta_{jh}\nu_{jht} \tag{2.7}$$

where ν is a random unobservable that drives the bargaining power disparity. These parametric assumptions can then be plugged into the (2.6), which one can then rearrange to obtain (cf. second-to-last step in deriving (2.6))

$$p_{jht}-mc_j=\beta_{jh}\nu_{jht}\underbrace{\left[\left(1+\frac{\partial q_{jht}}{\partial p_{jht}}\frac{(p_{jht}-mc_j)}{q_{jht}}\right)\frac{\big(\pi(p_{ht})-\pi_{-j}(p_{ht})\big)}{q_{jht}}\right]}_{g(\cdot)} \tag{2.8}$$

$$\ln\frac{p_{jht}-mc_j}{g(\cdot)}=\ln\beta_{jh}+\ln\nu_{jht} \tag{2.9}$$

Marginal costs and relative bargaining abilities are separately identified by the assumption of time-invariance of the former. Problem: changes in added value $g(\cdot)$ can be due to both to supply (marginal cost) and demand (eg. through π_{-j}) changes. If however demand does not change in response to anticipated changes in bargaining abilities, one can instrument added value with past values, resolving simultaneity.

Empirically, the author separately estimates the demand and supply parts of his model, using a

[3] "there is no simultaneity problem in using contemporaneous price as its own instrument" (p. 158)

GMM method á la Berry, Levinsohn and Pakes (1995). For demand, one first matches predicted and realised market shares, inverts the equality to isolate doctor/patient heterogeneity estimates (Berry, 1994 shows there will be a unique solution), then estimates model parameters by GMM orthogonality conditions on ξ_{jht}; for supply, Grennan makes use of the parametric assumptions above and similarly estimates the supply unobservable ν.

2.2 Results

Obtained own elasticities are > -1, consistent with buyers pushing prices in the inelastic part of demand:

TABLE 4—OWN- AND CROSS-ELASTICITY ESTIMATES

Price elasticity of q_j:	With respect to p_k:	Mean	SD	Min	Max
BMS	Own	−0.32 (0.03)	0.07 (0.01)	−0.70 (0.07)	−0.09 (0.01)
	Other BMS	0.02 (0.00)	0.02 (0.00)	0.00 (0.00)	0.47 (0.03)
	DES	0.12 (0.01)	0.14 (0.01)	0.00 (0.00)	1.70 (0.06)
DES	Own	−0.52 (0.04)	0.11 (0.01)	−0.99 (0.09)	−0.09 (0.01)
	BMS	0.01 (0.00)	0.01 (0.00)	0.00 (0.00)	0.24 (0.01)
	Other DES	0.01 (0.00)	0.02 (0.00)	0.00 (0.00)	0.20 (0.01)
Outside alternative	BMS	0.01 (0.00)	0.01 (0.00)	0.00 (0.00)	0.12 (0.01)
	DES	0.08 (0.01)	0.07 (0.01)	0.00 (0.00)	0.60 (0.05)

Notes: $\frac{\partial q_j}{\partial p_k}\frac{p_k}{q_j}$ distributions across hospitals, months, and stents of that type. Own-elasticities less than −1 are consistent with negotiated prices, but not with suppliers setting prices to price-taking buyers.

Moreover, cost estimates from the bargaining model seem to be reasonable (?), which cannot be said for Bertrand model estimates (*negative* marginal costs):

TABLE 6—COST ESTIMATES AND COMPARISON

	Bargaining model	Industry experts	Bertrand, $b_h = 0$	
			Mean	SD
BMS cost, γ_{bms} (\$)	34 (79)	100–400	−2,211 (471)	547 (75)
DES cost, γ_{des} (\$)	1,103 (286)	400–1,600	−2,481 (660)	1,325 (174)

Notes: The first column reports marginal cost estimates for the bargaining model used in this paper. Column two reports a range of industry expert estimates for per-unit costs. Column three reports marginal cost estimates (mean and standard deviation across stent-hospital-months) implied by the model if manufacturers were assumed to set prices. $N = 10{,}098$. Standard errors clustered by hospital, $N_H = 96$.

Lastly, the evidence from estimated changes in profits from switching to uniform pricing corroborates the evidence that allowing hospitals to team up in bargaining has positive effects on the public: forcing hospital bargaining power to zero would increase dramatically firm profits and shoot stent prices through the roof, reducing surplus for buyers.

TABLE 7—EFFECTS OF CHANGING TO UNIFORM PRICING

		Percent change with uniform prices		
	Current regime	$b_{\mathcal{H}} = 0$	$b_{\mathcal{H}} = \bar{\beta}_h$	$b_{\mathcal{H}} = \max(\beta_h)$
Manufacturer profits ($M/hospital/year)	1.24	81 (27)	8 (1)	−15 (3)
Hospital surplus ($M/hospital/year)	4.32 (0.58)	−48 (2)	−1.4 (0.3)	7.2 (0.5)
Total surplus ($M/hospital/year)	5.56 (0.75)	−19 (1)	0.7 (0.1)	2.2 (0.2)
Total stentings (stents/hospital/year)	977	−43 (2)	−1.1 (0.3)	5.9 (0.4)
Mean BMS price ($/stent)	1,016	207 (35)	1.7 (0.4)	−25 (1.6)
Mean DES price ($/stent)	2,509	114 (14)	1.7 (0.7)	−14 (0.9)

Notes: Standard errors in parentheses, clustered by hospital. Equilibrium outcomes under the current negotiated price regime compared to those under uniform pricing (e.g., GPO of all hospitals in sample) for September 2005. Column 2 sets $b_{\mathcal{H}}$ to zero, the case where hospitals do not bargain collectively and manufacturers set prices. Column 3 sets bargaining ability of the group of hospitals, $b_{\mathcal{H}}$, to the mean of individual hospitals, $\bar{\beta}_h$, in order to isolate the change to competition. Column 4 sets $b_{\mathcal{H}}$ to the maximum estimated bargaining ability of any individual hospital.