# Network Industries

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# Introduction

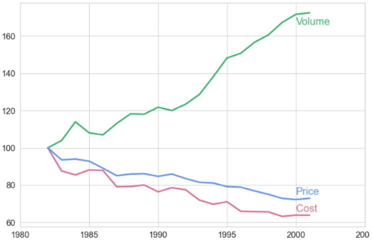
- Network industries
  - Telecommunications, natural gas, electric power, railroads, etc
  - Natural monopolies
- Long-term trend from state-owned or highly regulated monopolies to vertically segmented with parts deregulated

# Section 1

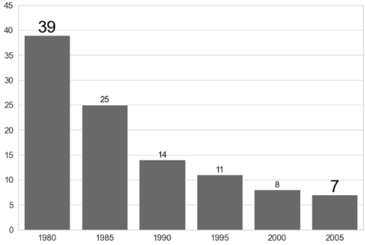
# Chen (2023)

# Network Structure and Efficiency Gains from Mergers: Evidence from US Freight Railroads

## Chen (2023)




(a) Shipment Price, Cost, and Volume




(b) Number of Class I Railroads

**Figure 1:** U.S. Freight Railroads

# Introduction

- Model of oligopolistic competition on transportation network
- Firms choose: pricing, routing, maintenance
- Estimate model
- Simulate effects of each merger from 1985-2004 (no mergers since then)
- On average after merger shipment cost reduces by 12.9%, shipment price reduces by 8.8%, and the additive markup increases by 7.2%
  - Increased markup from other firms allocating away from region where merged firm operates

# Data

- 3 data sets
  1. confidential Carload Waybill Sample
  2. Class I Railroad Annual Report
  3. Commodity Flow Survey

Rail network and ownership changes over time
https://yanyouchen.com/american-railroads/

# Data

**Table 1:** Summary Statistics of Market Competition

| Year | Number of Markets | Percentage of Interchange Lines | Number of Competitors in an $o$–$d$ Market | | | Number of Waybills |
|---|---|---|---|---|---|---|
| | | | mean | 25th percentile | 75th percentile | |
| 1985 | 12,088 | 41% | 3 | 1 | 3 | 262,703 |
| 1990 | 11,835 | 35% | 2 | 1 | 3 | 323,570 |
| 1995 | 11,632 | 26% | 2 | 1 | 3 | 453,802 |
| 2000 | 11,732 | 14% | 2 | 1 | 2 | 544,738 |
| 2005 | 11,611 | 11% | 2 | 1 | 2 | 611,033 |

Source: The Surface Transportation Board, Carload Waybill Sample

**Table 2:** Summary Statistics of Variables

| | Mean | Std. Dev. | 25th Percentile | Median | 75th Percentile |
|---|---|---|---|---|---|
| Price per Railcar ($) | 1,034 | 1,399 | 384 | 703 | 1,266 |
| Shipment Weight (Tons per Railcar) | 54 | 46 | 16 | 26 | 102 |
| Travel Distance (Miles) | 1,045 | 773 | 404 | 854 | 1,647 |
| Number of Waybills (Carrier-Origin-Destination-Date) | | | | 12,113,581 | |

Source: The Surface Transportation Board, Carload Waybill Sample

# Reduced Form Evidence

**Table 3:** Effect of Mergers on Price Change (by Route Types)

| | (1)<br>Log Price | (2)<br>Log Price |
|---|---|---|
| Indicator of Merger | $-0.093^{***}$ | |
| | (0.0142) | |
| Indicator of Merger<br>× Indicator of Interconnecting Route | | $-0.107^{***}$ |
| | | (0.0178) |
| Indicator of Merger<br>× Indicator of Competing Route | | $-0.0690^{***}$ |
| | | (0.0180) |
| Indicator of Merger<br>× Non-interconnecting, Noncompeting Route | | $-0.0641^{***}$ |
| | | (0.0171) |
| $N$ | 12,110,107 | 12,110,107 |
| Firm FE | Yes | Yes |
| Year FE | Yes | Yes |
| $o$–$d$ Route FE | Yes | Yes |

# Reduced Form Evidence

**Table 4:** Effect of Merger on Price Change (by Commodities)

| | (1) Log Price (Coal) | (2) Log Price (Food or Kindred Products) |
|---|---|---|
| Indicator of Merger | −0.179*** | −0.052*** |
| | (0.028) | (0.014) |
| Log Billed Weight | −0.030 | −0.212*** |
| | (0.020) | (0.010) |
| Ownership of Railcar (Private) | −0.096*** | −0.132*** |
| | (0.027) | (0.008) |
| Ownership of Railcar (Trailer Train) | −0.021 | −0.144*** |
| | (0.071) | (0.016) |

# Demand

- Utility of customer $i$, service $s$ between origin-destination $od$ at time $t$

$$u_{is,odt} = \alpha p_{s,odt} + \beta_1 \log Miles_{s,odt} + \underbrace{\alpha_{os} + \alpha_{ds} + \alpha_{od} + \alpha_t}_{\text{fixed effects} \equiv \Xi_{s,odt}} + \epsilon_{is,}$$

$\epsilon$ extreme value

- Demand

$$Q_{s,odt} = M_{odt} \frac{e^{\alpha p_{s,odt} + \beta_1 Miles_{s,odt} + \xi_{s,odt}}}{1 + \sum_{s'} e^{\alpha p_{s',odt} + \beta_1 Miles_{s',odt} + \xi_{s',odt}}}$$

# Firm's Problem

- Each period, firm $j$ chooses
  - Prices $\{p_{s,o_j,d_j}\}_{(o_j,d_j)\in\mathcal{Z}_j^2}$
  - Routing $\{\mathcal{R}_{j,o_j,d_j}\}_{(o_j,d_j)\in\mathcal{Z}_j^2}$
  - Maintenance $\{I_{j,ab}\}_{ab\in\mathcal{A}_j}$
- Profits

$$\pi_j = \max_{\{p\},\{\mathcal{R}\},\{I\}} \sum_{s\in S(j)} p_{s,od} Q_{s,od}(p_{s,od}, p_{-s,od}) - C(Q_j, R_j, I_j)$$

$$\text{s.t.} \sum_{ab\in\mathcal{A}_j} I_{j,ab} \leq K_j$$

$$\underbrace{\sum_{a\in\mathcal{Z}_j(z)} Q_{s,od} 1\{(a,z) \in \mathcal{R}_{j,o,d} + D_{j,z} = \sum_{b\in\mathcal{Z}_j(z)} Q_{s,od} 1\{(z,b)}_{\text{balanced flow}}$$

# Firm's Problem

- Costs

$$C(Q_j, R_j, I_j) = \sum_{od(s)} Q_{j,od(s)} \sum_{j' \in od(s)} \sum_{(a,b) \in R_{j',od(s)}} \delta \frac{Dist_{j',ab}}{I^{\gamma}_{j',ab}}$$

- Firm $j$ chooses $I_{j,ab}$ to minize its own costs, but does not take into account costs for other firms using its rails

# Equilibrium

- No congestion, constant marginal costs makes choice of $\mathcal{R}$ given $p$ and $I$ a linear program
- Assumption of no cross *od* demand elasticity and no effect of $Q_{s,o'd'}$ on cost of $Q_{s,o,d}$ helps keep price computation fast
- Equilibrium may not be unique

# Demand

**Table 5:** Results of Demand Estimation

| | OLS | | | IV | | |
|---|---|---|---|---|---|---|
| Variables | (1) | (2) | (3) | (4) | (5) | (6) |
| Price | 0.240*** | −0.280*** | −0.281*** | −0.708*** | −0.681*** | −0.720*** |
| | (0.013) | (0.012) | (0.012) | (0.059) | (0.059) | (0.059) |
| Log Track Miles | 0.485*** | 0.364*** | 0.334*** | 0.360*** | 0.358*** | 0.360*** |
| | (0.016) | (0.015) | (0.016) | (0.016) | (0.016) | (0.016) |
| Year Fixed Effect | Yes | Yes | Yes | Yes | Yes | Yes |
| $o$–$d$ Market Fixed Effect | – | Yes | Yes | Yes | Yes | Yes |
| Firm Fixed Effect | – | – | Yes | Yes | Yes | Yes |
| **Instruments** | | | | | | |
| BLP instruments | – | – | – | Yes | – | Yes |
| Predicted $\Delta HHI$ | – | – | – | – | Yes | Yes |
| First-stage F-statistic | – | – | – | 11.18 | 10.05 | 11.17 |
| **Own price elasticity** | | | | | | |
| Mean | 0.53 | −0.62 | −0.62 | −1.57 | −1.51 | −1.60 |
| Standard errors | 0.28 | 0.33 | 0.33 | 0.83 | 0.80 | 0.85 |
| Median | 0.51 | −0.60 | −0.60 | −1.51 | −1.45 | −1.53 |

Note: Demand estimates are based on 30,058 market–service–year observations in 1993, 1997, 2002, 2007. Figures in parentheses are standard errors. *** p<0.01, ** p<0.05, * p<0.1

# Costs

- Cost parameters:
  - $\eta =$ cost of interchange
  - $\delta =$ scaling factor
  - $\gamma =$ economies of scope in maintenance (important for merger efficiency changes)
- Estimated by indirect inference / simulated method of moments

# Cost Moment Fits

**Table 6:** Comparison of Data and Simulated Moments

| | (1) Identification | (2) Data Moments | (3) Simulated Moments |
|---|---|---|---|
| Average shipping price (per loaded car per mile) | pin down $\delta$ | \$0.65 | \$0.65 |
| Average difference of price between interconnecting route and non-interconnecting route (per loaded car per mile) | pin down $\eta$ | \$0.26 | \$0.24 |
| *Moments related to network measures* | | | |
| $m_1$ (coefficient of degree centrality) | pin down $\gamma$, $\delta$ | −\$0.0014 (0.0008) | −\$0.0016 (0.0000) |
| $m_2$ (coefficient of betweenness centrality) | pin down $\gamma$, $\delta$ | −\$0.2984 (0.0094) | −\$0.3017 (0.0083) |

# Cost Parameter Estimates

**Table 7:** Estimation Results for Cost Parameters

| | Point Estimate | 95% Confidence Interval |
|---|---|---|
| $\delta$ | 1.2 | [1.10, 1.29] |
| $\eta$ | 217 | [155, 279] |
| $\gamma$ | 0.17 | [0.14, 0.20] |

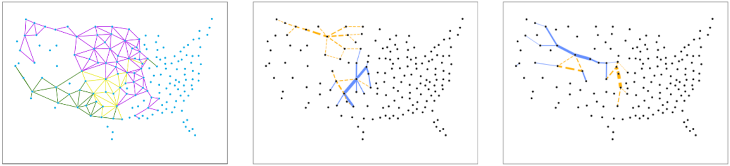
# Implied Merger Effects

**Table 8:** Average Merger Gains

| Percentage Change in: | Baseline<br>(1) Distance + Interchange Cost + Economies of Scope<br>$(\delta_0, \eta_0, \gamma_0)$ | Unpacking the Black Box<br>(2) Distance<br>$(\delta_0, 0, 0)$ | (3) Distance + Interchange Cost<br>$(\delta_0, \eta_0, 0)$ | (4) Distance + Economies of Scope<br>$(\delta_0, 0, \gamma_0)$ |
|---|---|---|---|---|
| Price | −8.8% | −1.4% | −2.8% | −3.8% |
| Cost | −12.9% | −1.9% | −3.4% | −7.2% |
| Markup | 7.2% | 0.7% | 0.7% | 6.9% |

# Mergers change resource allocation

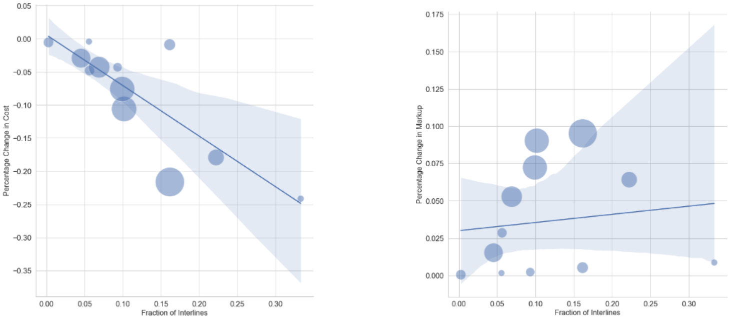
- Example: Burlington Northern & Santa Fe merged to BNSF



(a) BNSF Network (b) Changes in Resources, BNSF (c) Changes in Resources, UP

**Figure 5:** Changes in Allocation of Resources After ATSF–BN Merger

*Notes*: Panel (a) shows the combined network of the two merging firms. The purple areas in the northwest represent the network solely owned by BN, while the green areas in the south represent the network solely owned by SP. The yellow areas indicate the overlapping region of the two networks. Panel (b) shows the changes in resource allocation for BNSF's network after the merger, while Panel (c) shows the changes in resource allocation for UP's network. In Panels (b) and (c), the solid blue line represents increased allocation after merger, while the dashed yellow line represents decreased allocation. The line thickness represents the magnitude of change. Changes in allocation are calculated by comparing the equilibrium allocation of resources post merger with that pre merger.




(a) Cost Changes and Degree of Complementarity

(b) Markup Changes and Degree of Complementarity

**Figure 6:** Degree of Complementarity and Average Merger Effects

# Section 2

# Incentive regulation

- This section is based largely on Joskow (2014)

# Downsides of rate of return regulation

- Gives no incentive to control costs
  - Overinvestment
  - Too little managerial effort
- Gives no incentive for high quality
  - In transportation networks, quality $\approx$ lack of congestion
  - Uniformly applied rate of return does not give incentive about where to invest in network, e.g. http://faculty.arts.ubc.ca/pschrimpf/565/gasSlides.pdf

# Incentive regulation 1

- Incentive regulation : regulate prices such that regulated firm is the residual claimant on cost reductions and/or quality improvements
- If regulator knows the costs of an efficiently run firm, set prices such that revenues of any firm equals the costs of an efficient one

# Theoretical framework

- Allow revenues, $R = a + (1 - b)C$, where $C =$ realized costs
  - Rate of return / cost of service : $a = 0$, $b = 0$, so $R = C$.
  - Fixed price / price cap : $a = C^*$, $b = 1$
  - Sliding scale : $0 < a < C^*$, $0 < b < 1$
- $C$ depends on type of firm and managerial effort
  - Rate of return pricing gives no incentive for cost reducing effort
  - Fixed price fully incentives effort, but for all firms to be viable, $C^*$ must be set to cost of the highest cost type firm
  - Faced with distribution of cost types, optimal for regulator to offer menu of contract such that lowest cost firm chooses fixed price, others sliding scale getting closer to rate of return as cost type increases

# Practical issues

- How does regulator know $C^*$?
  - $C$ from cost accounting data like in FERC Form 2 for natural gas pipelines
  - $C^*$ typically based on either historical performance + expected improvements, and/or performance of similar firms
  - $C^*$ usually reset periodically ("ratchet") as regulator gains information
- Should a menu be used?
  - Explicit menus rarely offered, but negotiations between firms and regulator could be serving a similar purpose

# Examples 1

- England 1855-1930ish gas distribution : sliding scale mechanism, see Hammond, Johnes, and Robinson (2002)
- US electric power : some states adopted rate freezes and price caps since mid-1990s
- Price cap mechanisms : since mid 1980s UK, New Zealand, Australia, and Latin America electric, gas, water, and telecom ; US telecom
  - Initial price cap chosen, then each year changes by inflation minus target productivity growth

$$p_{t+1} = p_t(1 + RPI - x)$$

  - Periodic ratchets tradeoff incentives, rent extraction, and firm viability constraints

# UK electric distribution

- OFGEM - Office of Gas and Electricity Markets
- Operating costs - price cap with 5 year ratchet – measure of $C^*$ relatively easy and well-understood
- Capital costs - at price review, next price cap depends on future capital costs
  - Difficult to have efficient benchmark for capital costs because of variation in time and space
  - OFGEM offers menu of sliding scale contracts
    - Lower capital allowance with higher powered incentive and higher expected return on investment
- Price also affected by reaching quality of service targets

**Table 5.2** **Sliding scale matrix for capital expenditure allowance**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| DNO: PB Power ratio | 100 | 105 | 110 | 115 | 120 | 125 | 130 | 135 | 140 |
| Efficiency incentive | 40% | 38% | 35% | 33% | 30% | 28% | 25% | 23% | 20% |
| Additional income | 2.5 | 2.1 | 1.6 | 1.1 | 0.6 | –0.1 | –0.8 | –1.6 | –2.4 |
| As pretax rate of return | 0.200% | 0.168% | 0.130% | 0.090% | 0.046% | –0.004% | –0.062% | –0.124% | –0.192% |
| | | | | *Rewards and penalties* | | | | | |
| Allowed expenditure | 105 | 106.25 | 107.5 | 108.75 | 110 | 111.25 | 112.5 | 113.75 | 115 |
| Actual exp. | | | | | | | | | |
| 70 | 16.5 | 15.7 | 14.8 | 13.7 | 12.6 | 11.3 | 9.9 | 8.3 | 6.6 |
| 80 | 12.5 | 11.9 | 11.3 | 10.5 | 9.6 | 8.5 | 7.4 | 6.0 | 4.6 |
| 90 | 8.5 | 8.2 | 7.8 | 7.2 | 6.6 | 5.8 | 4.9 | 3.8 | 2.6 |
| 100 | **4.5** | 4.4 | 4.3 | 4.0 | 3.6 | 3.0 | 2.4 | 1.5 | 0.6 |
| 105 | 2.5 | **2.6** | 2.5 | 2.3 | 2.1 | 1.7 | 1.1 | 0.4 | –0.4 |
| 110 | 0.5 | 0.7 | **0.8** | 0.7 | 0.6 | 0.3 | –0.1 | –0.7 | –1.4 |
| 115 | –1.5 | –1.2 | –1.0 | **–0.9** | –0.9 | –1.1 | –1.4 | –1.8 | –2.4 |
| 120 | –3.5 | –3.1 | –2.7 | –2.5 | **–2.4** | –2.5 | –2.6 | –3.0 | –3.4 |
| 125 | –5.5 | –4.9 | –4.5 | –4.2 | –3.9 | **–3.8** | –3.9 | –4.1 | –4.4 |
| 130 | –7.5 | –6.8 | –6.2 | –5.8 | –5.4 | –5.2 | **–5.1** | –5.2 | –5.4 |
| 135 | –9.5 | –8.7 | –8.0 | –7.4 | –6.9 | –6.6 | –6.4 | **–6.3** | –6.4 |
| 140 | –11.5 | –10.6 | –9.7 | –9.0 | –8.4 | –8.0 | –7.6 | –7.5 | **–7.4** |
| Where, for example: | (top-left corner) | 16.5 = (105 – 70) × 40% + 2.5 | | | | | | | |
| | (bottom-right) | –7.4 = (115 – 140) × 20% – 2.4 | | | | | | | |

*Source:* OFGEM (2004d, 87).

# National Grid Company

- Electricity transmission in England and Wales
- Price cap with 5 year ratchets
- There is only one firm, so $C^*$ determined by historical data and engineering studies

" there are many similarities here with the way cost-of-service regulation works in practice in the United States. Indeed, perhaps the greatest difference is philosophical. OFGEM takes a view that recognizes that by providing performance based incentives for regulated utilities to reduce costs, it can yield consumer benefits in the long run by making it profitable for the firm to make efficiency improvements. If the firm overperforms against the target, consumers eventually benefit at the next price review. It has generally (though not always) been willing to allow the regulated firms to earn significantly higher returns than their cost of capital when these returns are achieved from cost savings beyond the benchmark, knowing that the next "ratchet" will convey these benefits to consumers. Under traditional US regulation, the provision of incentives through regulatory lag is more a consequence of the impracticality of frequent price reviews and changing economic conditions than by design."

# Empirical work

- Far more theory than empirical work
- Little to no structural empirical work about impact of incentive regulation
- Mostly case studies and some reduced form
- See Joskow (2014) for references

Section 3

# Cable television regulation and quality

"Monopoly Quality Degradation and Regulation in Cable Television" Gregory S. Crawford and Matthew Shum (2007)

# Introduction

- Firms with market power
  - Charge higher prices
  - If quality endogenous, provide lower quality
- Usual approach to measuring market power wrt prices : BLP - estimate demand and use optimality condition for prices to recover marginal costs
- This paper : optimality conditions for quality choice to measure quality degradation
- Relate variation in quality degradation to variation in local regulatory oversight

# Quality choice model 1

- Mussa and Rosen (1978)
- Consumer types $t_0 < t_1 < t_2$, probabilities $f_j$
- Firm chooses two qualities and prices:

$$\max_{p,q} \sum_{i=1}^{2} f_i \left[P(q_i) - C(q_i)\right]$$

s.t.

$$q_i = \arg\max q \in \{q_1, q_2\} v(q, t_i) - P(q)$$

$$v(q_i, t_i) - P(q_i) \geq 0$$

$$q_i \geq \underline{q}$$

- FOC:

$$v_q(q_1, t_1) - C_q(q_1) + \lambda = \frac{1 - F_1}{f_1}[v_q(q_1, t_2) - v_q(q_1, t_1)] \text{ and } v_q(q_2, t_2$$

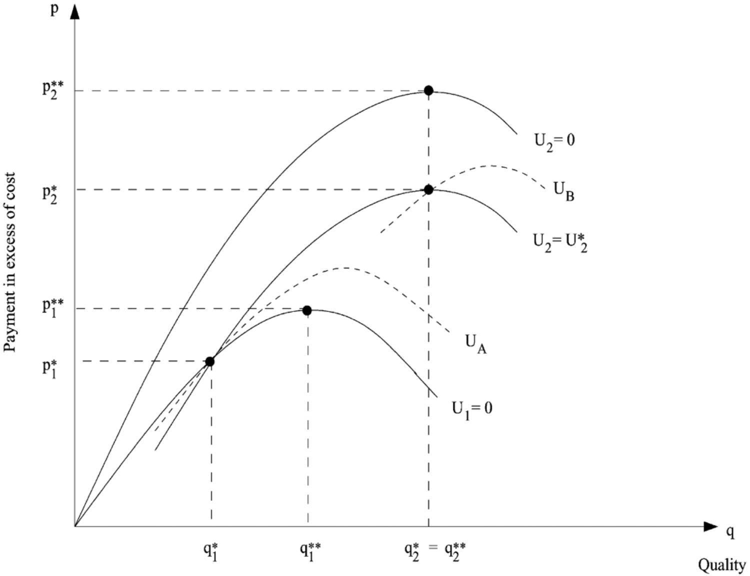



**Figure 1.** Quality degradation with two types adapted from Maskin and Riley (1984)

# Data

- US cable systems in 1995
- Quality = basic vs expanded basic service
- Regulation : 1992 cable act required price per channel reduction by 17% if local franchise authority or consumers complained to FCC

**Table 1**

Sample Statistics: Selected Characteristics

| Variable | All Markets | Three-Good Markets | Two-Good Markets | One-Good Markets |
|---|---|---|---|---|
| Expanded basic services: | | | | |
| Any | .30 | 1.00 | 1.00 | .00 |
| One | .23 | .00 | 1.00 | .00 |
| Two | .07 | 1.00 | .00 | .00 |
| Market shares: | | | | |
| $w_3$ | .66 | .47 | .61 | .70 |
| $w_2$ | .06[a] | .12 | .04 | . . . |
| $w_1$ | .04[a] | .04 | . . . | . . . |
| Prices: | | | | |
| $p_3$ | 20.40 | 25.64 | 22.69 | 19.13 |
| $p_2$ | 14.32[a] | 21.86 | 12.05 | . . . |
| $p_1$ | 16.78[a] | 16.78 | . . . | . . . |
| Programming: | | | | |
| Top 40 cable networks: | | | | |
| On service 3 | 16.55 | 22.29 | 20.85 | 14.57 |
| On service 2 | 9.14[a] | 18.15 | 6.44 | . . . |
| On service 1 | 11.94[a] | 11.94 | . . . | . . . |
| Broadcast networks: | | | | |
| Over the air | 2.54 | 3.19 | 2.85 | 2.37 |
| On cable | 5.74 | 6.57 | 6.51 | 5.40 |
| Other networks on basic | 14.36 | 10.85 | 13.18 | 15.09 |
| System characteristics: | | | | |
| Homes passed (1,000s) | 5.11 | 9.54 | 12.19 | 2.34 |
| Channel capacity | 38.87 | 43.21 | 43.55 | 36.91 |
| Market characteristics: | | | | |
| Income: | | | | |
| Mean | 28.83 | 28.27 | 30.11 | 30.15 |
| Standard deviation | 24.61 | 24.15 | 25.52 | 26.21 |
| Skew | 2.69 | 2.70 | 2.64 | 2.68 |
| Age: | | | | |
| Mean | 36.22 | 36.36 | 35.75 | 36.34 |
| Standard deviation | 23.20 | 23.36 | 22.74 | 23.03 |
| Skew | .16 | .15 | .18 | .15 |
| Household size: | | | | |

**Table 2**

Top 15 Cable Programming Networks

| Rank | Network | Subscribers (millions) | Programming Format |
|---|---|---|---|
| 1 | TBS Superstation | 77.0 | General interest |
| 2 | Discovery Channel | 76.4 | Nature |
| 3 | ESPN | 76.2 | Sports |
| 4 | USA Network | 75.8 | General interest |
| 5 | C-SPAN | 75.7 | Public affairs |
| 6 | TNT | 75.6 | General interest |
| 7 | FOX Family Channel | 74.0 | General interest/kids |
| 8 | TNN (The Nashville Network) | 74.0 | General interest/country |
| 9 | Lifetime Television | 73.4 | Women's |
| 10 | CNN (Cable News Network) | 73.0 | News |
| 11 | A&E | 73.0 | General interest |
| 12 | The Weather Channel | 72.0 | Weather |
| 13 | QVC | 70.1 | Home shopping |
| 14 | The Learning Channel (TLC) | 70.0 | Science |
| 15 | MTV: Music Television | 69.4 | Music |

**Note.** Data on network subscribers are from National Cable and Telecommunications Association, Top 20 Cable Programming Networks—as of December 2006 (http://www.ncta.com/ContentView.aspx?contentID=74). Data on programming formats from individual network promotional material are from National Cable and Telecommunications Association, Cable Networks (http://www.ncta.com/Organizations.aspx?type=orgtyp2&contentID=2907) or industry sources.

**Table 3**

Preliminary Evidence of Quality Degradation

| | Three-Good Markets | | Two-Good Markets | |
|---|---|---|---|---|
| Total Prices/Channels | Mean | Difference | Mean | Difference |
| $p_3$/channel | 1.06 (.03) | −.04 (.01) | 1.10 (.03) | −.61 (.06) |
| $p_2$/channel | 1.10 (.03) | −.13 (.02) | 1.72 (.07) | . . . |
| $p_1$/channel | 1.23 (.04) | | . . . | |
| $N$ | 72 | | 239 | |

**Note.** Reported are the average price per channel for each offered cable service. Channels include all top 40 satellite channels and, for the lowest quality service, all major broadcast networks. Ratios are formed with total price and total channels. Values in the Difference columns are the difference in price per channel in that row and the row that follows. The cable system in one two-good market included no satellite or broadcast networks in its lowest quality service. Standard errors are in parentheses.

# Estimation

- Functional forms $u(q,t) = tq - p$, $C(q) = q^2/2$
  - Implies socially optimal $q_i^{**} = t_i$
- Market shares $= \hat{f}_i$
- Prices $p_i = t_i q_i - u_i(q_i)$
- Quality $q_i = \begin{cases} t_n & \text{if } i = n \\ t_i = \frac{1-F_i}{f_i}(t_{i+1} - t_i) & \text{otherwise} \end{cases}$
- Utilities $u_i = \sum_{i'=1}^{i-1}(t_{i'+1} - t_{i'})q_{i'}$, $u_1 = 0$

**Table 5**

Recovered Parameter Values and Implied Qualities

| Variable | Three-Good Markets | Two-Good Markets | One-Good Markets |
|---|---|---|---|
| Net type distribution: | | | |
| $\bar{f}_3$ | .47 | .61 | .70 |
| $\bar{f}_2$ | .12 | .04 | . . . |
| $\bar{f}_1$ | .04 | . . . | . . . |
| $\underline{f}_0$ | .37 | .35 | .30 |
| $\bar{t}_3$ | 5.15 | 4.77 | 4.35 |
| $\bar{t}_2$ | 4.99 | 4.65 | . . . |
| $\bar{t}_1$ | 4.90 | . . . | . . . |
| Qualities: | | | |
| $q_3$ | 5.15 | 4.77 | 4.35 |
| $q_2$ | 4.43 | 2.57 | . . . |
| $q_1$ | 3.42 | . . . | . . . |
| % Degradation: | | | |
| $(\bar{t}_3 - q_3)/\bar{t}_3$ | .00 | .00 | .00 |
| $(\bar{t}_2 - q_2)/\bar{t}_2$ | .11 | .45 | . . . |
| $(\bar{t}_1 - q_1)/\bar{t}_1$ | .30 | . . . | . . . |
| Price/quality ratio | | | |
| $q_3/p_3$ | .20 | .21 | .23 |
| $q_2/p_2$ | .21 | .21 | . . . |
| $q_1/p_1$ | .21 | . . . | . . . |
| $N$ | 72 | 240 | 730 |

**Note.** Parameters of net type distribution are obtained using the procedure in Section 4.2. Quality measures are calculated using equation (12). Percentage of degradation evaluated at cut types is defined as the marginal type just inclined to purchase that quality.

# Table 6

## Interpreting Quality Measures

| Variable | Estimate | Implied Mean WTP ($) |
|---|---|---|
| WTBS | .53 (.03) | 2.39 |
| Discovery | .16 (.04) | .73 |
| ESPN | .94 (.04) | 4.22 |
| USA | .33 (.03) | 1.49 |
| CSPAN | .08 (.03) | .34 |
| TNT | −.13 (.04) | −.59 |
| Family | .47 (.03) | 2.13 |
| Nashville | .31 (.03) | 1.38 |
| Lifetime | .02 (.03) | .09 |
| CNN | .21 (.03) | .94 |
| A&E | .22 (.03) | 1.01 |
| Weather | .02 (.03) | .10 |
| QVC | .57 (.04) | 2.57 |
| Learning | .15 (.04) | .67 |
| MTV | .08 (.03) | .37 |
| Other networks | .04 (.00) | .18 |

**Note.** Coefficient estimates from regression of recovered quality levels on broadcast and cable programming variables. Reported are results for the top 15 cable networks listed in Table 2. The results are pooled across all markets and across all bundles within a market. Standard errors are in parentheses. The second column is from the authors' calculations; the estimated willingness

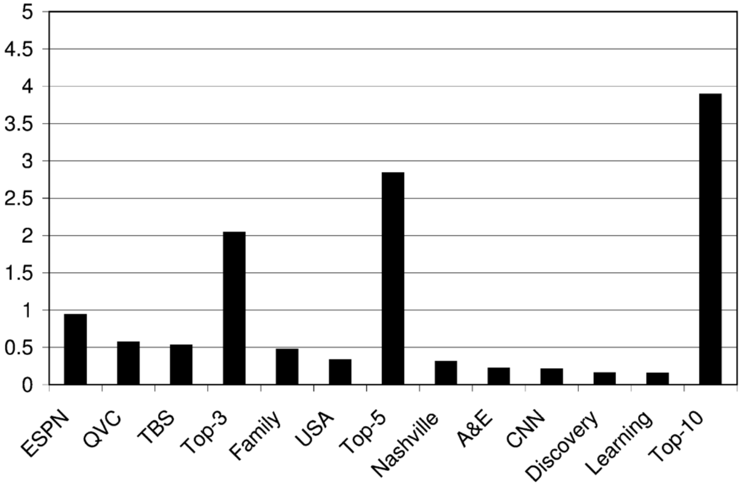



**Figure 3.** Recovered quality levels for top-networks results from Table 6

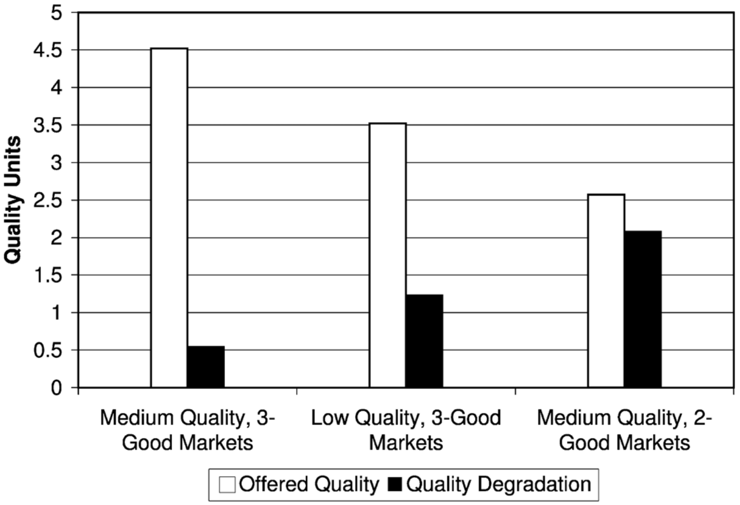



**Figure 4.** Quality and quality degradation by market results from Table 5

**Table 7**

Determinants of Cable Service Quality

| | Ordinary Least Squares | | | Instrumental Variables | | |
|---|---|---|---|---|---|---|
| Variable | All Qualities | High Quality | Low and Medium Qualities | All Qualities | High Quality | Low and Medium Qualities |
| System characteristics: | | | | | | |
| Homes passed | 2.600 (1.080) | 1.790 (.853) | 3.010 (1.560) | −3.020 (5.470) | 1.810 (2.400) | −5.430 (9.450) |
| Channel capacity | .007 (.001) | .010 (.001) | .005 (.002) | .000 (.007) | .010 (.003) | −.005 (.011) |
| Market characteristics: | | | | | | |
| Mean income | .002 (.004) | −.003 (.003) | .004 (.006) | .021 (.019) | −.003 (.008) | .034 (.033) |
| Skew of income | −.088 (.041) | −.018 (.032) | −.123 (.058) | −.164 (.101) | −.017 (.044) | −.237 (.174) |
| Mean age | .068 (.017) | .030 (.013) | .087 (.024) | .092 (.037) | .030 (.016) | .123 (.065) |
| Standard deviation of age | −.165 (.030) | −.080 (.024) | −.208 (.044) | −.085 (.091) | −.080 (.040) | −.088 (.157) |
| Mean household size | .275 (.128) | .143 (.101) | .341 (.184) | .449 (.279) | .143 (.123) | .602 (.482) |
| Skew of household size | .410 (.073) | .144 (.058) | .543 (.105) | .180 (.247) | .145 (.109) | .198 (.426) |
| Regulatory characteristic: certification | .522 (.057) | .147 (.045) | .710 (.082) | 5.271 (4.327) | .127 (1.901) | 7.843 (7.469) |
| $N$ | 1,426 | 1,042 | 384 | 1,426 | 1,042 | 384 |

**Note.** Instrumental variables regressions use share of primary county population living in rural areas to instrument for regulatory certification. Standard errors are in parentheses.

**Table 8**

Further Effects of Certification

| Variable | Quality Degradation, Low and Medium Qualities | Number of Services, All Qualities | Total Price | | Quality/Price Ratio | |
|---|---|---|---|---|---|---|
| | | | High Quality | Low and Medium Qualities | High Quality | Low and Medium Qualities |
| System characteristics: | | | | | | |
| Homes passed | .808 (.394) | 3.700 (1.060) | 15.200 (7.460) | 14.700 (7.630) | −.032 (.046) | .391 (.099) |
| Channel capacity | .003 (.001) | .004 (.001) | .082 (.010) | .025 (.010) | −.001 (.000) | .000 (.000) |
| Market characteristics: | | | | | | |
| Mean income | −.002 (.002) | .001 (.004) | −.011 (.028) | .027 (.029) | .000 (.000) | .000 (.000) |
| Skew of income | .038 (.030) | −.059 (.040) | −.179 (.280) | −.632 (.286) | .000 (.002) | −.006 (.004) |
| Mean age | −.007 (.010) | .049 (.016) | .289 (.116) | .429 (.118) | −.001 (.001) | .005 (.002) |
| Variance of age | .001 (.019) | −.129 (.030) | −.741 (.209) | −1.018 (.214) | .003 (.001) | −.014 (.003) |
| Mean household size | −.088 (.086) | .155 (.125) | 1.383 (.882) | 1.732 (.902) | −.006 (.005) | .016 (.012) |
| Skew of household size | −.118 (.047) | .286 (.071) | 1.077 (.503) | 2.597 (.515) | −.005 (.003) | .031 (.007) |
| Regulatory characteristic: certification | −.093 (.026) | .344 (.056) | 1.177 (.394) | 3.547 (.403) | −.006 (.002) | .035 (.005) |
| *N* | 384 | 1,042 | 1,042 | 384 | 1,042 | 384 |

**Note.** Reported are coefficient estimates from ordinary least squares regressions. Parameters are pooled across services given in the column headings, with the dependent variables. Standard errors are in parentheses.

# "The Welfare Effects of Endogenous Quality Choice in Cable Television Markets" Crawford, Shcherbakov, and Shum (2015)

# Introduction

- Firms with market power
  - Charge higher prices
  - If quality endogenous, provide non-optimal quality
- Compared with Gregory S. Crawford and Matthew Shum (2007)
  - More flexible preferences
  - Marginal social benefit of quality can be higher or lower than marginal cost
  - Find quality is distorted upward
- Decompose welfare loss from monopoly into price distortion and quality distortion

# Quality markups

- Inverse demand $P(\underbrace{s}_{\text{quantity}}, \underbrace{q}_{\text{quality}})$
- Cost $c(q)s$
- Social planner

$$\max_{s,q} \int_0^s P(s', q)ds' - c(q)s$$

$$[s]: \quad P(s^{SP}, q^{SP}) = c(q^{SP})$$

$$[q]: \quad \int_0^{s^{SP}} P_q(s', q^{SP})ds' = s^{SP} c_q(q^{SP})$$

- Price markup $PM(s, q) = P(s, q) - c(q)$
- Quality markup $QM(s, q) = \int_0^s P_q(s', q^{SP})ds' - sc_q(q)$

# Welfare effect decomposition

- Total surplus $TS(s,q) = \int_0^s P(s',q)ds' - c(q)s$
- Total welfare loss $\Delta TS(s,q) = TS(s^{SP}, q^{SP}) - TS(s,q)$
- Given quality, $p$ and $s$ one-to-one, so let $TS(p,q) = TS(s(p,q),q)$
- Welfare loss from market power over quality

$$MPQ = TS(p, q^{SP}(p)) - TS(p,q)$$

- Welfare loss from market power over price

$$MPP = TS(p^{SP}, q^{SP}) - TS(p, q^{SP}(p))$$

- $\Delta TS(p,q) = MPP(p,q) + MPQ(p,q)$

# Data

- Annual data on 3931 cable systems from 1997-2006
- Prices and market shares of cable and satellite tiers
- Quality = sum of average cost of channels offered

**Table 2:** Data summary statistics, 1997-2006

| | **Mean** | **StdDev** | **Min** | **Max** |
|---|---|---|---|---|
| Periods and Products | | | | |
| Time periods | 2.1 | 1.2 | 1 | 9 |
| Cable products | 1.5 | 0.7 | 1 | 3 |
| Satellite products | 5.2 | 1.4 | 3 | 6 |
| Market shares | | | | |
| $s^c$ | 0.54 | 0.19 | 0.05 | 0.90 |
| $s^s$ | 0.15 | 0.12 | 0.01 | 0.88 |
| Prices | | | | |
| Cable | | | | |
| $p^c_{Low}$ | \$20.44 | \$7.71 | \$2.68 | \$81.86 |
| $p^c_{Med}$ | \$32.77 | \$14.59 | \$7.88 | \$136.30 |
| $p^c_{High}$ | \$60.28 | \$23.79 | \$16.90 | \$291.08 |
| Satellite | | | | |
| $p^s_{Low}$ | \$21.69 | \$9.33 | \$14.44 | \$39.24 |
| $p^s_{Med}$ | \$27.15 | \$9.06 | \$19.26 | \$43.61 |
| $p^s_{High}$ | \$45.95 | \$22.94 | \$28.89 | \$87.22 |
| Quality | | | | |
| Cable | | | | |
| $q^c_{Low}$ | 3.09 | 1.81 | 0.30 | 13.13 |
| $q^c_{Med}$ | 5.76 | 2.63 | 0.71 | 16.86 |
| $q^c_{High}$ | 9.11 | 3.45 | 2.34 | 19.02 |
| Satellite | | | | |
| $q^s_{Low}$ | 5.12 | 3.49 | 1.78 | 11.73 |
| $q^s_{Med}$ | 6.48 | 3.16 | 3.30 | 12.67 |
| $q^s_{High}$ | 10.77 | 6.51 | 5.65 | 27.88 |
| Other Vars | | | | |
| Miles of plant | 0.160 | 0.560 | 0.000 | 17.690 |
| Channel capacity | 44.9 | 20.2 | 5 | 542 |

**Table 3:** Exploratory evidence of quality degradation

| | Three-Good Markets | | Two-Good Markets | |
|---|---|---|---|---|
| | **Mean** | **Diff** | **Mean** | **Diff** |
| Prices-per-channel | | | | |
| $p_2/channels_2$ | 1.28 (0.64) | 0.46 (0.34) | 1.38 (0.82) | -0.31 (1.50) |
| $p_1/channels_1$ | 0.81 (0.40) | -0.42 (0.87) | 1.69 (1.50) | |
| $p_0/channels_0$ | 1.23 (1.04) | | | |
| Prices-per-weighted-channel | | | | |
| $p_2/q_2$ | 7.27 (2.74) | 2.03 (1.74) | 6.60 (2.39) | -4.26 (10.02) |
| $p_1/q_1$ | 5.24 (2.21) | -5.11 (7.52) | 10.86 (10.20) | |
| $p_0/q_0$ | 10.34 (8.21) | | | |
| Observations | 1,360 | | 3,727 | |

*Notes:* Reported are the average price per channel and price per weighted channel for each offered cable service in our estimation sample. Weights are given by the national average input cost for that channel in the relevant year. Values in the "Difference" columns are the difference in price per channel in that row and the row that follows. Standard errors are in parentheses.

# Model

- Consumers : choose among cable, satellite, product

$$
\begin{aligned}
u_{ijgn} = & \alpha_g + (a_{i0} + a_y I_n + a_h H_n + a_u U_n) p_{jgn} + \\
& + (b_{i0} + b_y I_n + b_h H_n + b_u U_n) q_{jgn} + \xi_{gn} + \epsilon_{ijgn}
\end{aligned}
$$

- Supply :
  - assume satellite price is fixed (wrt counterfactual prices and qualities of cable systems)
  - FOC for cable systems :

$$
\begin{aligned}
[p] : \quad & s_{jcn} + \sum_r (p_{rcn} - mc_{rcn}) \frac{\partial s_{rcn}}{\partial p_{jcn}} = 0 \\
[q] : \quad & -\frac{\partial mc_{jcn}}{\partial q_{jcn}} s_{jcn} + \sum_r (p_{rcn} - mc_{rcn}) \frac{\partial s_{rcn}}{\partial q_{jcn}} = 0
\end{aligned}
$$

  - Functional form :

$$
mc_{jcn} = \exp\left( z_{jn}\theta_{s0} + v_{0jn} + (z_{jn}\theta_{s1} + v_{1jn}) \right)
$$

# Moment conditions and instruments

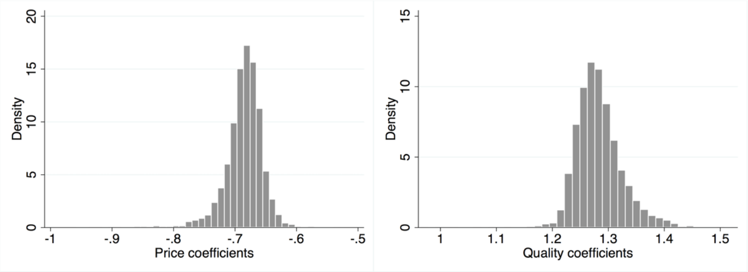
- $\mathrm{E}[\xi_{gn}|Z_{gn}] = 0$
- Average price and quality of other local cable systems owned by same multi-system operator
- Total number of subscribers of multi-system operator (shifts bargaining power)
- Average channel capacity of multi-system
- Total length of coaxial lines

**Table 4:** Estimation results

| parameter | (1) | | (2) | |
|---|---|---|---|---|
| | coef. | s.e. | coef. | s.e. |
| *price coefficient*, $\alpha_{ip}$ | | | | |
| mean | -0.673 | (0.001) | -0.682 | (0.023) |
| income | | | -0.418 | (0.091) |
| h-size | | | 0.396 | (0.062) |
| urban | | | -0.173 | (0.017) |
| sigma | 0.102 | (0.006) | 0.122 | (0.013) |
| *quality coefficient*, $\alpha_{iq}$ | | | | |
| mean | 1.108 | (0.032) | 1.225 | (0.083) |
| income | | | -0.337 | (0.413) |
| h-size | | | 0.221 | (0.144) |
| urban | | | 0.331 | (0.184) |
| sigma | 0.310 | (0.007) | 0.266 | (0.007) |
| $corr(a_{ip}, a_{iq})$ | -0.545 | (0.032) | -0.481 | (0.090) |
| demand t-dummies | Yes | | Yes | |
| supply t-dummies | Yes | | Yes | |

*Notes:* Reported are estimation results for key parameters from our structural model of demand, price, and quality choice. There are 12,214 observations, where an observation is a cable system-product-year. Full estimation results can be found in Appendix C. Specification (1) does not include market demographics in preferences, while specification (2) does. Instruments include all those described in Section 5.3; results using each variable as its own instrument (OLS-type) and a minimal set of instruments based on ownership (MSO) measures (min-IV) are presented in Appendix A. Standard errors are in parentheses.

**Figure 3:** Distributions of mean price and quality parameters across markets.

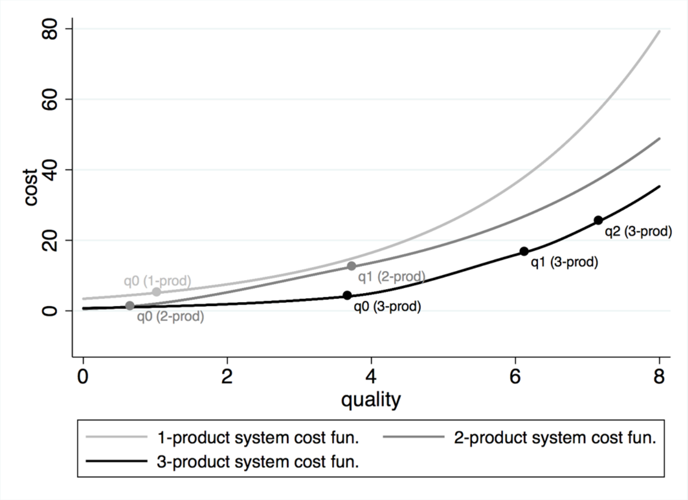



*Notes:* Reported are the estimated distributions of mean price and quality parameters across markets implied by the parameter estimates reported in Table 4.

**Table 5:** Summary statistics for the supply side estimates.

| system type | variable | mean | p50 | min | max | sd |
|---|---|---|---|---|---|---|
| 1-product | $mc_0$ | 16.81 | 17.15 | 0.03 | 46.79 | 5.79 |
| | $\partial mc/\partial q_0$ | 1.90 | 1.90 | 1.03 | 2.96 | 0.13 |
| 2-product | $mc_0$ | 13.36 | 11.44 | 0.00 | 70.42 | 9.42 |
| | $mc_1$ | 25.47 | 22.53 | 1.50 | 96.06 | 11.93 |
| | $\partial mc/\partial q_0$ | 1.79 | 1.84 | 0.07 | 2.41 | 0.25 |
| | $\partial mc/\partial q_1$ | 13.49 | 7.41 | 0.66 | 114.75 | 13.71 |
| 3-product | $mc_0$ | 12.88 | 12.16 | 0.06 | 60.46 | 8.58 |
| | $mc_1$ | 28.61 | 26.31 | 2.20 | 99.36 | 12.97 |
| | $mc_2$ | 47.80 | 45.12 | 11.46 | 119.67 | 17.43 |
| | $\partial mc/\partial q_0$ | 1.77 | 1.83 | 0.12 | 2.40 | 0.26 |
| | $\partial mc/\partial q_1$ | 4.03 | 3.64 | 0.27 | 14.31 | 1.89 |
| | $\partial mc/\partial q_2$ | 20.79 | 16.73 | 2.04 | 129.47 | 14.74 |

**Figure 4:** Estimated marginal cost functions by system type




*Notes:* Reported are the estimated marginal cost functions by system type (1, 2, or 3-product) and by product within each system type implied by the parameter estimates reported in Table 5.

**Table 6:** Estimated Price and Quality Markups

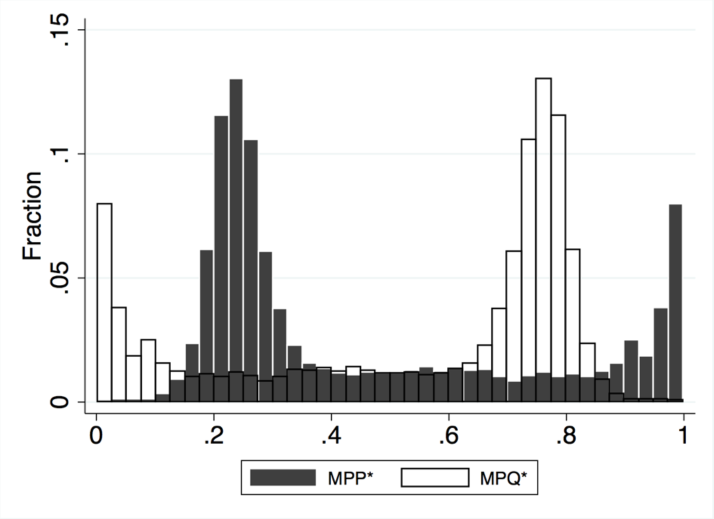
| | | Price Markups | | Quality Markups | |
|---|---|---|---|---|---|
| **Market Type** | **Obs** | **Mean** | **StdDev** | **Mean** | **StdDev** |
| One-product markets | 7,105 | 0.264 | 0.139 | 0.226 | 0.230 |
| Two-product markets | | | | | |
| Low-quality products | 3,615 | 0.320 | 0.202 | 0.426 | 0.541 |
| High-quality products | 3,615 | 0.226 | 0.100 | 0.014 | 0.049 |
| Three-product markets | | | | | |
| Low-quality products | 1,327 | 0.339 | 0.188 | 0.362 | 0.396 |
| Medium-quality products | 1,327 | 0.174 | 0.101 | 0.009 | 0.026 |
| High-quality products | 1,327 | 0.210 | 0.095 | 0.000 | 0.001 |

*Notes:* Reported are estimated price and quality markups from our baseline estimation results (Table 4, Column (2)). Price markups are reported as a percentage of price, $(p_j - mc_j)/p_j$. Quality markups are reported as a percentage of the (dollar-denominated) utility from the quality offered on that product, $FOC^{SP}[q_j]/(\frac{\alpha_{qn}}{\alpha_{pn}})q_{jn}$, where $FOC^{SP}[q_j]$ is the social planner's first-order condition for $q_j$, defined in equation (33) above. Estimated values are averaged across markets by market type (1, 2, or 3-product markets) and product type within market type.

**Table 7:** Welfare effects of market power over quality (and price)

| | **Column A**: Market Power over Quality (MPQ) | | **Column B**: Market Power over Price (MPP) | | **Column C**: Total Welfare Effect | |
|---|---|---|---|---|---|---|
| | $(p^{Obs},q^{Obs})$ vs $(p^{Obs},q^{SP})$ | | $(p^{Obs},q^{SP})$ vs $(p^{SP},q^{SP})$ | | $(p^{Obs},q^{Obs})$ vs $(p^{SP},q^{SP})$ | |
| | **Mean** | **StdDev** | **Mean** | **StdDev** | **Mean** | **StdDev** |
| Prices | | | | | | |
| Low-quality products | — | — | -0.330 | 0.180 | -0.330 | 0.180 |
| Medium-quality products | — | — | -0.590 | 0.220 | -0.590 | 0.220 |
| High-quality products | — | — | -0.740 | 0.130 | -0.740 | 0.130 |
| Qualities | | | | | | |
| Low-quality products | 0.550 | 0.720 | — | — | -0.230 | 0.910 |
| Medium-quality products | 0.070 | 0.110 | — | — | -0.370 | 0.410 |
| High-quality products | 0.070 | 0.040 | — | — | -0.550 | 0.260 |
| Welfare | | | | | | |
| Consumer surplus | 0.430 | 0.290 | 0.540 | 0.420 | 1.160 | 0.520 |
| Profit | -0.330 | 0.240 | -1.000 | — | -1.000 | — |
| Total Surplus | 0.100 | 0.060 | 0.070 | 0.050 | 0.170 | 0.070 |
| Share of welfare | | | | | | |
| Due to Market Power over Price (MPP) | | | | | 0.460 | 0.290 |
| Due to Market Power over Quality (MPQ) | | | | | 0.540 | 0.290 |

**Figure 5:** Histograms for $MPP^*$ and $MPQ^*$



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