# The Effect of Satellite Entry on Product Quality for Cable Television[*]

Chenghuan Sean Chu

January 2008

## Abstract

In vertically differentiated markets, the effects of firm entry are contingent upon whether incumbent firms can respond to entry by adjusting product quality in addition to simply lowering prices. Using market-level data, I estimate a structural model of supply and demand for subscription television that takes into account the endogeneity of quality choice. Using counterfactual analysis, I decompose the effect of satellite entry on existing cable into two components: the conventional price response and the effect of endogenous quality adjustments (measured by changes in programming content). Consistent with the empirical observation that cable prices rose during the 1990s and early 2000s "in spite of" increasing competition, I find that raising both price and quality for the most comprehensive subscription package—i.e., competing "head-to-head"—is the rational response to entry by cable systems in markets with relatively homogeneous consumer types. Elsewhere, incumbents respond less aggressively and relegate themselves to being the low-end provider. When an entrant credibly commits to serving consumers with the highest preferences for quality, competition over both price and quality lowers the welfare gains due to entry, relative to pure price competition. In particular, head-to-head competition results in "crowding" of quality choices toward the high end of the market and inefficiently low product differentiation. In such cases, consumers with weak quality preferences may actually become worse off following entry. The evidence also suggests that the observed degradation of the lowest-quality cable tier in many markets during this time period—while commonly seen as an attempt to evade price regulation—may actually have been welfare-enhancing.

---

[*] email: sean.chu@frb.gov. The views expressed in this paper are those of the author and do not necessarily reflect those of the Board of Governors or the staff of the Federal Reserve System. The author would like to thank DirecTV, Echostar, Warren Publishing, and Media Business Corp. for providing the data used in this study.

# 1 Introduction

A number of models imply that when firms have fixed costs, excess entry can result in social inefficiencies (Berry and Waldfogel, 1999; Anderson, de Palma and Nesterov, 1995). However, when markets are vertically differentiated, entry can also lead to inefficiencies through its effect on firms' choice of product characteristics, even with zero fixed costs. In the common case in which a "new and improved" good enters the market, the efficiency gains due to price competition may be mitigated by the endogenous quality response. In particular, the tendency for firms to crowd into the high end of the market implies that private incentives lead to insufficient product differentiation.

Because firms are competing over both price and quality, the welfare impact depends on the relative effect of entry on each dimension. Just as a monopolist decides on how "downmarket" to go by choosing the proportion of consumers with low quality preferences to exclude,[1] an incumbent faced with a higher-quality entrant must also choose the proportion of high-end consumers to cede to the new firm. The optimal incumbent response may involve lowering both quality and price (differentiating downward), raising quality and price (competing "head-to-head"), or some combination of lowering price and raising quality ("fighting"). The choice of response depends on cost and demand factors, as well as on whether the entrant can commit to high quality.

I study these issues empirically in the subscription television industry. Until the entry of Direct Broadcast Satellite (DBS) in 1994, most cable firms were local monopolies. The entry of satellite brought a higher-quality substitute with more channels and a clearer picture. In the years before and after entry, the average cable firm also expanded channel offerings in its most comprehensive package. Previous authors attribute this effect to increased competition.[2] However, average trends mask a considerable degree of heterogeneity in the supply response, and one of my contributions is to explain the relationship between the incumbent response and local market conditions.

I begin by estimating a structural model of supply and demand, in which consumers have heterogeneous preferences over content quality (measured by the amount of television programming), the satellite firm commits to offering a high-end good, and cable firms endogenously choose prices and quality levels. In the estimation, I exploit optimality conditions on consumer choice and on price-setting by the cable firms, and account for the endogeneity of cable quality through the use of instrumental variables. Because I do not impose optimality of quality choices in the estimation, the relationship between my parameter estimates and a firm's actual quality choices is not predetermined. However, actual cable menus are generally similar to the profit-maximizing outcomes.

---

[1] Mussa and Rosen (1978), Maskin and Riley (1984), Rochet and Stole (2002).

[2] Goolsbee and Petrin (2004).

The structural estimates make possible the key methodological contribution of this paper, which is a decomposition of the effects of entry into separate components corresponding to competition over price and competition over quality. First, I determine the overall effect of entry by computing the optimal choice of price and quality, in response to satellite as well as for the counterfactual scenario in which entry does not occur, and taking the difference. This comparison indicates that entry induces head-to-head competition in the majority of markets, dampening the oft heard complaint[3] that satellite entry has been ineffective in constraining growth in cable prices: while non–quality-adjusted prices have indeed risen in most cities, raising both price and quality is the incumbent firm's competitive response to entry. At the same time, head-to-head is by no means the universal response, for in other markets, entry induces the cable firm either to "fight" or to differentiate downward. Controlling for firm costs, for differences in satellite quality across locations, and for other "brand effects," the latter response is most likely to occur in markets in which consumers are relatively heterogeneous in their willingness to pay for quality.

The second step of the decomposition involves computing the profit-maximizing prices under actual entry conditions, but conditional on product qualities being held fixed at the optimal monopoly levels. In other words, I determine the optimal price response if incumbent firms were prevented from adjusting programming contents following entry. The contribution of the pure price response to the overall effect of entry is indicated by the difference in outcomes between this counterfactual ("no quality adjustment") and the previous counterfactual ("no entry"). Similarly, we can determine the contribution of endogenous quality adjustments by differencing between the no-quality-adjustment counterfactual and outcomes under the jointly optimal price and quality response.

While entry is unambiguously welfare-enhancing for consumers when firms only compete over price, taking into account endogenous quality adjustments implies that the overall effect of entry may actually make some consumers worse off. In many cases, the incumbent response actually creates "too much" quality, especially in markets where the cable system competes head-to-head. Because the entry-induced changes in cable offerings are determined by the preferences of consumer types that are marginal between consuming cable and satellite, and because such consumers have higher preferences for quality than the typical cable consumer, consumers as a whole would be better off if firms had a lower propensity to compete for the high-end market. Aggregate consumer surplus would be 4.3% higher ($118M for the entire economy, over the course of the representative year 1997) if the firms competed only over price. This aggregate loss of welfare reflects a combination of small changes in welfare for consumers with high preferences for content quality, together with large welfare losses for consumers with low preferences for content quality. Moreover, under conservative assumptions about satellite profit margins, *total* surplus would be $389M higher economywide (for

---

[3] For example, see FCC 06-179

the representative year 1997) if firms competed only over price.

Although the empirical model maintains that cable firms optimize prices jointly for all goods, my discussion focuses on the price and quality of the top cable package. This emphasis is motivated by the far greater empirical significance of the top package. While the average number of packages offered by each firm has increased over time, only 24% of all cable systems offer two or more packages in the average year. Even among firms offering multiple goods, the top good accounts for 86% of the total market share. Moreover, because satellite is a higher-quality substitute for cable, the first-order impact of competition is manifested at the top of the cable menu.

Nonetheless, my findings also give a new angle to recent controversies over quality degradation at the *bottom* of the cable menu. Consumer groups have alleged that cable systems remove channels from the bottom good in order to evade regulation of basic cable prices.[4] I cannot directly address the validity of this claim. However, I do find evidence that among cable markets offering two or more packages, all consumers (including those with low willingness to pay for quality) tend to benefit more from entry in exactly those markets in which the incumbent firm either degrades or leaves unchanged the quality of the lower good. With cable firms crowding toward the high-end market with their top product tier, keeping quality low at the bottom of the cable menu helps to preserve a greater degree of product heterogeneity. Having greater product heterogeneity is welfare-enhancing, because it gives consumers with low willingness to pay more alternatives besides purchasing nothing at all or purchasing a high-quality but expensive good.

The rest of this paper is organized as follows. The following section reviews prior research. Section 3 describes the data and surveys the observed heterogeneity in cable menu changes from 1994 to 2002. In Section 4, I present a model showing how demand conditions affect the nature of the incumbent's response to entry. This model also guides the empirical estimation. Section 5 presents the estimation results, counterfactual exercises, and welfare analysis. Section 6 concludes.

## 2 Prior Literature

Other than government reports (GAO, 2000; FCC, 2006), the primary existing study of the effect of DBS entry on cable is by Goolsbee and Petrin (2004). Goolsbee and Petrin estimate household demand for cable and satellite, quantify the aggregate consumer surplus gains due to entry, and find that higher satellite quality—as captured by an estimated fixed effect in each market—is negatively correlated with cable prices and positively correlated with cable quality. My study builds on theirs

---

[4] "In the Matter of Revisions to Cable Television Rate Regulations," FCC 02-144.

by investigating how firms jointly choose optimal prices and qualities in response to entry. In contrast to their focus on average effects, I am able to explain why different firms make different tradeoffs between quality and price changes, and explore the welfare implications of these decisions.

Another key difference in approach is that while Goolsbee and Petrin treat all cable subscriptions as a single good,[5] I account for the fact that cable menus often offer several vertically differentiated tiers. In this regard, my research draws from the work of Crawford and Shum (2005), who study quality- and price-setting using a screening model of price discrimination, but without taking into account the effect of competition. Crawford and Shum find that under monopoly, significant quality degradation occurs at the bottom of the cable menu, relative to socially optimal levels. In other work, Crawford and Shum (2006) establish that regulation of minimum cable quality tends to reduce the amount of degradation. My analysis of the entry of a high-end entrant serves as a counterpoint to Crawford and Shum's investigation of regulation at the bottom of the menu.

## 3 The Subscription Television Industry

This section provides background information on the subscription television industry and describes the data used in my analysis. Subscription television is an ideal industry in which to study the effect of a high-quality entrant on the behavior of a price- and quality-setting monopolist. Except for a handful of systems facing competition from "overbuilds," cable systems generally hold local monopolies, on terms negotiated with the city franchising authority. Moreover, except for certain rudimentary standards imposed by regulators (discussed below), firms exercise almost complete discretion over quality levels. As a result, quality is largely dictated by strategic considerations.

Individual cable networks are bundled together and sold as tiered services, with the lowest tier typically sold as "Basic Cable" and ones above it as "Expanded Basic," "Expanded Basic 2," and so on.[6] Tiers are "nested"—with all channels in a given tier also included in the ones above it—making cable television a textbook example of a vertically differentiated good. An exception to this rule are the pay-per-view and premium movie channels, which are sold on an a-la-carte basis. The arrival of DirecTV's DBS service in 1994 brought the first true substitute for cable. Similar to cable, the DBS firms offer nested service tiers, and also deliver many of the same networks. In 1997, Echostar's Dish Network entered the market with a slightly less expensive (and somewhat lower quality) DBS service. DirecTV and Dish Network have grown to claim 12.3M and 9.4M households in 2002, respectively, compared to 64.5M subscribers for cable.

---

[5] Goolsbee and Petrin also treat cable subscriptions that are combined with premium a-la-carte channels as a different good, but without incorporating the assumption of a vertically differentiated market.

[6] Occasionally, the lowest tier is called "Limited Basic," in which case "Basic" is the next lowest service tier.

From the start, the satellite subscriptions offered higher quality than most cable tiers. For example, within a year of their respective launch dates, DirecTV's flagship *Total Choice* package delivered 39 channels, and Dish Network's standard *America's Top 40* delivered 42 channels, in addition to optional sports subscriptions and other programming unavailable to cable consumers. By comparison, in 1995 the high cable good had only 14.1 channels on average, and 34 channels at the 99th percentile of the distribution of bundle sizes. DirecTV also offered a degraded "budget" package, but this lower-quality alternative was unpopular and, moreover, still offered more channels than the highest cable tier in most markets.[7] The high quality of satellite is also reflected in its price. In 1997, *Total Choice* cost $29.95 per month, compared to a mean of $20.25 for the highest cable tier. *America's Top 40* cost less than *Total Choice*, at $19.99, but as in the case of DirecTV, involved much higher installation fees than is typical for cable.

While each satellite firm offers a single nationwide menu, cable menus are set individually for each market. In part because of technological constraints,[8] satellite subscriptions offer virtually identical products across markets, apart from slight differences in regional sports networks. By contrast, even cable Multiple System Operators (MSOs) such as Time Warner Cable, Cox Cable, and Comcast typically offer different products across locations.

An open question is why satellite firms do not price discriminate across markets.[9] One possibility is that precommitting to a single nationwide menu complements committing to being the high-end competitor in each market (which presumably earns larger profits than the low-end competitor). Suppose satellite can somehow make its commitment to nationwide pricing credible (for example, by establishing a reputation via public announcements or advertising). Because no individual cable system can induce the satellite firm to differentiate downward through unilateral action, nationwide pricing reduces the incentive for cable firms to compete for the high end of the market.

**Regulation:** Subscription television is a partially regulated industry. Following deregulation in the 1980s, the 1992 Cable Act reinstated the following controls: (1) a minimum quality standard for the lowest tier, requiring systems to carry a certain number of local broadcast, public, educational, and government channels, (2) "must-carry" rules allowing local broadcasters to demand carriage by cable companies, (3) authorization for local authorities to regulate Basic prices, after "certifying" with the FCC, (4) empowerment of the FCC to regulate prices for non-Basic tiers, on a complaint

---

[7] The budget package cost $21.99 and was marketed as *Select Choice*. DirecTV stopped advertising it soon after its launch, and canceled it altogether in June 2000.

[8] The large "footprint" of satellite coverage areas precludes extensive tailoring of contents to individual markets. While "spot-beam" technology has made this easier in recent years, having vastly different channels in different markets remains an inefficient use of limited transponder capacity.

[9] Exceptions to the rule of nationwide pricing exist due to local promotions, as well as a special arrangement allowing the National Rural Telecommunications Cooperative to resell DirecTV.

basis, and (5) exemption from price regulation for systems facing “effective competition.”[10]

Due to the proximity in timing of the Cable Act, we may worry about the confounding effects of regulation on the analysis of satellite entry. One obvious concern is whether the minimum quality constraint binds. Under the standard monopoly screening model, regulating the bottom good leaves quality unchanged at the top of the menu, while either raising or lowering the high good's price, depending on how regulation affects the downward incentive-compatibility constraints (Besanko, Donnenfield, and White 1988; Corts 1995). Empirically, Crawford and Shum (2005) find that local regulatory oversight is in fact correlated with higher quality for the bottom cable good and slightly lower prices for the high good, while leaving high-good quality unaffected.

In practice, the price controls were seldom binding constraints. Most importantly, enforcement was weak to begin with, and the FCC further relaxed the price caps soon after their enactment by means of a number of “going-forward” rules.[11] The Telecommunications Act of 1996 went even further and rolled back all regulation of non-Basic rates, starting March 1999. In addition, in cases in which the price controls were actually relevant, cable systems often engaged in “evasive rebundling,” removing costly channels from Basic and, in some cases, marketing them as unregulated a-la-carte services.[12] This tactic facilitated higher quality-adjusted prices without actually violating the price caps.[13]

Because of the potential for evasive rebundling, slack price constraints do not necessarily imply that regulation had no effect. My empirical specification does not explicitly incorporate the regulatory constraints, but nor does it presume the optimality of firms' quality-setting decisions. On the other hand, I exploit the non-binding nature of the price caps: *conditional* on chosen quality levels, observed prices should match the prices that maximize profits in the absence of regulation.

One final observation: whether through price caps on Basic or through the minimum quality standard, regulation primarily affects the bottom cable tier. By contrast, satellite entry directly affects margins at the top of the cable menu. Therefore, existing regulations do not change the principal effects of satellite entry on cable menus.

---

[10] Communications Act 623(l), 47 U.S.C. 543(l). The price caps were to be based on a per-channel “benchmark” level determined from the prices charged by systems deemed to be facing “effective competition.” Effective competition was defined to exist wherever (1) the area is served by at least two unaffiliated “multichannel video” distributors that meet certain market share requirements, (2) where fewer than 30% of the households in the franchise area subscribe to the cable service, or (3) where the municipality operates a competing service.

[11] See Hazlett and Spitzer (1997) for details.

[12] FCC 02-144. Also see Hazlett and Spitzer (1997)

[13] In theory, the FCC implementation guidelines were supposed to make it unprofitable for firms to engage in evasive rebundling. For example, price caps were set on a *per-channel* basis (“Notice of Proposed Rulemaking and Order,” FCC 02-177). Nevertheless, the regulators only intervened on a case-by-case basis whenever they deemed that the “intent” was to circumvent regulation, and the firms were also able to exploit loopholes such as one created by confusion among regulators as to how the price caps should be adjusted for overhead costs when channels were added or dropped (FCC 02-144 and FCC 02-177).

### 3.1 Data

The data for cable firms come from annual editions of Warren Publishing's *Cable and Television Factbook* for the years 1992–2002. Covering all cable systems in the United States, the *Factbook* lists information on prices, channel contents, the number of subscribers for each product tier, and cable system characteristics, including the total number of homes passed, channel capacity, and franchise fees. Data on prices and demand for a-la-carte premium services (primarily movie channels such as HBO) are available, but not used in my study. After eliminating observations with missing data, 78,165 observations remain, each corresponding to a cable system in a single year. 59,069 of these have just one programming tier, 17,089 have two, 2,006 have three, and just one has 4. Due to inconsistencies across firms in naming practices, I simply refer to the best (and usually only) cable tier as the "high good" and the second best (whenever available) as the "low good." In my discussion and tables, though not in my estimation, I ignore the even lower tiers for systems with three or more tiers, and refer to all systems with two or more tiers as "two-good" systems.[14]

Data on Dish Network's prices and product offerings for each month of the firm's existence came to me from company executives. I also constructed an analogous history of prices and program offerings for DirecTV, by synthesizing archived versions of the DirecTV company website, press releases, and paper copies of old brochures.[15] To facilitate cross-year comparisons, I deflate all cable and satellite prices by the Consumer Price Index.

Satellite company officials declined to supply detailed demand data. However, I have counts of the total number of DBS subscribers in each of 210 Designated Market Areas (DMAs), aggregated across firms, for each year between 1997 and 2004.[16] Even though I have cable subscriber data for all years, satellite entered in 1994, so I do not have a complete picture of demand for the years 1994-1996. Therefore, in my estimation, I only use data for the years 1992, 1993 and 1997–2002.

Data on affiliation fees—the per-subscriber programming costs paid by cable and satellite firms to content providers—are available for various years for 81 out of the 166 cable networks represented in the cable data, including all of the empirically relevant channels. Certain networks, such as the shopping channels, are provided to carriers free of charge. A shortcoming of the cost data is that the figures are not actual amounts paid by the cable and satellite firms, which differ slightly across firms: for 1989–1998, the figures are the per-subscriber list prices; reported fees for 1999–2003 are the average amounts paid by all cable firms.[17]

---

[14] Among systems with three or more tiers, tiers lower than the second highest attract only 4.6% of all potential consumers, compared to 16.0% for the low good and 45.8% for the high good.

[15] Snapshots of DirecTV's webpage at various historical dates are from www.archive.org

[16] Source: Media Business Corp.

[17] 1989–1998 data are from Kagan Research, "Economics of Basic Cable Networks," pp. 48-49, "Cable Network

## 3.2 Heterogeneity in the Response to Entry

My goal is to explain not only the overall time trends in cable prices and qualities, before and after entry, but also the wide variety of responses to entry seen in different markets. In this section, I document the basic intertemporal and cross-sectional trends in the raw data. Table 1 summarizes prices as well as four alternative proxy measures for the content quality of various cable tiers. The measures are weighted sums of the number of channels, using the following weights:

- Uniform weights (i.e., counting the simple total number of channels).
- Average Nielsen ratings for each channel over the period July 1993 through December 2002. Channels that appear on Nielsen's weekly Top-15 list during this period receive a weight proportional to total viewership; all other channels receive a weight of zero.[18]
- Per-subscriber channel costs, averaged over the period 1993–2003.[19] Each channel receives a weight equal to the mean affiliation fee of that network over all markets and time periods. For example, ESPN receives a weight of 1.39, and USA receives a weight of .374.
- Uniform weights counting only the top five channels with the highest Nielsen Ratings (i.e., counting the number of channels from among ESPN, TNT, USA, CNN and Nickelodeon).

Overall trends are robust to the specific choice of weights. Table 1 shows an increase in the average channel content for one-good cable systems, from 11.4 to 18.0 channels over the period 1994–2002, while inflation-adjusted prices rise by \$2.15. Similarly, the high good offered by two-good systems increases from an average of 19.5 channels to 27.1, while prices rise by \$1.51. The quality of the low good, where available, falls from 10.5 to 9.0 (perhaps reflecting the effects of evasive rebundling), while its price falls from \$17.52 to \$11.25. In effect, the quality range widens, with the ratio of low-good quality to high-good quality declining by 38–40% (depending on the choice of weights).

Much variance in the behavior of individual systems underlies the industrywide means. Table 2 reports the number of markets experiencing improvement, degradation, or no change in the quality of each good. In most cases, the high good improves over time, but no change is also common, and declines in quality occur in 1–6% of all cases, depending on the measure used.

---

Affiliate License Fees (top-of-the-rate card)." 1999-2003 data are from Kagan Cable Program Investor (March 15, 2004), pp. 7-8. "Average License Fee per Subscriber per Month by Network."

[18] Nielsen Media assigns to each program a rating that is proportional to the total number of viewers. Over the years, Nielsen made periodic adjustments in the number of viewers corresponding to each ratings point. The weights I use are simply the sum over all weeks of the ratings points for all networks appearing on the Top-15 list, after correcting for these periodic adjustments.

[19] Cost data are available for earlier years, but only for a much smaller set of channels, whereas for 1993-2003, I have cost data for 55 of the 68 highest-penetration channels.

To see how changes in bundle quality vary conditionally with market characteristics, I regress the change from 1994 to 2002 on market observables, including region dummies, the number of over-the-air channels, and initial channel quality in 1994 (tables available on request). Including the initial quality is a way to control for unobserved factors that affect optimal quality levels under both monopoly and duopoly. Among the trends illustrated by the regressions, I find that in general, larger markets and more urbanized markets tend to experience greater content improvements in the high good. During this time period, an increase in cable system size (as measured by the number of homes passed by the network) by a factor of $e$ predicts the addition of 2.0 more channels. Moreover, after controlling for other observables, large MSOs add 2.7 fewer channels to the high good, on average, and 2.4 fewer channels to the low good.[20] The qualitative trends are robust to the choice of weighting scheme.

**Capacity constraints:** My model does not take into account the bandwidth constraints of cable technology. The two alternative modes of transmission—coaxial and fiber optic cable—both place upper limits on the number of channels that can be delivered. If binding, this constraint would make it harder to improve the quality of the high good. However, two pieces of evidence suggest that heterogeneity in the supply response is not merely driven by variation in firms' channel capacities.

First, firms with greater excess capacity in the initial year actually tend to add fewer channels over time. The *Factbook* includes data on the number of unused channel slots for each cable system. When I regress the 1994–2002 change in the number of channels on the number of excess slots in 1994, along with controls for market characteristics and the initial channel count, I find that each additional unused slot in the initial year predicts 0.10 fewer channel additions from 1994 to 2002. Second, the channel capacities appear to be a "soft" constraint: from 1993 to 2002, the average total capacity increased from 34.6 to 44.3, and the number of excess slots remained roughly constant, at 9.2 in 1993 and 9.8 in 2002. During this time period, new technologies for data compression and multiplexing became available, making it relatively easy for firms to add capacity.

# 4 Model

In this section, I present a model of demand and supply for subscription television. The range of incumbent responses to entry can be understood in terms of variation in the model's underlying

---

[20] I include only the seventeen largest nationwide MSOs as of September 2004, by subscriber count, under the definition of "large MSOs." The remaining MSOs, most of which are regional firms, are grouped with independent operators. Many horizontal mergers and acquisitions occurred between 1992 to 2002, such as the acquisition of TCI by AT&T Broadband in 1999, and that of AT&T Broadband by Comcast in 2001. In such cases, I treated systems as being owned by the acquiring firm starting from the year in which the acquisition occurred.

primitives. Following a discussion of the theoretical implications, I describe the estimation strategy.

## 4.1 Demand

I consider a model of vertical differentiation. In each market and time period, households choose either one subscription television package or the outside good. Prior to entry, the choice set comprises the set of all cable goods; following entry, the satellite good is added to the choice set.

Consumer types are drawn from a distribution $G(\cdot)$ over support $[0, \bar{t}]$, where $\bar{t}$ may equal $\infty$. A consumer's type describes his taste for television programming relative to all other goods. In particular, for a consumer $i$ with taste for quality $t_i$, consuming good $j$ from firm $k$ at time $t$ yields a utility that is quasilinear in price and has the form

$$u_{ijkt} = t_i q(x_{1,jkt}) - p_{jkt} + \xi_{jkt} \tag{1}$$

$x_{1,jkt}$ is a vector of indicators for included channels. The function $q(\cdot)$ translates $x_{1,jkt}$ into units of utility, is strictly increasing in each component of $x_{1,jkt}$, and is diminishing in returns to channel content ($q''(x) < 0$). $\xi_{jkt}$ measures the quality of product characteristics other than programming content, relative to the outside good.[21] This term varies across individual products $j$ as well as across firms $k$, because it includes noise from factors such as unobserved channels and product-specific discounts and promotions. However, for brevity I still refer to $\xi_{jkt}$ as the "brand effect," because non–content-related quality characteristics tend to be specific to firms rather than individual bundles. Of course, "brands" and "products" are clearly synonymous when a firm offers only a single tier.

A consequence of placing $\xi_{jkt}$ outside of multiplication by the vertical type $t$ in the utility function is that consumers differ from each other in their tastes for channel content $x_{1,jkt}$, but not for the brand effect $\xi_{jkt}$. The implication is that when consumers form preferences, their valuation of unobserved things such as reception quality and Digital Video Recorders (DVRs) is uncorrelated with their valuation of actual channel content.[22]

Defining $\delta_{jkt} \equiv -p_{jkt} + \xi_{jkt}$ and $q_{jkt} \equiv q(x_{1,jkt})$, we can reexpress (1) as

---

[21] For the satellite good, we can incorporate the brand effect into the price, $p_S$, and then eliminate the separate $\xi$ term. Because both the monetary price of satellite as well as its brand effect are exogenous, and because both terms enter linearly into the utility function, there is no loss of generality from doing so.

[22] An alternative specification would allow one or more components of the brand effect to also interact with the vertical type. However, many components of the brand effect, such as time dummies and MSO ownership, are not features over which consumer preferences seem likely to be strongly differentiated.

$$u_{ijkt} = t_i q_{jkt} + \delta_{jkt} \tag{2}$$

Letting $q_{0mt}$ denote the quality of the free outside good in market $m$ at time $t$, which can be thought of as over-the-air broadcast television, the reservation utility is

$$u_{i0t} = t_i q_{0mt} \tag{3}$$

In each period, consumers purchase their most preferred package from among the cable offerings or—following entry—the satellite good. With one dimension of consumer heterogeneity, the product qualities are strictly ordered, with each good competing only against its two nearest neighbors in quality. Thus, demand is characterized by cutoff types. To illustrate, suppose a market has three goods: a low-quality cable good (L), a high-quality cable good (H), and an even higher-quality satellite good (S). Omitting the subscripts for time and firm, the cutoff types are

$$v_L = -\frac{\delta_L}{q_L - q_0}, \; v_H = \frac{\delta_L - \delta_H}{q_H - q_L}, \text{ and } v_S = \frac{\delta_H - \delta_S}{q_S - q_H} \tag{4}$$

where types $t_i < v_L$ buy nothing, types $v_L < t_i < v_H$ buy the low cable good, types $v_H < t_i < v_S$ buy the high cable good, and types $t_i > v_S$ buy the satellite good.

Following the example of Mortimer (2005), I specify that $t_i$ follows a Weibull distribution with market-specific parameters $(\lambda_m, \rho_m) > 0$. The CDF and density of a Weibull distribution with parameters $(\lambda, \rho) > 0$ are, respectively:

$$\begin{gathered} F(t) = 1 - exp\left[-(\lambda t)^{\rho}\right], \qquad t \in [0, \infty) \\ f(t) = \lambda\rho\,(\lambda t)^{(\rho-1)}\, exp\left[-(\lambda t)^{\rho}\right], \qquad t \in [0, \infty) \end{gathered} \tag{5}$$

The Weibull family is flexible, and can approximate a wide variety of single-peaked empirical distributions.[23] $\lambda$ is inversely proportional to the scale of the distribution. When the "shape" parameter $\rho < 1$, the density function decreases monotonically, with a thinner right-hand tail as $\rho$ approaches zero. When $\rho > 1$, the density function has a positive-valued mode and resembles a normal distribution truncated at zero. Holding $\lambda$ fixed, as $\rho$ increases over the range $[1, \infty)$, the mean of the distribution changes very little, while the variance decreases and consumer types become

---

[23] Single-peakedness is an appealing feature because census microdata (PUMS) indicate that the household income distribution in most markets—which presumably corresponds to willingness to pay for quality—is also single-peaked.

more densely concentrated around the mode.[24] Therefore, over this range, higher $\rho$ corresponds to greater homogeneity in tastes. Freedom to adjust $\rho$ and $\lambda$ independently of each other allows for a distribution with an arbitrary mean and variance.

By combining the cutoff types with the Weibull distribution assumption, we can obtain explicit expressions for the market shares. Suppose that at time $t$, market $m$ has $J_{mt}$ inside goods. Without loss of generality, we can number the goods in increasing order of quality $1, \ldots, J_{mt}$. Omitting subscripts $m$ and $t$ for economy of notation, the following expressions give the market shares:

$$\begin{aligned}
s_0 &= 1 - exp\left[-\left(exp\,(\lambda)\cdot\frac{-\delta_1}{q_1-q_0}\right)^{\rho}\right] && (6)\\
s_j &= exp\left[-\left(exp\,(\lambda)\cdot\frac{\delta_{j-1}-\delta_j}{q_j-q_{j-1}}\right)^{\rho}\right] - exp\left[-\left(exp\,(\lambda)\cdot\frac{\delta_j-\delta_{j+1}}{q_{j+1}-q_j}\right)^{\rho}\right],\\
&\quad j = 1, \ldots, J-1 && (7)\\
s_J &= exp\left[-\left(exp\,(\lambda)\cdot\frac{\delta_{J-1}-\delta_J}{q_J-q_{J-1}}\right)^{\rho}\right] && (8)
\end{aligned}$$

## 4.2 Supply

I treat the number of cable products in a given market and time period as exogenous. While this is a standard assumption in the literature on multiproduct firms, it is a limitation of the analysis. Nevertheless, this feature of the model reflects the empirical reality that firms adjust bundle prices and qualities far more frequently than they adjust the number of bundles. The data also indicate that larger cable systems tend to offer more tiers. These facts suggest that fixed costs are involved in offering more complicated menus, even if doing so allows for more complete price discrimination. Hence, we see more bundles in large markets, where we would expect lower per-consumer menu costs. Section 5.5 discusses the impact of changing the number of goods on profits, but fully endogenizing the number of goods is beyond the scope of this paper.

Firm costs display constant returns to scale and are independent across goods. Specifically, firm $k$'s marginal cost of selling good $j$ to an additional consumer is $\tilde{mc}(x_{1,jk};\zeta_{jk})$. $\tilde{mc}(\cdot)$ is rising in each of its arguments, which include channel dummies $x_{1,jk}$ and a product-specific cost shock $\zeta_{jk}$. Because quality $q(x_{1,jk})$ is also monotone in each element of $x_{1,jk}$, we can redefine the cost function in terms of $q$ instead of $x$: $mc(q,\zeta) := \min_x\{\tilde{mc}(x,\zeta) \mid q(x) = q\}$. Also, $\frac{\partial \tilde{mc}}{\partial x} > 0$ and $q'(x) > 0$ imply that $\frac{\partial mc}{\partial q} > 0$.

---

[24] The mode exists when $\rho > 1$, and is a monotonically increasing function of $\rho$ for $\rho > 1$, approaching 0 as $\rho \to 1^+$ and approaching $1/\lambda$ as $\rho \to \infty$. When $\rho \leq 1$, the density function converges pointwise to zero as $\rho \to 0^+$, for $t > 0$.

In each period, the cable firm sets a menu of prices and quality levels, taking the number of cable goods as given. In pre-entry periods, the incumbent chooses prices and qualities that maximize profits as a multiproduct monopolist. At an exogenous time, satellite enters all markets simultaneously with a single higher-quality good, offered at the same price and quality in all markets. I treat satellite price and quality as exogenous to the cable firm's decision, because the satellite firms' nationwide menu-setting policy implies that they do not best-respond to cable systems at the level of individual markets. A particular cable system's menu choice therefore has a minimal effect on overall satellite profits, and we can think of satellite as a being a "big" player and each cable system as being a "small" player.

On the other hand, the cable firm chooses prices and quality levels as a best response to the satellite offering. Behavior is non-strategic, and the incumbent chooses statically profit-maximizing prices and qualities as a monopolist over the residual demand. Denoting the set of goods offered by firm $k$ at time $t$ by $\mathcal{F}_{kt}$, the market size by $M$, the fixed cost by $C_{kt}$, and the model parameters by $\theta$, the cable firm's ($k$) profit function in period $t$ is:

$$\pi_{kt} = \sum_{j \in \mathcal{F}_{kt}} (p_{jkt} - mc(q_{jkt}, \zeta_{jkt})) M s_{jkt}(p_t, q_t, xi_t, \theta) - C_{kt} \tag{9}$$

## 4.3 Theoretical Implications

In each market, different values of the underlying parameters imply different profit-maximizing choices of cable prices and qualities, both under monopoly as well as under competition from satellite. The effect of entry can be understood as the difference between the two settings. While there are no closed form expressions for the profit-maximizing solution, we can place bounds on the outcome for the polar cases in which satellite entry is either very "aggressive"—with extremely high quality and prices that are low in comparison to quality—or very "weak."[25] In particular, for any continually differentiable consumer type distribution, if there are either two incumbent goods (i.e., a high good $H$ and a low good $L$) or just a single high good ($H$), the following are true:

- If satellite quality is below a certain threshold, the incumbent's best response is to raise the quality of the high good. Intuitively, if satellite has only slightly better quality than the high

---

[25] The following implications require the assumption (formalized by A1 in Appendix A) that satellite entry be not so aggressive that it drives out all demand for the high cable good if, after entry, the incumbent retains its previously set, monopoly-optimal menu.

good, the incumbent can earn near-monopoly-level profits by mimicking the entrant's quality and undercutting it on price.

- If marginal costs $mc(q;\zeta)$ are sufficiently convex with respect to $q$ and consumer types are sufficiently homogeneous, then satellite qualities above a certain threshold induce the incumbent to lower the quality of the high-good. This threshold depends on the price premium for satellite over the high good. Additionally, if there is only one incumbent good, the price of that good moves in the same direction as its quality, following entry.
- As the proportion of consumers willing to pay the premium for satellite goes to zero, no level of satellite quality is sufficient to induce the incumbent to lower high-good quality.

Thus the incumbent's decision rule for the limit cases is as follows: compete for the high-end market if satellite is only slightly better quality or is sold at a high price premium; differentiate downward if satellite has much better quality and is sold at not too high a price premium. All formal statements of results and proofs are in Appendix A, which also discusses numerical simulations dealing with the mapping from parameters into market outcomes for the intermediate cases.

### 4.4 Model Covariates

This subsection details the observable covariates upon which the model components depend.

**Utility from content:** In the specification of consumer utility (1), the function $q(\cdot)$ maps from programming content $x_1$ into units of utility. Rather than attempt to estimate the effect of each individual channel, I treat consumer utility as a function of a univariate aggregate measure of cable programming. The alternative—computing a separate coefficient for each channel—would introduce high-dimensional combinatorics into the counterfactual exercises, making them less tractable.[26] Thus, I redefine $x_1$ to be the cost-weighted proxy measure, as defined in Subsection 3.2.[27] The cost weights are preferable to the alternatives for various theoretical reasons, though in practice, the specific choice of weights does not dramatically affect the results.[28]

---

[26] I also estimate a specification with separate coefficients for the most popular channels, for the aggregate count of all remaining channels, and for interactions between various pairings of channels. Because the top channels are highly collinear in the observed bundles, some of the estimated coefficients are negative. However, the parameter estimates for the cost function and the consumer type distribution differ very little from the base-specification.

[27] As a normalization, I divide the weighted sum by 3 in order to give the utility of content a similar scale to prices.

[28] Uniform weights have the unattractive feature of assigning the same weight to all channels, regardless of importance. Nielsen weights are also less attractive because they assign a weight of zero to any channel that never made it onto Nielsen's Top-15 list during the relevant time period. If a certain network aired a program that was consistently ranked 16th through 20th, say, that network would receive a lower ranking than another that made it onto the list one week but was unpopular the rest of the time.

Without loss of generality, we can normalize the utility for the outside good, $q_{0mt}$, to zero. The content quality of all inside goods depends on the number of over-the-air (OTA) local channels as well as on whether the format is cable ($satellite = 0$) or satellite ($satellite = 1$), because subscribing to cable or satellite does not preclude viewers from watching local broadcast but changes the effective quality of those channels. I assume that utility from content for good $j$ has the form:

$$q(x_{1,jkt}) = (\#\text{ OTA channels})_t \cdot (\beta_0 + \beta_1 \cdot satellite + \beta_2 satellite\_local) + \beta_3 log(x_{1,jkt})^2 \tag{10}$$

The dummy *satellite_local* is an indicator for satellite in market-years in which DirecTV retransmitted OTA channels, following the 1999 act rescinding the ban on DBS rebroadcasting of local channels.[29] The $log(\cdot)^2$ transformation makes utility convex in $x_1$, necessary for the existence of interior solutions.[30] To check for robustness, I also try a few alternative concave transformations, none of which significantly alters the estimates of the parameters outside of (10).

**Brand effects:** The brand effect $\xi_{jkt}$ is a function of observable firm characteristics and market covariates, $x_{2,kt}$, as well as an unobserved component $\Delta\xi_{jkt}$:

$$\xi_{jkt} = \xi' x_{2,kt} + \Delta\xi_{jkt} \tag{11}$$

$\Delta\xi_{jkt}$ is observed by the market participants, and is the structural error upon which my estimation strategy will depend. The observed characteristics $x_{2,kt}$ include the format (dummies for cable and for satellite) as well as dummies for specific MSOs. MSO ownership affects demand through differences in matters such as customer service, marketing, and the availability of technologies like DVRs. Format affects demand if consumers have preferences between the two technologies that are independent of regular subscription contents. For example, during the sample period, the satellite firms introduced an array of a la carte options for out-of-market professional sports (such as DirecTV's *NFL Sunday Ticket*), unavailable to cable customers. Similarly, toward the end of the sample period, cable firms began bundling television with broadband internet. Section 5.2 discusses the consequences of having random coefficients for horizontal format preferences, but for now I assume fixed effects for each format, interacted with year dummies.

---

[29] Satellite Home Viewers' Improvement Act. Following its passage, the DBS firms introduced local at different times for each DMA. For tractability, I abstract away from the potentially endogenous timing of local introduction.

[30] I square $log(x_1)$ because the untransformed $log(x_1)$ has extremely high curvature for low values of $x_1$, resulting in implausibly many corner solutions in the counterfactual exercises. In order to ensure that $log(x_1) > 0$, I redefine $x_1 = 1$ for cases in which $x_1 < 1$. With average programming quality at 16.729, this assumption is rather innocuous.

As controls, I also include dummies that interact satellite format with region dummies and with the percentage of the consumers in each market living in multiunit dwellings (defined by the 2000 Census as buildings with two or more housing units). The region dummies control for differences in reception quality caused by the positioning of the DBS satellites, which transmit from fixed points above the equator. Similarly, multiunit housing residents may not be able to get a proper signal if they cannot find a well-situated attachment point for their receivers.

**Consumer type distribution:** The parameters of the consumer type distribution $(\lambda, \rho)$ depend on a vector of market demographics $z_m$, taken from the 2000 Census, which includes a constant, summary measures of household income distribution, and the total population and population density (including households not passed by cable) of the town in which the franchise is located. I restrict these parameters to plausible ranges by specifying $\lambda_m = exp(z_m'\gamma_1)$ and $\rho_m = n_1 + n_2 exp(z_m'\gamma_2)/(1 + exp(z_m'\gamma_2))$, for constant terms $n_1$ and $n_2$.[31]

**Marginal costs:** The marginal cost of serving an additional consumer has two components: the cost of content and all other costs. Contracts between content providers and cable firms are signed on a per-subscriber-per-month basis, resulting in content costs that scale linearly with the number of consumers.[32] The remaining component includes all non–content-related costs of providing service that scale with the number of customers but are invariant in the actual programming selection. I specify the marginal cost function as:

$$mc(x_{1,jkt}, x_{2,kt}, z_m, \zeta_{jkt}) = \psi_1'(x_{1,jkt}, (x_{1,jkt} \cdot MSO_{kt})) + \psi_2'(x_{2,kt}, z_m) + \zeta_{jkt} \tag{12}$$

The $\psi_1'(\,\cdot\,)$ term is the cost of content and depends on $x_{1,jkt}$, the same proxy measure of programming content that enters into consumers' utility function. $MSO_{kt}$ is a dummy indicating ownership by any MSO. I allow for MSOs and non-MSOs to have different content costs, reflecting differences in bargaining power for horizontally integrated firms. The non–content-related costs $\psi_2'(\,\cdot\,)$ depend on the time-and-firm–varying covariates $x_{2,kt}$ (which include fixed effects for each MSO and for each year) as well as market demographics $z_m$.

The error $\zeta_{jkt}$ is observed by firms but not by the econometrician. In addition to capturing the unobserved component of non-content costs, $\zeta_{jkt}$ also absorbs violations of the assumption that

---

[31] In practice, I set $n_1 = 0.1$ and $n_2 = 14$. The transformation $exp()/(1 + exp())$ implies that if $z_m'\gamma_2$ is roughly symmetrically distributed about zero, then $\rho$ is also symmetrically distributed, corresponding to my prior beliefs about how the $\rho$ parameter is distributed across markets. By contrast, because the scale of consumer tastes is the inverse of $\lambda$, the convexity of the simple exponential transformation $exp()$ ensures that the cross-market distribution of the scale is not severely skewed, given a roughly symmetrical distribution of $z_m'\gamma_2$.

[32] For example, the per-subscriber fee for ESPN in 2002 was, on average, \$1.60/month.

channel costs are purely additive. For example, in some cases, upstream owners of horizontally integrated content networks[33] pressure cable firms to package the commonly owned networks in certain ways. Therefore, the effective cost of each channel may depend on interactions with other channels as well as the product tier in which it is offered.

### 4.5 Estimation

The initial estimation step involves recovering the structural errors $\Delta\xi$ (unobserved quality) and $\zeta$ (the unobserved cost shock).

The key dependent variable that enables us to recover the unobserved qualities $\Delta\xi$ is the product market shares. Given the parameters of the type distribution $(\lambda, \rho)$ and the channel coefficients $(\beta)$, we begin by inverting (6) to obtain an expression for $\delta_1$ in terms of the empirical share of the outside good $s_0$. We can then determine $\delta_2, \ldots, \delta_j \ldots \delta_J$ as functions of the empirical market shares by recursively solving (7) and (8). One complication is that while the number of subscribers is observed for individual cable products, the demand data for satellite are aggregated over all products offered by DirecTV and Dish Network. I deal with this problem by treating satellite as an aggregate good, a solution detailed in Appendix B alongside several other measurement issues. Finally, the unobserved quality $\Delta\xi$ can be recovered as the residual of the brand effect:

$$\Delta\xi_{jkt} = \delta_{jkt} + p_{jkt} - \xi' x_{2,kt} \tag{13}$$

The constant term for the scale parameter $(\lambda)$ of the type distribution is not separately identified from the scale of the coefficients for content quality, $\beta$: in (6)–(8), scaling up content quality $q_j$ and $\lambda$ by the same factor would leave the market shares unchanged. Therefore I normalize the demand coefficient for $log(x_1)^2$ in (10) at $\beta_3 = 1$.

The cost shock $\zeta$ is implied by optimality conditions on cable menus. In particular, the statically optimal $J_{kt} \times 1$ price vector solves the following system of first-order conditions:

$$\frac{\partial \pi_{kt}}{\partial p_{kt}} \;=\; s(p_t, q_t, \xi_t, \theta) - \frac{\partial s_{kt}(p_t, q_t, \xi_t, \theta)}{\partial p_{kt}} \cdot (p_{kt} - mc(q_{kt}, \zeta_{kt})) \;=\; \mathbf{0} \tag{14}$$

where $\frac{\partial s_{kt}(p_t,q_t,\xi_t,\theta)}{\partial p_{kt}}$ is the $J_{kt} \times J_{kt}$ matrix of cross-price elasticities, which we can obtain analytically

---

[33] e.g., Disney Channel and ESPN (Disney); MTV and Black Entertainment Television (Viacom)

under the Weibull distributional assumption. Because quality is vertically differentiated, the cross-elasticities are non-zero only for goods that are adjacent in the quality space. After inverting (14) to solve for the imputed marginal costs $\hat{mc}$ , the cost shock for good $j$ can be recovered as the residual in (12):

$$\zeta_{jkt} = \hat{mc}_{jkt} - \psi_1' x_{1,jkt} - \psi_2'(x_{2,kt}, z_m) \tag{15}$$

By recovering the cost shocks from the price- rather than quality first-order conditions, the estimation procedure implicitly assumes that cable prices are fully profit-maximizing, given quality levels. On the other hand, I do not incorporate optimality assumptions about quality-setting, although the model implies that quality is endogenous and must therefore be instrumented for. It would also be possible to impute the marginal costs from the first-order conditions on quality, instead of imposing the optimality of prices.[34] However, this alternative would make the estimation routine more difficult, because the econometric errors would no longer be linear in the parameters for content costs.[35] Moreover, recall that the 1992 Cable Act may have given two-good cable firms incentives to alter the quality of the low good, whereas the price caps were generally non-binding. If regulation is a factor, estimates based on quality moments could be biased.

Parameter estimates are estimated using the generalized method of moments. The key moment assumptions are that the residual brand effect ($\Delta\xi$) and the residual cost shock ($\zeta$) are orthogonal to the brand-quality covariates ($x_2$, denoted in matrix notation by $X_2$), the type-distribution covariates ($z_m$, denoted in matrix notation by $Z$), and the number of over-the-air channels (# OTA channels). A standard concern is that price is correlated with unobserved quality ($\Delta\xi$), and that channel quality is correlated with both structural errors ($\Delta\xi$ and $\zeta$), invalidating their use as instruments. As such, one more moment restriction is necessary for identification of the demand equation, and two more for identification of the cost function.[36]

Additional demand instruments come from assuming that the following components of $x_2$ are cost shifters that can be excluded from the demand equation: (1) mean per-worker wages for firms in the "Information" sector, (2) mean per-worker wages for firms in the "Broadcasting, except Internet"

---

[34] However, we cannot impute the marginal costs using the quality first-order conditions *in addition* to the price first-order conditions, as we would then have more equations than unknowns.

[35] The first-order conditions with respect to quality are:

$$\frac{\partial \pi_{kt}}{\partial q_{kt}} \;=\; -\frac{\partial mc(q_{kt}, \zeta_{kt})}{\partial q_{kt}} \cdot s(p_t, q_t, \xi_t, \theta) + \frac{\partial s_{kt}(p_t, q_t, \xi_t, \theta)}{\partial q_{kt}} \cdot (p_{kt} - mc(q_{kt}, \zeta_{kt})) \;=\; \mathbf{0} \tag{16}$$

[36] Both price and content quality are endogenous, but the normalization of the price coefficient to 1 provides an additional identifying restriction for the demand equation.

subsector of "Information",[37] (3) log of cable system size, measured by the total number of homes passed. Local wages proxy for the cost of non–content-related inputs (Appendix B details the assumptions underlying these variables), and cable system size captures economies of scale, which I assume to be uncorrelated with demand after controlling for total population.

For identification of the supply side, I assume that (# OTA channels) does not enter into the cost function. I also assume that interactions between MSO-ownership and the above cost shifters can be excluded from both the supply and demand functions.[38]

As an alternative to the above base specification, we can also exploit additional overidentifying restrictions for the demand equation by constructing "quality" instruments, just as the cost shifters instrument for price. Specifically, I consider measures of vertical integration between cable systems and content providers. To a greater extent than would be expected based on cost incentives alone, MSOs tend to favor carrying channels with which they are vertically integrated, while excluding rival firms' channels. This effect may arise from either efficiency considerations (lower transaction costs) or from incentives to engage in vertical foreclosure.[39] Therefore, additional demand instruments are dummies for each of the networks owned by Turner Broadcasting (equal to 1 if included in a bundle) interacted with an indicator for vertical integration between the owning MSO and Turner. Turner is vertically integrated with the MSOs Time Warner, ATC and TCI, which together own 38.3% percent of all the systems in the estimation dataset.[40] To the extent that each of the Turner channels (CNN, TNT, Headline News, TBS, Cartoon Network and Turner Classic Movies) contributes more or less to the content quality of a bundle than substitute channels owned by rival firms, the instruments will be correlated with quality. By assumption, vertical integration status has no direct effect on consumer utility and can be excluded from the demand equation. However, because vertically integrated firms may receive additional discounts on contents, the vertical integration proxies cannot be used as instruments for the supply equation.

The joint estimator minimizes the GMM objective function, $Q = \omega(\theta)'\hat{Z}V\hat{Z}'\omega(\theta)$, where $\omega(\theta) = [\Delta\xi' \;\; \zeta']'$ is the stacked vector of errors. Each element of $\Delta\xi$ corresponds to a system, year, and a cable or satellite product. $\zeta$ only has elements corresponding to cable goods, because we are only modeling the supply decision of the cable firms. $\hat{Z}$ is a conformably defined block-diagonal

---

[37] North American Industry Classification System (NAICS) sector 51 and subsector 515, respectively.

[38] Taken together, the assumptions of this and the previous paragraph yield five overidentifying restrictions for the demand side and two for the supply side. In practice, the second-stage parameter estimates do not change much when the set of excluded instruments is limited to a smaller set.

[39] See Chipty, 2001.

[40] Time Warner (the parent company of the Time Warner Cable and ATC) and TCI have held controlling interests over Turner Broadcasting since before the beginning of the relevant period, with Time Warner fully acquiring Turner Broadcasting in 1996. Other vertical integration measures are possible. For example, Viacom owns the networks Nickelodeon and MTV. However, in this particular case, Viacom accounts for far too small a number of the cable systems to affect the estimates by much.

matrix with a block of demand instruments $Z_D$ and a block of supply instruments $Z_S$. Specifically, $Z_D = [X_2 \;\; Z \;\; W_D]$, with $W_D$ being the excluded cost shifters (as well as the vertical integration instruments, in the alternative specification). $Z_S$ is similar to $Z_D$, but excludes the satellite observations as well as any variable that interacts with the dummy for satellite products. $V$ is the weighting matrix.[41]

I find the minimum of the objective function using a combination of gradient-based and simplex methods, starting from various initial estimates. Because the demand parameters $\xi$ and the cost parameters $\psi$ enter linearly into the expression for the econometric errors, they can be "concentrated out" and expressed as functions of the nonlinear parameters $\beta$ (the programming-content–related coefficients) $\gamma_1$ (covariates for the scale parameter of the vertical-type distribution) and $\gamma_2$ (covariates for the shape parameter of the vertical-type distribution), thereby reducing the number of parameters over which nonlinear search must be performed.

## 4.6 Identification

How do observed market shares and bundle characteristics identify the parameters of the consumer type distribution? The demand moment conditions suffice on their own, but the supply moments also aid in identification. First, note that because the brand effects $\xi$ are unrestricted in the values they can take in a given market-year, the type distribution for a given market would *not* be identified if it were allowed to vary completely freely: given any choice of $\lambda$ and $\rho$, we can find brand effects that would exactly explain the observed market shares. However, we can restore identification by "pooling" information across markets through the assumption that $\rho$ and $\lambda$ are either perfectly determined by observable market covariates or (to make a weaker assumption) are observed up to an error term that is independent of the covariates in the demand equation.[42]

The scale parameter $\lambda$ determines the importance of programming content to consumers' utility, relative to price and brand effects: doubling the value of $1/\lambda$ in a given market, say, implies a doubling in each consumer's valuation of channel content relative to all other goods. If $1/\lambda$ is positively correlated with an observable market characteristic, then in markets with that characteristic, demand is greater for high-quality goods (as well as for subscription television as a whole).

---

[41] I set $V = (\hat{Z}'\omega(\theta)\omega(\theta)'\hat{Z})^{-1}$, the optimal weighting matrix under uncorrelated but heteroskedastic errors.

[42] Allowing $\rho$ (the following remarks also apply to $\lambda$) to be completely free introduces an additional error besides $\Delta\xi$ and $\zeta$, causing the system of equations to be underidentified. In principle, identification could be restored by placing more structure on the errors, e.g., through cross-time restrictions on $\Delta\xi$ and $\zeta$. But if the error on $\rho$ is independent of the observable covariates included in the demand equation, assuming away the error merely amounts to a normalization: taking the predicted value of $\rho$ as its true value, the implied values of $\Delta\xi$ will continue to satisfy the demand moment conditions. On the other hand, if the error on $\rho$ is dependent on observable covariates in the demand equation, treating the predicted values of $\rho$ as the true values would lead to bias.

The shape parameter $\rho$ is identified by the degree of *similarity* in consumers' purchases. Controlling for $\lambda$, higher values of $\rho$ imply that consumer types are more densely concentrated. At one extreme, certain goods offer a great deal of quality at a high price, and appeal to consumers with high preferences for quality; other goods offer little quality at a low price, with the outside good at the extreme. When $\rho \to \infty$, only one good in each market (possibly the outside good) has positive market share; when $\rho \to 0$, the variance of the type distribution increases without bound, leading to higher demand for the "extremal" goods.

It is tempting to try to fit the data by allowing both $\lambda$ and $\rho$ to covary with as many demographic characteristics as possible. However in practice, separate identification of all the covariate parameters is weak unless we restrict certain demographic characteristics to affect only one of $\lambda$ or $\rho$. For example, intuition suggests that median income is a more important predictor for mean tastes (and thus $\lambda$), while income dispersion is a more important predictor for the heterogeneity of tastes (and thus $\rho$). Given the finite amount of data, if we imposed no restrictions, the effect of each covariate on $\lambda$ would be poorly identified separately from its effect on $\rho$. To understand why, recall from (6–8) that a low $\rho$, holding $\lambda$ fixed, would imply large market shares for goods appealing to consumers with extreme tastes. However, the data place most of the observed cutoff types within one or two standard deviations—usually to right—of the mode; the lowest-type consumers are priced out of the market and are thus unobserved. Within the range of the type distribution in which we observe actual cutoff types, lower $\rho$ (holding $\lambda$ fixed) and lower $\lambda$ (holding $\rho$ fixed) have similar implications, with both implying a fatter right-hand tail and larger shares for high-end goods.

The contribution of the supply moments to identification of the type distribution parameters is subtle. The imputed markups (net of the unobserved cost shock $\zeta$) are a function of prices and cost covariates. This function is defined by the first-order conditions on price, which imply that the markup on good $j$ must be higher when its market share is more elastic with respect to price or quality. In turn, the elasticity at a given cutoff point depends on the type distribution parameters: higher $\rho$ implies higher (lower) elasticity for goods whose cutoffs are close to (far away from) the mode of the distribution; higher $\lambda$ implies higher (lower) elasticity for goods with low (high) cutoffs. Thus, so long as there are cross-equation restrictions on the supply and demand covariates, the link between markups and the type-distribution parameters provides an additional source of identification. However, the above logic is somewhat imprecise because the cutoff types are endogenous. Moreover, determining the impact of $\rho$ and $\lambda$ on markups is hard when there is more than one good, because markups also depend on the cross elasticities between adjacent goods.

Identification of the remaining parameters is straightforward. On the supply side, the cost coefficients $\psi_1$ and $\psi_2$ are identified by variation in the imputed marginal costs with respect to the instruments. On the demand side, the coefficients for over-the-air channels ($\beta_0, \beta_1, \beta_2$) are identified by variation in the market share of all inside goods with respect to the number of over-the-air channels and its interaction with cable or satellite format. The parameters $\xi$ for the observed components of the brand effect are identified by variation in market share with respect to non–content-related observable product characteristics.

# 5 Results

## 5.1 Parameter Estimates

The estimation sample contains observations for 10,405 market-years, 4,937 of which are for two-good markets (a higher proportion than in the full dataset). These are the observations that remain after excluding observations with missing data as well as those for markets with overbuilds (to rule out the effects of unobserved competition). I also exclude observations for cities with populations outside the range of 5,000–200,000. The upper cutoff limits the confounding effects of partially overlapping markets, which tend to be in the largest cities. The lower cutoff is motivated by the fact that the Factbook is not updated every year for certain markets, and is least likely to be current for the smallest markets.

Tables 3 and 4 report the second-stage demand and supply estimates. In addition to the estimates from the base case (Column 1), I also report specifications that make use of the vertical-integration instruments for quality (Column 2) and that replace simple year fixed effects for costs with year-specific channel content costs (Column 3). The estimates are similar across specifications, so unless otherwise noted, the remainder of the discussion focuses on the base case.

The tables report the estimates from a parsimonious specification in which the scale of tastes $\lambda$ depends on the median household income ($MED.\ INC$) and the log of population density ($POP.\ DENSITY$), the latter of which proxies for differences between urban and rural areas (e.g, tastes for television might be stronger in rural areas due to the absence of alternative entertainment options). The shape parameter $\rho$ is assumed to depend on the total population of the town in which the franchise is located and on income dispersion, as measured by the difference between the 90th quantile and the median ($INC90 - INC50$).[43]

The cross-market averages of the estimated distributional mean and standard deviation for con-

---

[43] I choose the median as the lower number because the lowest-income consumers are likely to be priced out of the market and therefore not observed in the data.

sumer types are 1.56 and .51, respectively. The former implies that the mean-of-mean consumer derives \$12.84 in utility from the programming content of a typical package (excluding the valuation of the non–content-related brand effect). For comparison, the typical package (averaged over all years, firms and products) is priced at \$22.06. Estimates for the $\lambda$ covariates indicate that tastes for quality are higher in high-income and low-population-density markets. Estimates for the $\rho$ covariates indicate that consumer types are more homogeneous in larger markets and in markets with less income dispersion. This negative correlation between total population and heterogeneity in tastes is driven in the data by the fact that cable menus tend to be somewhat similar across all large markets, relative to the amount of cross-market variation in market shares. As a check for robustness, I also try a specification allowing $\lambda$ and $\rho$ each to depend on all of the demographic covariates, as well as a specification allowing only $\rho$ to depend on demographics. However, estimates of the remaining parameters do not vary much across specifications.

Demand is lower for MSOs, with MSO ownership associated with a disutility of \$2.57 per month. The year dummies indicate no strong time trends. Positive fixed effects for cable systems offering two or more service tiers indicate that such systems have higher quality than one-tier systems, for reasons not captured by my content quality proxy. The satellite-region interaction effects (not reported) are small and positive. The satellite-year interactions are negative, perhaps a reflection of learning or switching costs that prevent consumers from moving freely into the new good. The interaction effect between multiunit housing ($PCT.\ MULTIUNIT$) and satellite format is positive—which is somewhat surprising—but small.

The supply-side estimates point to higher non–content-related costs in high-wage, low-density, large-population, and higher-income markets. The base-specification estimates indicate that for non-MSOs, ten units of programming content cost \$6.08, implying a content cost of \$10.72 for the average-sized package, which has 17.62 units of programming content. MSOs have only slightly lower content costs (\$0.11 less per ten units of programming content) as well as lower non–content-related costs (\$2.73 less per month).

### 5.2 Random Horizontal Preferences

In the model, differentiation between satellite and cable based on non–content-related product characteristics is captured by fixed effects in the demand equation (for format and its interaction with year dummies, regions, and $PCT.\ MULTIUNIT$). The model abstracts away randomness in horizontal preferences between the two formats, both in order to focus on the effects of entry on vertical quality, as well as to preserve closed-form expressions for the market shares.

However, if true horizontal preferences are randomly distributed (e.g., along a Hotelling interval $[0, 1]$ with cable and satellite on either end), then the imputed marginal costs for the post-entry years are biased upward, assuming independence between horizontal and vertical tastes. The bias arises because ignoring horizontal differentiation results in overestimation of the cross-price elasticity between the high cable good and satellite.[44]

It therefore comes as no surprise that the estimated cost of content rises over time when the model provides such flexibility (specification 3), or that the year fixed effects trend upward in the base specification. In effect, the model uses a rising time trend in marginal costs in order to explain why prices do not fall by as much as would otherwise would be predicted in the absence of horizontal random effects. That the cost of content is indeed rising over time is corroborated by the independent Kagan cost data, but the especially large jump from 1993 to 1997 may suggest the influence of unobserved randomness in horizontal preferences between cable and satellite.

### 5.3 The Impact of Entry

Using the parameter estimates, I calculate the expected profit-maximizing cable qualities and prices under various market regimes. While my estimation approach does *not* impose optimality of quality, as a post-estimation exercise we can calculate the jointly optimal prices and qualities both for the pre-entry period (hereafter “M”) as well as for the duopoly regime during the post-entry period (”D”). When we use the parameter estimates from specification 3 (time-varying content costs) rather than from the base specification, the optimal choices of price and quality tend to be higher and lower, respectively. However, the differences across specifications do not affect the analysis in any qualitative way, and I only report the results based on the base specification.

I also compute the profit-maximizing cable qualities and prices for two counterfactual scenarios. The first addresses how cable firms would set prices and content quality over the period 1994–2002 if there were no satellite entry (“NSE”) and cable firms remained monopolies. The second scenario, which I call “no quality adjustment” (“NQ”), addresses how cable firms would respond to entry if

---

[44] To see why, note that with random horizontal effects, each horizontal type corresponds to a unique set of vertical cutoff types for the various products. Define $v_S(\xi)$ as the cutoff vertical type between the high cable good and satellite that is associated with consumers located at position $\xi$ in the Hotelling space. Ex ante the realization of the horizontal type, $v_S(\xi)$ is a random variable. The relatively small empirical market shares of satellite, together with the assumption of independence, imply that the mass of $v_S(\xi)$ lies mostly to the right of the modal vertical type. Model misspecification that constrains the horizontal type to having only a single value $\hat{\xi}$ in each market implies an imputed cutoff vertical type $v_S(\hat{\xi})$ that is lower and thus closer to the modal vertical type than the true mean of $v_S(\xi)$. This bias follows from the fact that horizontal types that are closer to satellite contribute disproportionately to the overall market share of satellite; the bias would be in the other direction if the empirical market shares of cable and satellite were switched. Because $v_S(\hat{\xi})$ is closer to being modal than the true cutoff type for the “typical” horizontal type $\xi$, the cross-price elasticity of demand implied by erroneously attributing horizontal type $\hat{\xi}$ to all consumers is also higher than the cross-price elasticity implied by integrating over the true distribution of $\xi$.

they could only adjust prices but not content quality. Under NQ, I assume that the satellite good is present and offered at the prices and quality levels actually observed in the data, but that cable qualities are constrained to equal the optimal qualities under NSE.

The counterfactual findings for the post-entry period allow us to assess the overall entry effect, as well as to decompose it into two constituent parts: the endogenous quality response and the pure price response. The entry effect is determined by comparing outcomes under NSE either against outcomes under D, or against actual outcomes. The two comparisons have slightly different interpretations: comparing NSE to D asks how profit-maximizing cable behavior differs with and without entry; comparing NSE to actual values asks what the actual effect of entry is, assuming that behavior sans entry would be optimal. Of course, the comparisons are identical if actual cable firm behavior is optimal. The endogenous quality response compares fully profit-maximizing behavior under duopoly (D) against profit-maximizing duopoly behavior if cable firms cannot adjust content quality (NQ). This effect captures the component of the supply response to entry that can be attributed to quality adjustments. Finally, the pure price response is the difference between NQ and NSE, and indicates the changes that would occur if firms only competed over price.

For each counterfactual, I constrain the number of cable goods to be less than or equal to the actual number, and fix the unobserved cost shocks $\zeta$ and brand effects $\xi$ at levels implied by the parameter estimates.[45] When there are multiple goods in the market, computing the profit-maximizing prices and qualities is made difficult by the existence of corner solutions or, in some cases, multiple roots to the price- and quality first-order conditions. To find the globally optimal menu, I do the following for each market-year: (1) gridsearch to obtain initial values for qualities, including test cases for all possible quality orderings,[46] (2) compute initial values for prices that ensure positive demand for each good, taking as given the quality levels chosen in step 1, and finally, (3) perform joint maximization over prices and qualities starting from the initial values given by steps 1 and 2.

Table 5 counts the number of market-years in which entry induces increases or decreases in the price and quality of the high good, respectively. When the comparison is between actual outcomes and the NSE counterfactual, *more than half (60.3%) of all market-years respond to entry by raising quality, accompanied by price increases ("head-to-head").* However, *in 22.5% of market-years, the incumbent lowers price as well as raises quality ("fighting").* Finally, *in 17.2% of cases the incumbent differntiates downward.* Comparisons between D and NSE also show heterogeneity in

---

[45] This assumption is not entirely innocuous: a more realistic view is that cable can make itself more appealing to consumers either by adding contents or through non–content-related quality improvements. Therefore, the effect of entry on cable price and content quality implied by the counterfactuals is an upper bound on the magnitudes that we would observe if brand effects are endogenously determined.

[46] For the case of 2 cable goods (L and H) and 1 satellite good (S), there are 3 possible configurations: LHS, LSH, or SLH. For the case of 1 cable good (H), there are 2 possible configurations: HS or SH.

response, but with a larger proportion of firms competing head-to-head.

Table 6 summarizes prices, quality levels, market shares, and cable profits under each scenario. To conserve space, I only report outcomes for multiproduct firms, because there are no qualitative differences (on average) between one-good firms' offerings and the high good offered by two-good firms, with regard to either the impact of entry or the endogenous quality response.[47] For 9.5% of the observations for two-good firms, the profit-maximizing solution under M or NSE involves offering only a single, high, good. Likewise, 2.8% of these markets offer only one good under D.[48] Actual prices do not exactly match the optimal prices (M for years before 1994, and D for 1994–2002) because the estimation only imposes conditional optimality of prices given qualities, while $M$ and $D$ compute the jointly optimal prices and qualities. The main findings from Table 6 are as follows:

- Over the period 1992–1993, quality and prices for the high good are close to optimal (M), suggesting that the NSE counterfactual is a reasonable benchmark for assessing the effect of entry in later years. The optimal quality choice underpredicts actual levels during the pre-entry period by only 12%, on average. Optimal prices are on average only 2.4% below actual prices ($21.67 versus $22.20). However, the degree of underprediction is greater for the low good's price (by $3.82) and quality (by 62%).

- Reflecting the prevalence of head-to-head competition, entry raises average high-good quality and price, as indicated by comparing levels under NSE (quality of 14.7 and price of $23.93) against the corresponding levels under D (quality of 21.6 and price $25.75) for the period 1994–2002. The mean entry effect is somewhat smaller in magnitude when the comparison is between NSE and actual values (quality of 17.9 and price of $23.19), because D slightly overpredicts the actual post-entry quality and price.[49] The correlation between these two measures of the effect of entry on the high good (i.e., actual minus NSE, versus D minus NSE) is .665. The model does poorly at predicting the actual entry effect on the low good (with a correlation of -.052), perhaps reflecting the effects of regulation.

- Endogenous quality choice results in higher post-entry cable prices than would be the case under pure price competition. If cable firms could not adjust content quality in response to entry (NQ), satellite entry would result in *lower* cable prices relative to no-entry (NSE). The

---

[47] Tables for one-good firms are available on request.

[48] Firms have a screening incentive to degrade the low good but, by assumption, only control quality through the choice of channel content. Therefore, if the brand effect of the low good is positive, it may be optimal not to offer the low good at all.

[49] In some market-years, the optimal menu under D involves setting the high good's quality to exactly match satellite quality and setting its price at a level such that all consumers prefer it to satellite. In other cases, the optimal response involves setting the high good's quality above satellite quality and "leapfrogging" over the entrant.

average NQ price of the high good is \$21.45, versus \$23.93 under NSE and \$25.75 under D.

- Cable profits under NSE exceed profits under D by 49%, and exceed profits under NQ by 74%. (At \$2.01 per consumer-month, actual post-entry cable profits are somewhat lower than the profits of \$2.39 under D). Note that profits under D must weakly exceed NQ profits, because the optimal menu under NQ is also feasible under D. The numbers suggest the *degree* to which content changes enable higher profits: quality adjustments allow firms to recoup 22.5% of the profit losses due to entry.[50]

The model implies that the form of the optimal incumbent response depends on the distribution of consumer types and therefore on the observable market covariates. The most salient empirical relationship is between larger market population and the tendency to compete head-to-head, which the parameter estimates rationalize by making large population the strongest predictor for a concentrated consumer-type distribution (high $\rho$). Table 7 demonstrates this point by reporting the mean entry effect on the high good for various groupings of observations, as classified by total population and by high-good quality or price under NSE.[51] (Grouping observations by NSE quality and price is a control for unobserved product characteristics and cost shocks, which affect optimal cable menus both with and without entry.) The numbers indicate that after controlling for NSE quality, the amount of quality improvement tends to be greater in larger markets.

## 5.4 Consumer Welfare

Table 8 reports the actual and counterfactual consumer surplus (which is analytically computable under the Weibull assumption) for the post-entry period, both in the aggregate and for specific subsets of consumers. For the same reason as in the previous section, I focus on two-good firms, except when discussing economywide totals.[52] Not surprisingly, competition generally benefits consumers, with actual total consumer surplus (\$3.16 per consumer per month) and surplus under D (\$2.94) exceeding the total consumer surplus under NSE (\$1.32) during the post-entry period.

However, differences in consumer surplus at different quantiles of the type distribution indicate that *entry has large distributional effects, with the greatest absolute consumer surplus gains going to consumers with stronger preferences for quality.*[53] Table 8 reports average consumer welfare for various subsets of consumers, as grouped according to their purchasing decisions. Generally,

---

[50] This percentage is the mean across observations of $(\pi_D - \pi_{NQ})/(\pi_{NSE} - \pi_{NQ})$.

[51] Cross-tabulating the entry effect by the value of $INC90 - INC50$ or by the value of $\rho$ itself, for that matter, would convey the same information.

[52] Detailed consumer surplus figures for one-good firms are available on request.

[53] Quantile values are computed separately for each market-year.

consumers purchasing higher-quality goods experience greater surplus gains. For example, gains due to entry average \$4.61 for the typical consumer who actually consumes satellite post-entry but would consume the high cable good under NSE (in the table, “H to sat”). The gain is less, at \$2.48, for purchasers of the high good under both NSE and in reality (“H to H”). At the lower end of the market, consumers who would switch from the low good to the high good (“L to H”) gain \$0.97 in surplus, while switchers from the outside good to the low good (“O to H”) gain \$0.19. In fact, in some cases, entry actually reduces surplus for consumers with weak preferences for quality. In 10.1% of markets, consumers at the 10th percentile of the distribution have lower surplus under D than under NSE. The same holds for consumers at the 25th percentile in 11.5% of markets. Comparing the welfare of such consumers under NSE against their actual outcomes yields qualitatively similar findings.

We can also quantify the impact that is specifically due to the endogenous quality component of the entry response. Over all markets (including the set of one-cable-good markets), aggregate consumer surplus is 4.3% higher under pure price competition (NQ) than under competition over both price and quality (D). The percentage difference implies an absolute difference of \$118M over the course of a typical year (1997) for the entire United States, assuming the estimation sample is representative. For comparison, the total consumer welfare gain due to entry in 1997 (D minus NSE) is \$1.509B. Table 8 also breaks down the effect of endogenous quality choice by consumer type. The reduction in welfare from NQ to D is greatest for types that purchase lower-end goods, while consumers with high preferences are almost equally well off under the two regimes.[54] For example, quality adjustments result in a 56% and 34% welfare reduction for types that switch from the outside good to the low cable good or to the high cable good, respectively (”O to L” and ”O to H”), but only by 1.2% for types that switch from the high good to satellite (”H to sat”). Likewise, the quantile figures indicate that consumer types other than those with the highest preferences for quality (for example, at the 90th quantile) prefer not to have quality adjustments.

Because we lack information on the satellite firms’ costs, the exact size of the total social surplus is indeterminate. However, as long as the satellite markup is not much lower than that of cable, total social surplus is also higher under pure price competition (NQ) than with quality adjustments (D). Although cable firm profits are lower under NQ than under D (\$2.05 against \$2.39 for two-good firms, shown in Table 6; \$1.97 against \$2.51 for one-good systems, not shown), this difference is offset by higher profits for satellite. A very conservative assumption is that, as a large competitor, satellite firms have the same costs per unit of content as MSOs and the same non–content-related cost shock ($\zeta$) as the average high cable good. This assumption is similar in spirit to existing models of vertically differentiated oligopoly that find higher markups and profits for the highest-

---

[54] Obviously, switchers to satellite—for whom post-entry cable is an irrelevant alternative—are indifferent.

quality good.[55] Under this assumption, the total surplus averaged across all (one-good and two-good) markets is \$6.444 per consumer per month under NQ, compared to \$5.958 under D. For a representative year (1997), the aggregate total surplus loss is \$183M for the estimation sample and \$389M economywide.[56]

To summarize, head-to-head competition in response to entry results in inefficiently little differentiation in the available range of product qualities, relative to pure price competition. Intuitively, the incumbent chooses the "least costly" mix of price reduction and quality increase in order prevent marginal consumers from switching to the new good. Under D, the firm has a larger set of instruments for accomplishing this objective than under NQ. Therefore, if there were only one consumer type (i.e., $\rho \to \infty$), that consumer must have weakly higher utility under D than under NQ. But with any nondegenerate distribution of consumers, most consumers are *not* marginal between cable and satellite, and have weaker preferences for quality than the potential switchers to satellite. Therefore, from the perspective of maximizing consumer surplus, the chosen mix of price reductions and quality increases too heavily favors quality increases. While high types benefit from the higher-quality goods, low types would prefer that the incumbent respond to entry with greater price reductions and fewer quality increases.

## 5.5 Discussion

The result of "too little differentiation" rests on the assumption that satellite is exogenously committed to offering the highest-quality good, which precludes it from responding to rising cable quality by offering a lower-quality good, undercutting cable on price, and taking the bottom of the market. This is a reasonable assumption in the case of subscription television, due to the nationwide menu-setting by satellite. On the other hand, if the two competitors were *identical* and both best-responding to each other, there may be more product differentiation following entry than implied by my model.[57] However, the result of excessive quality could be restored if firms are sufficiently asymmetrical. For example, if satellite has lower unit costs for quality, or if satellite has a much higher brand effect than cable because people intrinsically prefer the newer technology, then even in equilibrium, the cable incumbent will seldom find it profitable to set quality so high that the satellite firm's best response is to differentiate downward.

---

[55] See Shaked and Sutton (1982)

[56] NQ would be more efficient than D even if we were still more conservative and assumed either that: (1) satellite firms have the same cost of content as non-MSOs, or (2) satellite firms have the same markup as the average (as opposed to the highest) cable good (i.e., total firm profits = cable firm profits inflated by $(share_{cable} + share_{sat.})/(share_{cable})$).

[57] Shaked and Sutton (1982) study the duopoly equilibrium for the case of zero costs and zero brand effects.

Furthermore, my analysis focuses on the high cable good. It turns out that offering a second (low) good may mitigate some of the welfare losses due to the quality response. If cable offers only one good and competes with satellite for the high-end market, consumers with low willingness to pay for quality face a stark choice between consuming the outside good or purchasing an expensive good, neither of which gives them much net utility. On the other hand, with a second cable good, the price and quality of the lower-quality good are no longer directly determined by the preferences of the potential switchers to satellite. Indeed, the counterfactuals indicate that conditional on entry causing high-good quality to go up, the average increase in consumer surplus (from NSE to D) at each quantile of the type distribution is higher among markets in which low-good quality goes in the opposite direction or stays unchanged rather than also increasing, leading to an aggregate consumer surplus gain of \$4.75 versus \$1.43.[58] Thus, in many markets, the observed degradation of the lowest-quality cable tier during the sample period may actually have been welfare-enhancing.

In the data, the average number of actual cable bundles increases gradually over time, but it remains an open question why—given the size of the foregone screening profits—firms do not offer a broader range of goods. We can recompute profits and consumer welfare under the counterfactual supposition that all one-good cable firms offered instead two bundles, or that conversely, all multi-good cable firms were limited to having a single bundle.[59] The results indicate that if the one-good firms offered an additional bundle, their per-consumer monthly profits would increase by 33.5% during the pre-entry period (under optimal monopoly bundling) and by 41.4% post-entry (under optimal duopoly bundling). Conversely, if the two-good firms could only offer a single bundle, optimal profits would fall by 13.9% pre-entry and 14.8% post-entry. Moreover, aggregate consumer welfare decreases as the number of bundles goes up, suggesting that firms are better at extracting surplus when they have a broader range of goods.[60] As we would expect, the counterfactual welfare losses due to having more goods are borne by consumers with medium and high preferences for quality, while lower-end consumers tend to experience welfare gains.

## 6 Conclusions

For many goods in the economy—retail, hotels, airline routes, and cell phone plans, to name a few—a common occurrence is for a competitor to enter the market with a product targeting

---

[58] Likewise, conditional on entry causing high-good quality to go down, the average increase in consumer surplus at each quantile of the type distribution is higher among markets in which low-good quality also goes down rather than up, for an aggregate consumer surplus gain of \$1.02 versus \$0.54.

[59] For the 2-good counterfactual, I assume $\xi$ and $\zeta$ for the fictitious good are identical to the estimated values for the actual good. For the 1-good counterfactual, I set $\xi$ and $\zeta$ to the estimated values for the actual high good.

[60] If one-good firms offered two bundles, total consumer surplus would decrease 26.2% pre-entry and 15.1% post-entry. If two-good firms could only offer one bundle, consumer surplus would rise 11.0% pre-entry and 5.9% post-entry.

higher-end consumers. The incumbent then faces pressure both to lower prices as well as to raise quality. The precise manner in which firms make this tradeoff has importance both for distributional reasons as well as because a strong quality response can eliminate some of the efficiency gains from competition. I estimate a vertically differentiated discrete-choice model of supply and demand for cable and satellite television, using market-level data on prices, product characteristics, observed demand, and demographic covariates. My model allows for the supply response to entry to depend on local demand conditions, cost shocks, and brand effects.

The structural parameter estimates enable me to determine the effect of entry on cable prices and qualities in each market, as well as the associated consumer surplus and cable firm profits. Additionally, through a decomposition of the entry effect, I am able to determine the component that is specifically due to firms' ability to endogenously choose product qualities. I find that 60.3% of cable firms respond to entry by raising both quality and price. The remaining firms either differentiate downward or use price cuts in combination with quality enhancements. While entry enhances welfare for most consumers, some buyers are made worse off. Additionally, the endogenous quality response diminishes the entry-induced gains in aggregate consumer surplus and (under weak assumptions) total social surplus, relative to the gains that would be realized if cable firms competed only over price. These welfare losses due to endogenous quality choice are amplified for consumers with weak preferences for television content.

On the other hand, if the incumbent cable firm offers a low good and does not raise its quality in response to entry, entry tends to result in large consumer welfare gains for all consumers, even if the cable firm adjusts the high good to compete head-to-head against satellite. This result implies that consumers might benefit from a regulation compelling cable systems to unbundle their most basic services and retain a lower-quality package. More generally, my findings suggest that when firms compete head-to-head, the crowding of products toward the high end of the market can lead to inefficiently small amounts of product differentiation. The social benefits of entry by a higher-quality competitor are largely mediated by the actual mechanics of the supply response.

# References

Anderson, S., A. de Palma and Y. Nesterov (1995): “Oligopolistic Competition and the Optimal Provision of Products,” *Econometrica*, 63(6), 1281-1301.

Armstrong, M. (1999): “Price Discrimination by a Many-Product Firm,” *Review of Economic Studies*, 66(1), 151-168.

Armstrong, M. and J. Vickers (2001): “Competitive Price Discrimination,” *RAND Journal of Economics*, 32(4), 579-605.

Berry, S. and J. Waldfogel (1999): “Free Entry and Social Inefficiency in Radio Broadcasting,” *RAND Journal of Economics*, 30(3), 397-420.

Besanko, D., Donnenfeld, S. and L. White (1988): “The Multi-product Firm, Quality Choice and Regulation,” *Journal of Industrial Economics* 36(4). 411-429.

Champsaur, P. and J.-C. Rochet (1989): “Multiproduct Duopolists,” *Econometrica*, 57(3), 533-557.

Chipty, T. (2001): “Vertical Integration, Market Foreclosure, and Consumer Welfare in the Cable Television Industry,” *American Economic Review*, 91(3), 428-453.

Cohen, Andrew M. and Michael J. Mazzeo (2004): “Identifying Price Discrimination when Product Menus are Endogenous,” Finance and Economics Discussion Series 2004-10, Board of Governors of the Federal Reserve System.

Cohen, Andrew M. and Michael J. Mazzeo (2004b): “Competition, Product Differentiation and Quality Provision: An Empirical Equilibrium Analysis of Bank Branching Decisions,” Finance and Economics Discussion Series 2004-46, Board of Governors of the Federal Reserve System.

Corts, Kenneth (1995): “Regulation of a Multi-Product Monopolist: Effects on Pricing and Bundling,” *Journal of Industrial Economics*, 43(4), 377-397.

Crawford, G. (2000): “The Impact of the 1992 Cable Act on Household Demand and Welfare,” *RAND Journal of Economics*, 31(3), 442-449.

Crawford, G. and M. Shum (2005): “Monopoly Quality Degradation and Regulation in Cable Television,” *Journal of Law and Economics* (forthcoming).

Crawford, G. and M. Shum (2006): “The Welfare Effects of Endogenous Quality Choice: The Case of Cable Television” (Working Paper).

Crawford, G. (2006): “The Discriminatory Incentives to Bundle in the Cable Television Industry” (Working Paper).

FCC (2002): “In the Matter of Revisions to Cable Television Rate Regulations,” *Comments of the National Association of Telecommunications Officers and Advisors (4 Nov. 2002)*, MB Docket No. 02-144.

FCC (2002b): “Notice of Proposed Rulemaking and Order,” 19 June 2002, MB Docket No. 02-177.

FCC (2006): “Annual Assessment of the Status of Competition in the Market for the Delivery of Video Programming,” *Twelfth Annual Report to Congress*, MB Docket No. 05-255.

FCC (2006b): “Report on Cable Industry Prices,” FCC 06-179, MM Docket No. 92-266.

Goolsbee, A. and Amil Petrin. (2004): “The Consumer Gains From Direct Broadcast Satellites and the Competition with Cable TV,” *Econometrica*, 72(2), 351–381.

Hazlett, T. and M. Spitzer (1997): *Public Policy Towards Cable Television: The Economics of Rate Controls*, MIT Press.

Johnson, Justin P. and David P. Myatt (2006): “On the Simple Economics of Advertising, Marketing, and Product Design,” *American Economics Review*, 96(3), 756-784.

Maskin, E. and J. Riley (1984): “Monopoly with Incomplete Information,” *RAND Journal of Economics*, 15, 171-196.

Mortimer, J. (2006): “Price Discrimination, Copyright Law, and Technological Innovation: Evidence from the Introduction of DVDs” (Working Paper).

Mussa, M. and S. Rosen (1978): “Monopoly and Product Quality,” *Journal of Economic Theory*, 18, 301-17.

Rochet, J.-C. and L. Stole (2002): “Nonlinear Pricing with Random Participation,” *Review of Economic Studies*, 47, 277-311.

Shaked, A. and J. Sutton (1982): “Relaxing Price Competition through Product Differentiation,” *Review of Economic Studies*, 49(1), 3-13.

Stennek, Johan (2007): “Exclusive Quality—Why Exclusive Distribution may Benefit the TV-viewers,” Research Institute of Industrial Economics Working Paper No. 691.

U.S. General Accounting Office (2000): “The Effect of Competition from Satellite Providers on Cable Rates,” *Report to Congressional Requesters, GAO/RCED-00-164*, Washington, DC.

Table 1: Mean price and content quality by year and good, for goods present in both 1994 and 2002

| Menu structure | Num obs. | Price ($'s) High | Price ($'s) Low | Quality, No weights High | Quality, No weights Low | Quality, Nielsen wts. High | Quality, Nielsen wts. Low | Quality, Cost wts. High | Quality, Cost wts. Low | Quality, Top-5 wts. High | Quality, Top-5 wts. Low |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-good, 1992 | 2731 | 17.59 | | 10.84 | | 12311 | | 3.09 | | 3.27 | |
| 1-good, 1994 | 2801 | 18.06 | | 11.44 | | 12657 | | 3.22 | | 3.42 | |
| 1-good, 1996 | 2590 | 17.59 | | 11.88 | | 12850 | | 3.33 | | 3.50 | |
| 1-good, 1998 | 2502 | 19.40 | | 13.56 | | 13847 | | 3.69 | | 3.79 | |
| 1-good, 2000 | 2535 | 20.31 | | 16.23 | | 14830 | | 4.14 | | 4.04 | |
| 1-good, 2002 | 2559 | 20.21 | | 18.00 | | 15370 | | 4.42 | | 4.17 | |
| 2-good, 1992 | 115 | 21.19 | 16.99 | 16.50 | 9.13 | 17093 | 7972 | 4.11 | 1.77 | 4.43 | 1.76 |
| 2-good, 1994 | 415 | 22.13 | 17.52 | 19.50 | 10.53 | 18080 | 7841 | 4.56 | 1.61 | 4.73 | 1.51 |
| 2-good, 1996 | 390 | 20.99 | 15.32 | 20.08 | 10.15 | 18026 | 7284 | 4.61 | 1.51 | 4.72 | 1.38 |
| 2-good, 1998 | 391 | 22.19 | 11.62 | 21.97 | 10.16 | 18378 | 6757 | 4.88 | 1.47 | 4.81 | 1.26 |
| 2-good, 2000 | 400 | 23.02 | 11.60 | 23.65 | 9.75 | 18534 | 6133 | 5.18 | 1.40 | 4.84 | 1.14 |
| 2-good, 2002 | 415 | 23.64 | 11.25 | 27.05 | 9.03 | 18722 | 5070 | 5.64 | 1.23 | 4.87 | .90 |

Samples for 1-good and 2-good firms are the sets of firms for which the number of goods remained unchanged from 1994 to 2002.

All prices are adjusted by CPI for all items less food and energy, in 1997 dollars.

Table 2: Frequency of increases and decreases in content quality and price, by good

| Change, 1994-2002, by tier: | Price High | Price Low | Quality, unif. wts High | Quality, unif. wts Low | Quality, Nielsen wts High | Quality, Nielsen wts Low | Quality, cost wts High | Quality, cost wts Low | Quality, top-5 High | Quality, top-5 Low |
|---|---|---|---|---|---|---|---|---|---|---|
| All, Down | 2210 | 377 | 200 | 196 | 123 | 185 | 55 | 182 | 31 | 163 |
| All, No change | 0 | 0 | 718 | 132 | 992 | 165 | 867 | 153 | 2081 | 233 |
| All, Up | 1160 | 38 | 2452 | 87 | 2255 | 65 | 2448 | 80 | 1258 | 19 |
| 1-good, Down | 1174 | | 162 | | 82 | | 41 | | 23 | |
| 1-good, No change | 0 | | 598 | | 836 | | 727 | | 1594 | |
| 1-good, Up | 1027 | | 2041 | | 1883 | | 2033 | | 1184 | |
| 2-good, Down | 436 | | 38 | | 41 | | 14 | | 8 | |
| 2-good, No change | 0 | | 120 | | 156 | | 140 | | 487 | |
| 2-good, Up | 133 | | 411 | | 372 | | 415 | | 74 | |

1 obs. = 1 cable system. “Down”:= decrease in value, 1994–2002. “Up”:= increase in value, 1994–2002.

Table 3: Demand estimates (and standard errors)

| *Channel coefficients $\beta$* | (1) Base specification estimates | (1) Base specification SEs | (2) Quality instruments estimates | (2) Quality instruments SEs | (3) Content cost year effects estimates | (3) Content cost year effects SEs |
|---|---|---|---|---|---|---|
| OTA ($\beta_0$) | -.0107 | (.0087) | -.0041 | (.0073) | -.0161 | (.0061) |
| OTA·*satellite* ($\beta_1$) | -.0316 | (.0063) | -.0273 | (.0055) | -.0284 | (.0055) |
| OTA·*satellite_local* ($\beta_2$) | -.0073 | (.0065) | -.0064 | (.0065) | -.0074 | (.0074) |
| $log(x_1)^2$ ($\beta_3$) | 1 | (—) | 1 | (—) | 1 | (—) |
| *Market covariates $\gamma_1$ of scale parameter ($\lambda$) for type distribution** | | | | | | |
| CONSTANT | -.543 | (.127) | -.695 | (.044) | -.569 | (.057) |
| MED. INC. | -.0053 | (.0041) | -.0016 | (.0037) | -.0048 | (.0033) |
| log(POP. DENSITY) | -.0105 | (.0048) | -.0114 | (.0044) | -.0093 | (.0042) |
| *Market covariates $\gamma_2$ of shape parameter ($\rho$) for type distribution** | | | | | | |
| CONSTANT | -.969 | (.323) | -1.087 | (.227) | -.132 | (.306) |
| log(TOTAL POP.) | .242 | (.061) | .220 | (.046) | .367 | (.087) |
| INC90 - INC50 | -.193 | (.039) | -.186 | (.030) | -.274 | (.027) |
| *Linear parameters $\xi$ (satellite–region interactions not reported)* | | | | | | |
| year 92 | 9.741 | (1.248) | 8.397 | (0.262) | 8.742 | (0.544) |
| year 93 | 10.56 | (1.26) | 9.253 | (0.252) | 9.483 | (0.546) |
| year 97 | 9.583 | (1.198) | 8.449 | (0.251) | 8.357 | (0.531) |
| year 98 | 9.819 | (1.204) | 8.749 | (0.265) | 8.494 | (0.531) |
| year 99 | 10.19 | (1.24) | 9.114 | (0.289) | 8.762 | (0.547) |
| year 00 | 10.67 | (1.29) | 9.615 | (0.336) | 9.110 | (0.571) |
| year 01 | 11.05 | (1.32) | 10.01 | (0.36) | 9.434 | (0.588) |
| year 02 | 10.93 | (1.33) | 9.944 | (0.402) | 9.184 | (0.601) |
| *satellite*·(year 98) | -1.900 | (0.249) | -2.123 | (0.224) | -1.878 | (0.199) |
| *satellite*·(year 99) | -2.400 | (0.238) | -2.491 | (0.229) | -2.494 | (0.213) |
| *satellite*·(year 00) | -1.252 | (0.245) | -1.244 | (0.254) | -1.395 | (0.225) |
| *satellite*·(year 01) | -2.544 | (0.289) | -2.565 | (0.295) | -2.736 | (0.261) |
| *satellite*·(year 02) | -2.194 | (0.320) | -2.059 | (0.339) | -2.469 | (0.276) |
| *satellite*·PCT. MULTIUNIT | 0.141 | (0.060) | 0.137 | (0.070) | 2.972 | (0.583) |
| 2 cable goods | 0.854 | (0.237) | 1.041 | (0.090) | 3.044 | (0.156) |
| >= 3 cable goods | 2.967 | (0.155) | 2.954 | (0.163) | -2.536 | (0.205) |
| MSO | -2.566 | (0.215) | -2.607 | (0.213) | 0.960 | (0.375) |
| No. Obs. | 23,194 | | 23,194 | | 23,194 | |

* $log(\lambda)$ and the log-transform of $\rho$ are taken to be linear in the covariates, i.e., $\lambda = exp(\gamma_1' z)$ and $\rho = 0.1 + 14 \cdot exp(\gamma_2' z)/(1 + exp(\gamma_2' z))$. The transformations keep $\rho$ and $\lambda$ within a reasonable range. $MED.\ INC.$ and $INC90 - INC50$ are normalized to be centered around zero with a variance of one. $log(POP.\ DENSITY)$ and $log(TOTAL\ POP.)$ are normalized to equal zero at the sample means of $POP.\ DENSITY$ and $TOTAL\ POP.$, respectively. NOT REPORTED: coefficients for individual MSOs and for satellite-region interactions. To conserve space, the excluded instruments for each specification are listed in Appendix C.

Table 4: Supply estimates (and standard errors)

| *Cost coefficients* $\psi$ | (1) Base specification estimates | (1) Base specification SEs | (2) Quality instruments estimates | (2) Quality instruments SEs | (3) Content cost year effects estimates | (3) Content cost year effects SEs |
|---|---|---|---|---|---|---|
| programming proxy ($x_1$) | 6.082 | (0.015) | 5.747 | (0.015) | 4.317 | (0.024) |
| $x_1$·(year 93) | | | | | 0.149 | (0.026) |
| $x_1$·(year 97) | | | | | 2.466 | (0.028) |
| $x_1$·(year 98) | | | | | 2.452 | (0.030) |
| $x_1$·(year 99) | | | | | 2.779 | (0.032) |
| $x_1$·(year 00) | | | | | 2.381 | (0.044) |
| $x_1$·(year 01) | | | | | 2.871 | (0.088) |
| $x_1$·(year 02) | | | | | 2.709 | (0.081) |
| $x_1$·MSO | -0.105 | (0.023) | -0.154 | (0.024) | 0.991 | (0.043) |
| $x_1$·MSO·(year 93) | | | | | 0.459 | (0.046) |
| $x_1$·MSO·(year 97) | | | | | -1.827 | (0.052) |
| $x_1$·MSO·(year 98) | | | | | -1.774 | (0.053) |
| $x_1$·MSO·(year 99) | | | | | -1.984 | (0.060) |
| $x_1$·MSO·(year 00) | | | | | -0.832 | (0.076) |
| $x_1$·MSO·(year 01) | | | | | -1.263 | (0.120) |
| $x_1$·MSO·(year 02) | | | | | -1.374 | (0.116) |
| MSO | -2.734 | (0.075) | -2.781 | (0.077) | -2.976 | (0.058) |
| MED. INC. | 0.110 | (0.003) | 0.085 | (0.003) | 0.175 | (0.003) |
| log(POP. DENSITY) | -0.324 | (0.005) | -0.398 | (0.005) | -0.202 | (0.005) |
| log(TOTAL POP.) | 0.415 | (0.006) | 0.495 | (0.007) | 0.377 | (0.006) |
| INC90 - INC50 | -0.566 | (0.002) | -0.606 | (0.002) | -0.609 | (0.002) |
| log(system size) | 0.421 | (0.004) | 0.418 | (0.005) | 0.415 | (0.004) |
| info sector wage | 1.259 | (0.033) | 1.302 | (0.033) | 1.130 | (0.032) |
| broadcasting wage | 0.153 | (0.025) | 0.111 | (0.026) | -0.182 | (0.023) |
| year 92 | 5.480 | (0.072) | 4.941 | (0.076) | | |
| year 93 | 6.306 | (0.070) | 5.753 | (0.072) | | |
| year 97 | 7.521 | (0.077) | 7.471 | (0.079) | | |
| year 98 | 7.448 | (0.080) | 7.369 | (0.082) | | |
| year 99 | 7.817 | (0.0877) | 7.834 | (0.089) | | |
| year 00 | 8.027 | (0.101) | 8.102 | (0.104) | | |
| year 01 | 8.285 | (0.109) | 8.332 | (0.112) | | |
| year 02 | 7.868 | (0.115) | 7.978 | (0.118) | | |
| Constant | | | | | 8.462 | (0.062) |
| No. Obs. | 15,685 | | 15,593 | | 15,749 | |

No. obs. varies across specifications because cost parameters are based on the remaining sample after dropping observations with imputed marginal costs that are either negative or that exceed the price. Info sector wage: mean annual per-employee payroll for NAICS sector 51 (“Information”). Broadcasting wage: mean annual payroll costs for NAICS sector 515 (“Broadcasting, except Internet”). NOT REPORTED: coefficients for individual MSOs and for satellite-region interactions. To conserve space, the excluded instruments for each specification are listed in Appendix C.

Table 5: Post-entry change in top cable bundle, relative to no-entry counterfactual

Comparison between Actual and No-Entry (NSE)

| | 1-good firms Price rises | 1-good firms Price falls | 2-good firms Price rises | 2-good firms Price falls | All firms Price rises | All firms Price falls |
|---|---|---|---|---|---|---|
| Quality rises, frequency | 1856 | 411 | 1760 | 935 | 3616 | 1346 |
| Quality rises, percent | (70.8%) | (15.7%) | (52.2%) | (27.7%) | (60.3%) | (22.5%) |
| Quality falls, frequency | 0 | 354 | 0 | 676 | 0 | 1030 |
| Quality falls, percent | | (13.5%) | | (20.1%) | | (17.2%) |

Comparison between profit-maximizing Duopoly (D) and No-Entry (NSE)

| | 1-good firms Price rises | 1-good firms Price falls | 2-good firms Price rises | 2-good firms Price falls | All firms Price rises | All firms Price falls |
|---|---|---|---|---|---|---|
| Quality rises, freq. | 2156 | 398 | 2383 | 633 | 4539 | 1031 |
| Quality rises, per cent. | (82.3%) | (15.2%) | (70.7%) | (18.8%) | (75.8%) | (17.2%) |
| Quality falls, freq. | 0 | 67 | 0 | 355 | 0 | 422 |
| Quality falls, per cent. | | (2.6%) | | (10.5%) | | (7.0%) |

This table displays the frequencies of observations for which the price and quality of the top cable good increase or decrease following entry, relative to the counterfactual scenario of no-entry. An observation is a market-year.

Table 6: Average cable package characteristics by scenario (counterfactual or actual), two-good firms

| Sample period | 1992-1993 | 1992-1993 | 1994-2002 | 1994-2002 | 1994-2002 | 1994-2002 | 1994-2002 |
|---|---|---|---|---|---|---|---|
| Scenario | Actual | M | Actual | NSE | D | NQ | Actual – NSE |
| Low cable quality, $x_L$ | 7.34 | 2.76 | 5.52 | 4.01 | 5.75 | 4.01 | 1.45 |
| SD, Low cable quality, $x_L$ | (2.77) | (4.99) | (4.21) | (5.16) | (5.95) | (5.16) | (6.92) |
| High cable quality, $x_H$ | 15.76 | 13.94 | 17.88 | 14.69 | 21.60 | 14.69 | 3.19 |
| SD, High cable quality, $x_H$ | (1.77) | (4.44) | (2.56) | (7.06) | (4.89) | (7.06) | (7.46) |
| Low cable price, $p_L$ | 18.05 | 14.23 | 11.89 | 11.60 | 12.54 | 11.20 | .30 |
| SD, Low cable price, $p_L$ | (4.18) | (4.98) | (4.79) | (6.36) | (6.47) | (6.09) | (5.23) |
| High cable price, $p_H$ | 22.20 | 21.67 | 23.19 | 23.93 | 25.75 | 21.45 | -.73 |
| SD, High cable price, $p_H$ | (3.40) | (4.46) | (5.53) | (7.46) | (5.90) | (6.90) | (5.21) |
| Cable profit, $\pi$ | 3.67 | 4.44 | 2.01 | 3.56 | 2.39 | 2.05 | -1.56 |
| SD, Cable profit, $\pi$ | (2.15) | (2.85) | (1.88) | (2.71) | (2.16) | (1.66) | (1.23) |
| Low cable share, $s_L$ | .139 | .390 | .089 | .328 | .270 | .190 | -.237 |
| SD, Low cable share, $s_L$ | (.187) | (.163) | (.129) | (.167) | (.139) | (.143) | (.149) |
| High cable share, $s_H$ | .484 | .503 | .551 | .482 | .479 | .495 | .068 |
| SD, High cable share, $s_H$ | (.178) | (.198) | (.172) | (.238) | (.214) | (.190) | (.143) |
| Satellite share, $s_{sat}$ |  |  | .100 |  | .071 | .199 |  |
| SD, Satellite share, $s_{sat}$ |  |  | (.068) |  | (.117) | (.142) |  |
| $N_L$ | 587 | 535 | 3371 | 3052 | 3278 | 3052 | 3052 |
| $N_H$ | 587 | 587 | 3371 | 3371 | 3371 | 3371 | 3371 |

This table reports the average values of bundle characteristics computed for no-entry (NSE), duopoly (D), and duopoly with no quality response (NQ), along with their actual values. An observation is a market-year. For each counterfactual case, the reported low-good means only include observations for which a lower good is offered in that case. Numbers in parentheses are standard deviations.

Table 7: Mean entry effect on high-good quality and price, for 2-good firms, by total population of city and values under no-entry

**mean(actual quality − NSE quality)**

| *Tot. pop. (quartile)* | *"Initial" (NSE) quality* OTA only | *"Initial" (NSE) quality* Q1 | *"Initial" (NSE) quality* Q2 | *"Initial" (NSE) quality* Q3 | *"Initial" (NSE) quality* Q4 |
|---|---|---|---|---|---|
| Q1, mean | 16.00 | 6.84 | 4.55 | 2.93 | -6.76 |
| Q1, SE | (.32) | (.20) | (.16) | (.16) | (.62) |
| Q2, mean | 17.26 | 7.06 | 5.32 | 3.36 | -6.56 |
| Q2, SE | (.43) | (.19) | (.14) | (.19) | (.78) |
| Q3, mean | 17.32 | 7.82 | 5.24 | 4.17 | -6.67 |
| Q3, SE | (.53) | (.25) | (.15) | (.20) | (.54) |
| Q4, mean | 17.81 | 8.36 | 6.68 | 4.67 | -5.56 |
| Q4, SE | (.28) | (.25) | (.27) | (.18) | (.39) |

$N = 3371$

**mean(actual price − NSE price)**

| *Tot. pop. (quartile)* | *"Initial" (NSE) quality* OTA only | *"Initial" (NSE) quality* Q1 | *"Initial" (NSE) quality* Q2 | *"Initial" (NSE) quality* Q3 | *"Initial" (NSE) quality* Q4 |
|---|---|---|---|---|---|
| Q1, mean | 8.36 | 1.53 | .230 | -.968 | -8.26 |
| Q1, SE | (.22) | (.13) | (.082) | (.095) | (.64) |
| Q2, mean | 7.86 | 1.65 | .552 | -.488 | -7.74 |
| Q2, SE | (.25) | (.11) | (.089) | (.115) | (.61) |
| Q3, mean | 8.26 | 2.20 | .727 | -.015 | -6.80 |
| Q3, SE | (.25) | (.13) | (.103) | (.138) | (.43) |
| Q4, mean | 8.26 | 2.66 | 1.54 | .626 | -5.91 |
| Q4, SE | (.48) | (.15) | (.12) | (.118) | (.25) |

$N = 3371$

The table reports the mean (std. err.) of the difference between actual content quality or price and the corresponding "initial" value under no-entry (NSE), conditional on total population and the "initial" value. In a few cases, the optimal NSE bundle contains no content besides over-the-air. I classify these cases under a separate initial category ("OTA only"). 1 obs. = 1 market-year for years 1994–2002.

Table 8: Actual and counterfactual consumer surplus for various subsets of consumers, for 2-cable-good markets (in 1997 $'s per month)

| | No. obs. | Actual Mean | Actual std. | NSE Mean | NSE std. | D Mean | D std. | NQ Mean | NQ std. |
|---|---|---|---|---|---|---|---|---|---|
| Aggregate | 3371 | 3.16 | 1.47 | 1.32 | .47 | 2.94 | 1.32 | 3.20 | 1.43 |
| *By good consumed under NSE vs. actual good consumed ("O"= outside good)* | | | | | | | | | |
| O to L | 1181 | .091 | .134 | 0 | — | .186 | .281 | .424 | .345 |
| O to H | 967 | .774 | .361 | 0 | — | .738 | .510 | 1.11 | .43 |
| L to L | 2205 | .359 | .786 | .098 | .237 | .348 | .650 | .918 | .731 |
| L to H | 2819 | 1.70 | 1.05 | .373 | .722 | 1.34 | 1.13 | 2.12 | .92 |
| L to sat | 399 | 5.73 | 1.25 | 4.40 | 1.66 | 5.93 | 1.35 | 5.97 | 1.36 |
| H to H | 2972 | 4.90 | 2.34 | 2.03 | 1.36 | 4.51 | 2.19 | 4.79 | 2.81 |
| H to sat | 3371 | 10.62 | 4.75 | 6.04 | 4.24 | 10.65 | 4.74 | 10.78 | 5.83 |
| *Consumers at various quantiles of type distribution:* | | | | | | | | | |
| Q 10 | 3371 | .053 | .270 | .019 | .028 | .066 | .292 | .270 | .745 |
| Q 25 | 3371 | .487 | .847 | .045 | .078 | .377 | .761 | .814 | 1.111 |
| Q 50 | 3371 | 2.38 | 1.59 | .452 | .502 | 1.90 | 1.51 | 2.36 | 1.46 |
| Q 75 | 3371 | 4.99 | 2.15 | 2.11 | .83 | 4.64 | 1.96 | 4.72 | 1.83 |
| Q 90 | 3371 | 7.52 | 2.95 | 3.91 | 1.25 | 7.48 | 2.74 | 7.44 | 2.97 |

| | No. obs.* | D/NSE Mean | D/NSE std. | %(D<NSE) Mean | %(D<NSE) std. | D/NQ Mean | D/NQ std. | %(D<NQ) Mean | %(D<NQ) std. |
|---|---|---|---|---|---|---|---|---|---|
| Aggregate | 3371 | 3.03 | 5.64 | .0039 | .0620 | .924 | .127 | .869 | .338 |
| *By good consumed under NSE vs. actual good consumed ("O"= outside good)* | | | | | | | | | |
| O to L | 1181 | — | — | 0 | 0.000 | .366 | .367 | .930 | .256 |
| O to H | 967 | — | — | 0 | 0.000 | .632 | .519 | .953 | .211 |
| L to L | 2205 | 3.58 | 7.53 | .133 | .340 | .328 | .425 | .964 | .186 |
| L to H | 2819 | 4.33 | 6.44 | .0096 | .0974 | .586 | .438 | .942 | .234 |
| L to sat | 399 | 1.53 | 1.30 | .0075 | .0865 | .993 | .014 | .732 | .444 |
| H to H | 2972 | 3.47 | 6.32 | .0013 | .0367 | .952 | .138 | .640 | .480 |
| H to sat | 3371 | 4.10 | 12.45 | .0080 | .0891 | .997 | .036 | .267 | .443 |
| *Consumers at various quantiles of type distribution:* | | | | | | | | | |
| Q 10 | 3371 | 2.86 | 7.20 | .1009 | .3012 | .312 | .375 | .613 | .487 |
| Q 25 | 3371 | 4.52 | 7.93 | .115 | .319 | .506 | .462 | .681 | .466 |
| Q 50 | 3371 | 5.88 | 7.61 | .019 | .138 | .902 | .974 | .718 | .450 |
| Q 75 | 3371 | 3.76 | 8.40 | .0053 | .0729 | .980 | .367 | .481 | .500 |
| Q 90 | 3371 | 3.69 | 10.05 | .0030 | .0544 | 1.009 | .054 | .171 | .376 |

Top columns summarize actual and counterfactual CS under various cases. Figures "by good consumed" are means for subsets of consumers grouped by purchasing decision under NSE and in reality. e.g., types "H to sat" buy (high) cable good under NSE and satellite in reality. No. obs. differ across groups because not all groups exist in all markets. 2nd and 4th columns on bottom display ratio of CS under D to CS under NSE and NQ, respectively—the denominator may equal zero, so summary statistics are for the remaining observations.* 3rd (5th) column on bottom reports no. obs. with CS declining from $NSE$ ($NQ$) to $D$. 1 obs. = 1 market-year for years 1994-2002.

* Going from top (O to L) to bottom (Q 90), no. obs. for $D/NSE$ are 0, 0, 386, 1109, 399, 2947, 3363, 66, 431, 2191, 3317, 3360. No. obs. for $D/NQ$ are 958, 957, 2166, 2816, 399, 2972, 3371, 66, 431, 2191, 3317, 3360.

# A Model Implications

Section A.1 of this appendix gives a rigorous statement of the propositions in Subsection 4.2. All proofs follow at the end. Section A.2 provides details on the assumptions behind the simulation results.

## A.1 Propositions and Proofs

For all results, I assume the distribution of consumer types $t$, $G(t)$, is continuously differentiable with density $g(t)$. Therefore, the profit function is continuously differentiable almost everywhere. I define $t_{sup}$ as the supremum of the support of the consumer type distribution, or $\infty$ if the support is unbounded. Let $t_H$ denote the lower cutoff for consumers of the high good, i.e., $\frac{p_H-\xi_H}{q(x_H)}$ if there is only one cable good, and $\frac{p_H-\xi_H-p_L+\xi_L}{q(x_H)-q(x_L)}$ if there are two cable goods. The superscripts $M$ and $D$ denote the cable firm's monopoly (i.e., no-entry) and duopoly solutions. To simplify the proofs, assume that satellite entry is not *too* aggressive:[61]

**Assumption 1 (A1)** *If satellite enters with quality $x_S$ and price $p_S$, and cable keeps monopoly price and quality in the high good $(p_H, x_H)$, positive demand still remains for the high good:*

$\frac{p_S-p_H-\xi_H}{q(x_S)-q(x_H)} > t_H^M$.

**Proposition 1** *Suppose that A1 holds. Then, the following is true: $\exists \epsilon > 0$ such that if $x_H^M < x_S < x_H^M + \epsilon$, then $x_H^D \geq x_H^M$.*

Intuitively, if the satellite good has price and quality that are very similar to those of the high good, the cable firm could make profits that are almost as high as monopoly profits ($\pi^M - \epsilon$, for some small $\epsilon$) by choosing high quality to match satellite quality and undercutting the satellite price by a little. On the other hand, choosing to differentiate vertically downward must entail losing a measurable share of consumers to the entrant. If the satellite good is similar enough to the cable good, mimicking satellite quality becomes nearly costless, so the former action must yield strictly higher profits.

**Assumption 2 (A2)** *Either the cost function has enough curvature, or the density of the distribution of consumer types at the monopoly solution has high enough elasticity, i.e.:*

*(1)* $\frac{d\,log(g(t))}{d\,log(t)} \geq \frac{mc'(q)}{mc''(q)q}$ *evaluated at $t = t_H^M$ and $q = q(x_1^M)$.*

*(2) When there is one good,* $\frac{d\,mc(q_H)}{d\,q_H} \cdot \frac{q_H}{mc(q_H)} \geq 1 - \frac{\xi_1}{mc(q_H)}$, *evaluated at $q_H = q(x_H^M)$. When there are two goods,* $\frac{d\,mc(q_H)}{d\,q_H} \cdot \frac{q_H - q_L}{mc(q_H)-mc(q_L)} \geq 1 - \frac{(\xi_H - \xi_L)}{mc(q_H)-mc(q_L)}$, *evaluated at $q_L = q(x_L^M)$ and $q_H = q(x_H^M)$.*

---

[61] Assumption A1 is consistent with the real-world fact, implied by my estimation model, that the $t_H^M$ type is far below the lowest type that switches over to satellite, once entry occurs.

**Proposition 2** *Suppose that A1 and A2 hold. Then, for all* $\alpha \in (t_H^M, t_{sup})$*, we can find a* $x_\alpha$ *such that the following hold:*

*(1)* $\{x_S \geq x_\alpha \text{ and } p_S = (p_H - \xi_H) + \alpha \cdot (q(x_S) - q(x_H))\} \;\;\Rightarrow\;\; \{x_H^D < x_H^M\}$.

*(2)* $\{x_S \geq x_\alpha \text{ and } p_S = (p_H - \xi_H) + \alpha \cdot (q(x_S) - q(x_H))\} \;\;\Rightarrow\;\; \{p_H^D < p_H^M\}$ *if there is just one cable good.*

Assumption A2 states that either the type distribution is sufficiently elastic at the lower cutoff for the high good under monopoly, or that costs are sufficiently convex. The proposition states that this condition is sufficient to guarantee that if satellite comes in with a good of sufficiently high quality, the cable firm's optimal response is to differentiate vertically downward (and to lower price, if there is only one good). The dependence of $x_\alpha$ on $\alpha$ implies that the cable firm's propensity to differentiate vertically downward depends on both the quality and the price of the new good. We cannot definitively say what will happen to the high good's price if there is more than one cable good, because it will depend on the price and quality of the lower bundle (though, in general, it seems plausible that the high good's price should also go down).

For the final proposition, make the following definition:

**Definition 1** $\forall \alpha \in (t_H^M, t_{sup})$, $\underline{x}_\alpha := inf\, x_\alpha$ *such that*
$\{x_S \geq x_\alpha \text{ and } p_S = (p_H - \xi_H) + \alpha \cdot (q(x_S) - q(x_H))\} \quad\Rightarrow\quad x_H^D < x_H^M$.

**Proposition 3** *Suppose that A1 holds. Then,* $\lim\limits_{\alpha \to t_{sup}} \underline{x}_\alpha = \infty$.

Whereas the second proposition states that sufficiently high quality and sufficiently low price for the entrant's good will induce downward vertical differentiation, this proposition establishes that regardless of how much better the satellite good is than $x_H^M$, if the price of satellite is high enough relative to its quality (i.e., $\alpha \to t_{sup}$), the cable system will not differentiate vertically downward.

**Remark** Since $q(\cdot)$ is a strictly increasing function, we can do all of the proofs in terms of $q(x)$ instead of $x$. Define $q_L := q(x_L)$, $q_H := q(x_H)$, $q_S := q(x_S)$, and $\underline{q}_\alpha := q(\underline{x}_\alpha)$.

**Preliminary results for proofs of Propositions 1 and 3**

<u>Case of one cable good</u>

Under monopoly, the cable firm's profit function is

$$\pi = \left[1 - G\left(\frac{p_H - \xi_H}{q_H}\right)\right](p_H - mc(q_H)) \tag{17}$$

The first-order conditions that maximize profits are,

$$\begin{aligned}
\frac{\partial \pi}{\partial p_H} &= \left[-g\left(\frac{p_H-\xi_H}{q_H}\right)\frac{1}{q_H}\right](p_H - mc(q_H)) + \left[1-G\left(\frac{p_H-\xi_H}{q_H}\right)\right] = 0 && (18)\\
\frac{\partial \pi}{\partial q_H} &= \left[g\left(\frac{p_H-\xi_H}{q_H}\right)\frac{p_H-\xi_H}{q_1^2}\right](p_H - mc(q_H)) - \\
&\quad \left[1-G\left(\frac{p_H-\xi_H}{q_H}\right)\right] mc'(q_H) = 0 && (19)
\end{aligned}$$

Following entry, the cable firm's profit function is

$$\pi = \left[G\left(\frac{p_S-p_H+\xi_H}{q_S-q_H}\right) - G\left(\frac{p_H-\xi_H}{q_H}\right)\right](p_H - mc(q_H)) \tag{20}$$

The first-order conditions that maximize profits are,

$$\begin{aligned}
\frac{\partial \pi}{\partial p_H} &= \left[-g\left(\frac{p_S-p_H+\xi_H}{q_S-q_H}\right)\frac{1}{q_S-q_H} - g\left(\frac{p_H-\xi_H}{q_H}\right)\frac{1}{q_H}\right](p_H - mc(q_H)) \\
&+ \left[G\left(\frac{p_S-p_H+\xi_H}{q_S-q_H}\right) - G\left(\frac{p_H-\xi_H}{q_H}\right)\right] = 0 && (21)\\
\frac{\partial \pi}{\partial q_H} &= \left[g\left(\frac{p_S-p_H+\xi_H}{q_S-q_H}\right)\frac{p_S-p_H+\xi_H}{(q_S-q_H)^2} + g\left(\frac{p_H-\xi_H}{q_H}\right)\frac{p_H-\xi_H}{(q_H)^2}\right](p_H - mc(q_H)) \\
&- \left[G\left(\frac{p_S-p_H+\xi_H}{q_S-q_H}\right) - G\left(\frac{p_H-\xi_H}{q_H}\right)\right] mc'(q_H) = 0 && (22)
\end{aligned}$$

Substituting (18)–(19) into (21)–(22) yields the duopoly first-order conditions, evaluated at the optimal monopoly solution $(p_H^M, q_H^M)$:

$$\begin{aligned}
\left.\frac{\partial \pi}{\partial p_H}\right|_{(q_H^M, p_H^M)} &= -g\left(\frac{p_S-p_H^M+\xi_H}{q_S-q_H^M}\right)\frac{1}{q_S-q_H^M}(p_H^M - mc(q_H^M)) \\
&+ \left[G\left(\frac{p_S-p_H^M+\xi_H}{q_S-q_H^M}\right) - 1\right] < 0 && (23)\\
\left.\frac{\partial \pi}{\partial q_H}\right|_{(q_H^M, p_H^M)} &= g\left(\frac{p_S-p_H^M+\xi_H}{q_S-q_H^M}\right)\frac{p_S-p_H^M+\xi_H}{(q_S-q_H^M)^2}(p_H^M - mc(q_H^M)) \\
&- \left[G\left(\frac{p_S-p_H^M+\xi_H}{q_S-q_H^M}\right) - 1\right] mc'(q_H^M) > 0 && (24)
\end{aligned}$$

The inequalities in (21) and (22) stem from the fact that price must exceed marginal cost in the optimal solution, and the fact that $\frac{\partial mc}{\partial q} > 0$.

Case of two cable goods

Under monopoly, the cable firm's profit function is

$$\begin{aligned}\pi &= \left[1 - G\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right)\right](p_H - mc(q_H)) \\ &\quad + \left[G\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right) - G\left(\frac{p_L - \xi_L}{q_L}\right)\right](p_L - mc(q_L)) \qquad (25) \\ & \qquad (26)\end{aligned}$$

The first-order conditions with respect to $p_H$ and $q_H$ are,

$$\begin{aligned}\frac{\partial \pi}{\partial p_H} &= \left[-g\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right)\frac{1}{q_H - q_L}\right](p_H - mc(q_H)) \\ &\quad + \left[g\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right)\frac{1}{q_H - q_L}\right](p_L - mc(q_L)) \\ &\quad + \left[1 - G\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right)\right] = 0 \qquad (27) \\ \frac{\partial \pi}{\partial q_H} &= \left[g\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right)\frac{p_H - \xi_H - p_L + \xi_L}{(q_H - q_L)^2}\right](p_H - mc(q_H)) \\ &\quad - \left[g\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right)\frac{p_H - \xi_H - p_L + \xi_L}{(q_H - q_L)^2}\right](p_L - mc(q_L)) \\ &\quad - \left[1 - G\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right)\right] mc'(q_H) = 0 \qquad (28)\end{aligned}$$

Following entry, the cable firm's profit function is

$$\begin{aligned}\pi &= \left[G\left(\frac{p_S - p_H + \xi_H}{q_S - q_H}\right) - G\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right)\right](p_H - mc(q_H)) \\ &\quad + \left[G\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right) - G\left(\frac{p_L - \xi_L}{q_L}\right)\right](p_L - mc(q_L)) \qquad (29) \\ & \qquad (30)\end{aligned}$$

The first-order conditions with respect to $p_H$ and $q_H$ are,

$$
\begin{aligned}
\frac{\partial \pi}{\partial p_H} &= \left[-g\left(\frac{p_S - p_H + \xi_H}{q_S - q_H}\right)\frac{1}{q_S - q_H} - g\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right)\frac{1}{q_H - q_L}\right](p_H - mc(q_H)) \\
&\quad + \left[g\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right)\frac{1}{q_H - q_L}\right](p_L - mc(q_L)) \\
&\quad + \left[G\left(\frac{p_S - p_H + \xi_H}{q_S - q_H}\right) - G\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right)\right] = 0 \qquad (31) \\
\frac{\partial \pi}{\partial q_H} &= \left[g\left(\frac{p_S - p_H + \xi_H}{q_S - q_H}\right)\frac{p_S - p_H + \xi_H}{(q_S - q_H)^2} + g\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right)\frac{p_H - \xi_H - p_L + \xi_L}{(q_H - q_L)^2}\right](p_H - mc(q_H)) \\
&\quad - \left[g\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right)\frac{p_H - \xi_H - p_L + \xi_L}{(q_H - q_L)^2}\right](p_L - mc(q_L)) \\
&\quad - \left[G\left(\frac{p_S - p_H + \xi_H}{q_S - q_H}\right) - G\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right)\right] mc'(q_H) = 0 \qquad (32)
\end{aligned}
$$

Substituting (27)–(28) into (31)–(32) yields the duopoly first-order conditions, evaluated at the optimal monopoly solution $(p_L^M, q_L^M, p_H^M, q_H^M)$:

$$
\begin{aligned}
\left.\frac{\partial \pi}{d p_H}\right|_{(p_L^M, q_L^M, p_H^M, q_H^M)} &= -g\left(\frac{p_S - p_H^M + \xi_H}{q_S - q_H^M}\right)\frac{1}{q_S - q_H^M}(p_H^M - mc(q_H^M)) \\
&\quad + \left[G\left(\frac{p_S - p_H^M + \xi_H}{q_S - q_H^M}\right) - 1\right] < 0 \qquad (33) \\
\left.\frac{\partial \pi}{d q_H}\right|_{(p_L^M, q_L^M, p_H^M, q_H^M)} &= g\left(\frac{p_S - p_H^M + \xi_H}{q_S - q_H^M}\right)\frac{p_S - p_H^M + \xi_H}{(q_S - q_H^M)^2}(p_H^M - mc(q_H^M)) \\
&\quad - \left[G\left(\frac{p_S - p_H^M + \xi_H}{q_S - q_H^M}\right) - 1\right] mc'(q_H^M) > 0 \qquad (34)
\end{aligned}
$$

**Proof of Proposition 1**

Observation: if there is one cable good, by choosing $p_H = p_H^M$ and $q_H = q_H^M + \epsilon$ (the same quality as satellite), the cable firm can earn profits strictly higher than $\pi^M - \left[mc(q_H^M + \epsilon) - mc(q_H^M)\right]\left[1 - G(t_H^M)\right] \equiv \pi^M - A$, because the lower cutoff for consumers of good $H$ would be less than $t_H^M$. If there are two cable goods, by choosing $p_L = p_L^M$, $q_L = q_L^M$, $p_H = p_H^M$, and $q_H = q_H^M + \epsilon$, the cable firm can earn profits strictly higher than $\pi^M - A - \left[p_L^M - mc(q_L^M) - p_H^M + mc(q_H^M + \epsilon)\right]\left[G(t_H^M) - G(\frac{p_H^M - \xi_H - p_L^M + \xi_L}{q_H^M + \epsilon - q_L^M})\right] \equiv \pi^M - A - B$. The optimality of $\pi_D$ implies $\pi^D \geq \pi^M - A$ if there is one cable good, and $\pi^D \geq \pi^M - A - B$ if there are two cable goods.

To prove the proposition, suppose the contrary: $\forall\ \epsilon > 0$, $\exists\ (p_S, q_S)$, with $q_S = q_H^M + \epsilon$ and $\frac{p_S - p_H^M - \xi_H}{q_S - q_H^M} \in (t_H^M, t_{sup})$, such that $q_H^D \leq q_H^M$. Consider a set of points $\{(\epsilon, p_S, q_S),\ \epsilon > 0\}$ such that the above conditions hold.

(23)–(24) and (33)–(34) establish that as $\epsilon \to 0$, $\frac{\partial \pi}{\partial p_H} \to -\infty$ and $\frac{\partial \pi}{\partial q_H} \to +\infty$ when evaluated at the monopoly solution. Because the profit function is locally continuously differentiable, combining the previous result with $q_H^D \leq q_H^M$ implies the following: there exists a positive constant $a$ such that $\forall\ \epsilon > 0$, the duopoly solution lies outside the $a$-neighborhood of the monopoly solution: $\parallel (p_H^D, q_H^D) - (p_H^M, q_H^M) \parallel > a$. Therefore, there exists a positive constant $b$ such that $\forall\ \epsilon > 0$, $\pi_D < \pi_M - b$. But we know from the initial observation that we can find an $\epsilon$ close enough to 0 such that the cable firm's profit under duopoly exceeds $\pi > \pi^M - b$, because $A \to 0$ and $B \to 0$ as $\epsilon \to 0$. Thus, we have a contradiction ■

**Lemma 1** *Suppose that assumptions A1 and A2 hold. Then, for all* $\alpha \in (t_H^M, t_{sup})$*:*

*Suppose that the consumer type distribution is truncated from above at* $\alpha$*, and denote* $(p_H^M(\alpha), q_H^M(\alpha))$ *as the monopoly solution for the truncated distribution. Then,* $\frac{dq_H^M(\alpha)}{d\alpha} > 0$*. Also,* $\frac{dp_H^M(\alpha)}{d\alpha} > 0$ *if there is only one cable good.*

**Proof of Lemma**

Case of one cable good

Under monopoly, the cable firm's profit function for the truncated distribution is

$$\pi = \left[G(\alpha) - G\left(\frac{p_H - \xi_H}{q_H}\right)\right](p_H - mc(q_H)) \tag{35}$$

The first-order conditions that maximize profits are,

$$\frac{\partial \pi}{\partial p_H} = \left[-g\left(\frac{p_H - \xi_H}{q_H}\right)\frac{1}{q_H}\right](p_H - mc(q_H)) + \left[G(\alpha) - G\left(\frac{p_H - \xi_H}{q_H}\right)\right] = 0 \tag{36}$$

$$\begin{aligned}\frac{\partial \pi}{\partial q_H} = & \left[g\left(\frac{p_H - \xi_H}{q_H}\right)\frac{p_H - \xi_H}{q_1^2}\right](p_H - mc(q_H)) - \\ & \left[G(\alpha) - G\left(\frac{p_H - \xi_H}{q_H}\right)\right] mc'(q_H) = 0\end{aligned} \tag{37}$$

Dividing (37) by (36), we obtain

$$\frac{p_H - \xi_H}{q_H} = mc'(q_H) \tag{38}$$

Insert (38) into (36) to obtain the following implicit function, which must equal zero when evaluated at the monopoly-optimal quality ($q_H^M$). (For notational convenience, I omit the argument for $mc(q)$, $mc'(q)$ and $mc''(q)$):

$$\phi(\alpha, q) = \frac{g(mc')}{q}(mc'q + \xi_H - mc) - [G(\alpha) - G(mc')] \tag{39}$$

The implicit function theorem states that $\frac{dq_H^M}{d\alpha} = -\left(\frac{\partial \phi}{\partial q}\right)^{-1}\frac{\partial \phi}{\partial \alpha}\Big|_{(q_H^M, p_H^M)}$

$\frac{\partial \phi}{\partial \alpha} = -g(\alpha) < 0$. All that remains to be proved is that $\frac{\partial \phi}{\partial q}|_{(q_H^M, p_H^M)} > 0$. Differentiating and simplifying:

$$
\begin{aligned}
\frac{\partial \phi}{\partial q} &= [\frac{g'(mc')mc''}{q} - \frac{g(mc')}{q^2}][mc'q + \xi_H - mc] \\
&\quad +2g(mc')mc'' \qquad (40)
\end{aligned}
$$

The second statement of Assumption A2 guarantees that $mc'q+\xi_H-mc > 0$ when evaluated at the monopoly solution. The first statement of Assumption A2 guarantees that $\frac{g'(mc')mc''}{q} - \frac{g(mc')}{q^2} > 0$ when evaluated at the monopoly solution. The term $2g(mc')mc''$ is also positive. Therefore, the entire expression is positive.

To see that $\frac{dp_H^M}{d\alpha} > 0$, simply note that $p_H^M = \xi_H + mc'(q_H^M)q_H^M$ under (38), and that both $mc'(q)$ and $q$ itself are rising in $q$.

Case of two cable goods

Under monopoly, the cable firm's profit function for the truncated distribution is

$$
\begin{aligned}
\pi &= \left[G(\alpha) - G\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right)\right](p_H - mc(q_H)) \\
&\quad + \left[G\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right) - G\left(\frac{p_L - \xi_L}{q_L}\right)\right](p_L - mc(q_L)) \qquad (41) \\
& \qquad (42)
\end{aligned}
$$

The first-order conditions with respect to $p_H$ and $q_H$ are,

$$
\begin{aligned}
\frac{\partial \pi}{\partial p_H} &= \left[-g\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right)\frac{1}{q_H - q_L}\right](p_H - mc(q_H)) \\
&\quad + \left[g\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right)\frac{1}{q_H - q_L}\right](p_L - mc(q_L)) \\
&\quad + \left[G(\alpha) - G\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right)\right] = 0 \qquad (43) \\
\frac{\partial \pi}{\partial q_H} &= \left[g\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right)\frac{p_H - \xi_H - p_L + \xi_L}{(q_H - q_L)^2}\right](p_H - mc(q_H)) \\
&\quad - \left[g\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right)\frac{p_H - \xi_H - p_L + \xi_L}{(q_H - q_L)^2}\right](p_L - mc(q_L)) \\
&\quad - \left[G(\alpha) - G\left(\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L}\right)\right] mc'(q_H) = 0 \qquad (44)
\end{aligned}
$$

Dividing (44) by (43), we obtain

$$
\frac{p_H - \xi_H - p_L + \xi_L}{q_H - q_L} = mc'(q_H) \qquad (45)
$$

Insert (45) into (43) to obtain the following implicit function, which must equal zero when evaluated at the monopoly-optimal qualities $(q_L^M, q_H^M)$:

$$\begin{aligned}\phi(\alpha, q_L, q_H) &= \frac{g(mc'(q_H))}{q_H - q_L}(mc'(q_H)(q_H - q_L) + \xi_H - \xi_L - mc(q_H) + mc(q_L)) \\ &\quad -[G(\alpha) - G(mc'(q_H))] \qquad (46)\end{aligned}$$

As in the one-good case, we invoke the implicit function theorem. $\frac{\partial\phi}{\partial\alpha} = -g(\alpha) < 0$, so all that remains to be proved is that $\frac{\partial\phi}{\partial q}|_{(q_L^M, q_H^M, p_L^M, p_H^M)} > 0$. To economize on notation, omit the argument for $mc'(q)$ and $mc''(q)$ whenever the argument is $q_H$. Differentiating and simplifying:

$$\begin{aligned}\frac{\partial\phi}{\partial q} &= [\frac{g'(mc')mc''}{q_H - q_L} - \frac{g(mc')}{(q_H - q_L)^2}][mc'(q_H - q_L) + \xi_H - \xi_L - mc(q_H) + mc(q_L)] \\ &\quad +2g(mc')mc'' \qquad (47)\end{aligned}$$

Similar to the one-good case, Assumption A2 guarantees that this expression evaluates to a positive number.

### Proof of Proposition 2

For any $\alpha$, define $(p^M(\alpha), q^M(\alpha))$ as the optimal monopoly solution when the type distribution is truncated from above at $\alpha$ (where $p^M$ and $q^M$ are of dimensionality equal to the number of cable goods).

The lemma implies that $q_H^M(\alpha) < q_H^M$, and $p_H^M(\alpha) < p_H^M$ for the case of only one cable good, where $(p_H, q_H)$ is the monopoly solution to the original (untruncated) distribution function (which is equivalent to truncating the distribution at $\alpha = \infty$). Define $\bar{\epsilon} := q_H^M - q_H^M(\alpha)$ if there is more than one cable good, and $\bar{\epsilon} := min(q_H^M - q_H^M(\alpha), p_H^M - p_H^M(\alpha))$ if there is only one cable good.

The range of possible values for satellite quality $q_S$ is unbounded from above. Therefore, for any $\delta > 0$ and any $\alpha \in (t_H^M, t_{sup})$, $\exists\, q_\alpha$ such that $\forall q_S > q_\alpha$ and $p_S = (p_H - \xi_H) + \alpha(q_S - q_H)$, none of the first-order conditions to the duopoly problem is violated by more than $\delta$, when evaluated at $(p^M(\alpha), q^M(\alpha))$ instead of at the true optimum. Because profits are locally continuous with respect to $(p, q)$, by choosing $\delta$ arbitrarily close to zero, we can also make $\parallel (p^M(\alpha), q^M(\alpha)) - (p^D, q^D) \parallel < \epsilon$ for any $\epsilon > 0$, where $\parallel \cdot \parallel$ is the Euclidean metric. In particular, we can make
$\parallel (p^M(\alpha), q^M(\alpha)) - (p^D, q^D) \parallel < \bar{\epsilon}$. $q_H^M - q_H^M(\alpha) \geq \bar{\epsilon}$ by construction, implying $q_H^D < q_H^M$. Also, if there is only one cable good, $p_H^M - p_H^M(\alpha) \geq \bar{\epsilon}$, implying $p_H^D < p_H^M$. ■

### Proof of Proposition 3

Substituting $\frac{p_S - p_H^M + \xi_H}{q_S - q_H^M} = \alpha$ into (24) and (34), we obtain

$$\lim_{\alpha \to t_{sup}} \frac{\partial \pi}{\partial q_H}\bigg|_{(q_H^M, p_H^M)} = \lim_{\alpha \to t_{sup}} g(\alpha)\alpha \cdot \frac{p_H^M - mc(q_H^M)}{q_S - q_H^M}$$

$$\lim_{\alpha \to t_{sup}} \frac{\partial \pi}{d q_H}\bigg|_{(p_L^M, q_L^M, p_H^M, q_H^M)} = \lim_{\alpha \to t_{sup}} g(\alpha)\alpha \cdot \frac{p_H^M - mc(q_H^M)}{q_S - q_H^M}$$

Suppose the proposition is not true. Then $\exists\, N < \infty$ such that $\forall \alpha < t_{sup}$, $\underline{q}(\alpha) = N$. By construction, $\forall\, \alpha$, $q_S = N$ induces $q_H^D < q_H^M$. $q_S < \infty$ implies that for the case of one cable good, $\lim_{\alpha \to t_{sup}} \frac{\partial \pi}{\partial q_H}\bigg|_{(q_H^M, p_H^M)} > A$, where $A > 0$ is a constant (Fact 1). Likewise, for the case of two cable goods, $\lim_{\alpha \to t_{sup}} \frac{\partial \pi}{d q_H}\bigg|_{(p_L^M, q_L^M, p_H^M, q_H^M)} > B$, where $B > 0$ is a constant (Fact 2). Combining Facts 1 and 2 with the fact that $q_H^D < q_H^M$ implies that $(p_H^D, q_H^D)$ is not in a neighborhood of $(p_H^M, q_H^M)$, i.e. $\exists\, \epsilon > 0$ such that $\forall\, \alpha < t_{sup}$, $\parallel (p_H^M, q_H^M) - (p_H^D, q_H^D) \parallel > \epsilon$.

Denoting $\pi^D(p^M, q^M)$ as the duopoly profits when the cable firm chooses $(p^M, q^M)$, we know from the profit function that $\lim_{\alpha \to t_{sup}} \pi^D(p^M, q^M) = \pi^M$ (Fact 3). Combining Facts 1 and 2 with the fact that $(p_H^D, q_H^D)$ is not in a neighborhood of $(p_H^M, q_H^M)$ implies that $\forall\, \alpha < t_{sup}$, there is a path of length greater than $C$ beginning from $(p_H^M, q_H^M)$ over which $\frac{\partial \pi}{\partial q_H} > 0$, where $C > 0$ is a constant. Combining this fact with Fact 3 implies that in the limit as $\alpha \to t_{sup}$, strictly higher profits than $\pi^M$ are possible under duopoly. Thus, we have a contradiction. ■

## A.2 Simulation Details

For the simulation exercise, I compute the incumbent response to entry under the assumption that cable firms sell a single good and that consumers are drawn from the Weibull distribution. The response to entry is indicated by the difference between the optimal cable bundle (price and quality) under monopoly and the optimal cable bundle with the satellite entrant.

Parameter values are chosen in the following way:

- $(p_S,\ x_S,\ \rho)$, i.e., satellite price, satellite channel content, and the shape parameter of the type distribution, are taken from a grid. The values of $(p_S,\ x_S)$ are evenly spaced over the range $[5, 25] \times [19, 32]$, with the bounds roughly corresponding to the empirical range of the satellite good's price and channel content, as seen in the actual data. The channel content is defined as the normalized, cost-weighted proxy used in the actual estimation, discussed in Section 4.4. $\rho$ is drawn from the set of values $\{1.7, 2, 2.5, 3, 4, 6, 8\}$.
- $\lambda$ is set at .5793, the mean value for the estimation sample, as determined following the model estimation.
- Independent, random draws of $\zeta$ are taken from a lognormal distribution:
  $\zeta \sim LN(1.393, 0.706)$
- Independent, random draws of $\xi$ are taken from a lognormal distribution:
  $\xi \sim LN(2.253, 0.169)$

Simulating over a range of values for $\zeta$ and $\xi$ allows us to study how the response to entry depends on idiosyncratic cost shocks and brand effects. The lognormal parameters are set such that the simulated distributions of $\zeta$ and $\xi$ have the same first and second moments as in the actual data, as determined following the model estimation. The goal in taking the value of $(p_S,\ x_S,\ \rho)$ from a grid is not to depict the actual empirical joint distribution, but instead to span the range of observed values.

The key findings are as follows: (1) The incumbent is more likely to respond to entry by raising quality when entry is *moderately* aggressive, and less likely when entry is either extremely aggressive or extremely weak. (2) Increases in quality and declines in price tend to be substitute strategies: while in principle the firms could respond to entry by both raising quality and lowering price, this seldom occurs in practice. (3) Firms in high-$\rho$ markets (i.e., markets with homogeneous consumer types) and firms with low cost shocks (low $\zeta$) have a greater tendency compete head-to-head.

Figures 1 and 2 plot the (simulated) conditional probability of the cable firm raising quality and lowering price, respectively, in response to entry. On the horizontal axis, the probabilities are conditioned on the proportion of cable's market share that *would* be captured by the satellite firm if cable continued offering the monopoly-optimal price and quality, which is a way to quantify the aggressiveness of the entrant. Formally, the measure of aggressiveness is defined as $[1 - G(\alpha)]/[1 - G(t_H^M)]$, with $\alpha$ being the cutoff type between cable and satellite *provided* the cable firm retains monopoly prices and qualities even after entry, and with $t_H^M$ being the lower cutoff type for the high good under monopoly. Figure 1 indicates that competing for the high end of the market (raising high-good quality) is most likely when entry is moderately aggressive, and least likely when entry is either very aggressive or very weak, confirming finding (1). Figure 2 shows that cable price is also least likely to fall when the aggressiveness of entry is in the intermediate range, demonstrating that price drops tend to be concurrent with downward vertical differentiation and thus confirming finding (2). Finally, at each level of aggressiveness, cable firms are more likely to raise quality and less likely to lower price when $\rho$ is high, supporting finding (3).

We can also relate the incumbent response to underlying marginal costs and brand effects. Figures 3 and 4 plot the propensity to raise quality or lower price, by different quantiles of the distribution of $\zeta$, against the same measure of the aggressiveness of entry as in the previous figures. Firms with high cost shocks have a lesser propensity to raise quality and a stronger propensity to differentiate downward, supporting finding (3). This relationship reflects the fact that higher-cost firms already choose higher quality under monopoly, making price drops a more efficacious instrument for retaining market share following entry.[62] Figures 5 and 6 plot the propensity to raise quality or lower price, by different quantiles of the distribution of $\xi$, against the measure of aggressiveness. The incumbent response exhibits no straightforward trends with respect to the brand effect—being nonmonotonic in $\xi$ and dependent on the aggressiveness of entry—suggesting the importance of parameters not controlled for in the figures.

---

[62] Intuitively, higher $\zeta$ reduces the incentive-compatible markup that is possible for any given choice of cutoff type. Therefore, high-$\zeta$ firms optimally choose a higher cutoff type.

Figure 1: Simulated probability (conditional on consumer type-distribution parameter $\rho$) of increasing quality in response to entry, as a function of the proportion of the market share that would go to the entrant in the absence of price- or quality adjustments by the incumbent. Probabilities are Lowess-smoothed with a bandwidth of 0.4.

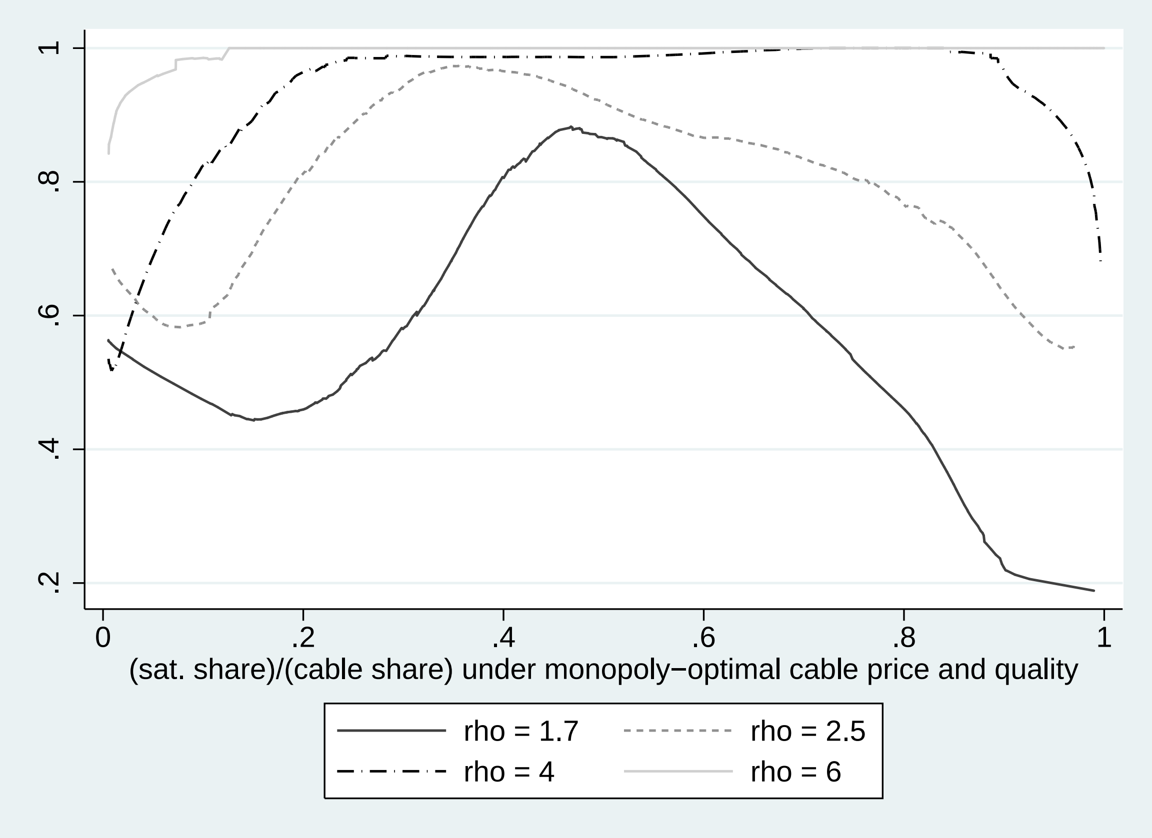


Figure 2: Simulated probability (conditional on consumer type-distribution parameter $\rho$) of lowering price in response to entry, as a function of the proportion of the market share that would go to the entrant in the absence of price- or quality adjustments by the incumbent. Probabilities are Lowess-smoothed with a bandwidth of 0.4.

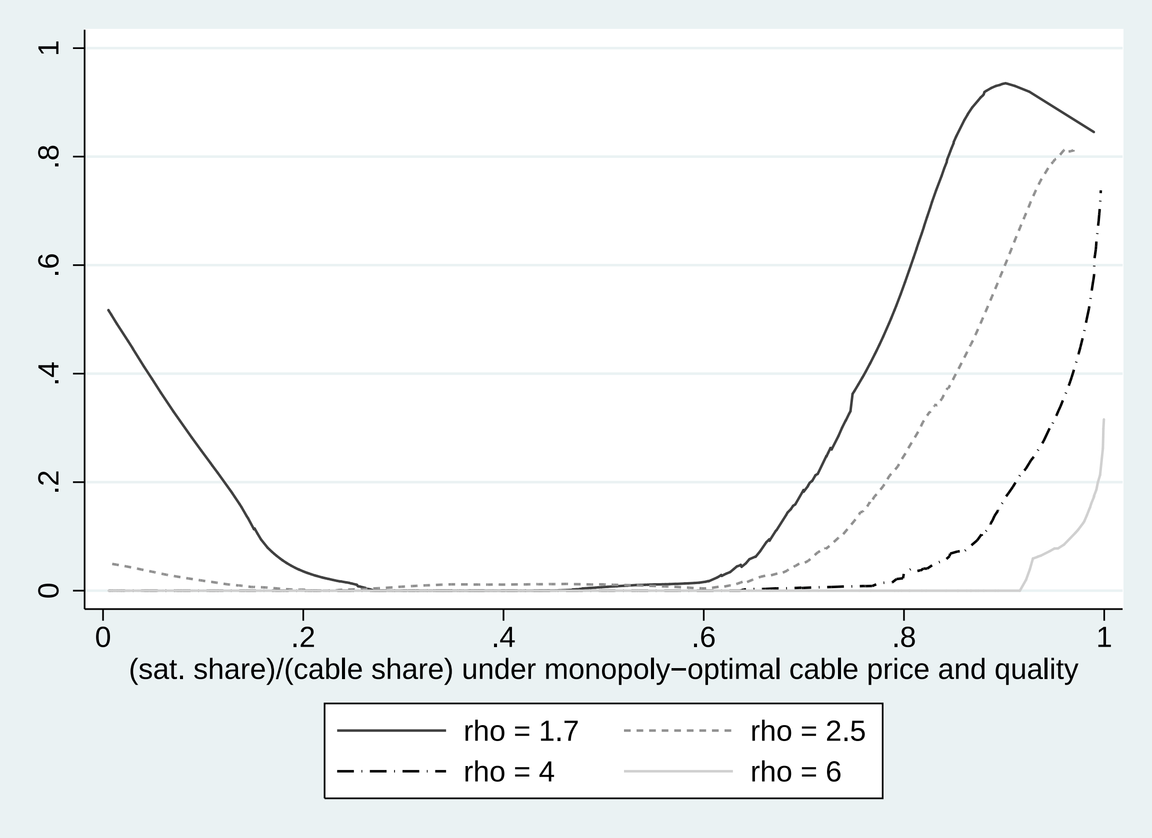


Figure 3: Simulated probability (conditional on marginal cost shock $\zeta$) of increasing quality in response to entry, as a function of the proportion of the market share that would go to the entrant in the absence of price- or quality adjustments by the incumbent. Probabilities are Lowess-smoothed with a bandwidth of 0.4.

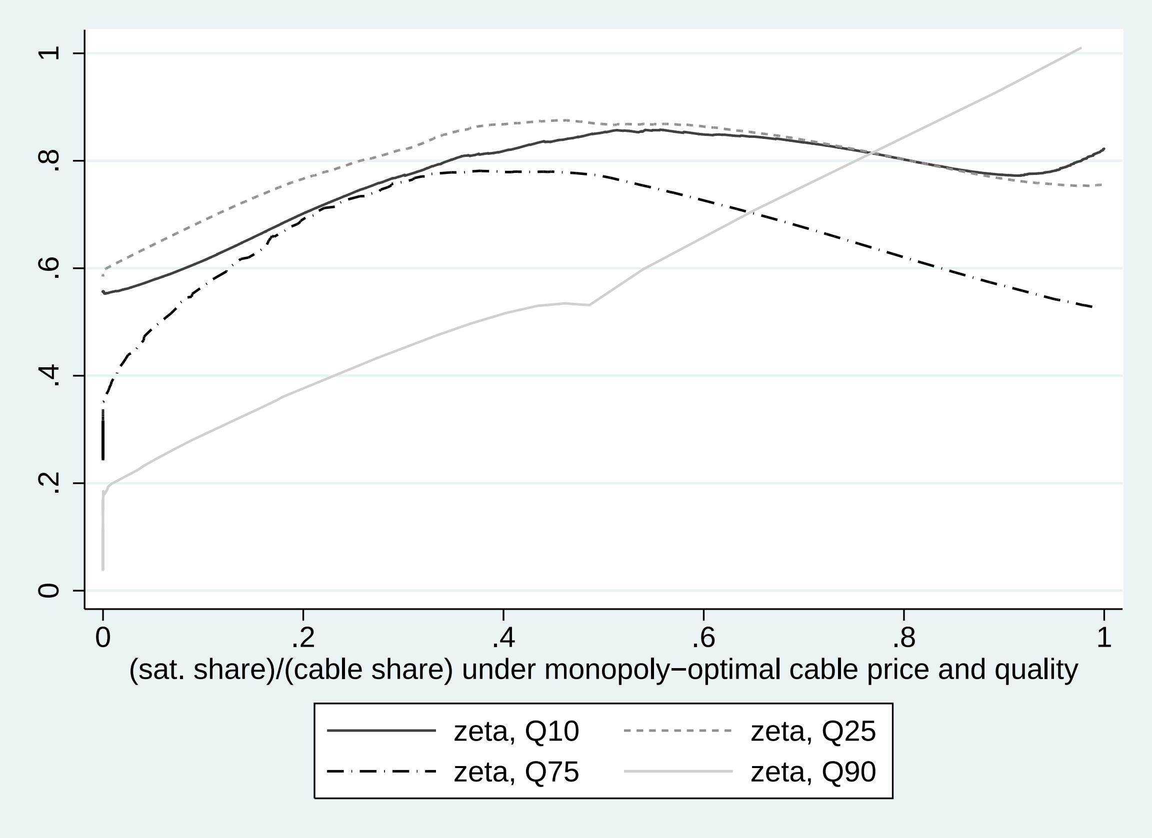


Figure 4: Simulated probability (conditional on marginal cost shock $\zeta$) of lowering price in response to entry, as a function of the proportion of the market share that would go to the entrant in the absence of price- or quality adjustments by the incumbent. Probabilities are Lowess-smoothed with a bandwidth of 0.4.

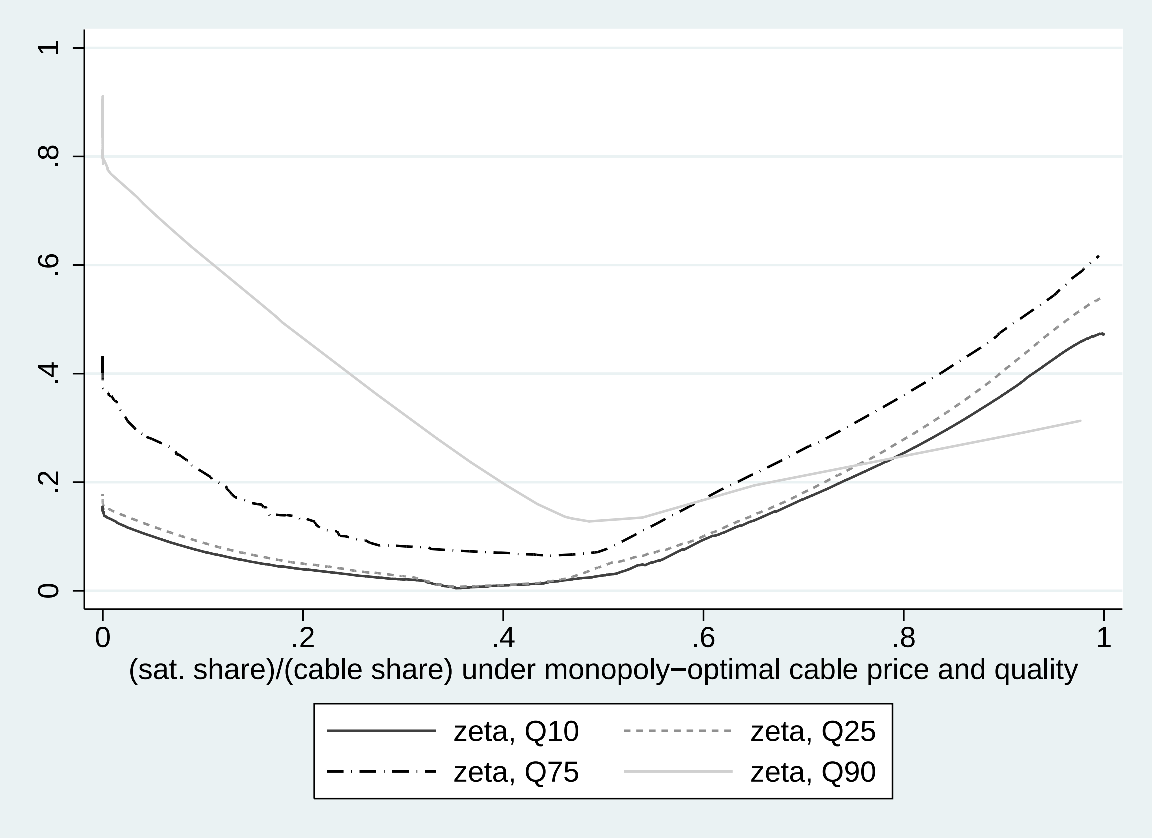


Figure 5: Simulated probability (conditional on brand effect $\xi$) of increasing quality in response to entry, as a function of the proportion of the market share that would go to the entrant in the absence of price- or quality adjustments by the incumbent. Probabilities are Lowess-smoothed with a bandwidth of 0.4.

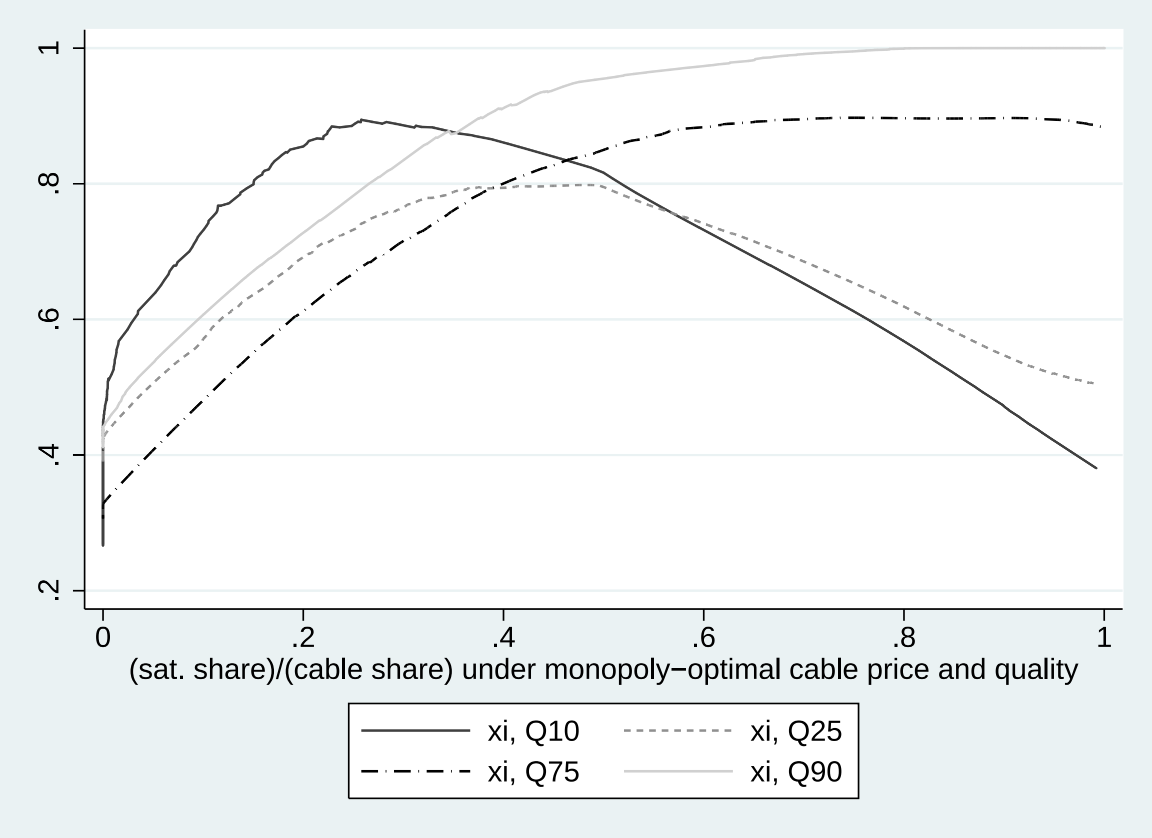
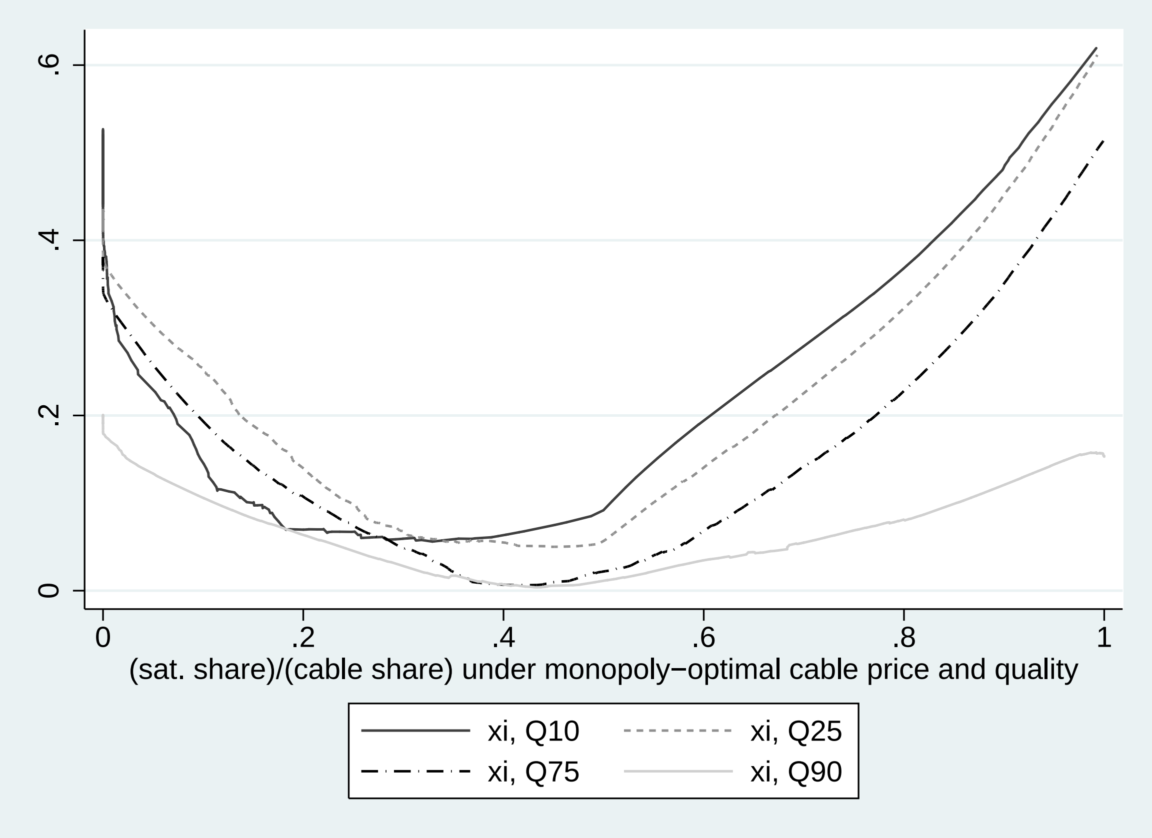


Figure 6: Simulated probability (conditional on brand effect $\xi$) of lowering price in response to entry, as a function of the proportion of the market share that would go to the entrant in the absence of price- or quality adjustments by the incumbent. Probabilities are Lowess-smoothed with a bandwidth of 0.4.



# B Data Appendix

## B.1 Measurement of Market Share

The basic definition of the market share of good $j$ sold by firm $k$ at time $t$ is straightforward:

$$s_{jkt} = \frac{\#\text{ households purchasing good } j \text{ from firm } k \text{ at time } t}{\text{total } \# \text{ of households in market at time } t} \tag{48}$$

The *Factbook* supplies subscriber counts for individual cable products, as well as the total number of households in each market. However, the satellite demand data (from Media Business Corp.) are aggregated over all products offered by the two satellite firms. To get around this shortcoming of the data, I treat satellite as an aggregate good with the price and product characteristics of DirecTV's "flagship" *Total Choice* package, which sold at a price between \$29.95 (in 1994) and \$31.99 (in 2002). DirecTV also offered several premium packages that were bundled with premium sports, movie, and digital channels. However, the premium packages and *Total Choice* contain essentially the same channels from among those that are explicitly taken into account by the proxy for programming quantity.[63] The packages differ primarily with regard to premium offerings that are not observed under the empirical specification. Similarly, Dish Network is widely regarded as being inferior to *Total Choice*, but mostly due to having worse premium offerings and a narrower range of season sports subscriptions, as opposed to any differences that would affect the proxy measure. Therefore, treating satellite as an aggregate good may bias the brand effects, but not the key parameters.

The second data limitation is that satellite demand is broken down geographically at the DMA level, but not at the finer level of individual cable markets. There are, on average, 7143 cable systems in each year of the data, but only 210 DMAs. Therefore, I make the simplifying assumption that the proportion of households purchasing satellite, *as a proportion of non-cable-consuming households*, is constant across all systems within a given DMA. This proportion is chosen so that the number of cable consumers, summed over cable systems, matches the DMA-level data.

A relatively minor issue is that the satellite subscriber counts also include small contributions from the older C-Band satellite technology and from fringe DBS competitors such as PrimeStar and USSB, which over time were acquired by the two main competitors. Additionally, before 2001, counts are for the total number of household satellite receiver devices, which is slightly higher than the actual number of subscribers, because some households have more than one receiver. In order to account for C-Band and for households with multiple receivers, I deflate the counts using an independent source of data, from the Satellite Broadcasting and Communications Association

---

[63] The availability of a degraded Select Choice package is some cause for concern, because it lacks certain channels that *are* taken into account by the measure of channel quality, such as Disney, Turner Classic Movies, and Fox News. However, conversations with industry representatives point to Select Choice being a rather unpopular package, until it was altogether phased out in June 2000.

(SBCA), on the total number of DBS subscriber households nationwide in each year. For each year, I use the same deflation factor for all DMAs, based on the assumption that the amount of distortion due to C-Band and multiple-receiver households is the same across markets.

Finally, the potential markets for satellite and cable are nonidentical. 41% of all franchises contain households unserved by cable, which account for 13% of all homes, on average. Most unserved households still have access to satellite. Conversely, satellite is infeasible for certain households with access to cable, due to the presence of buildings and other obstructions. An alternative to defining the denominator as the total number of households (as I do above) is to define it as the slightly smaller number of "homes passed" by the cable system (from the *Factbook*). However, using the latter number would exaggerate the cable market shares, because cable firms' decisions with regard to coverage areas may be influenced by perceptions about where demand is highest. Moreover, using "homes passed" as the denominator also exaggerates the overall satellite share, because unserved households are more likely to subscribe to satellite.

## B.2 BLS Wage Data

All wage data come from the Bureau of Labor Statistics Quarterly Census of Employment and Wages (QCEW). The QCEW data are disaggregated at various levels of industry-specificity, and include a category for "Cable and other subscription programming" (NAICS Sector 5152). However, while virtually all counties contain establishments at the 51 level, only a minority do at the 515 level, and even fewer do at the 5152 level. When a particular sector is absent from a given county, only state-level wage data are available for that sector. Thus, there is a tradeoff between disaggregation by geography versus disaggregation by industry. The decision to use the 51-level and 515-level data, but not the 5152-level data, is a compromise. If county-level data are missing for either Sector 51 or Sector 515, I substitute the state-level data. Sector 51 is represented in virtually all counties, so the former instrument tends to capture more geographic detail; the Sector 515 instrument relies heavily on state-level data, but is more specific to the subscription television industry.

# C Excluded Instruments for Estimation

This table lists the excluded instruments for specifications (1), (2), and (3) in Tables 3 and 4. The F-statistics test the joint significance of the excluded instruments in the first-stage regressions.

| **Specification (1)** | **Specification (2)** | **Specification (3)** |
|---|---|---|
| **Excluded demand instruments** | | |
| log(system size),<br>info sector wage<br>broadcasting wage | log(system size),<br>info sector wage<br>broadcasting wage | Same as for specification (1) |
| MSO interactions w/ :<br>log(system size),<br>info sector wage,<br>broadcasting wage | MSO interactions w/ :<br>log(system size),<br>info sector wage,<br>broadcasting wage | |
| | vertical integ. dummies | |
| *F-stat (and P-value) for joint significance in first-stage regression for price* | | |
| 19.618 (0.0000) | 222.28 (0.0000) | |
| *F-stat (and P-value) for joint significance in first-stage regression for* $log(x_1)^2$ | | |
| 5.735 (0.0000) | 544.81 (0.0000) | |
| **Excluded supply instruments** | | |
| # OTA channels | Same as for specification (1) | # OTA channels |
| MSO interactions w/ :<br>log(system size),<br>info sector wage,<br>broadcasting wage | | MSO interactions,<br>year interactions, and<br>(MSO·year) interactions w/:<br>log(system size),<br>info sector wage,<br>broadcasting wage |
| *F-stat (and P-value) for joint significance in first-stage regression for* $x_1$ | | |
| 4.265 (0.0001) | | 2.291 (0.0000) |
| *F-stat (and P-value) for joint significance in first-stage regression for* $x_1 \cdot MSO$ | | |
| 1.284 (0.2536) | | 1.625 (0.0040) |

Not reported: F-stats for year-interactions with $x_1$ and $x_1 \cdot MSO$ in specification (3). The corresponding P-values are all 0.0000.