

The Welfare Effects of Monopoly Quality Choice: Evidence from Cable Television Markets*

Gregory S. Crawford Oleksandr Shcherbakov
Dept. of Economics Dept. of Economics
University of Warwick University of Mannheim

Matthew Shum
Dept. of Economics
California Institute of Technology

This draft: September 19, 2011

Abstract

We measure the welfare consequences of market power over quality in cable television markets. We extend the analytical approach commonly used in the theoretical screening literature to specify an empirical model that endogenizes the prices and qualities offered by multiproduct monopoly cable television systems. We estimate the model on an unbalanced panel of xxx cable systems between xxx and 2000. Preliminary results using a single cross-section in 1998 and a simplified empirical model show significant degradation in the quality of offered cable service relative to first-best levels, the welfare consequences of which are roughly half that from monopoly pricing. The proposed empirical framework readily adapts itself to analyzing competition in prices and qualities.

*** Preliminary. Comments welcome. Please do not cite or quote. ***

*This draft is preliminary. Please do not cite or quote. Comments welcome. We would like to thank Eugenio Miravete, Gary Biglaiser, and seminar participants at Arizona, UCLA, Northwestern and the CEPR Conference on Competition in the New Economy for helpful comments. Special thanks goes to Chenghuan (Sean) Chu for providing the data used in this analysis and to Ali Yurukoglu, with whom we have had many fruitful discussions about cable television markets. Correspondance may be sent to Gregory S. Crawford, Department of Economics, University of Warwick, Coventry, CV4 7AL, United Kingdom, phone +44 2476 523470, email crawford@warwick.ac.uk, Matthew Shum, Department of Economics, 301D Baxter Hall, MC 228-77, California Institute of Technology, Pasadena, CA 91125, phone 626.395.4022, email mshum@caltech.edu, or Oleksandr (Alex) Shcherbakov, Department of Economics, University of Mannheim, L7, 3-5, 68131 Mannheim, Germany, phone +49 621 181 1838, email o.s.shcherbakov@gmail.com.

1 Introduction

Market power over price (MPP) is one of the most widely understood and enduring concepts in economics. Whereas competitive markets, under standard assumptions, ensure the maximization of welfare, MPP creates a wedge between the marginal social benefits and costs of production, introducing inefficiency in the form of deadweight loss. It is not surprising, then, that MPP is the primary focus of antitrust and/or competition law and economics.¹

There is much less focus on concerns about market power over quality (MPQ), or over non-price attributes more generally.² While the theoretical literature establishes that a single-product monopolist may offer more or less quality than a social planner in the same market (Spence (1975)), results for multi-product monopolists (under standard assumptions) demonstrate incentives to “degrade quality” for all products except the one with the highest quality (Mussa and Rosen (1978), Rochet and Stole (2002)). Despite this potential, demonstrating the presence of such “quality degradation” is rare (McManus (2007), Crawford and Shum (2007)) and, to our knowledge, there are no papers quantifying the consequences of it for consumer and total welfare.

The purpose of this paper is to measure the welfare effects of endogenous quality choice by multi-product monopolists in U.S. cable television markets. We combine the economic insights of the theoretical literatures described above to extend the recent empirical literature analyzing demand and pricing in differentiated product markets (Berry (1994), Berry et al. (1995)) to include optimal quality choice. While there are some modest methodological innovations in this extension, we intend our primary contribution to be economic. We introduce the concept of a “quality markup” measuring the difference between the marginal social benefit and cost of a change in a product’s quality. Much as a price markup is often used as a shorthand measure for the welfare loss from MPP for the marginal quantity (consumer), a product’s quality markup measures the welfare loss associated with MPQ at the marginal quality.³ We also measure how much offered qualities differ from their those given by a welfare-maximizing social planner, the welfare consequences of these differences, and the relative importance of MPP and MPQ for consumer and total welfare.

Our analysis builds on and extends previous empirical research looking at related questions. Berry and Waldfogel (2001), Sweeting (2010), and Fan (2010) empirically analyze the effects of increased market power on product variety and/or quality, but do not optimally solve for those qualities. Clerides (2002) and Verboven (2002) analyze quality-based price discrimination, but focus primarily on documenting its presence. Leslie (2004) and Draganska et al. (2009) both endogenize prices and the latter also endogenizes whether or not a product is offered, but neither compare

¹Examples include price-fixing, predatory pricing, and attempted monopolization, among others (Elhauge (2008)). Similarly, the primary concern of merger review is exercise of MPP due to unilateral or coordinated action (States (2010)).

²States (2010, Chap 1) is a notable exception, stating, “Enhanced market power can also be manifested in non-price terms and conditions that adversely affect customers, including reduced product quality, reduced product variety, reduced service, or diminished innovation.” They go on to say, “When the Agencies investigate whether a merger may lead to a substantial lessening of non-price competition, they employ an approach analogous to that used to evaluate price competition,” but do not discuss how such an analysis would proceed.

³Unlike a price markup, however, a quality markup may be positive or negative.

offered with efficient qualities. The papers closest in spirit to this one are McManus (2007) and Crawford and Shum (2007). These were the first empirical papers to measure quality degradation, but neither quantified the welfare consequences of that fact.⁴ We differ most from these two (and all the papers above) in our measurement of quality markups, the absolute and relative welfare effects of MPQ, and the integration of empirical models of differentiated product demand and pricing with optimal quality choice.

We estimate the model on a panel dataset of xxx U.S. cable television systems between 19xx and 2000. U.S. cable television markets during our sample period are well suited for our model for two reasons. First, the products cable systems offer are bundles of television networks with higher-quality bundles uniformly including all of the networks in lower quality bundles (and more). Limiting an empirical analysis to a single dimension of product quality is therefore reasonable in this setting. Second, cable television systems in this period are largely local monopolies; while satellite competitors entered in the mid-1990s, regulations on their ability to import local broadcast networks limited their ability to compete with incumbent cable systems.⁵ Cable systems in our data serve geographically distinct local cable markets. Within the sample, each offers at most 3 bundles of networks. For each offered bundle, we observe the price charged, its market share, and the television networks it offers. Following previous work in this literature (Chu (2006), Shcherbakov (2010)), we use a weighted total number of television networks in a bundle as our measure of quality for that bundle, with weights for each channel given by the input costs paid by cable systems for that channel.⁶ We also observe (at the market level) variables that shift demand and costs across markets.

The empirical framework we propose is based closely on the empirical analysis of differentiated product markets popularized by Berry (1994) and Berry et al. (1995).⁷ On the demand side, we specify a Random Coefficient Logit (RCL) model with a single random coefficient on quality.⁸ We specify total costs that are linear in quantity, with the marginal cost of a product increasing and convex in its quality. We also estimate a distribution of fixed costs associated with offering either two or three products. Firms maximize profits choosing the number of products to offer and, for that number, the optimal prices and qualities of those products. Estimation is by GMM using

⁴This paper extends the analysis in Crawford and Shum (2007) by (1) using a much larger, panel, dataset, (2) extending the empirical model to reconcile it with those more commonly used in the empirical IO literature, and (3) (critically) quantifying the welfare consequences of endogenous quality choice.

⁵Furthermore, while cable system prices were regulated in 1992, the effects of these regulations were mitigated due to the nature of their implementation and were effectively withdrawn for the vast majority of cable bundles by 1996. See Crawford and Shum (2007) for more detail on the regulations and the effects they had on cable market quality.

⁶Thus channels that are expensive to the cable system (ESPN, TNT, CNN, etc.) contribute more to the measured quality of a cable bundle than channels that are inexpensive to the system.

⁷Applications using this framework are too numerous to count but include measuring the market power of firms (Nevo (2001)), conducting simulations of potential mergers (Berry and Pakes (1993)), testing for price discrimination (Verboven (2002)), and quantifying the welfare benefits of new goods (Petrin (2003)).

⁸This could be extended to allow more dimensions of consumer heterogeneity, but we wish to keep the empirical model tied as closely as possible with the theoretical models of optimal nonlinear pricing/quality choice à la Rochet and Stole (2002).

moments generated by (1) demand, (2) the first-order conditions for prices and qualities, and (3) inequalities associated with offering the observed number of products (as in Pakes et al. (2007)). Demand, marginal (quantity) cost and marginal quality cost shifters serve as instruments.⁹ There are some idiosyncratic features of implementing the estimation,¹⁰ but the overall framework strongly resembles existing empirical approaches after (1) endogenizing the number of offered products and (2) accommodating endogenous quality for those products.

Based on our estimates of preferences and costs, we measure consumer surplus, profit, and thus total surplus associated with observed prices and qualities. We then simulate counterfactual prices and qualities for a social planner maximizing total surplus in each market. We also calculate quality markups along the lines described above. We then compare the qualities offered in the market with those offered by a social planner, the difference in consumer and total surplus between what the monopolist and social planner would offer, and the relative share of this total due to MPP versus MPQ.

We have obtained preliminary estimates of our model on a single cross-section of cable markets in 1998 using a simplified empirical model based on Rochet and Stole (2002). These preliminary results appear reasonable: estimated willingness-to-pay for quality is higher and more tightly distributed in markets offering more goods¹¹ and offered qualities implied by these estimates (as measured by the networks provided on each cable service) are (weakly) more plausible than previous results that ignore endogenous quality choice. We find quality for low- and medium-quality goods offered in monopoly markets to be between 5% and 24% less than that offered by a social planner. The associated “quality markups” for these goods are between 14 and 21%, less than half of the estimated price-cost markup.

To further assess the consequences of endogenous quality, we compare the average consumers surplus, firm profit, and total surplus from our baseline results with two counterfactuals: one with qualities fixed at that set by the multiproduct monopolist but with prices equal to marginal costs at that quality and another with qualities set at the efficient level but allowing monopoly pricing. While not realistic counterfactuals for policy purposes, these are useful in describing the relative importance of monopoly pricing versus monopoly quality choice in driving welfare outcomes. Indeed we find that monopoly quality choice can be quite important: total surplus increases between 3.3% and 55.7% from efficient pricing with monopoly qualities and between -2.4% and 62.1% from monopoly pricing at efficient qualities.

⁹Note our framework also addresses the endogeneity of quality in the estimation of demand, an important econometric problem in its own right. It requires, however, that a single dimension of quality adequately summarizes product and that there exist instruments for this quality. This is manageable in our framework with only a single quality dimension, but would be challenging were there multiple endogenous characteristics. See Akerberg et al. (2010) for methods to consistently estimate (only) price elasticities in the presence of endogenous product characteristics.

¹⁰For example, doing the inversion for mean utility is complicated by a random coefficient on the econometric error term and solving for the cost-side errors must be done numerically due to the nonlinearities inherent in the cost function.

¹¹A result consistent with the bundling of networks into services by cable systems (Armstrong (1999b), Bakos and Brynjolfsson (1999), Crawford (2008)).

The rest of the paper proceeds as follows. In the next section we describe the economic intuition underlying the measurement of market power over quality. In Section 3 we introduce our empirical framework and in Section 4 describe the institutional features of U.S. cable television markets that make estimating the model there attractive. We also describe there the data we will use for our analysis. Section 6 presents our preliminary results and Section 7 concludes.

2 Market Power over Quality

In this section, we describe the economic intuition underlying our measurement of market power over quality (MPQ). We begin by summarizing the insights of the single-product and multi-product monopoly literatures. In the single-product case, we follow Spence (1975) and show why a single-product monopolist could offer higher or lower quality than a social planner and the factors that determine this outcome. In the multi-product case, we follow Mussa and Rosen (1978) and demonstrate how similar incentives may apply for high-quality goods, but that quality degradation is the norm for low-quality goods. We conclude by introducing quality markups and describe how we measure the absolute and relative welfare effects of MPP versus MPQ.

2.1 Single-Product Monopoly Quality Choice (Spence (1975))

While our empirical model to come will estimate the demand for cable television services, it is convenient to introduce the effects of MPQ for a single-product monopolist using inverse demand curves. Following Spence, let the price associated with quantity Q of a product of quality q be given by $P(Q, q)$. Let costs of such a product be given by a constant-returns-to-scale cost function, $C(Q, q) = c(q)Q$. The monopolist's first-order conditions for both quantity and quality simply equate the marginal revenue of each with their marginal cost:

$$\begin{aligned} P(Q, q) + P_Q(Q, q)Q &= c(q) \\ P_q(Q, q) &= c_q(q) \end{aligned} \tag{1}$$

$P_q(q, Q)$ is Spence's "Marginal Valuation of Quality" (MVQ) for the Q^{th} consumer. That is, if $P(Q, q)$ measures the willingness-to-pay of the Q^{th} consumer, then $P_q(q, Q)$ measures how much her WTP increases with increases in quality. Similarly, if $c(q)$ is the marginal (quantity) cost of a product of quality q , then $c_q(q)$ measures how much this marginal cost increases with increases in quality.

A social planner maximizes total surplus rather than profit:

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

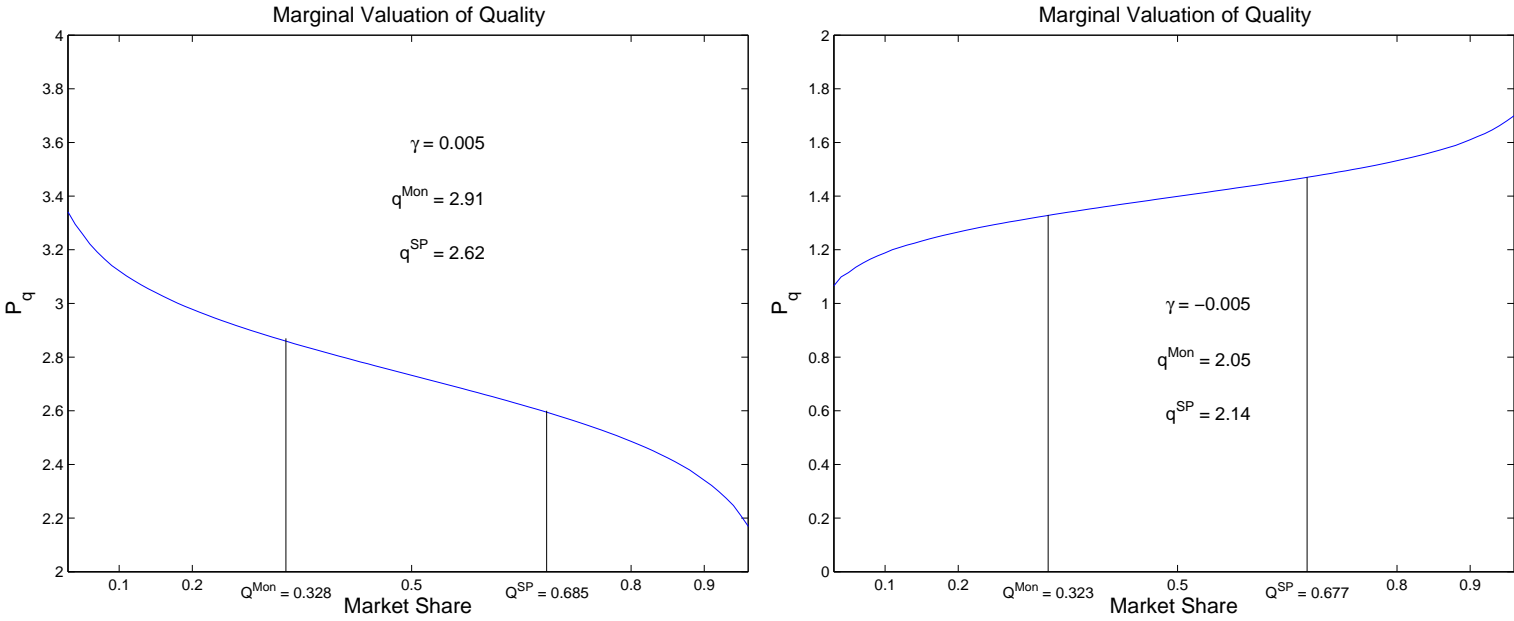
yielding first-order conditions for quantity and quality that equate the marginal social benefit

of each with their marginal cost:

$$\begin{aligned}
 P(Q, q) &= c(q) \\
 \left[\frac{1}{Q} \int_0^Q P_q(s, q) ds \right] &= c_q(q)
 \end{aligned} \tag{2}$$

Comparing these first-order conditions yields first the well-known finding that the social planner sets price equal to marginal cost while the monopolist raises price above it. It also shows that the monopolist equates the marginal (quality) cost to the marginal value of quality for the *marginal* consumer ($P_q(Q, q)$) while the social planner equates it to the marginal value of quality for the *average* consumer ($[\frac{1}{Q} \int_0^Q P_q(s, q) ds]$).

Figure 1: Optimal quality choice when MVQ ($P_q(Q, q)$) decreases vs. increases with quantity



Notes: Reported is the difference in WTP across the demand curve due to a unit increase in quality for a single-product logit model given by $\log(\frac{s}{1-s}) = \alpha_0 + \alpha_p p + \alpha_q q + \gamma pq$. In this setting, positive values of γ (as in the left panel) mean increasing product quality makes demand curves steeper, while negative values of γ (as in the right panel) mean increasing quality makes demand curves flatter. The monopolist provides a higher (lower) quality in the left (right) panel.

As Spence shows, which of the two chooses the larger quality depends on two critical factors: (1) How MVQ varies with Q , i.e. whether high-WTP or low-WTP consumers value more increases in quality, and (2) the extent of quantity reduction under monopoly (as that influences both who is the monopolist's marginal consumer as well as the set of consumers over which the social planner averages). Figure 1 demonstrates this effect in a simple Logit specification. γ is the coefficient on a price-quality interaction term.¹² Positive values for γ mean increments to quality make the demand

¹²See the notes to the figure for details..

curve progressively steeper. In this case, described in the left panel of Figure 1, MVQ increases more for high-WTP consumers, the monopolist restricts quantities considerably ($Q^{Mon} \ll Q^{SP}$), and the monopolist over-provides quality. In the second panel, MVQ increases more for *low*-WTP consumers and the monopolist still substantially restricts quantities, but he now *under*-provides quality.¹³ Which of the two occurs in practice is, of course, an empirical question.

2.2 Multi-Product Monopoly Quality Choice (Mussa and Rosen (1978))

Models of multi-product monopoly choice typically apply principal-agent models of adverse selection like those used in the analysis of optimal nonlinear pricing. The seminal paper in this area is Mussa and Rosen (1978) (MR), although in the next section we also discuss an important extension by Rochet and Stole (2002).

A simple example motivated by MR demonstrates the intuition of this class of models. Consider a monopolist selling two products to three types of consumers distributed in the population with probabilities $\{f_0, f_1, f_2\}$. Assume preferences are given by $u_j = t_j q_j - p_j$, where each consumer of type j , $j = \{1, 2\}$, has a different WTP for quality, t_j . Assume costs are given by $C(q_j) = 0.5q_j^2$. Total surplus is therefore, $S(q_j, t_j) = t_j q_j - 0.5q_j^2$. For convenience, note now that the quality that maximizes total surplus for each type is $q_j = t_j$.

Under the single-crossing condition ($u_{qt} > 0$), optimal qualities solve

$$q_j = t_j - \frac{1 - F_j}{f_j} (t_{j+1} - t_j), \quad j = 1, \dots, 2. \quad (3)$$

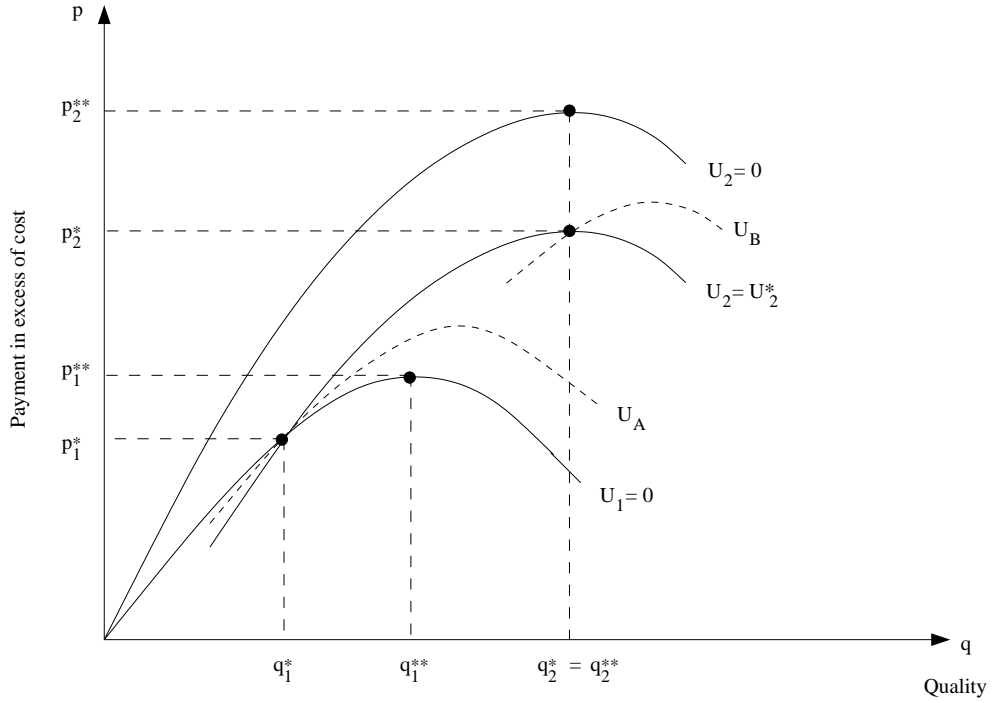
where $F_j = \sum_{k=0}^j f_k$ is the CDF of f . Prices follow from the incentive compatibility constraints given optimal qualities (i.e. p_1 solves $u(t_1, q_1) = 0$ and p_j solves $u(t_j, q_j) = u(t_j, q_{j-1})$ for $j > 1$).

Standard results from this model include: (1) qualities to the high type (type 2) are set efficiently (note $F_2 = 1$), (2) qualities to the low type are degraded downwards, (3) prices are set such that utility to the low type is zero, and (4) the high type earns positive surplus (“information rents”). Figure 2, adapted from Maskin and Riley (1984), provides the intuition.¹⁴ The monopolist would like to offer the efficient qualities, q_j^{**} , and set prices to extract all the surplus from each type, p_j^{**} . Consumers prefer price-quality combinations to the southeast in the figure, however, and at these prices and qualities, the high type has an incentive to buy the low type’s product. To prevent this from happening, the monopolist optimally keeps q_2 unchanged, but degrades q_1 until the high type is indifferent from choosing the low type’s price-quality combination, (p_1^*, q_1^*) , and his own, (p_2^*, q_2^*) . He adjusts prices to keep utility to the low type at zero, but must lower prices to the high type, yielding for them positive rents ($p_2^* < p_2^{**}$).

¹³It may be of interest to the reader to note that for a straight Logit model (i.e. one with $\gamma = 0$), there is no heterogeneity across consumers in MVQ. As a result, the WTP increase of the monopolist’s marginal consumer is identical to the WTP increase of the social planner’s average consumer and they both choose the same (efficient) quality. One should therefore be careful accommodating endogenous quality choice within a simple Logit.

¹⁴Maskin and Riley (1984) and Mussa and Rosen (1978) developed very similar models. The first analyzed optimal choice of prices and quantities while the latter analyzed optimal choice of prices and qualities.

Figure 2: Optimal quality choice with three consumer types



Notes: This figure, adapted from Maskin and Riley (1984), demonstrates the intuition underlying optimal quality choice by a multi-product monopolist facing three consumer types (only two of whom purchase products). The monopolist would prefer to offer prices and qualities denoted with **s and extract all surplus, but the high type (type 2) will prefer the low type's product. To prevent this, he reduces quality to the low type ($q_1^* < q_1^{**}$), leaving quality to the high type unchanged (but lowering its price).

2.3 Quality Markups and the Welfare Effects of MPQ

A price markup, given by the difference between a product's price and its marginal cost, is frequently used as a shorthand measure of MPP at the marginal quantity (consumer). To understand the welfare consequences of MPQ, we introduce here a similarly measure.

Let the total social benefit (SB) associated with a given quality, q , quantity, Q , and price, $P(Q, q)$, be given by the sum of revenue plus consumer surplus.¹⁵ A price markup, $P(Q, q) - c(q)$, is then just the difference between the marginal social benefit of an additional unit of quantity (P) and the marginal social cost of that unit (c).

We define analogously a quality markup. Let the marginal social benefit and marginal social cost of an additional unit of quality for a single-product monopolist be given by:

$$MSB \equiv \frac{\partial SB}{\partial q} = \int_0^Q P_q(s, q) ds \quad (4)$$

$$MSC \equiv \frac{\partial SC}{\partial q} = c_q(q)Q \quad (5)$$

Then a quality markup in this setting is just the difference in these:¹⁶

$$QMarkup \equiv MSB - MSC = \int_0^Q P_q(s, q) ds - c_q(q)Q$$

There are both similarities and differences between price and quality markups. Both measure the social losses due to market power at the margin and both are zero for the social planner and non-zero for the monopolist. An important difference is that, unlike price markups, quality markups for a monopolist *can* be negative. Whether they are or not depends on whether the MVQ ($P_q(Q, q)$) increases or decreases with quantity among the monopolist's inframarginal consumers.

The Welfare Effects of MPQ Like a price markup, a quality markup is useful for characterizing the consequences of market power over quality (MPQ) at the margin. However, we also want to measure the consequences of MPQ (and MPP) for inframarginal consumers.

It is conceptually easy to calculate the *total* welfare effect of market power over *both* prices and qualities. If $\{q^r, Q^r\}$, $r = \{Mon, SP\}$ are the qualities and quantities provided by the monopolist and social planner, respectively, then the welfare costs of monopoly are given by the difference in total surplus from facing the social planner outcomes versus monopoly outcomes: $\Delta TS \equiv TS(q^{SP}, Q^{SP}) - TS(q^{Mon}, Q^{Mon})$.

The question remains, however, how we should "apportion" this total welfare effect between MPP and MPQ. As a first approximation, we do so by keeping fixed each of q or Q at their monopoly values and setting the other at their social-planner values. Thus, to measure the incremental welfare effect of MPP, we fix qualities at their monopoly level and evaluate the difference in total surplus from marginal cost pricing at these qualities. Similarly, to measure the incremental

¹⁵Equivalently, it is the area under the demand curve up to Q . Total surplus is then just total social benefit minus cost, $C(Q, q)$.

¹⁶For a multi-product monopolist in the MR model, the quality markup for product j is just $QM_j = f_j(t_j - q_j)$.

welfare effect of MPQ, we fix quantities at their monopoly level and evaluate the difference in total surplus from changes in quality.¹⁷ Formally,

$$\Delta TS_{MPP} \equiv TS(q^{Mon}, Q^{SP}) - TS(q^{Mon}, Q^{Mon}) \quad (6)$$

$$\Delta TS_{MPQ} \equiv TS(q^{SP}, Q^{Mon}) - TS(q^{Mon}, Q^{Mon}) \quad (7)$$

Comparing either ΔTS_{MPP} or ΔTS_{MPQ} with ΔTS provides a measure of “how close” each of MPP and MPQ get in achieving the maximum possible welfare gain with endogenous prices and quantities.

3 An Empirical Framework for Measuring MPQ

3.1 Overview

Both Spence and MR are particular specifications of preferences and costs that are convenient for evaluating the theoretical consequences of MPQ. Neither is particularly well-suited for being taken to data, in the first case because single-product monopolists are rare and in the second because of some strong assumptions on the structure of the economic environment.

The recent empirical literature in Industrial Organization has focused considerable effort on the specification and estimation of flexible models of differentiated product demand and pricing. While these are commonly estimated using aggregate data on market shares, prices, and characteristics of products, they are themselves based on a consumer-level random-utility framework that is explicitly aggregated to the level of the data. Different assumptions underlying the distribution of unobserved-to-the-econometrician random preferences yield different functional forms for demand and pricing equations. Logit, Nested Logit, and Random Coefficients Logit models of differentiated product demand are among the most common such specifications (Berry (1994), Berry et al. (1995)). Unfortunately, while widely recognized as a cause for concern, very few papers in this framework allow firms to optimally choose qualities as well as prices.¹⁸

An important contribution by Rochet and Stole (2002) begins to reconcile these differences. They specify a model similar to Mussa and Rosen (1978), but with *random participation*.¹⁹ This enhances the realism of models of optimal nonlinear pricing while retaining a convenient “vertical” structure to preferences that facilitates model solution.²⁰ They note:

“We are struck by the fact that, in this instance, econometric practice is ahead of the theoretical literature. It has long been an accepted practice when estimating consumer demands in discrete-choice multiproduct environments to include an additive disturbance to capture consumer heterogeneity in choice...”

¹⁷We have also considered a more general version of the latter measure that evaluates the difference in total surplus between the monopoly outcome and an “intermediate” outcome that allows for monopoly pricing (and thus a different quantity) at the social planner’s quality(ies).

¹⁸xxx cites to papers mentioning exogenous product characteristics xxx.

¹⁹i.e., random utility, but only for the outside good.

²⁰By contrast, any Logit model is fully “horizontal” in that all products compete with all others. Thus a change in the price of one product will have a non-zero effect on the quantity demanded of all others.

While a generous concession, they go on to say:

“Because we are optimizing over both prices and qualities, we have generated additional implications about ... profit-maximizing product designs and allocations.”

Our empirical framework to follow proposes to build on RS’s insights. In particular, we extend popular existing empirical methods to allow for endogenous quality choice and evaluate the insights of the theoretical literatures analyzing this question within this empirical framework. In this paper, we do so (1) for monopolists, (2) choosing a single product characteristic, quality, (3) in a static setting. Each of these are important methodological limitations, but each is also capable of being relaxed. We talk more about such extensions at the end of the paper.

3.2 Demand

Consider a market, n , served by a multi-product monopolist offering J_n distinct products characterized by monthly subscription fees, p_{jn} , and quality of programming content, q_{jn} . Suppose that there are a continuum of consumers, indexed by i , whose preferences are described by the following utility function

$$u_{ijn} = \begin{cases} \alpha_0 + \alpha_p p_{jn} + \alpha_{qi} q_{jn}^* + \epsilon_{ijn}, & \text{if } j = \{1, 2, \dots, J_n\} \\ \epsilon_{i0n}, & \text{otherwise.} \end{cases} \quad (8)$$

In the above, q_{jn}^* denotes the actual quality level chosen by firms and perceived by consumers. However, the researcher observes quality imperfectly; specifically, we assume that observed quality q_{jn} is measured with error:

$$q_{jn} = q_{jn}^* + \eta_{jn}$$

where η_{jn} denotes unobserved (to the researcher) components of quality, with $Cov(q_{jn}^*, \eta_{jn}) = 0$.

Substituting the above into Eq. (8), we obtain that, for the inside goods $j = 1, 2, \dots, J_n$:

$$u_{ijn} = \alpha_0 + \alpha_p p_{jn} + \alpha_{qi} q_{jn} - \alpha_{qi} \eta_{jn} + \epsilon_{ijn}.$$

Consumer i ’s utility function can also be written in terms of the population mean utility for good j and consumer i ’s deviation from it. Namely, let $\alpha_{qi} = \bar{\alpha}_q + \tilde{\alpha}_{qi}$. Then the population mean utility is given by

$$\delta_{jn} = \alpha_0 + \alpha_p p_{jn} + \bar{\alpha}_q (q_{jn} - \eta_{jn}), \quad (9)$$

with deviations from population mean coefficients weighted by the corresponding service characteristics denoted by

$$\mu_i(q_{jn}, \eta_{jn}) = \tilde{\alpha}_{qi} (q_{jn} - \eta_{jn}) \quad (10)$$

Consumer i ’s utility net of the idiosyncratic product-specific preference draw, ϵ_{ijn} , can be written as

$$\delta_{ijn} = \delta_{jn} + \mu_i(q_{jn}, \eta_{jn}) \quad (11)$$

with δ_{jn} denoting the “mean utility”, the component of u_{ijn} which is the same across all consumers.

Now consumer i 's utility (8) becomes

$$u_{ijn} = \begin{cases} \delta_{ijn} + \epsilon_{ijn}, & \text{if } j = \{1, 2, \dots, J_n\} \\ \epsilon_{i0n}, & \text{otherwise.} \end{cases} \quad (12)$$

Note that we implicitly normalized (net) utility from the outside option to zero.

Following standard practice, we assume that the idiosyncratic preferences for products (preferences for variety) have type 1 extreme values distribution, i.e.,

Assumption 1: *Idiosyncratic preference draws ϵ_{ijn} are independently identically distributed with*

$$\begin{aligned} \epsilon_{ijn} &\stackrel{iid}{\sim} \text{Extreme Value Type 1, with density} \\ f(\epsilon_{ijn}) &= \exp(-\epsilon_{ijn}) \exp(-\exp(-\epsilon_{ijn})) \end{aligned}$$

By assumption (1) market shares for each of the consumer types, i , and each product, j , in market n are given by

$$s_{ijn} = \frac{\exp(\delta_{ijn})}{\sum_{r \in \mathcal{J}} \exp(\delta_{irn})}, \quad (13)$$

where δ_{ic} is defined in equation (11).

In order to compute aggregate market shares we integrate over the distribution of consumer types, i.e.,

$$s_{jn}(\delta_{jn}; \alpha) = \int s_{ijn}(\delta_{jn}; \alpha_{ijn}) dF(\alpha_{ijn} | \Theta) \quad (14)$$

The structural error for the demand side is η_{jn} . In estimation, we will follow the usual BLP literature and “invert” the system of market share equations (14) to obtain η_{jn} as a function of the parameters and the observables:

$$\eta_{jn}(\theta) = l(s_n, p_n, q_n; \theta). \quad (15)$$

Note that it is the *observed* quality q_n on the RHS of the above equation.

Generalized Inversion Our inversion for η_{jn} in Equation (15) above is more complicated than the standard Berry/BLP inversion due to the interaction of unobserved tastes for quality, $\tilde{\alpha}_{qi}$, and the market unobservable, η_{jn} , inside $\mu_i(q_{jn}, \eta_{jn})$ above. We propose to resolve this issue with a mild generalization of the Berry (1994) inversion.

The typical inversion solves for mean utilities, δ_{jn} , as a function of market shares, s_{jn} , given any nonlinear covariates and parameters in the model and obtains the econometric error as a simple linear function of δ_{jn} and the linear parameters and covariates in the model.²¹ This is relatively straightforward in the typical application of these methods because the econometric error doesn't

²¹In a typical model, ξ_{jn} is the econometric error and is given by $\xi_{jn} = \delta_{jn} - \alpha p_{jn} - X'_{jn} \beta$.

enter the household-specific component of preferences, $\mu_i(\cdot)$. In our case, however, it does: both δ_{jn} in (9) and μ_i in (10) above include η_{jn} .

To solve this problem we implement the following iterative algorithm. For a given parameter vector, we begin with arbitrary candidate values for both our econometric error, $\hat{\eta}_{jn}$, and for the population mean utility, $\hat{\delta}_{jn}$. Then, we obtain type-specific utilities

$$\hat{\delta}_{ijn} = \hat{\delta}_{jn} + \mu_i(q_{jn}, \hat{\eta}_{jn}),$$

and aggregate market shares are calculated as in (14). In the next step, we update the population mean utility using the following contraction mapping:

$$\hat{\delta}_{jn}^{l+1} = \hat{\delta}_{jn}^l + s_{jn} - s_{jn}(\hat{\delta}_{jn}^l; \alpha), \quad (16)$$

where superscript l and $l + 1$ stand for the current and the next iteration values of the population mean utility. Using this new value of the population mean utility, we update our candidate variable for η_{jn} as follows

$$\hat{\eta}_{jn}^{l+1} = \frac{1}{\bar{\alpha}q} (\hat{\delta}_{jn}^{l+1} - \alpha_0 - \alpha_p p_{jn} - \bar{\alpha}_q q_{jn}). \quad (17)$$

These updated values of our econometric error are then used to compute the value of $\mu_i(\cdot)$ in the following step. We iterate the whole procedure until convergence of the current and future values of η_{jn} .

3.3 Supply

On the supply side there is a monopolist producer offering J_n products characterized by different levels of price and quality. We assume that marginal cost of product j in market n is written as

$$mc_{jn} = mc(q_{jn}^*, W_{jn}, \omega_{jn}^1, \omega_{jn}^2) \quad (18)$$

where W_{jn} is a vector of observable cost shifters and $(\omega_{jn}^1, \omega_{jn}^2)$ is a pair of unobserved shocks to the marginal costs of quantity and quality, respectively. Note that the errors must enter the cost function in a way that makes the system of first-order conditions exactly identified as discussed next. Further note that it is the true quality, q_{jn}^* , that enters the marginal cost equation. Given a value of η_{jn} from Equation (15) above, we can always solve for true quality, q_{jn}^* as a function of observed quality, q_{jn} and η_{jn} .

We assume the cost of providing a cable service of quality q_{jn}^* is given by $C(q_{jn}^*, Q_{jn}, W_n) = mc(q_{jn}^*, W_{jn}, \omega_{jn}^1, \omega_{jn}^2)Q_{jn} + F_{J_n n}(W_n)$, where $Q_{jn} = M_n s_{jn}(p_n, q_n^*, \theta)$, M_n is the size of market n , $F_{J_n n}(W_n)$ are the fixed costs of providing J_n cable services in market n , and $mc_{jn}(q_{jn}^*, W_{jn}, \omega_{jn}^1, \omega_{jn}^2)$ is given by the relationship below:

$$mc_{jn}(q_{jn}^*, W_{jn}, \omega_{jn}^1, \omega_{jn}^2) = c_0 + W_{1jn}\gamma_1 + (c_1 + W_{2jn}\gamma_2 + \omega_{2jn})q_{jn}^* + c_2 q_{jn}^{*2} + \omega_{1jn} \quad (19)$$

where ω_{jn}^1 captures shocks to marginal quantity costs and ω_{jn}^2 captures shocks to the marginal cost of quality for product j in market n , with $E(\omega_{jn}^1) = E(\omega_{jn}^2) = 0$. Thus, marginal costs are constant across quantity, but vary with the offered quality. W_{1jn} includes variables which influence the

marginal quantity cost for given quality and W_{2jn} includes variables which influence the marginal cost of producing a given quality. The elements of W_{1jn} and W_{2jn} are discussed in greater detail below.

We assume fixed costs vary with the number of products offered by the firm in each market and differ across markets. [The balance of this paragraph remains to be written]

Given the demand system in (8), the profit of the monopolist can be written as

$$\Pi_n = \sum_{j \in \mathcal{J}_n} (p_{jn} - mc_{jn}) M_n s_{jn}(p_n, q_n^*; \theta) - F_{J_n}(W_n), \quad \text{with } s_{jn}(p_n, q_n^*; \theta) = \int s_{ijn}(p_n, q_n, \alpha_i) dG(\alpha_i) \quad (20)$$

Given J_n , we assume the profit maximizing monopolist optimally chooses both price p_n and quality q_n^* of its products, we can write the following system of first order conditions ($j = 1, 2, \dots, J_n$)

$$[p_{jn}] : \int s_{ijn}(p_n, q_n^*, \alpha_i) dG(\alpha_i) + \sum_{r \in \mathcal{J}_n} (p_{rn} - mc_{rn}) \int \frac{\partial s_{irn}(p_n, q_n^*; \alpha_i)}{\partial p_{jn}} dG(\alpha_i) = 0 \quad (21)$$

$$[q_{jn}^*] : - \frac{\partial mc(q_{jn}^*, W_{jn}, \omega_{jn}^1, \omega_{jn}^2)}{\partial q_{jn}^*} \int s_{ijn}(p_n, q_n^*; \alpha_i) dG(\alpha_i) + \sum_{r \in \mathcal{J}_n} (p_{rn} - mc_{rn}) \int \frac{\partial s_{irn}(p_n, q_n^*; \alpha_i)}{\partial q_{rn}^*} dG(\alpha_i) = 0. \quad (22)$$

Under standard regularity conditions, the system of equations (21) and (22) has a unique solution for the pair $(\omega_{jn}^1, \omega_{jn}^2)$ for each j . Let

$$\begin{aligned} \omega_{jn}^1(\theta) &= g(p_n, q_n^*, W_{jn}; \theta) \\ \omega_{jn}^2(\theta) &= h(p_n, q_n^*, W_{jn}; \theta) \end{aligned} \quad (23)$$

describe the solution.

We also assume the monopolist optimally chooses the number of products it offers in each market. [The balance of this section remains to be written]

3.4 Social Planner

After estimation, we compare the monopoly outcome with counterfactual outcomes given by a social planner. For convenience, we describe those choices here.

The social planner's problem is to maximize total surplus, defined as the sum of consumer surplus and producer profit. For the preferences outlined above, consumer surplus is:

$$CS_n(p_n, q_n^*; \theta) = -\frac{1}{\alpha_p} \int \log \left(\sum_{j=0}^{J_n} \exp(\delta_{ijn}(p_n, q_n^*; \alpha_i)) \right) dG(\alpha_i)$$

with partial derivatives

$$\frac{\partial CS_n}{\partial p_{jn}} = - \int s_{ijn}(p_n, q_n^*, \alpha_i) dG(\alpha_i); \quad \frac{\partial CS_n}{\partial q_{jn}^*} = - \int \frac{\alpha_{qi}}{\alpha_p} s_{ijn}(p_n, q_n^*, \alpha_i) dG(\alpha_i).$$

The first-order conditions satisfied by the social planner’s price and quality choices are:

$$[p_{jn}] : \frac{\partial \Pi_{jn}(p_n, q_n^*)}{\partial p_{jn}} + \frac{\partial CS_n(p_n, q_n^*)}{\partial p_{jn}} = 0 \quad (24)$$

$$[q_{jn}^*] : \frac{\partial \Pi_{jn}(p_n, q_n^*)}{\partial q_{jn}^*} + \frac{\partial CS_n(p_n, q_n^*)}{\partial q_{jn}^*} = 0. \quad (25)$$

where the partial derivatives of Π_{jn} are given in Eqs. (21) and (22) above.

3.5 Estimation

Estimation of this model proceeds via a straightforward extension of the Berry et al. (1995) GMM-based estimation method, extended to have two estimating equations per product, corresponding to the first-order conditions for price and quality, in Eqs. (21)-(22) above.

Estimation will proceed based on the population orthogonality restrictions. At the true $\theta = \theta^0$, we have

$$E[\eta_{jn}(\theta^0)Z_{jn}^\eta] = 0; \quad E[\omega_{jn}^1(\theta^0)Z_{jn}^1] = 0; \quad E[\omega_{jn}^2(\theta^0)Z_{jn}^2] = 0. \quad (26)$$

Suitable instruments for p_{jn} and q_{jn} in the demand equation are variables that shift marginal quantity or quality costs, W_{1jn} and W_{2jn} . Candidates for variables that shift marginal quantity costs that are not affected by quality (W_{1jn}) include wage rates and/or population density. Candidates for variables that shift marginal quality costs include the size of the Multiple System Operator (MSO) parent of and/or vertical integration status of the cable system in market n . The former is a proxy for the bargaining power of the downstream system and the latter for the possibility that integrated operators may face costs closer to the true marginal cost of providing content (and thus lower than those for unintegrated operators). Further candidate instruments include the average of prices and/or qualities of cable television service in markets outside n . The latter is an analog to the “prices-in-other-markets” instruments introduced by Hausman (1996) and used successfully in cable markets by Crawford and Yurukoglu (2011).

The estimation algorithm has the same “nested-fixed point” setup as in Berry et al. (1995). In the “inner loop”, given particular values for the parameters θ , we solve for the structural errors as a function of θ , corresponding to $\eta_{jn}(\theta)$, $\omega_{jn}^1(\theta)$ and $\omega_{jn}^2(\theta)$ in the previous notation. As described above, because η_{jn} enters both δ_{jn} and μ_{ijn} and because ω_{jn}^1 and ω_{jn}^2 enter the first-order conditions non-linearly, we solve for these structural errors using conceptually similar, but computationally more challenging approaches than those used in Berry et al. (1995).

For the supply side, the two structural errors $\omega_{jn}^1(\theta)$ and $\omega_{jn}^2(\theta)$ are solved jointly from the two first-order conditions (21) and (22). Note that there are a set of ω ’s for each product; so in a two-good market, for instance, we will have $(\omega_1^1; \omega_1^2; \omega_2^1; \omega_2^2)$. This completes the “inner loop.”

In the “outer loop”, we evaluate the GMM objective function. For suitable choices of instruments satisfying Eq. (26), we construct the vector of sample moment conditions: let $G_{J_n T}(\theta)$ denote this vector, and $W_{J_n T}$ denote a weighting matrix of suitable dimension. Then in the outer loop, we seek values of the parameters θ to maximize $G_{J_n T}(\theta)'W_{J_n T}G_{J_n T}(\theta)$.

4 The Cable Television Industry [For Preliminary Results]

[The balance of the paper presents preliminary estimates based on a single cross-section of data and a model based on Rochet and Stole (2002)]

Cable television systems select a portfolio of programming networks, bundle them into one or more services and offer these services to households in local, geographically separate, monopoly cable markets. Systems typically offer three types of networks: broadcast networks, cable networks, and premium networks.²²

Broadcast and cable networks are typically bundled by cable systems and offered as Basic Service. Some systems, however, elect to split up these networks and offer some portion of them as smaller bundles of networks known as Expanded Basic Services. Premium networks are typically separated into individual services and sold on a stand-alone basis. Despite the presence of separate Expanded Basic and Premium Services, households may not buy them directly. They are first required to purchase Basic Service.

An important feature of cable system management is their almost complete control over the content and price of service bundles. With respect to content, while certain regulations mandate they carry all broadcast television stations available over the air in their service area (so-called Must-Carry requirements), beyond these restrictions they may select and package whatever television networks they like for sale to households. With respect to prices, cable systems have been subject to cyclical regulatory oversight.²³ Most recently, the 1996 Telecommunications Act removed price controls on Expanded Basic Services, leaving only Basic Service subject to (possible, though extremely weak) regulation. Furthermore, while Direct-Broadcast Satellite service is now a significant competitor to cable service in almost all cable markets, it had only 9.9% of the multi-channel video programming marketplace in 1998, the year of our data (FCC (2000)), and that was concentrated among early adopters in rural areas without access to cable service.²⁴

The institutional and economic environment in the cable television industry suggests the choice of quality and price of Basic and Expanded Basic Services may map well to the theory. Since households that buy Expanded Basic Services must necessarily first purchase Basic Service, these services are by construction increasing in overall quality. Furthermore, since they consist of (generally large) bundles of individual networks, the range of qualities possibly chosen is plausibly continuous, and

²²Broadcast networks are television signals broadcast in the local cable market and then collected and retransmitted by cable systems. Examples include the major, national broadcast networks - ABC, CBS, NBC, and FOX - as well as public and independent television stations. Cable networks are advertising-supported general and special-interest networks distributed nationally to systems via satellite, such as MTV, CNN, and ESPN. Premium networks are advertising-free entertainment networks, typically offering full-length feature films, such as HBO and Showtime.

²³The most recent incident of price regulation was the 1992 Cable Act, the intent of which was to limit the prices charged for Basic and Expanded Basic Services. Due to a combination of factors, including strategic responses by cable systems to the imposed regulations and relatively weak cost pass-through (“going-forward”) requirements, these provided little benefit to households (Hazlett and Spitzer (1997), Crawford (2000)).

²⁴The watershed date in U.S. cable-satellite competition was November, 1999, when satellite providers were permitted to distribute local broadcast networks into local markets. Since then, every net new subscriber to multi-channel video programming has been a satellite subscriber (Crawford (2011)).

offered qualities are clearly discrete.²⁵ Finally, cable systems at this time are arguably monopolists. In the balance of the paper, we therefore focus on modeling endogenous quality choice for Basic Cable Services.

4.1 Data [For preliminary results]

We've compiled a market-level dataset on a cross-section of United States cable systems to estimate the model. The primary source of data for these systems is Warren Publishing's Television and Cable Factbook Directory of Cable Systems. The data for this paper consists of the population of cable systems recorded in the 1998 edition of the Factbook for which complete information was available.²⁶ From the population, a sample of 5,702 systems remained.

Table 1 present sample statistics for selected variable for these systems. In the preliminary results to follow, we focus on simple measures of quantity (or market share), price, and quality. The identities of the networks offered on cable services in particular are important determinants of the quality of offered cable services (Crawford (2000)). We disaggregate programming networks into groups according to the size of their potential audience. The top 20 cable programming networks available in the United States in 1998 are listed in Table 2.

While all systems offer a Basic Service, Table 1 shows that slightly less than 30% of systems offer Expanded Basic Services. Of these, most offer just one Expanded Service. Aggregating over all Basic and Expanded Basic Services, systems typically offer almost 16 cable networks and over 22 other (including broadcast) networks on their highest-quality cable service. Note a convention we will follow throughout the paper is evident from Table 1: to compare cable services across markets with different numbers of services, we generally use a "top-down" approach that compares the highest quality of offered cable services in each market.

5 Empirical Specification [For Preliminary Results]

We currently estimate the Mussa-Rosen and Rochet-Stole models under some simplifying assumptions on preferences and costs. We begin with the preference structure common in screening models

²⁵In a complementary line of analysis, Crawford (2008) and Crawford and Yurukoglu (2011) consider the incentives to bundle networks into Basic Services. This line of work tests the *discriminatory* incentives to bundle: namely that it by reducing heterogeneity in consumer tastes, bundling implicitly sorts consumers in a manner similar to 2nd-degree price discrimination. See Armstrong (1999a) and Bakos and Brynjolfsson (1999) for an exposition of the theory. This effect contrasts directly with the screening theory presented in this paper: there the monopolist *unbundles* goods to *explicitly* sort consumers. Understanding firms' incentives to bundle versus screen is an interesting area of future research.

²⁶While there are over 11,000 systems in the sample, persistence in non-response over time as well as incomplete reporting of critical variables required imposing a large number of conditions in order for a system to be included in each sample. Missing information on prices, quantities, and reporting dates were responsible for the majority of the exclusions.

of endogenous quality choice:

$$\begin{aligned} u_{ijn} &= t_{in}q_{jn} - p_{jn} \\ u_{ij0} &= -\epsilon_{ijn} \end{aligned} \tag{27}$$

where for convenience we've reversed the sign on the random participation error, ϵ_{ijn} . We then assume willingness-to-pay for cable quality has the following form:

$$t_{in} = \tau_{in} + \eta_n + NG'_n \mu_{NG} + \gamma y_n \tag{28}$$

where $\tau_{in} \sim N(\mu, \sigma^2 + NG'_n \sigma_{NG})$, $\eta_n \sim N(0, \sigma_\eta^2)$, y_n is per-capita income in market n , NG_n is the vector of dummy variables indicating the number of goods offered in market n (2 or 3), and σ_{NG} captures variation in the dispersion of preferences in markets offering different numbers of goods. In this specification, there is both within-market heterogeneity in tastes, τ_{in} , as well as both observed and unobserved across-market heterogeneity, y_n and η_n . Furthermore, $\epsilon_{ijn} \sim \text{Exp}(\lambda)$.

We assume the marginal (quantity) cost of providing a cable service of quality q_{jn} is

$$c_{jn}(q_{jn}) = c_0 + (c_1 - \nu_{jn})q_{jn} + (c_2/\rho)q_{jn}^\rho \tag{29}$$

where ν_{jn} are shocks to marginal costs of quality for product j in market n , with $E(\nu_{jn}) = 0$. Thus, marginal costs are constant across quantity, but vary with the offered quality. For now, we do not introduce cost shifters.

5.1 Identification [for preliminary results]

Equations (27)-(29) characterizing preferences and costs form the core of the econometric model. Before describing the estimating equations in detail, it is useful to consider the variation in the data that provides identification of these parameters in these equations.

In the preliminary results that follow, we consider the quality of each good j in market n , q_{jn} , to be unobserved to the econometrician. Its place is taken in the empirical model by the value implied by the solution to the monopolist's screening problem given the current estimate of the preference and cost parameters, i.e. $q_{jn} = q_{jn}(\theta)$ where $\theta = (\mu, \sigma, \sigma_\eta, \gamma, \mu_{NG}, \sigma_{NG}, c_0, c_1, c_2, \rho, \lambda)$. We show in the next subsection that the market shares and prices that come out of the model are complicated nonlinear functions of these parameters.

What, then, is driving identification? The main source of variation in our dataset is across markets n . In this version of the paper, we have few covariates and identification exploits the fact that markets with the same number of goods NG_n and similar incomes y_n should exhibit similar prices and market shares. If, for example, prices are higher in one market, it must be the case that there are higher unobserved tastes for quality, η_n , a fact that will also induce higher chosen quality, q_{jn} , by the monopolist (at least for the high-quality good). Parameters in the cost function are identified by what best fits the sample data.

5.2 Estimating Equations [for preliminary results]

The estimation compares moments of the observed data with those generated by the model. As we consider quality to be unobserved to the econometrician, we rely only on the model predictions for market shares, w_{jn} , and prices, p_{jn} , for products $j = 1, \dots, J_n$ in market n .²⁷

For the economic structure underlying these preliminary results, firms optimally select both the cut-types in each market as well as prices and qualities given these cut-types. In a standard screening model without random participation, cut-types are those consumers, \bar{t}_j , that are just indifferent between purchasing products j and $j - 1$. Cut-type \bar{t}_{jn} purchases product j in the Rochet-Stole model with random participation as long as its utility is greater than that from the outside good, i.e. $\bar{t}_{jn}q_{jn} - p_{jn} \geq \epsilon_{ijn}$. This implies market shares are given by

$$w_{jn} = \int_{\bar{t}_j}^{\bar{t}_{j+1}} \left[\int_{-\infty}^{u_{jn}(t)} g(\epsilon) d\epsilon \right] f_n(t) dt \quad (30)$$

where $u_{jn}(\bar{t}_{jn}) = \bar{t}_{jn}q_{jn} - p_{jn}$. In the estimation, we calculate (30) using simulation with 100,000 draws.

We assume there is measurement error in market shares such that

$$w_{jn}^{\text{obs}} = w_{jn}(X, \theta) + \tau_{jn} \quad (31)$$

where w_{jn}^{obs} are the observed market shares (cf. Table 1), $w_{jn}(X, \theta)$ are the market shares predicted by the model as a function of exogenous variables, X , and parameters, θ . The exogenous variables in this specification are a constant, average income, and dummy variables for each product/number-of-product combination (i.e. good 1 in 1-good markets, goods 1 and 2 in two-good markets, etc.). The parameters to be estimated are $\theta = (\mu, \sigma, \sigma_\eta, \gamma, \mu_{NG}, \sigma_{NG}, c_0, c_1, c_2, \rho\lambda)$.

Firms solve optimally first for cut-types, \bar{t}^* and then for qualities and utility to the lowest cut-type given these values. Following Rochet and Stole (2002), optimal qualities and the utility to the lowest cut-type solve the first-order conditions:

$$\begin{aligned} u_{1n}^{\text{rs}} \text{ solves } & \sum_{j=1}^{J_n} f_{jn} [g(u_{jn})(S_{jn} - u_{jn}) - G(u_{jn})] = 0 \\ q_{jn}^{\text{rs}} = & \begin{cases} \bar{t}_{J_n} & \text{if } j = J_n \\ \bar{t}_{jn} - \sum_{j'=j+1}^{J_n} \Delta \bar{t}_{j'n} \frac{f_{j'n}}{f_{jn}} \frac{G_{j'n}}{G_{jn}} \left(1 - \frac{g_{j'n}}{G_{j'n}} (S_{j'n} - u_{j'n}) \right) & \text{else} \end{cases} \end{aligned} \quad (32)$$

Given u_{1n}^* and q_{jn}^* for the optimal cut-types, \bar{t}^* , prices are given by

$$\begin{aligned} p_{jn} &= \bar{t}_{jn}^* q_{jn}^*(\bar{t}^*) - u_{jn}^* \quad \text{where} \\ u_{jn}^* &= u_{1n}^*(\bar{t}^*) + \sum_{j'=1}^{j-1} \Delta \bar{t}_{j'n}^* q_{j'n}^*(\bar{t}^*) \end{aligned} \quad (33)$$

where $\Delta \bar{t}_{jn}^* \equiv \bar{t}_{j+1,n}^* - \bar{t}_{jn}^*$. Since q_{jn} is linear in marginal quality cost shocks, ν_{jn} , so too is p_{jn} .

²⁷We can also (but don't yet) predict the number of products, J_n .

Formally, let

$$p_{jn}^{\text{obs}} = p_{jn}(X, \theta) + \tilde{v}_{jn} \quad (34)$$

where p_{jn}^{obs} are the observed prices and $p_{jn}(X, \theta)$ are the prices predicted by the model.

Let $\omega = [\tau' \tilde{v}']'$ be the stacked vector of econometric errors and let $X = [D_{jn} \ D_{jn}Y_n]$ be the matrix of instruments, where D_{jn} = dummy variables for each combination of product/number-of-products pairings (e.g. good 1 in 1-good markets, goods 1 and 2 in 2-good markets, etc.) and Y_n = per-capita income in market n .

Formally, we minimize the objective function

$$Q = \omega(\theta)' X W X' \omega(\theta) \quad (35)$$

where W is the weighting matrix. In the results presented here, we use an estimate of the optimal weighting matrix $W = [V(X'\omega(\theta))]^{-1}$, where we obtained an initial consistent estimate of θ using weighting matrix $W = (X'X)^{-1}$.

5.3 Estimation Specifics [for preliminary results]

The estimation procedure is a three-level nested estimation algorithm. In the *inner loop*, we solve for the optimal qualities (and lowest utility), (q_j, u_1) , as a function of the current estimate of cut-types, \bar{t}_{jn} , in market n . Predictions for the observed prices and market shares follow from these qualities/utility. This is done numerically either by solving the nonlinear system of FOC defined in (32) or by a non-derivative routine that maximizes:

$$\max_{u_{jn}, q_{jn}} E[\pi_n] = \sum_{j=1}^{J_n} f_{jn} G[u_{jn}] [S(q_{jn}) - u_{jn}] \quad (36)$$

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 . Together, the inner and middle loops are described by

$$\max_{\bar{t}_{jn}} \left[\max_{q_{jn}, u_{1n}} E[\pi_n | \bar{t}_n] = \sum_{j=1}^{J_n} w_{jn}(\bar{t}_n) \{S(q_{jn} | \bar{t}_n) - u_{jn}(q_{jn}, u_{1n} | \bar{t}_n)\} \right] \quad (37)$$

In the *outer loop*, we search for values of model parameters, θ , that minimize our objective function, Q . At each level, we use non-derivative (simplex) methods with informative starting values.

An important computational issue arises in practice: our three-level estimation algorithm is slow. Very slow: a single evaluation of Q for our 5,717 markets using Matlab on a 2.00 GHz PC with 1 GB of RAM takes roughly 2 hours. The structure of our problem provides an attractive solution, however. While the distribution of types is assumed to vary across markets (with NG_n , Y_n , and η_n), in all cases it is a normal distribution with mean μ_n and standard deviation σ_n . These preference parameters – μ_n , σ_n , and λ – along with the cost parameters – c_0 , c_1 , c_2 , and ρ – are all that are required to solve for the optimal prices and qualities, associated market shares, and all other outcome variables of interest (e.g. consumer welfare and profit measures). As a result,

we establish a grid over the range of reasonable values of these parameters, solve the model at those grid points, and interpolate values for all the outcome variables between those points. For the results presented in Table 3, we used a range of [2,7.5] for μ_n , [0.3,.7] for σ_n , [0.11,0.91] for λ , [0.3,0.7] for c_0 , [0.2,0.6] for c_1 , [0.5,1.0] for c_2 , and [2,2.6] for ρ with 3 grid points in each dimension.²⁸ For these values, solving for the outcome variables across the whole of the grid for each number of goods offered in each market (1, 2, and 3) took 3 hours, but reduced the time required to evaluate Q to about 0.1 seconds!

6 [Preliminary Results]

Table 3 presents parameter estimates from the endogenous quality model. Reported are point estimates and heteroskedasticity-consistent asymptotic standard errors. All the estimates are statistically significant at conventional levels and appear reasonable: mean WTP for quality varies between \$4.77 and \$5.62 across markets, with corresponding standard deviations between \$0.46 and \$0.33.²⁹ While the impact of income (γ) is not significant, unobserved variation in tastes for cable service quality (σ_η) is important. Preferences for random participation are quite diffuse, suggesting significant substitution for the outside good even among those with high preferences for quality.

Given these estimates, we have an estimate of the distribution of preferences in each cable market, n . From these, we next calculate the optimal cut-types (measuring willingness-to-pay for quality for the household just indifferent between purchasing that and the lower quality), implied qualities, and associated market shares and prices. We can also calculate the amount of degradation of offered qualities relative to that provided by a competitive market offering the same number of goods.³⁰ Table 4 report our estimates of these values as well as how the prices and shares compare with those in the sample.

Looking first at the fit in the top panel of the table, we see that the fit is adequate. There is no discernable pattern to either market share or price errors. The assumption of normally-distributed tastes is strong in our context; we will relax it in subsequent revisions.³¹

With respect to quality degradation, we find that there is significant degradation, particularly for markets offering more than one good. We find that offered qualities are an estimated 5% and 24% less in 3-good markets and 23% less in 2-good markets for households just indifferent between purchasing each good and the good of the next lowest quality.³² Quality to the highest-quality

²⁸We interpolate using the Matlab Interpn function which necessarily constrains us to linear interpolation. Fortunately, almost all the outcome variables are monotonic in each dimension - the exception is for σ for some values of μ - suggesting interpolation will be an effective strategy. For some simple experiments using 10 grid points and linear interpolation, there was a maximal difference of about 0.2% between the interpolated and true outcome variables across the whole of the grid (and a much lower average difference). Approximation errors are much lower with shape-preserving approaches to interpolation, something we will implement in future revisions.

²⁹The increase in mean and reduction in dispersion in preferences for bundles is consistent with the impact of increasing bundle size (cf. Table 1) on preferences for bundles (e.g. Crawford (2008)).

³⁰ $q_i^* = 2\bar{t}_i$ for the cut-types in the specification presented here.

³¹Allowing a more flexible distribution of preferences in each market appears feasible but requires expanding the "state space" of the endogenous quality model to include a flexible specification of \bar{t} and \bar{f} .

³²This is a lower bound on the average degradation for all households. [To Do: Calculate the average degradation.]

good is estimated to be higher than that is efficient for the marginal consumer.

What impact does this quality degradation have on consumer and social welfare? To address this question, we first calculate the "quality markup" for the marginal consumer. This is given by the percentage difference in the derivative of willingness-to-pay with respect to quality ($\partial u/\partial q = \partial(tq)/\partial q = t$) and the derivative of marginal cost with respect to quality ($\partial c(q)/\partial q = c_1 + c_2q^{\rho-1}$), evaluated at the marginal consumers, \bar{t}_j . Consistent with the quality degradation figures above, quality markups are all negative (-12%, -1%, and -5%) for the high-quality good in each type of market, but are between 5% and 24% for lower-quality goods.³³ By comparison, price-cost markups are between 37 and 58% across goods and markets. At least for the marginal consumer, the welfare consequences of quality reductions under monopoly are between one-third and one-half that of quantity reductions under monopoly.

Welfare effects [preliminary results] Given the structure of preferences and costs, we can also simulate the profit and welfare consequences of alternative portfolios of offered qualities. We consider two counterfactuals: one with qualities fixed at that set by the multiproduct monopolist but with prices equal to marginal costs at that quality and another with qualities set at the efficient level but allowing monopoly pricing. While not realistic counterfactuals for policy purposes, these are useful in describing the relative importance of monopoly pricing versus monopoly quality choice in driving welfare outcomes. Table 5 presents the results of these counterfactuals. As expected, qualities that maximize total surplus are generally higher, but allowing monopoly pricing increases prices to consumers. Consumer surplus jumps significantly under either counterfactual, although generally more from efficient pricing of monopoly qualities. Total surplus increases between 3.3% and 55.7% across markets from efficient pricing given monopoly qualities and by -2.4% and 62.1% from monopoly pricing at efficient qualities.³⁴

While firm conclusions are not warranted due to differences in econometric assumptions, these results suggest controlling for endogenous quality may be important for the consistent measurement of consumer tastes in differentiated product markets. More work needs to be done regarding specification choice for our estimation, however, before taking these results as conclusive.

7 Conclusions

The purpose of this paper is to measure the econometric and economic consequences of endogenous quality choice by a multiproduct monopolist. It is based on a model of nonlinear pricing with random participation recently developed by Rochet and Stole (2002). Preliminary results appear reasonable and suggest the welfare consequences from monopoly quality choice may be on the order of half as large as those from monopoly pricing.

³³Negative numbers here mean that the change in marginal cost w.r.t. quality actually exceeds the change in WTP w.r.t. quality for the marginal consumer.

³⁴The discrepancy between the markup and welfare figures for these preliminary results appear to be driven by large welfare gains to consumers with extreme tastes for quality, a common problem arising when using distributions of preferences with unbounded support (e.g. Petrin (2003)). We will explore this issue further in subsequent revisions.

Several immediate extensions of the existing analysis are suggested. First, the empirical specification can be extended to allow for a more flexible structure of consumer preferences. So too can we model the choice of the number of products offered by firms. Since more products are necessarily more profitable, that they are not offered suggests fixed costs from offering multiple cable services, something we will be able to estimate from the data. These extensions will permit greater confidence in the estimated effects of endogenous quality, as well as quantifying its consequence on existing approaches that ignore these effects.

More broadly, one goal of this paper is to introduce the empirical literature to the value of screening models for modeling endogenous product choices. Two areas of current theoretical research look promising for using these techniques in applications outside monopoly cable markets. The first is to incorporate multiple dimensions of consumer preferences. Consumers typically care about multiple product attributes, especially horizontal (e.g. brand) attributes. While this requires models of multidimensional screening, the same simplifications that arose in the single-dimensional setting from the discreteness of firms' offered products may make these models empirically feasible. The second, complementary, extension is to consider competition with endogenous quality choice. While also challenging, models of competition under nonlinear pricing or endogenous quality choice exist (Stole (1995), Rochet and Stole (2002), Miravete and R oller (2003)) and are more generally applicable than the monopoly model considered here. Both of these are promising areas of further research.

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

Notes: Data on cable systems, including service, market share, price, and programming data from Warren (1998). Data on demographic information from Census (1994).

Table 2: Top-20 Cable Programming Networks

Rank	Network	% U.S. Homes	Programming Format
1	TBS Superstation	74.9	General Interest
2	ESPN	74.3	Sports
3	Discovery Channel	74.2	Nature
4	CNN (Cable News Network)	74.1	News
5	C-SPAN	74.0	Public Affairs
6	USA Network	73.8	General Interest
7	TNT	73.7	General Interest
8	Nick	72.5	Kids
9	Family Channel	72.2	General Interest/Kids
10	TNN	72.0	General Interest/Country
11	A&E	71.5	General Interest
12	Lifetime Television	70.8	Women's
13	The Weather Channel	70.2	Weather
14	MTV: Music Television	69.4	Music
15	AMC (American Movie Classics)	68.5	Movies
16	Headline News	68.4	News
17	QVC	65.7	Home Shopping
18	CNBC	64.7	News
19	The Learning Channel (TLC)	63.7	Science
20	VH1	61.7	Music

Notes: Data on percent coverage for 1997 from Kagan World Media (1998). Data on programming formats from individual network promotional material (available from <http://www.ncta.com>), NCTA (1998), or industry sources.

	Preference Params		Cost Params
	Estimate		Estimate
	Std. Err.		Std. Err.
μ	4.77 (0.96)	c_0	0.32 (0.70)
σ	0.46 (0.17)	c_1	0.20 (0.04)
σ_η	0.72 (0.21)	c_2	0.99 (0.21)
γ	0.002 (0.002)	ρ	2.21 (0.17)
μ_2	0.13 (0.11)		
σ_2	-0.02 (0.17)		
μ_3	0.85 (0.22)		
σ_3	-0.13 (0.19)		
λ	0.87 (0.07)		
Obs.			7,571

Notes: Reported are results from GMM estimation of the Rochet-Stole endogenous quality model. Number of observations is 4,034 for Basic, 1,467 for Expanded I, and 201 for Expanded II. Heteroscedasticity-consistent standard errors are reported in parentheses. μ_j and σ_j for $j = \{2, 3\}$ are increments to the mean and standard deviation of household WTP for quality in 2- and 3-good markets, respectively.

Table 4: Fit, Quality Degradation, and Welfare

	3-Good Markets			2-Good Markets			1-Good Markets		
Fit	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	—	—	—	—	—	—
Welfare	CS	Profit	TS	CS	Profit	TS	CS	Profit	TS
Welfare	6.15	11.36	17.52	4.32	8.98	13.29	3.06	8.37	11.43
Observations	201			1,467			4,034		

Notes: Reported are measures of fit, estimated quality, quality degradation, and welfare measures from the baseline (Rochet-Stole) specification. Reported for fit are the sample and predicted market shares and prices as well as their difference. "Offered quality" is the average across markets estimated from the endogenous quality model given the parameter estimates in Table 3 and market-specific variables. "Efficient quality" is that which would equate WTP for quality with its marginal cost for the household just indifferent between purchasing each offered good and the lower-quality good. Percentage degradation is relative to the efficient quality. CS = Consumers Surplus, TS = Total Surplus. Welfare measures are estimated 1998 dollars per household per month.

Table 5: Estimated and Counterfactual Outcomes

	3-Good Markets			2-Good Markets			1-Good Markets		
	Mon Q Mon P	Mon Q Eff P	Eff Q Mon P	Mon Q Mon P	Mon Q Eff P	Eff Q Mon P	Mon Q Mon P	Mon Q Eff P	Eff Q Mon P
Shares									
w_3	0.51	0.85	0.35	0.53	0.81	0.04	0.63	0.85	0.62
w_2	0.18	0.05	0.16	0.12	0.05	0.56	—	—	—
w_1	0.05	0.00	0.21	—	—	—	—	—	—
Prices									
p_3	26.97	14.76	33.73	21.89	11.93	32.75	19.82	10.65	22.59
p_2	22.62	10.98	30.83	15.98	7.07	26.12	—	—	—
p_1	17.62	7.24	27.46	—	—	—	—	—	—
Quality									
q_3	4.39	4.39	5.57	3.86	3.86	5.54	3.61	3.61	4.10
q_2	3.58	3.58	5.06	2.64	2.64	4.56	—	—	—
q_1	2.70	2.70	4.47	—	—	—	—	—	—
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

References

- Akerberg, D., Crawford, G. S., and Hahn, J. (2010). Orthogonal instruments: Estimating price elasticities in the presence of endogenous product characteristics. Working Paper, University of Warwick.
- Armstrong, M. (1999a). Price discrimination by a many-product firm. *Review of Economic Studies*, 66(1):151–168.
- Armstrong, M. (1999b). Price discrimination by a multi-product firm. *Review of Economic Studies*, 66(1):151–168.
- Bakos, Y. and Brynjolfsson, E. (1999). Bundling information goods: Pricing, profits, and efficiency. *Management Science*, 45(2):1613–1630.
- Berry, S. (1994). Estimating discrete choice models of product differentiation. *Rand Journal of Economics*, 25(2):242–262.
- Berry, S., Levinsohn, J., and Pakes, A. (1995). Automobile prices in market equilibrium. *Econometrica*, 63(4):841–890.
- Berry, S. and Pakes, A. (1993). Some applications and limitations of recent advances in industrial organization: Merger analysis. *American Economic Review*, 83(2):247–252.
- Berry, S. and Waldfogel, J. (2001). Do mergers increase product variety? evidence from radio broadcasting. *Quarterly Journal of Economics*.
- Census, editor (1994). *County and City Data Book*. Bernan Associates. Economic data from U.S. Census Bureau on CD-Rom.
- Chu, C. S. (2006). The effects of satellite entry on product quality for cable television. mimeo, Stanford University.
- Clerides, S. (2002). Book value: intertemporal pricing and quality discrimination in the us market for books. *International Journal of Industrial Organization*, 20:1385–1408.
- Crawford, G. (2011). Cable regulation in the satellite era. In *Economic Regulation and Its Reform: What have we Learned?*, chapter 6. University of Chicago Press. forthcoming, chapters available online at http://www.nber.org/books_in_progress/econ-reg/.
- Crawford, G. and Yurukoglu, A. (2008). The welfare effects of bundling in multi-channel television markets. mimeo, University of Arizona.
- Crawford, G. S. (2000). The impact of the 1992 cable act on household demand and welfare. *RAND Journal of Economics*, 31(3):422–449.
- Crawford, G. S. (2008). The discriminatory incentives to bundle in the cable television industry. *Quantitative Marketing and Economics*, 6(1):41–78.

- Crawford, G. S. and Shum, M. (2007). Monopoly quality degradation in the cable television industry. *The Journal of Law and Economics*, 50(1):181–219.
- Crawford, G. S. and Yurukoglu, A. (2011). The Welfare Effects of Bundling in Multichannel Television Markets. forthcoming, *American Economic Review*.
- Draganska, M., Mazzeo, M., and Seim, K. (2009). Beyond plain vanilla: Modeling joint product assortment and pricing decisions. *Quantitative Marketing and Economics*, 7:105–146.
- Elhauge, E. (2008). *United States Antitrust Law and Economics*. Thompson/West, 1st edition.
- Fan, Y. (2010). Ownership consolidation and product quality: A study of the u.s. daily newspaper market. Working Paper, University of Michigan.
- FCC (2000). Sixth annual report on the status of competition in the market for the delivery of video programming (1999 report). Technical report, Federal Communications Commission. Available at <http://www.fcc.gov/mb/csrptpg.html>.
- Hausman, J. (1996). Valuation of new goods under perfect and imperfect competition. In Bresnahan, T. and Gordon, R., editors, *The Economics of New Goods*. University of Chicago Press.
- Hazlett, T. and Spitzer, M. (1997). *Public Policy Towards Cable Television: The Economics of Rate Controls*. MIT Press.
- Kagan World Media (1998). Economics of basic cable television networks. Technical report, Kagan World Media.
- Leslie, P. (2004). Price discrimination in Broadway theatre. *Rand Journal of Economics*, pages 520–541.
- Maskin, E. and Riley, J. (1984). Monopoly with incomplete information. *RAND Journal of Economics*, 15(2):171–196.
- McManus, B. (2007). Nonlinear pricing in an oligopoly market: The case of specialty coffee. *Rand Journal of Economics*, 38:512–532.
- Miravete, E. and Roller, L.-H. (2003). Competitive nonlinear pricing in duopoly equilibrium: The early u.s. cellular telephone industry. CEPR Discussion Paper No. 4069.
- Mussa, M. and Rosen, S. (1978). Monopoly and product quality. *Journal of Economic Theory*, 18(2):301–17.
- NCTA (1998). Cable television developments. Technical report, National Cable Television Association. Available at <http://www.ncta.com>.
- Nevo, A. (2001). Measuring market power in the ready-to-eat cereal industry. *Econometrica*, 69(2):307–342.

- Pakes, A., Porter, J., Ho, K., and Ishii, J. (2007). Moment inequalities and their application. Working Paper, Harvard University.
- Petrin, A. (2003). Quantifying the benefits of new products: The case of the minivan. *Journal of Political Economy*, 110(4):705–729.
- Rochet, J.-C. and Stole, L. A. (2002). Nonlinear pricing with random participation. *Review of Economic Studies*, 69(1):277–311.
- Shcherbakov, A. (2010). Measuring consumer switching costs in the television industry. mimeo., Yale University.
- Spence, A. M. (1975). Monopoly, quality, and regulation. *Bell Journal of Economics*, 6(2):417–29.
- States, U. (2010). *Horizontal Merger Guidelines*. United States. Jointly authored by U.S. Department of Justice and Federal Trade Commission.
- Stole, L. (1995). Nonlinear pricing and oligopoly. *Journal of Economics and Management Strategy*, 4(4):529–562.
- Sweeting, A. (2010). The effects of merger on product positioning: Evidence from the music radio industry. *Rand Journal of Economics*, 41(2):372–97.
- Verboven, F. (2002). Quality-based price discrimination and tax incidence: evidence from gasoline and diesel cars. *Rand Journal of Economics*, 33(2):275–297.
- Warren, editor (1998). *Television and Cable Factbook*. Warren Publishing, Inc.
- Whinston, M. (1990). Tying, foreclosure, and exclusion. *American Economic Review*, 80(4):837–859.