

The Welfare Effects of Endogenous Quality Choice: The Case of Cable Television

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Motivation

- The past decade has seen a surge in empirical analysis of differentiated product markets incorporating a common empirical framework (Berry (1994), Berry, Levinsohn, and Pakes (1995)):
 1. Random utility demand
 2. Imperfectly competitive supply (pricing) and Nash equilibrium
- Many applications, inc.
 - Measuring market power (Nevo (2001)),
 - Conducting merger simulations (Berry and Pakes (1993)),
 - Testing for price discrimination (Verboven (2002)),
 - Quantifying the benefit of new goods (Petrin (2003)),

Motivation, cont.

A possible problem:

- Most of these papers take the set of products offered by firms as given.

Why care?

1. Offered products are likely *endogenous*.
 - Existing approaches yield inconsistent estimates of consumer preferences.
2. Offered products differ from efficient offerings.
 - Understanding these differences important for competition and regulation policy.

This Paper

- Measures the welfare effects of endogenous quality choice by a multiproduct monopolist.
 - By how much do offered qualities differ from efficient levels?
 - What are the welfare consequences of these differences?

How?

- Introduce screening models of optimal nonlinear pricing (Mussa and Rosen (1978), Rochet and Stole (2002))
 - Adapt them to the (empirically relevant) case of continuous types but discrete qualities.
- Apply them to analyze quality choice for Basic cable television services.

Related Literatures

1. Empirical studies of quality-based price discrimination
 - Clerides (2002), Verboven (2002), Leslie (2004)
 - McManus (2001)
2. Research analyzing entry and product choice
 - Bresnahan and Reiss (1987), Berry (1992)
 - Stavins (1995), Mazzeo (2002), Cohen and Mazzeo (2005)
3. Empirical research applying principal-agent models of adverse selection
 - Wolak (1994), Miravete (2002)
 - Ivaldi and Martimort (1994), Miravete and Roller (2003)

What is "Quality"?

- Firms in most product markets select an array of product characteristics in addition to price.
- We will consider the case of a one-dimensional product space (i.e. "quality").
 - This works in cable television where products are bundles of TV networks that include smaller offered bundles.
 - If time, we can discuss how to extend the framework presented here to multi-dimensional characteristic spaces.

What We Measure

- There are two sources of quality distortion that we measure in our empirical work:
 1. Single-Product-Monopoly-Type distortions due to differences in marginal valuation of quality for the marginal versus average consumer (Spence (1975)).
 - This is most relevant in one-good markets and for the highest-quality good in multiple-good markets.
 2. Multi-Product-Monopoly-Type distortions (degradation) due to screening incentives (Mussa and Rosen (1978), Rochet and Stole (2002)).

Quality Choice by a Single-Product Monopolist (Spence (1975))

- Optimal quality choice by a monopolist equates

$$P_q(q, Q) = c_q(q) \quad (1)$$

where

- $P_q(q, Q)$, the derivative of WTP w.r.t. quality, is the "Marginal Valuation of Quality" (for the marginal consumer, Q)
- $c_q(q)$, the derivative of marginal (quantity) cost w.r.t. quality, is the "Marginal Marginal Cost of Quality".

Efficient Quality Choice

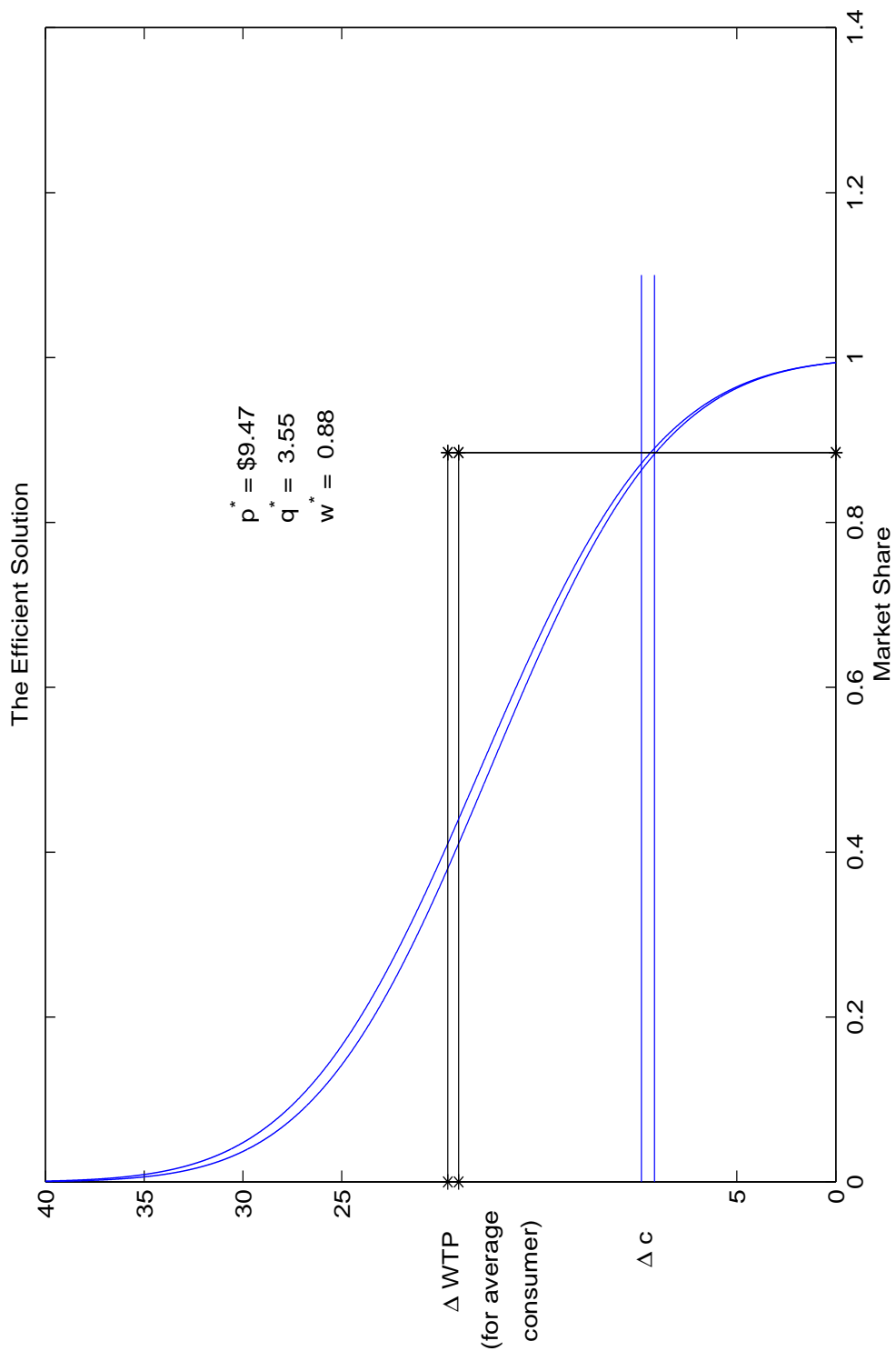
- Optimal quality choice by a social planner equates

$$\left[\frac{1}{Q} \int_0^Q P_q(s, q) ds\right] = c_q(q) \quad (2)$$

where

– $\left[\frac{1}{Q} \int_0^Q P_q(s, q) ds\right]$ is the Marginal Valuation of Quality for the *average* consumer in $[0, Q]$.

The Efficient Solution



Which is More Important? Quality Choice or Pricing?

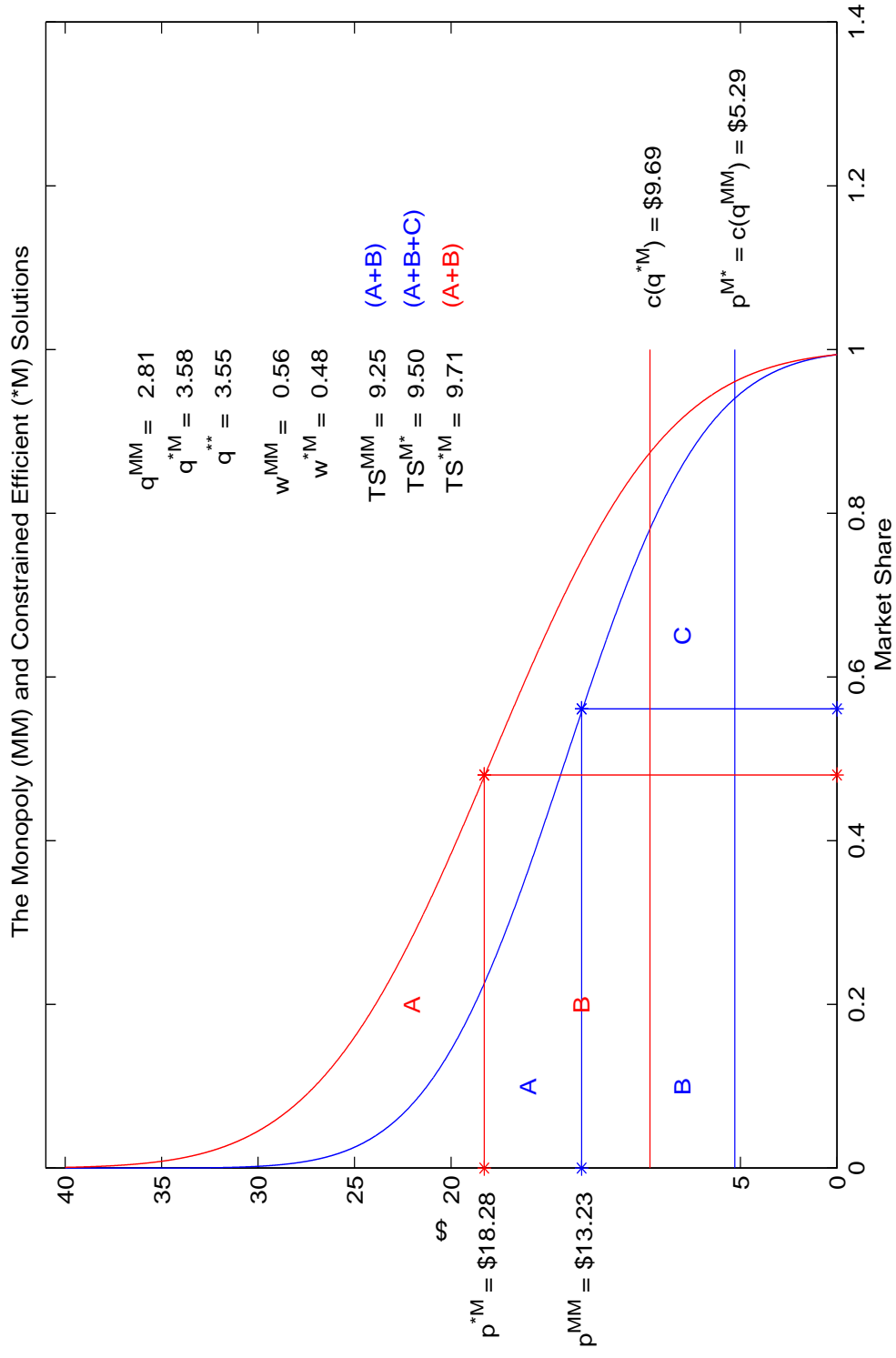
- The first figure had monopoly choice of both quality and price.
- The second figure had efficient choice of both quality and price.
- For our welfare estimates, we will take the monopoly model as the baseline.

We will then consider:

- Efficient pricing at the monopoly quality, and
- Efficient quality choice conditional on monopoly pricing...

And ask which has the greater effect on welfare: quality choice or pricing?

Which is More Important? Quality Choice or Pricing?



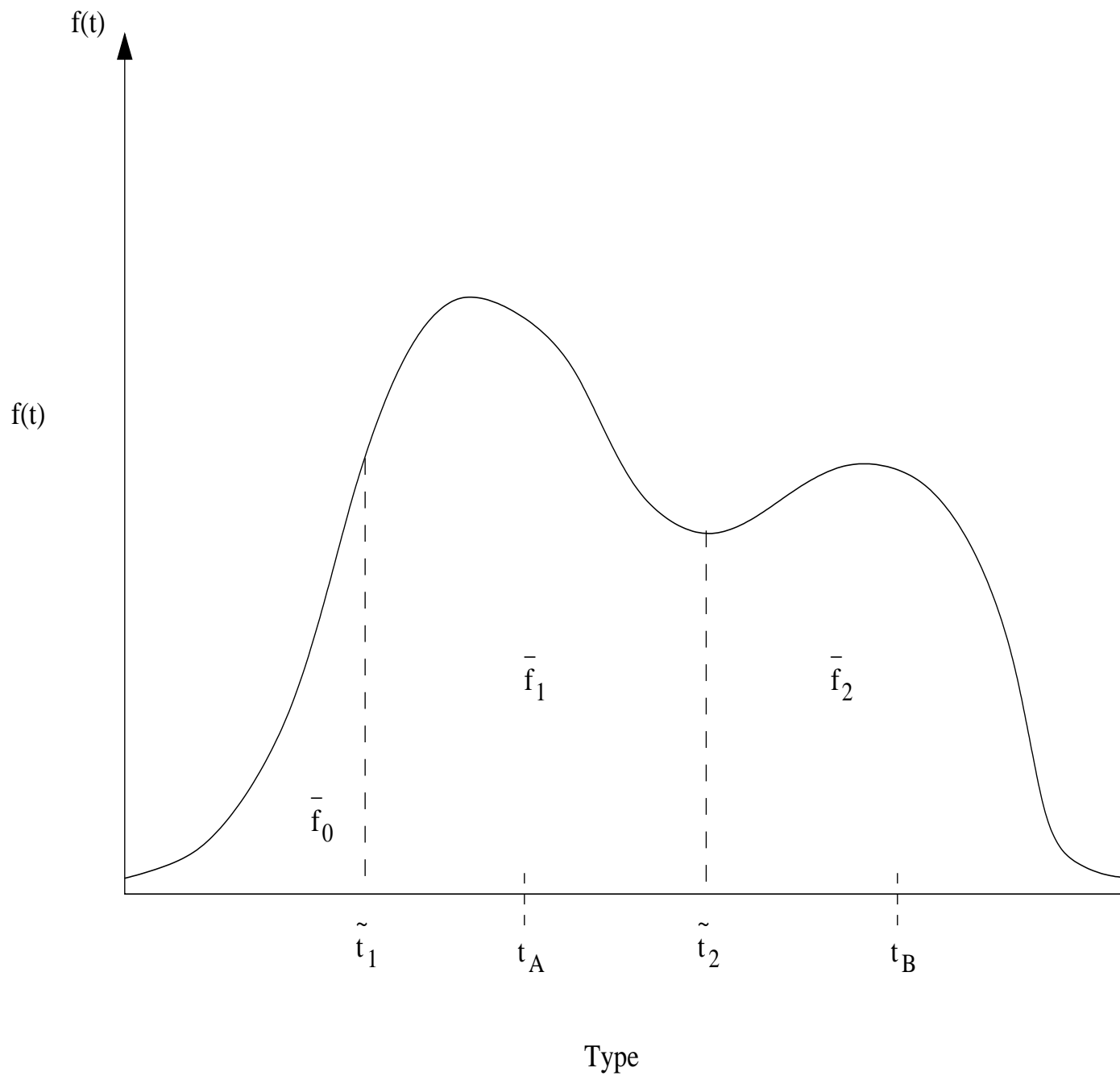
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Quality Choice by a Multi-Product Monopolist

- To optimally solve for prices and qualities for a multi-product monopolist, we apply screening models of optimal quality choice (Mussa and Rosen (1978), Rochet and Stole (2002)).
- **However**, most of the theoretical screening literature assumes either
 - Discrete preferences and discrete numbers of goods, or
 - Continuous preferences and a continuous price-quality schedule.
- Question: How do we adapt the theory to the empirically relevant case of continuous preferences but discrete numbers of goods???
- Answer: Apply the discrete-type theory (with endogenous cut-types).

Graphically:



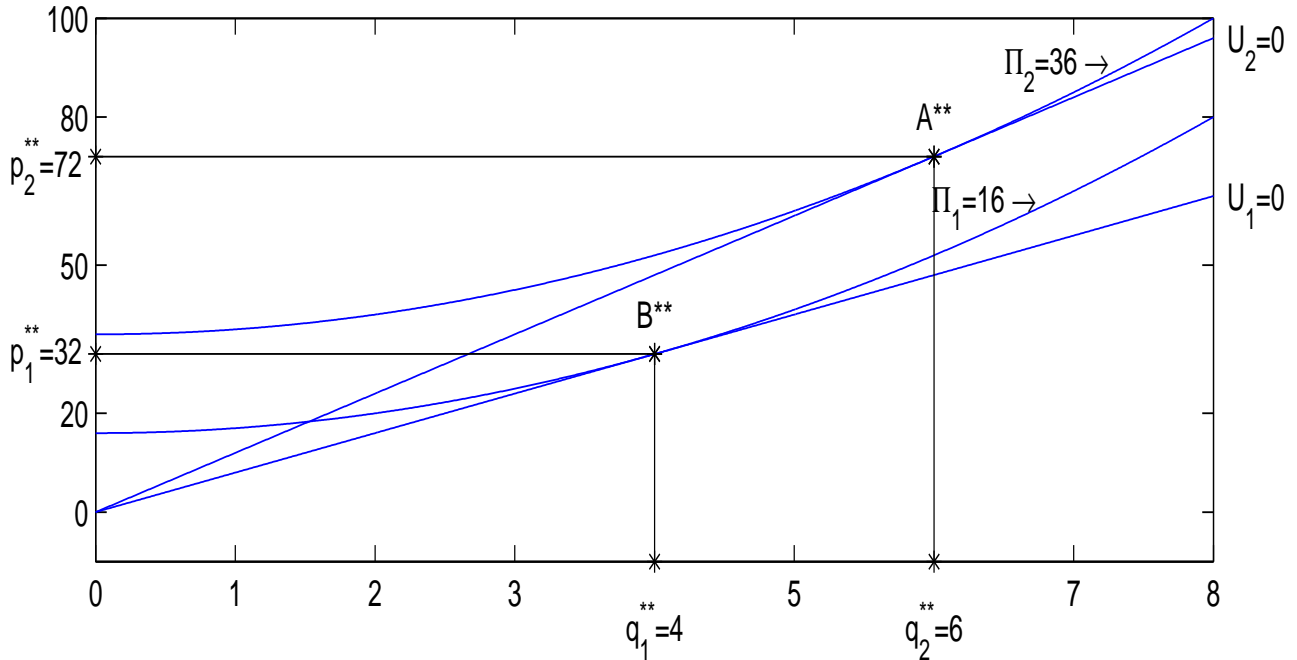
- The monopolist selects the optimal cut-types (and the optimal prices and qualities given those cut-types).

Standard Results from the Screening Literature

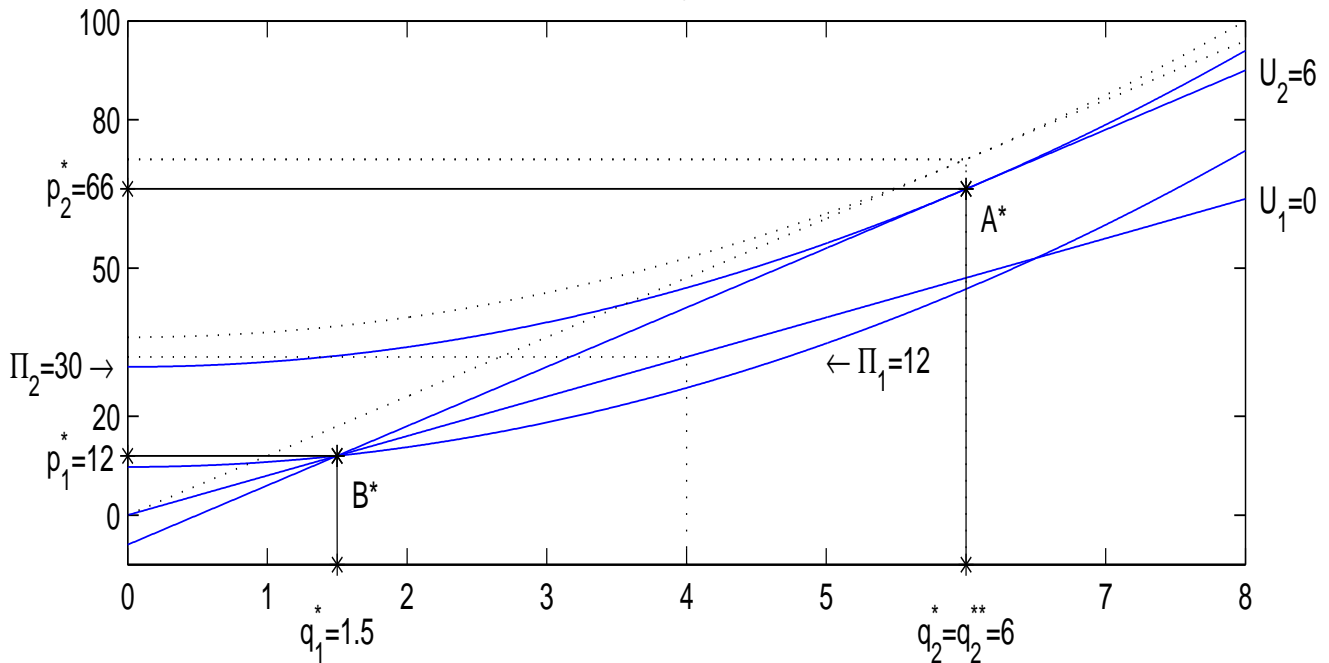
- Optimal qualities exhibit:
 - ”No-distortion at the top”, i.e. offered qualities to the highest type equate marginal valuation of quality with marginal cost of quality.
 - Qualities for other types are distorted downwards.

A Two-Type Example

A Perfectly Discriminating Monopolist



A Screening Monopolist



Rochet-Stole with Continuous Types and Discrete Qualities

- In our application, we use:
 - The Rochet and Stole (2002) model of optimal non-linear pricing *with random participation*.
 - * This is empirically more realistic than standard (Mussa and Rosen (1978)) screening models.
 - We then modify it to allow for continuous types and discrete qualities.
- The monopolist selects optimal cut-types, with optimal qualities and prices following from a discrete-type Rochet-Stole model:

$$\max_{t_{jn}} \left[\max_{q_{jn}, u_{1n}} E[\pi_n | \bar{t}_n] = \sum_{j=1}^{J_n} w_{jn}(\bar{t}_n) \{ S(q_{jn} | \bar{t}_n) - u_{jn}(q_{jn}, u_{1n} | \bar{t}_n) \} \right] \quad (3)$$

- As for the single-product case, we also consider the qualities and prices chosen by a social planner (offering the same number of goods).

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The Cable Television Industry

- Cable television systems bundle networks into services.
 - We look at
 - * Broadcast networks (ABC, CBS, NBC, Fox) and
 - * Cable networks (MTV, CNN, ESPN, etc.)
 - offered on Basic and Expanded Basic Services.
- Does cable map well to the theory?
 - Almost all U.S. cable systems (circa 1998) are monopolists
 - Little regulatory oversight: systems basically control the content and pricing of services
 - Basic and Expanded Basic services *cumulative*
 - * By definition increasing in overall quality, these are the focus of the empirical model.

Table 1: Sample Statistics

Selected Characteristics

Variable	All Markets	3-Good Markets	2-Good Markets	1-Good Markets
Expanded Basic Services				
Any Exp. Basic Svcs.	0.29	1.00	1.00	0.00
One Exp. Basic Svc.	0.26	0.00	1.00	0.00
Two Exp. Basic Svcs.	0.04	1.00	0.00	0.00
Market Shares				
w_3	0.61	0.47	0.60	0.62
w_2	0.03	0.13	0.09	—
w_1	0.00	0.05	—	—
Prices				
p_3	21.10	29.06	23.06	19.99
p_2	4.08	22.65	12.75	—
p_1	0.64	18.26	—	—
Programming				
Top-20 Cable Networks				
On Service 3	11.86	16.40	15.62	10.27
On Service 2	2.28	13.18	7.05	—
On Service 1	0.30	8.57	—	—
Other Than Top-20 Cable Networks				
On Service 3	4.09	8.43	5.97	3.19
On Service 2	0.87	5.62	2.61	0.00
On Service 1	0.15	4.36	0.00	0.00
Homes Passed (millions)	6.50	8.63	14.22	3.58
Channel Capacity	38.61	43.83	44.96	36.04
Per-Capity Income	16.58	17.33	17.76	16.11
Franchise Fee	1.44	3.09	2.05	1.13
Observations	5,702	201	1,467	4,034

- Note:

- Systems in the data offer either 1, 2, or 3 services.

- Products are indexed "from-the-top":

- * The product with the most networks/highest price is product 3, even if it is the only product in the market.

Table 2: Quality Degradation in the Data

Total Prices/Channels	3-Good Markets		2-Good Markets	
	Mean	Difference	Mean	Difference
p_3 /channel	1.23 (0.02)	-0.06 (0.01)	1.18 (0.02)	-1.11 (0.06)
p_2 /channel	1.29 (0.03)	-0.41 (0.07)	2.28 (0.06)	—
p_1 /channel	1.69 (0.08)		—	
Observations	199		1,408	

The Empirical Model: Preferences

- Preferences:

$$u_{ijn} = t_{in}q_{jn} - p_{jn} \quad (4)$$

$$u_{ij0} = \epsilon_{in}$$

– with:

$$t_{in} = \tau_{in} + \eta_n + NG'_n \mu_n + \gamma y_n \quad (5)$$

- * $\tau_{in} \sim N(\mu, \sigma^2 + NG'_n \sigma_n)$

- * $\eta_n \sim N(0, \sigma_\eta^2)$

- * y_n = per-capita income in market n

- * NG'_n = the number of goods offered in market n

- * $\epsilon_{in} \sim \text{Exp}(\lambda)$

- Note the model accommodates both

- within-market heterogeneity (τ_{in}) as well as

- observed and unobserved across-market heterogeneity (y_n, η_n).

The Empirical Model: Costs

- Costs:

$$c_{jn}(q_{jn}) = c_0 + (c_1 - \nu_{jn})q_{jn} + (c_2/\rho)q_{jn}^\rho \quad (6)$$

- ν_{jn} = shocks to marginal costs of quality for product j in market n .
- For now, we do not introduce cost shifters.

Identification

- In the estimation, quality is assumed to be unobserved.
 - It comes from the solution of the monopolist's problem, i.e.
$$q_{jn} = q_{jn}(\mu_n, \sigma_n, \lambda, \text{etc.}).$$
- Market shares and prices are therefore complicated nonlinear functions of all the structural parameters...

So What's Driving the Identification???

Identification, cont.

- Identification for our current estimates is driven by the restrictions implied by the model:
 - For example, if two markets have similar market shares but different prices, it must be that WTP is higher in the higher-price market.
- Going forward, note that the *networks* offered on cable service are common across markets.
- Differences in (e.g.) prices for similar bundles of programming should therefore be driven by differences in WTP or costs.
 - We will be able to exploit variation in the contents of bundles, demographic features of markets (e.g. income, household size), and the identities of cable systems to separately identify quality, preferences, and costs.

The Empirical Model: Estimation

- The estimation compares moments of the observed data with those generated by the model.
- q_{jn} is assumed to be unobserved
 - We rely on model predictions for market shares, w_{jn} , and prices, p_{jn} , for products $j = 1, \dots, J_n$ in n .
 - * We can also (but don't yet) predict the number of products, J_n .

Estimation Specifics, Step 1:

Parameter Estimation

- Recall the monopolist maximizes

$$\max_{\bar{t}_n} \left[\max_{q_{jn}, u_{1n}} E[\pi_n | \bar{t}_n] = \sum_{j=1}^{J_n} w_{jn}(\bar{t}_n) \{S(q_{jn} | \bar{t}_n) - u_{jn}(q_{jn}, u_{1n} | \bar{t}_n)\} \right] \quad (7)$$

- We employ a three-level nested estimation algorithm:
 1. In the *inner loop*, we solve for the optimal qualities and lowest utility, (q_{jn}, u_{1n}) , as a function of the current cut-types, \bar{t}_{jn} , in market n
 - Predictions for the observed prices and market shares follow from these qualities/utility.
 2. In the *middle loop*, we solve for the optimal cut-types, \bar{t}_{jn} in market n given the current estimate of the model parameters, θ .
 3. In the *outer loop*, we search for values of model parameters, θ , that minimize the objective function, Q .

Parameter Estimation: A Computational Difficulty

- Our 3-level nested estimation algorithm can be *very* slow.
- The structure of our problem provides a solution:
 - While $f(t_{in})$ varies across markets (with NG_n , Y_n , and η_n), in each it is a normal distribution with mean μ_n and standard deviation σ_n .
 - These preference parameters – μ_n , σ_n , and λ – and the cost parameters – c_0 , c_1 , c_2 , and ρ – are all that are required to solve for all the outcome variables.
- We establish a grid over the range of reasonable values for these parameters, solve the model at those grid points, and interpolate values for all the outcome variables between those points.
- For today's (preliminary) results, we used a range of [2,6] for μ_n , [0.3,0.7] for σ_n , [0.41,0.81] for λ , [0.3,0.7] for c_0 , [0.2,0.6] for c_1 , [0.4,0.8] for c_2 , and [2,2.6] for ρ with 2 grid points in each dimension.

Table 3: Estimates

Preference Params		Cost Params	
	Estimate Std. Err.		Estimate Std. Err.
Mean WTP	4.7678	c_0	0.3233
for quality	0.9557		0.6997
StdDev WTP	0.4638	c_1	0.2002
for quality	0.1659		0 0.0411
σ_n	0.7228	c_2	0.994
	0.2141		0 0.2093
Income	0.0023	ρ	2.2115
	0.0021		0.1727
Mean ₂	0.1251		
	0.1078		
StdDev ₂	-0.0246		
	0.1688		
Mean ₃	0.8509		
	0.2206		
StdDev ₃	-0.1276		
	0.1875		
Random Part. Parameter	0.8748 0.0706		
Obs.		7,571	

Results:

- Mean WTP for quality is 4.77/4.90/5.62 in 1/2/3-good markets, respectively, with corresponding standard deviations 0.46/0.44/0.33.
- The impact of income (γ) is not significant; Unobserved across market heterogeneity (σ_η) is.

Model Fit and Quality Degradation

Fit	3-Good Markets			2-Good Markets			1-Good Markets		
	Sample	Pred	Diff	Sample	Pred	Diff	Sample	Pred	Diff
w_3	0.47	0.51	-0.04	0.60	0.53	0.07	0.62	0.63	-0.01
w_2	0.13	0.18	-0.05	0.09	0.12	-0.03	—	—	—
w_1	0.05	0.05	0.00	—	—	—	—	—	—
p_3	29.06	26.97	2.08	23.06	21.89	1.17	19.99	19.82	0.17
p_2	22.65	22.62	0.02	12.75	15.98	-3.23	—	—	—
p_1	18.26	17.62	0.64	—	—	—	—	—	—
Quality Degradation	Offered Quality	Efficient Quality	% Deg	Offered Quality	Efficient Quality	% Deg	Offered Quality	Efficient Quality	% Deg
q_3	4.41	3.97	-0.12	3.86	3.83	-0.01	3.61	3.45	-0.05
q_2	3.60	3.79	0.05	2.64	3.41	0.23	—	—	—
q_1	2.71	3.55	0.24	—	—	—	—	—	—
Observations	201			1,467			4,034		

Results:

- Moderate estimated quality degradation relative to efficient levels:
 - Offered quality to lower-quality goods at least an estimated 5% and 24% less in 3-good markets and 23% less in 2-good markets.
 - Analogous "quality markups" are -12/5/24% in 3-good markets, -1/23% in 2-good markets, and -5% in 1-good markets, substantially less than estimated price markups.

Welfare Consequences of Endogenous Quality Choice

- To assess the welfare consequences of endogenous quality choice, we consider two counterfactuals:
 1. Qualities at that set by the monopolist, but with efficient pricing.
 2. Qualities at those chosen to maximize social welfare, but monopoly pricing.

Table 4: Estimated and Counterfactual Outcomes

	3-Good Markets				2-Good Markets				1-Good Markets					
	Mon Q	Mon Q	Eff Q	Mon Q	Mon Q	Mon Q	Eff Q	Mon Q	Mon Q	Mon Q	Mon Q	Eff Q	Mon Q	Eff Q
	Mon P	Eff P	Mon P	Mon P	Eff P	Mon P	Mon P	Eff P	Mon P	Mon P	Eff P	Mon P	Mon P	Mon P
Welfare														
CS	6.15	26.93	9.15	4.32	20.71	12.85	2.98	11.96	2.87					
Profit	11.36	0.00	10.88	8.98	0.00	8.52	8.60	0.00	8.41					
TS	17.52	26.93	20.03	13.29	20.71	21.37	11.57	11.96	11.29					
Relative to Baseline														
CS	—	3.37	0.50	—	3.77	2.00	—	3.02	-0.04					
Profit	—	-1.00	-0.04	—	-1.00	-0.05	—	-1.00	-0.02					
TS	—	0.54	0.15	—	0.56	0.62	—	0.03	-0.02					

Conclusions:

- Moderate welfare consequences of monopoly quality choice:
 - Total surplus increases an estimated 3.3/55.7/53.7% in (1/2/3)-good markets from efficient pricing with monopoly qualities,...
 - By -2.4/62.1/15.1% from monopoly pricing at efficient qualities, ...
 - (And by 5.9/142.8/206.2% from efficient qualities and prices).

Conclusions

- Measures the welfare effects of endogenous quality choice by a multiproduct monopolist.
- Our preliminary results:
 1. Moderate estimated quality degradation relative to first-best levels.
 2. Welfare effects from endogenous quality can be substantial.

Short-Run Extensions

- Introduce fixed costs and optimal choice of the number of products.
- Generalize the distribution of tastes within markets.
 - Incorporate information about the distribution of demographics (income, household size, age) within markets.

Extensions

- Horizontal (brand) as well as vertical preferences?
 - Would require multi-dimensional screening approach
 - * A hard problem (e.g. Rochet and Chone (1998)), but...
 - * Discrete characteristics can simplify the problem
- Competition with endogenous product choices?
 - Would need at least two-dimensional screening plus a characterization of equilibrium.
 - Models exist, however: Stole (1995), Miravete and Roller (2003).
 - Satellite systems enter during the period in which we have data.
 - * Suggests cable/satellite a good place to look.

References

- BERRY, S. (1992): “Estimation of a model of entry in the airline industry,” *Econometrica*, 60(4), 889–917.
- (1994): “Estimating Discrete Choice Models of Product Differentiation,” *Rand Journal of Economics*, 25(2), 242–262.
- BERRY, S., J. LEVINSOHN, AND A. PAKES (1995): “Automobile Prices in Market Equilibrium,” *Econometrica*, 63, 841–890.
- BERRY, S., AND A. PAKES (1993): “Some Applications and Limitations of Recent Advances in Industrial Organization: Merger Analysis,” *American Economic Review*, 83(2), 247–252.
- BRESNAHAN, T., AND P. REISS (1987): “Do Entry Conditions Vary Across Markets,” *Brookings Papers on Economic Activity: Microeconomics*, pp. 833–871.
- CLERIDES, S. (2002): “Book value: intertemporal pricing and quality discrimination in the US market for books,” *International Journal of Industrial Organization*, 20, 1385–1408.
- COHEN, A., AND M. MAZZEO (2005): “Competition, Product Differentiation, and Quality Provision: An Empirical Analysis of Bank Branching Decisions,” mimeo, Northwestern University.
- CRAWFORD, G. (2000): “The Impact of the 1992 Cable Act on Household Demand and Welfare,” *RAND Journal of Economics*, 31(3), 422–449.
- IVALDI, M., AND D. MARTIMORT (1994): “Competition Under Non-linear Pricing,” *Annales d’Economie et de Statistique*, 34.
- LESLIE, P. (2004): “Price Discrimination in Broadway Theatre,” *Rand Journal of Economics*, pp. 520–541.
- MAZZEO, M. (2002): “Competitive Outcomes in Product Differentiated Oligopoly,” *Review of Economics and Statistics*, 84(4), 716–728.

- MCMANUS, B. (2001): “Nonlinear Pricing in an Oligopoly Market: The Case of Specialty Coffee,” mimeo., Olin School of Business, Washington University.
- MIRAVETE, E. (2002): “Estimating Demand for Local Telephone Service with Asymmetric Information and Optional Calling Plans,” *Review of Economic Studies*, 69, 943–971.
- MIRAVETE, E., AND L.-H. ROLLER (2003): “Competitive Nonlinear Pricing in Duopoly Equilibrium: The Early U.S. Cellular Telephone Industry,” CEPR Discussion Paper No. 4069.
- MUSSA, M., AND S. ROSEN (1978): “Monopoly and Product Quality,” *Journal of Economic Theory*, 18, 301–17.
- NEVO, A. (2001): “Measuring Market Power in the Ready-To-Eat Cereal Industry,” *Econometrica*, 69, 307–342.
- PETRIN, A. (2003): “Quantifying the Benefits of New Products: The Case of the Minivan,” *Journal of Political Economy*, 110, 705–729.
- ROCHET, J.-C., AND P. CHONE (1998): “Ironing, Sweeping, and Multidimensional Screening,” *Econometrica*, 66(4), 783–826.
- ROCHET, J.-C., AND L. STOLE (2002): “Nonlinear Pricing with Random Participation,” *Review of Economic Studies*, 69(1), 277–311.
- SPENCE, A. M. (1975): “Monopoly, Quality, and Regulation,” *Bell Journal of Economics*, 6, 417–29.
- STAVINS, J. (1995): “A Model of Entry and Exit in a Differentiated-Product Industry: The Personal Computer Market,” *Review of Economics and Statistics*, 77(4), 571–584.
- STOLE, L. (1995): “Nonlinear Pricing and Oligopoly,” *Journal of Economics and Management Strategy*, 4(4), 529–562.
- VERBOVEN, F. (2002): “Quality-based price discrimination and tax incidence: evidence from gasoline and diesel cars,” *Rand Journal of Economics*, 33(2), 275–297.

WOLAK, F. (1994): "Estimating Regulated Firm Production Functions with Private Information: An Application to California Water Utilities," *Annales d'Economie et de Statistique*, 34, 13–69.