# The Consumer Gains from Direct Broadcast Satellites and the Competition with Cable TV*

AUSTAN GOOLSBEE
*University of Chicago, GSB*
*American Bar Foundation and NBER*
and
AMIL PETRIN
*University of Chicago, GSB, and NBER*
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**Abstract**

This paper examines the introduction of Direct Broadcast Satellites as an alternative to cable television and the welfare gains such satellites generated for consumers. The extent to which satellites compete with cable has become an important issue in the debate over re-regulation of cable prices. We estimate a consumer level demand system for satellite, basic cable, premium cable and local antenna using extensive micro data on the television choices of more than 15,000 people as well as price and characteristics data on cable companies throughout the nation. The results indicate that, after properly controlling for unobservable product attributes and the endogeneity of prices, the direct welfare gain to satellite buyers averages between \$100 and \$200 per year or approximately \$1-\$2 billion annually in the aggregate. Estimates that do not control for unobserved attributes and endogenous prices yield upward sloping demand curves.

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# 1 Introduction

In the last two decades economists have devoted increasing attention to the importance of new goods. Although debate remains over the magnitude of the welfare gains arising from these new products, considerable strides have been made in developing methods to quantify such gains in ways that address the traditional difficulties such as unobservable product quality, the endogeneity of prices, and the importance of functional form assumptions that existed in welfare gains calculated using hedonic regressions or other methods.[1]

The role of new goods is especially important in industries like telecommunications and consumer electronics. In this paper we will analyze the introduction of a major consumer electronics good, the direct broadcast satellite (DBS). Starting in the mid-1990s, consumers could purchase a small satellite dish for their home, pay a monthly subscription fee, and then receive hundreds of channels of programming without having to subscribe to cable. This product has been quite successful from its onset in 1994. Indeed, by 1998, 10 million households had a dish, making it one of the fastest adopted consumer products in U.S. history.

Americans seeming love affair with television makes DBS a particularly important new product. In 1999, some 97% of households had a television and almost 75% had cable or a satellite (the so called multichannel video distribution systems). The average household watched more than seven hours of television per day(!), making it the number one leisure activity in the nation (Nielsen Media Research (1999)). Total television advertising in 1999 exceeded $45 billion and consumers spent an additional $37 billion on cable subscriptions (National Cable Television Association (2001)). In an industry this big, even minor product improvements have the potential to generate large welfare gains.

Analyzing the demand for DBS is particularly important for another reason, as well. The degree to which DBS provides a substitute for cable has become a central

[1] See Trajtenberg (1989), Hausman (1997b), Crawford (1997), Hausman (1998), Berry and Pakes (1999), Nevo (2000), Petrin (2001), and the papers in Bresnahan and Gordon (1997), as well as the discussion over the Consumer Price Index such as Boskin Commission (1996) and Shapiro and Wilcox (1996).

issue in the current debate over the regulation of cable prices. For the most part, cable television is dominated by local monopolies whose prices were once rather heavily regulated. The Telecommunications Act of 1996, however, phased out most price regulation and instead tried to promote competition as a check on prices. The explicit goal of the act was to stimulate local phone companies or new cable start-ups to enter the market.

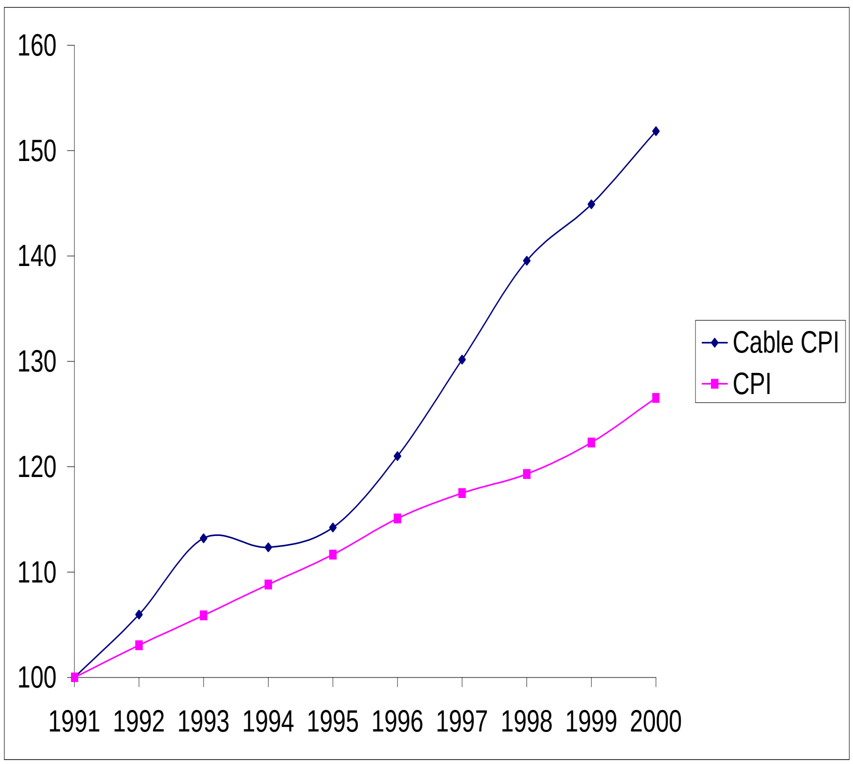
As a general matter, this effort to encourage entry failed. Phone company and new cable entrants have been rare. Consumer advocates say that unfettered monopolies can now raise prices with impunity (Consumers Federation of America (2001)). As the CPI and the Cable Television CPI data presented in figure 1 indicate, since the phase out of price regulation began in 1996, the prices of cable have grown about 2.5 times faster than overall prices in the economy.[2] This has lead to increasing public calls for congress and the FCC to re-regulate cable, at least until there is "viable competition" (Kimmelman (1998)). For most markets in the U.S., the only serious alternative to getting multichannel video from the cable monopoly is to buy a satellite dish. Indeed the National Cable Television Association, in their rebuttal to the consumer advocates' calls for regulation, has cited the fact that DBS is available in every market and growing rapidly as direct evidence that there *is* effective competition (Gregory, Brenner, Schooler, and Nicoll (2000)).

In this paper we will analyze these issues by estimating the demand system for cable and satellite using discrete choice methods developed in recent years and applying them to new micro data on the television choices of more than 15,000 households. The estimated demand system will allow us to infer both the welfare gains from the existence of DBS for the new adopters as well as the own and cross-price elasticities of basic cable, premium cable, and DBS.[3]

[2]There is debate over the importance of unmeasured quality change in the cable price index, especially in periods following major regulatory shifts such as this one. See the work of Crawford (1997) and Hazlett and Spitzer (1997).

[3]Within the literature on cable, Crawford (1997) and Crawford (2000) are the first papers to apply the new industrial organization methods for analyzing the cable industry. Our work is in the spirit of an older literature that sought to examine the demand for (the then newly available) cable television and the impact it was expected to have on the existing demand for network television

Figure 1: Cable Prices and the CPI, 1991-2000



After accounting for unobservable product attributes and the endogeneity of price, we find a low own-price elasticity for cable around one and a satellite elasticity of close to three. These demand curves imply that the direct welfare gain from DBS for the adopters (above the price they have to pay for it) is about $100 to $200 per year per satellite consumer for a total of approximately $1 to $2 billion in the aggregate (and that this result is robust). We also find that naive estimates that do not control for the endogeneity problems yield upward sloping demand curves.

The paper proceeds in seven sections. In section II, we give background on the cable and satellite industries. In section III we describe our data. In section IV we lay out our demand model and estimation method. In section V we discuss the basic results and price elasticities. In section VI we estimate the welfare gains in our model and using other methods. In Section VII we conclude.

# 2 Cable Television, Satellite, and the Market for Video Services

In this section we discuss the two primary alternatives for multi-channel video distribution that exist for most U.S. customers.

## 2.1 Cable Television

Over the past three decades, cable television has had an extraordinary rise to prominence. Cable began as a way for rural customers to improve their network television signal but by the 1980s had become a major alternative source of programming. By 1999, almost 70 percent of households in the United States had cable and the average customer received 57 channels from their cable provider (Nielsen Media Research (1999).)

(see Ellickson (1979) and Park (1971)). It is also in the spirit of the large literature that seeks to test for market power among cable companies such as Wildman and Dertouzos (1990), Rubinovitz (1993), Jaffe and Kanter (1990), Prager (1990), Zupan (1989), Mayo and Otsuka (1991), or Hazlett and Spitzer (1997).

Cable television has faced a winding road of regulatory treatment over this same time period. For most of its lifetime, the cable industry's high fixed cost nature lead regulators to treat it as a natural monopoly in each local market. As a result, cable firms bid to become the official monopoly provider in an area and paid a franchise fee generally amounting to a few percent of gross revenue. Prices were then regulated. In 1984, the government began deregulating cable prices. Over the next seven years, average prices rose two to three times faster than the overall rate of inflation, although considerable controversy remains over whether this was due to quality improvements or to increased markups.[4] Regardless of the true answer, it is clear that the public outcry over rising prices lead the government to reregulate cable in 1992. The impact and evolution of cable after this period is analyzed in Crawford (2000).

Only a few years later, general dissatisfaction with regulatory solutions caused the government to again deregulate cable prices as part of the Telecommunications Act of 1996. Previous to this bill, people noted that in the markets where there had been entry of a second cable company (known as overbuild markets) prices were lower and services better than in traditional monopoly markets. The effort of the 1996 act was to encourage direct competition as an alternative to regulation. The act tried to encourage local phone companies to enter local cable markets (FCC (1997)). Somewhat on the presumption of this future competition, the act also began phasing out price regulation of cable during the 1996-1999 period. By mid-1999, everything but the minimum basic channel package was deregulated.[5]

Since 1996, however, few phone companies have entered the cable business and the number of overbuild markets has remained small. As indicated at the outset, prices of cable have risen almost three times faster than inflation and, as a result, there are increasing calls to re-regulate cable prices. In most locations, the only competitor to the local cable monopoly is DBS.

[4] See Rubinovitz (1993), Jaffe and Kanter (1990), and Crandall and Furchtgott-Roth (1996).

[5] For details on how the regulations were phased out in the period from 1996 to 1999 see Bracco (1996). For more information on the act itself see Aufderhide (1999) and FCC (1997).

## 2.2 Home Satellite Systems

Television satellites broadcast from a geosynchronous orbit (i.e., they remain fixed in the same point in the sky as the earth turns).[6] As the number of television satellites increased in the 1970s and 1980s and the cost of a satellite receiver fell to a few thousand dollars some rural viewers bought 9 foot C-band satellite dishes for their own personal use. By the mid-1980s, however, most broadcasts were encrypted so they could not get free programming. Currently the C-band dishes tend to have a weak signal and are difficult to use. They seem to be used primarily by rural customers and we will restrict our sample to major metropolitan areas in order to avoid them since they are not considered a serious competitor to cable.

Although the 9-foot C-band dishes did not catch on with consumers, by the mid-1990s, an explosion in the amount of programming and distinct improvements in satellite receiver and digital compression technology set the stage for the next generation of home satellite systems.[7] These new DBS systems broadcast on the Ku-band at frequencies of up to 17.8 gigahertz to satellite dishes as small as a 18 inches in diameter. The most popular of the systems at the time of our sample were DirecTV, the DISH Network, and Primestar (since then, Primestar ceased operating independently). These satellites offer subscribers hundreds of channels, including more extensive sports, movie, and pay-per-view options than are available on cable systems. In addition, their digital video and sound is superior to traditional cable television or local-antenna reception.

These advantages can be expensive, however. In addition to the monthly programming fees, consumers subscribing to these services usually pay for the equipment themselves, averaging around $266 including installation time in 1998 (down from an average of $350 in 1997). The comparable programming packages are slightly more expensive on DBS than on most cable systems, as well. In 1998, the average cost of expanded basic was $31 for the average cable system (FCC 97-423) while the average cost for the standard cable channels on DirecTV was $32, and this did not include the major networks (e.g., ABC, NBC, CBS, Fox). With its pricing and programming

[6] To do so, they must be 22,300 miles above the earth at the equator.

[7] See Owen (1999) for a history of DBS systems.

options, DBS seems intended for the higher end of the market.

Table 1

**Cable and DBS Subscribers (millions of households)**

| Year | Cable | DBS |
|---|---|---|
| 1994 | 59.4 | 0.4 |
| 1995 | 62.1 | 2.2 |
| 1996 | 63.5 | 4.3 |
| 1997 | 64.9 | 5.0 |
| 1998 | 66.1 | 7.2 |
| 1999 | 66.7 | 10.1 |

Source: FCC, 2000.

Despite the large installation costs and higher programming fees, consumers have embraced the product. As table 1 shows, from a base of about 400,000 in 1994, the number of households that subscribe to satellite exceeded 7 million by 1998 and 10 million in 1999 (FCC, 2000). DBS now accounts for about two-thirds of all new subscriptions to multichannel video systems.

There have been some physical and regulatory disadvantages of DBS systems, however, that have limited their spread. At the time of our sample (end-of-year 1998), the most well known problem with satellites was the regulatory restriction preventing the DBS systems from broadcasting local network content to anyone that can get such channels with a regular television antenna.[8] This meant that people living in television markets where antenna reception is spottier (such as mountainous places or places with bad weather) might find the satellites to be a worse substitute for cable.

A second regulatory hurdle at the time of our sample was the unclear interpretation of the 1996 Satellite Home Viewer Act. That act forbid most regulations against

[8] Technically, anyone that could receive a grade B signal was ineligible. This rule was changed in the Satellite Home Viewer Improvement Act of 1999 so that consumers in most major television markets can now receive their local channels for an additional fee.

home owners putting up satellite dishes. However, the act did not give a clear right for renters to do the same.[9] Thus, at the time of our sample, we would expect that, holding other individual characteristics equal, renters will be less likely to prefer satellites to cable.

The most important physical problem with DBS systems is that the user must have a clear line-of-sight to the broadcast satellite in the sky in order to receive the signal. Buildings, geography, and even trees can block the signal and make it so the user receives either no signal or a degraded signal. This means that people living in single family homes or trailers have a much better chance of being able to get the signal than people living in multi-unit dwellings. It also means that people living in higher latitudes should have a greater chance of ground based interference because their dishes will be pointed closer to the horizon. A person in Seattle, for example, needs a clear line of site at 31.5 degrees above the horizon. In Houston, they need a clear line at only 55 degrees (straight up is 90 degrees).[10] We will control for these various factors in our estimation.

# 3 Data and Identification

In this section we describe our data sources and provide an overview of how our data and modeling approach are related.

## 3.1 Micro Data on Television Choices and Characteristics

Since our goal is to estimate the demand system for cable and satellite, the basis of our estimation will be data on individual consumers' television choices. This information comes from surveys done by Forrester as part of their Technographics 1999

[9] In January of 1999, an added clarification established the right of a renter to install a dish on any well-defined space that they "controlled", such as a patio. They are still not allowed to put a satellite dish on the roof of a building without the landlord's permission even if they have free access to it.

[10] This problem of greater interference at higher latitudes is well known in the industry and, incidentally, explains the efforts of the Soviet Union (almost all of which is at a high latitude) to develop satellite systems in non-geosynchronous orbits (see Owen (1999)).

program (conducted in December 1998). Forrester is a leading market research company focusing on the information economy and in this survey they asked people about their ownership and use patterns of various electronic and computer related goods. The survey is meant to be nationally representative and more details about it can be found in McQuivey, et al. (1999) or Goolsbee (2000).

The survey provides various demographic information about the individuals in the sample including gender, family income, marital status, presence of children, education, race, and age, as well as their state and their television market (known as the DMA). Additionally, consumers report which cable company they have if their cable company is one of the nine largest in the country (such as AT+T/TCI, Time Warner and Media One.)

We will model consumers' television choice between expanded basic cable, premium cable (which can only be purchased with expanded basic), DBS, and no multichannel video (i.e., local antenna reception only).[11] We look at the top 60 television markets. Here our sample sizes are sufficiently large and we know that access to cable is not likely to be limited and that C-band dishes are uncommon. These markets include more than 70 percent of the U.S. population (Nielsen Media Research (2000)).[12]

Table 2 gives summary statistics for some of the variables used in the study for this sample of more than 15,000 households. Approximately 20% of households choose not to have multi-channel video (i.e., they have local antenna reception only). Almost 70% of households have either expanded basic or premium cable and about 10% of the sample has DBS.[13] Notice that our sample, which is restricted to the

[11] We classify respondents as choosing premium if they report that they have cable and that the amount they pay on premium channels is greater than zero. The survey also asks the number of hours of television watched per week. In future work we will try to improve our welfare calculations by incorporating this information and allowing consumers to jointly choose both the television medium and amount of television they watch.

[12] Of course, consumers living in areas that do not have access to cable may be the biggest beneficiaries from the introduction of DBS. Unfortunately, the Forrester survey is not detailed enough to allow us to estimate the value to these consumers so we will look only at the welfare gains to consumers in major metropolitan areas.

[13] As described above, satellite users have the option of also signing up for cable, and about 3% in

larger metropolitan areas, generates approximately the same relative market shares for satellite relative to cable as the FCC report in table 1. Our survey takes place just before the start of 1999 and has 6.8 times more cable subscribers than satellite. This is close to the ratio of 6.6 found in the FCC report for the year 1999.

Table 2

**Summary Statistics: Consumer Data**

| Variable | Mean | Std. Dev. |
|---|---|---|
| Indicators | | |
| Local Antenna Only | 0.212 | 0.409 |
| Expanded Basic Cable | 0.378 | 0.484 |
| Premium Cable | 0.302 | 0.459 |
| Satellite | 0.107 | 0.310 |
| Rent | 0.227 | 0.419 |
| Male | 0.496 | 0.500 |
| Single | 0.187 | 0.390 |
| Single Unit Dwelling | 0.787 | 0.409 |
| Household Size | 2.743 | 1.897 |
| Household Income | $56,292 | $28,115 |
| Observations | 15,153 | |

Source: Forrester Technographics, 1999.

To these individual data on consumer choices, we will match information on the cable system prices and characteristics that each individual faces. There is variation in prices and characteristics across markets and this will allow us to identify their effects on television choices. These cable system data come from Warren Publishing's 1999 Television and Cable Factbook (Warren Publishing (1999)). This is the most comprehensive reference for cable system characteristics in the industry. Since there

our sample does so. Since the higher channel offerings on satellite fully dominate the cable offerings in almost all markets during our sample, we assume that anyone reporting that they subscribe to both satellite and cable are subscribing to the minimum cable package that gives access to the local networks only.

can be many different cable franchises within a given DMA market and we do not have a finer level of geographic detail, we take the largest cable franchise in the television market-state combination for the information.[14] We allow consumer preferences to be affected by the channel capacity of a cable system, the number of pay channels available, whether pay per view is available from that cable franchise, and the price of basic plus expanded basic for the system. We also get from the Factbook the number of over the air channels available in the market area and the city franchise fee as a percent of revenue. Finally, as a proxy for the average price of premium channels in a market we use the observed price of HBO, the most common premium channel. Table 3 reports some summary statistics of these numbers.

Table 3

**Summary Statistics: Television Markets**

| Variable | Mean | Std. Dev. |
|---|---|---|
| Monthly Expanded Cable Price | \$28.00 | \$8.17 |
| Monthly HBO Cable Price | \$11.50 | \$1.58 |
| Over-Air Channels | 10.50 | 3.90 |
| Channel Capacity | 68.20 | 19.30 |
| Premium Channels | 5.86 | 1.42 |
| Pay-Per-View Available | .940 | .238 |
| Angle | $41.88^o$ | $6.45^o$ |
| City Fixed Fee | .046 | .012 |
| Observations | 60 | |

Source: Warren Publishing 1999 Television and Cable Factbook (except angle).

For each of the television markets, we also calculate the angle of elevation (up/down) at which a potential user of DBS would have to position their dish by taking the primary zip code for the major city from the World Almanac (1999) and plugging it into the DirecTV dish pointer (DirecTV (2000)). The higher the angle, the less likely DBS

[14]Many of the television markets cross state lines. The New York City DMA, for example, covers individuals in New York, New Jersey, and Connecticut so we would include the characteristics of the largest company in each of the three areas.

is to have ground based interference. To measure interference problems, we calculate the variance of the local terrain and average elevation using data from the One Degree U.S. Geologic Survey Digital Elevation Model data.[15] We take a measure of the local weather the Climate Stability Index from the *Places Rated Almanac* (Savageau and Lotus (1997)). These will affect the quality of local antenna reception. Various other data we use include the total population of the DMA given by Nielsen Media Research (2000) and the aggregate market share for cable television in each DMA (from Warren Publishing (1999)).[16]

## 3.2 Identification

The goal of our empirical work is to estimate the price sensitivity of demand for both cable and satellite television and to compute the welfare gains from the existence of DBS. To make this calculation, we will employ a discrete choice model of demand and use the variability of price and characteristics of cable companies across the United States to estimate demand elasticities. In essence, our demand estimates are identified by comparing people with the same observable characteristics but in markets where the prices and characteristics of cable differ to see how their likelihood of buying a satellite changes (satellite prices are the same across the U.S.).

One concern when estimating such a demand curve, of course, is the potential for price endogeneity. If we cannot observe some of characteristics of the local cable franchise that are known by both the consumers and the suppliers and if cable prices respond to these factors, the price elasticity will typically be biased towards zero. For example, a cable system with the same observables but with relatively good service will tend to be more desirable and have higher prices, making it seem as though consumer demand does not respond to high prices. For this reason we will include a full set of product dummies that will account for the unobservable product quality of basic cable and premium cable in each market, in addition to our individual level

[15] We choose a point at the center of the DMA and calculate a variance of the elevation in a 30 pixel by 30 pixel area centered at that point.

[16] These shares will provide a useful check on the effect the sampling error that exists in the Forrester sample has on our final results.

demographic variables.

We observe a detailed set of demographics at the individual level that may affect demand, like renter status, single-unit dwelling status, income, cable company, and so on. We also observe some demand shifters at the market-level including characteristics of cable companies and features of the DMA such as satellite angle. As table 4 indicates, these factors tend to be correlated with the share of people in the market who choose DBS over cable. In particular, satellite ownership is much higher for people with higher dish angles, people who do not rent, and people living in single-unit dwellings.

Table 4

**Characteristics of Multi-Channel Video Consumers**

| | High Angle | Low Angle | Own | Rent | Single Residence | Multiple Residence |
|---|---|---|---|---|---|---|
| Satellite | 16.6% | 10.0% | 14.9% | 9.0% | 15.3% | 6.8% |
| Cable | 83.4% | 90.0% | 85.1% | 91.0% | 84.7% | 93.2% |

To identify the price coefficient in the demand equation, however, we still need a cost shifter on the supply side. We have two potential variables. The first is the city franchise fee paid by the cable company, as described above. This is a percent of gross revenue that varies by market and is reported in Warren Publishing (1999). The second is the density of population in the area, computed using the data in Cutler, Glaeser, and Vigdor (1999) since more densely populated areas are thought to have lower costs for operating a cable franchise (see Owen (1999)).

# 4 Utility Theory and Estimation

## 4.1 Utility Theory and Discrete Choice

We assume that consumers choose the type of television that gives them the highest utility and that their utility can be written as a function of tastes for the characteristics of those goods.[17] Here the four goods are local antenna reception (Ant), expanded basic cable (Base), premium cable (Prem), and Direct Broadcast Satellite (Sat). Thus, a given household $i$ will choose the type of television that yields highest utility. In other words, the one that solves

$$V_i = \max_{j \in \{Ant, Base, Prem, Sat\}} V(p_j, y_i, i, j), \tag{1}$$

where $V_i$ and $V(\cdot)$ are the unconditional and conditional (on product choice) indirect utility functions, $j$ indexes the four different television viewing mediums available, $y_i$ is income, and $p_j$ is price of medium $j$.

The utility function for the "outside good" in our framework is the utility derived from having only local antenna reception and no multi-channel video. In our framework this utility is

$$V_{iAnt} = \alpha_i(y_i - 0) + \delta_{Ant} + \beta'_{Ant} Z_i + \epsilon_{iAnt}, \tag{2}$$

where for now we suppress the market index $m$ to ease exposition. Here $\alpha_i$ is a marginal utility of income parameter for household $i$. The cost of antenna reception is zero, so all income (i.e. $(y_i - 0)$) is left for consuming other goods, and we assume these goods are separable from television medium consumption.

The utility term common to all consumers, $\delta_{Ant}$, is the average quality for antenna reception in the television market. It embodies things like the number of over-the-air channels available in the market and the quality of local reception. $Z_i$ is a vector of household-specific characteristics that affect people's preferences (via the taste vector $\beta_{Ant}$) for antenna-only reception, including things like household size and education. Finally, $\epsilon_{iAnt}$ represents household specific tastes for antenna reception not captured by their observable demographic characteristics or the average quality of antenna reception in their area. For example, if the household has a particular aversion to the mature content of cable/satellite type channels that leads them to be hostile to anything but network programming, this will show up as a high $\epsilon_{iAnt}$ (if it is not explained by the demographics).

[17] Gorman-Lancaster introduced the characteristics approach to modeling demands. McFadden (1981) developed much of the econometrics.

Similarly, the utility functions for expanded basic, premium, and satellite are written as

$$V_{ij} = \alpha_i(y_i - p_j) + \delta_j + \beta_j' Z_i + \epsilon_{ij}, \tag{3}$$

where $p_j$ is the annual cost of the medium, $\delta_j$ represents the common quality/utility for the product, $\beta_j' Z_i$ is the household-specific utility associated with product $j$ (due to demographics), and $\epsilon_{ij}$ is the idiosyncratic unobserved taste for product $j$. To allow for income effects that seem prevalent in the data (i.e., as income rises, average shares shift away from antenna-only reception) we let the $\alpha_i$ term vary by income quintile.[18] We restrict the demographic coefficients to be the same across geographic markets. Finally, we normalize average (unobserved) utility for antenna-only to be zero.

## 4.2 Estimation

Much of the existing work uses some kind of logit form for the idiosyncratic error to estimate this type of discrete choice model, principally because it simplifies computational problems associated with estimation. Logit models have been criticized, however, for imposing unrealistic restrictions on demand systems (see Berry and Pakes (1999), for example.) More importantly for our purposes, Petrin (2001) shows that adding the logit error can lead to significant upward biases in welfare calculations from new products. Because we have a small number of products, we can avoid the computational difficulties that force most researchers to use a logit error in one form or another. Instead, we employ a multinomial probit (MNP), allowing the variances and covariances to vary freely across the four choices (up to the necessary normalizations.)

We use maximum likelihood to obtain parameter estimates for the discrete choice model with four choices: antenna-only, expanded basic cable, premium cable, and satellite. In each market we include a fixed-effect for basic cable and a fixed effect for premium cable to deal with any unobservable quality issues.

[18] Petrin (2001) shows that allowing for such income effects makes an important difference in demand and welfare estimates in the automobile market.

There are four distinct vectors of parameters that enter our likelihood function: $\alpha$, the marginal utility of income parameters, $\beta$, the parameters associated with taste for television viewing related to observables in our data, $\delta$, the common utility component fixed effects, and $\sigma$, the diagonal and off-diagonal terms of the covariance matrix of errors.

The likelihood function with the consumer level data takes the form

$$L = \Pi_{i=1}^{N} \Pi_{j=1}^{J} s_j(\alpha, \beta, \sigma, \delta; Z_i)^{j(i)} \tag{4}$$

where $j(i)$ is the indicator function

$$\mathrm{J}(i) = \begin{cases} 1 & \text{if } i \text{ chose } j \\ 0 & \text{otherwise} \end{cases}$$

$i$ indexes households and $s_j(\cdot)$ is the probability with which household $i$ is predicted to purchase good $j$. This share obtains by conditioning on the parameter values and integrating out the errors (using simulation), or

$$s_j(Z_i) = \int_{\epsilon} \{V_{ij} = max_{k\in(A,E,P,S)} V_{ik}(\epsilon; Z_i, \alpha, \beta, \sigma, \delta)\} dP(\epsilon).$$

We then get the DMA market shares by averaging over the $Z_i$'s in a market.

We employ an insight in Berry (1994) to concentrate out the 120 fixed effects. For discrete choice models satisfying standard regularity conditions he shows that there exists a vector of $\delta$'s (fixed effects) that equates the model predictions for market shares to those observed in the data. Thus, we proceed by first fixing $(\alpha, \beta, \sigma)$ at a potential solution. Then, market by market, we solve for the pair $(\delta_E^*, \delta_P^*)$ such that $s_E^* = s_E(\alpha, \beta, \sigma, \delta_E^*, \delta_P^*)$ and $s_P^* = s_P(\alpha, \beta, \sigma, \delta_E^*, \delta_P^*)$. Finally, we compute the value of the likelihood function for this $(\alpha, \beta, \sigma)$ and then repeat this procedure until we locate the maximum.[19]

In the final stage of the estimation we use these parameter estimates to evaluate the own- and cross-price elasticities of demand for the various goods and to evaluate

[19] To locate the fixed effects, we use the Nelder-Mead non-derivative search, which required more function evaluations than a Gauss-Newton approach, but did not require the computation of the Jacobian or Hessian matrix.

the welfare coming from the existence of DBS as a choice. It is important to note that the welfare calculations and the elasticity computations, in many ways, are two versions of the same question. The elasticities indicate what would happen to demand from a very small increase in the price of satellite. The welfare gain reflects what would happen to utility from a very large increase in the price of satellite (raising its price high enough that demand goes to zero).

# 5 Demand Results

Using the method described above, we estimate the parameters of the demand system in table 5.[20] We include coefficients on variables that the cable literature indicates are important (see Hazlett and Spitzer (1997), Crandall and Furchtgott-Roth (1996)): gender, household size, marital status, and education in all of the equations (except, of course, the baseline of antenna-only) to allow them to influence the taste for each good differently. We allow the angle of reception and the renter status and single-unit dwelling status of the individual to influence the taste for a satellite dish. We allow the number of over-the-air channels and the quality of local reception as measured by the variance of elevation in the market and the weather index for the market to influence the taste for antenna-reception relative to other media, and we allow for the separate fixed effects by market for basic and for premium cable to fully account for quality differences across markets.

The coefficients are not marginal effects so the magnitudes are difficult to interpret directly from the table. Most of the variables, however, do have the predicted signs. For example, living in a single unit dwelling angle and not renting all increase the likelihood of having satellite relative to antenna-only (conditional on everything else). Generally, most parameters are precisely estimated, a consequence of having more than 15,000 observations.

Since these demand estimates will form the basis of our welfare gain calculations

[20]Recall that these estimates give the change in utility *relative* to the choice of television via local antenna reception. Thus a positive sign does not necessarily mean an increase in purchase probability; it means an increase in purchase probability relative to local antenna.

Table 5

## Parameter Estimates

Four Choices: Antenna Only, Expanded Basic, Premium, and Satellite

| Variable | Coefficient | Asymp. Std. Error |
|---|---|---|
| Antenna Only: | | |
| Over-the-Air Channels | 0.1144 | 0.0042 |
| Variance in Elevation | 0.0078 | 0.0017 |
| Climate | -0.0057 | 0.0007 |
| Expanded Basic: | | |
| Male | -0.0204 | 0.0313 |
| HHSize | -0.0003 | 0.0144 |
| Single | 0.1648 | 0.0560 |
| Education | -0.0091 | 0.0123 |
| Premium: | | |
| Male | 0.0500 | 0.0492 |
| HHSize | -0.0082 | 0.0220 |
| Single | -0.0595 | 0.0681 |
| Education | 0.0534 | 0.0169 |
| Satellite: | | |
| Angle | -0.0314 | 0.0023 |
| Rent | -0.4672 | 0.0998 |
| HHsize | 0.1197 | 0.0358 |
| Single | 0.4009 | 0.1239 |
| Education | -0.0446 | 0.0290 |
| Male | 0.4908 | 0.0785 |
| Single Unit Dwelling | 0.4593 | 0.1102 |
| Log Likelihood | -15039 | |
| Observations | 15153 | |

Note: Specification is estimated using top 60 television markets and an annualized fixed cost of $50 for satellite. Specification includes 4 income effect terms, dummy variables for expanded basic*cable company (9) and premium*cable company (9) for the top 9 U.S. cable companies, and the 5 parameters characterizing the distribution of the unobserved terms. See the table in the Appendix for additional estimates.

Table 6

## Marginal Effects on Purchase Probabilities

| Changing from | MU Dwelling | HH Inc. = $15K | High Sch Educ. (HoH) |
|---|---|---|---|
| To | SU Dwelling | HH Inc. = $40K | Post College Educ. (HoH) |
| Changes avg prob (%): | | | |
| Antenna Only | -1.12 | -0.95 | -0.20 |
| Expanded Basic (EB) | -2.44 | 0.33 | -0.84 |
| EB and Some Premium | -0.17 | 0.43 | 2.15 |
| Satellite | 3.74 | 0.18 | -1.10 |

| Changing from | Renting | HH Size=2 | Not Single |
|---|---|---|---|
| To | Not Renting | HH Size=4 | Single |
| Changes avg prob (%): | | | |
| Antenna Only | -1.15 | -0.53 | -2.35 |
| Expanded Basic (EB) | -2.50 | -1.36 | 1.47 |
| EB and Some Premium | -0.18 | -0.30 | -1.95 |
| Satellite | 3.83 | 2.20 | 2.82 |

Notes: Specification is estimated using top 60 television markets and an annualized fixed cost of $50 for satellite. Probabilities obtained by evaluating each household's change in probability (holding all other characteristics constant), and then averaging these changes across households. MU/SU Dwelling is Multi-Unit/Single Unit Dwelling, HH Inc is household income, and HH Size is household size.

and our elasticity estimates, we want to be sure that the results are plausible. In table 6 we translate these parameters into more understandable marginal effects. We compute these effects by first fixing one characteristic at a common value for all households (holding other characteristics at their observed levels). We then change it (for everyone) to a different value and then compute the implied change in probability of buying the various types of television for each individual. Averaging across all the individuals gives us the changes in market share reported in table 6.[21]

The first column at the top of the table shows the change in the market share that results from everyone in the sample moving from a multi-unit dwelling to a single-family home, holding all other characteristics constant at their observed levels. As we expected, having a single-family home makes it much more likely that a household gets satellite. This comes largely in favor of expanded basic and antenna-only. Similarly, holding other characteristics equal, switching from non-renter to renter has a large impact on satellite at the expense of antenna only and expanded basic. As income rises, the share of customers receiving only local antenna reception falls as people substitute to cable and satellite. Also, increasing household size reduces the likelihood of antenna-only reception in favor of satellite.

## 5.1 Deriving Price Elasticities

At first glance, getting price elasticity estimates from the demand system above may seem difficult. The price of expanded basic and of premium cable are not included as regressors in the table because they are embodied within the market fixed effects for each product. Furthermore, the price of satellite does not vary across locations. As we show below, however, we can still use the demand estimates to get the price elasticities if we have valid instruments.

Recall that the fixed effects are the components of utility that are common across consumers (i.e., the average quality). These fixed effects are determined by the cable companies' characteristics (both observed and unobserved) in market $m$. We write

[21] Instead of evaluating the marginal effect at (for example) the average of the household demographics, this approach evaluates the effect at every household, and then averages across households. This is the appropriate calculation for the aggregate change in this non-linear setting.

this as

$$\delta_{jm} = -\alpha_0 p_{jm} + \overline{\beta}' X_{jm} + \xi_{jm}, \tag{5}$$

where $\alpha_0$ and $\overline{\beta}$ are the price and taste terms common across consumers for characteristics ($X_{jm}$), and $\xi_{jm}$ is the unobserved quality of the product. An endogeneity problem will arise whenever the unobserved quality component, $\xi_{jm}$, which is known by consumers and the cable company but not by us, is also correlated with price.[22]

To estimate price elasticities we need an estimate of

$$\frac{\partial V_i}{\partial p_j} = -\alpha_0 + \alpha_i.$$

Although we have estimated $\alpha_i$ in our demand system, $\alpha_0$ (the coefficient on price) is nested inside the fixed effect. We can estimate the $\alpha_0$ and the $\overline{\beta}$'s on observed cable characteristics by running a regression of the expanded basic fixed effects in each market on the cable company's observable characteristics, including price, channel capacity, pay-per-view availability, number of premium channels available and franchise age. In essence, we are directly estimating equation (5) using market-level variation.[23] Note that the fixed effects that make up the dependent variables in this regression came from estimates that conditioned on all the other observables so nothing guarantees that the coefficients here will have the correct signs. As such, they will also serve as a check on the plausibility of our model since we expect that better characteristics should improve utility.

We present the results in table 7. In column 1 we estimate the regression with OLS. This is equivalent to assuming that there is no correlation between price and the unobservable component of quality ($\xi_{Base}$). We would expect that the price elasticity in this case should be biased toward zero since the unobserved characteristics are likely to be positively correlated with price. In columns 2 and 3 we then list the results from two different instrumental variable approaches that control for the potential price endogeneity. The approaches are two stage least squares (2SLS) and a generalized

[22] This is not a problem for satellite or for local antenna reception since their prices are the same in every market.

[23] Berry, Levinsohn, and Pakes (1998) suggest other ways to identify the price coefficient in a demand framework similar to ours but where market-level variation is not available.

2SLS that accounts for the sampling variability in the market shares (and the variance they introduce into the estimated fixed effects.) Our instruments for price are the city franchise fee and the city density, and in neither case do we reject the over-identifying restriction.[24]

There is clear and strong evidence of price endogeneity. The OLS coefficient on price is positive, even after controlling for channel capacity, availability of pay-per-view, number of pay channels available, and year established. The upward sloping demand curves imply that the unobserved qualities (or omitted variables) of the cable services in an area are positively correlated with the price of cable. In addition, the coefficients we obtain on the other variables generally suggest that higher quality (as measured by the fixed effects) is associated with systems that have more channel capacity, availability of pay-per-view, and are more recently established (with presumably newer technology). The only potential anomaly is the negative sign on the number of pay channels available.

With our estimate of $\alpha_o$, we can estimate what happens to utility (and thus demand) when the price of cable changes. It is still problematic to figure out what happens when the price of satellite changes, however, since we don't see any price variation for DBS across markets. To get an elasticity calculation, however, we can exploit the discrete choice nature of our problem coupled with some simple demand theory.

The sum of the market shares across goods must be 1 so the derivative of the shares with respect to the price of satellite must sum to zero, or

$$\frac{\partial s_{Sat}}{\partial p_{Sat}} = -\frac{\partial s_{Base}}{\partial p_{Sat}} - \frac{\partial s_{Prem}}{\partial p_{Sat}} - \frac{\partial s_{Ant}}{\partial p_{Sat}}, \tag{6}$$

where $s_{Sat}$, $s_{Base}$, $s_{Prem}$, and $s_{Ant}$ index the market share for satellite, expanded basic, premium, and antenna-only, and similarly for the price terms. We observe the satellite share vary as expanded basic's price varies across markets. We use this

[24] Here there are 9 missing values for city fixed fees, leaving us with 51 observations to estimate the coefficient on price. The P-values under the null hypothesis of no specification error were greater than 0.9.

Table 7

## Parameter Estimates from Market Fixed Effects

| Variable | OLS Coefficient (Std. Error) | 2SLS Coefficient (Std. Error) | G2SLS Coefficient (Std. Error) |
|---|---|---|---|
| price | 0.008 | -0.437 | -0.391 |
| | (0.031) | (0.437) | (0.288) |
| intercept | 16.1 | 6.9 | 7.85 |
| | (12.7) | (27.4) | (19.5) |
| channel capacity | 0.007 | 0.021 | 0.020 |
| | (0.003) | (0.015) | (0.009) |
| pay-per-view avail. | 0.166 | 0.608 | 0.546 |
| | (0.049) | (0.618) | (0.407) |
| number pay channels avail. | 0.008 | -0.215 | -0.189 |
| | (0.049) | (0.239) | (0.143) |
| year established | -0.007 | -0.002 | -0.002 |
| | (0.006) | (0.010) | (0.010) |
| R-squared | 0.173 | n.a. | n.a. |
| Reject Using Overidentification Test? | —- | NO | NO |
| Observations | 51 | 51 | 51 |

Note: Specification is estimated using top 60 television markets and an annualized fixed cost of $50 for satellite. Generalized 2SLS accounts for sampling variation in market shares.

variation combined with the symmetry of demand, or

$$\frac{\partial s_{Base}}{\partial p_{Sat}} = \frac{\partial s_{Sat}}{\partial p_{Base}}, \tag{7}$$

to estimate the first term on the right hand side of the equality in (6). We can do the same thing for premium cable to get the second term from (6).[25]

For the third term we see no price variation in local antenna reception. Here we use the chain rule to write

$$\frac{\partial s_{Ant}}{\partial p_{Sat}} = \frac{\partial s_{Ant}}{\partial s_{Base}} \frac{\partial s_{Base}}{\partial p_{Sat}}.$$

We have an estimate for the second term on the right hand side of this equation from our calculation in equation (7). For the first term on the right hand side we take the model prediction of the fraction of customers that switch to antenna-only when satellite is taken out of the choice set and we divide it by the predicted fraction that switch to expanded basic when satellite is removed from the choice set. The cross price terms are estimated in a similar manner.

Table 8 presents the relevant own and cross-price elasticities of market share for each television choice. Columns 1 and 2 use the top sixty markets and treat as $50 the annual perceived cost for satellite. In column 1 we present OLS and column 2 is IV. To check the robustness we also estimate the model with $100 annualized cost and with the top 83 markets (columns 3 and 4).[26]

One of the most important results in table 8 comes from OLS. Assuming there is no endogeneity problem leads to estimates of the own price elasticities of expanded basic, premium, and satellite that are positive (increasing prices increases demand). Without instruments, one would conclude from the magnitudes that none of the component markets of television are price sensitive at all. This is the root of the problem with using conventional hedonic methods in a situation where there are unobservable attributes.[27]

[25] We are implicitly assuming here that total spending on cable is sufficiently small that a small change in cable prices will not affect household income by enough to induce any indirect change television demand through the income effect term.

[26] The top 83 markets have at least 100 observations each.

[27] For a discussion of the importance of instruments in the context of estimating welfare gains, see the debate in Hausman (1997a) and Bresnahan (1997), and Petrin (2001).

Table 8

## Elasticity of Demand with Respect to Price

| Method: | OLS | IV | IV | IV |
|---|---|---|---|---|
| Elasticity of | | | | |
| Expanded Basic w.r.t. | | | | |
| Expanded Basic | 0.07 | -1.15 | -0.92 | -0.86 |
| Premium | -0.01 | 0.18 | 0.11 | 0.10 |
| Satellite | -0.12 | 0.57 | 0.33 | 0.33 |
| | | | | |
| Premium w.r.t. | | | | |
| Premium | 0.03 | -0.43 | -0.34 | -0.31 |
| Expanded Basic | 0.03 | -0.52 | -0.51 | -0.46 |
| Satellite | -0.0 | 0.05 | 0.10 | 0.09 |
| | | | | |
| Satellite w.r.t. | | | | |
| Satellite | 0.18 | -2.81 | -2.95 | -2.20 |
| Expanded | -0.12 | 1.62 | 0.83 | 0.83 |
| Premium | 0.01 | 0.05 | 0.08 | 0.08 |
| Number of Markets | 60 | 60 | 60 | 83 |
| Annualized Fixed Cost | \$50 | \$50 | \$100 | \$100 |

Notes: IV is the generalized two-stage least squares that has weights that in part account for the sampling variation in market shares. Each market has separate fixed effects for expanded basic and for premium. Annualized fixed cost is the amount consumers perceive they pay each year towards the cost of dish and installation.

The other results are not sensitive to any of the choices. The own price of expanded basic ranges between -0.86 and -1.15 and satellite ranges between -2.20 and -2.95. These cable price elasticities are similar in magnitude to the results found in the literature such as Crawford (1997), Hazlett and Spitzer (1997), U.S. General Accounting Office (2000), or Crawford (2000). The elasticity of expanded basic being smaller than one (in absolute value) is not consistent with static monopoly profit maximizing behavior and is likely to be due either to dynamic pricing considerations or to real or perceived regulatory restrictions (official price regulation on expanded basic was removed just after our sample).

Other cross-price elasticity results also look reasonable. The cross-price elasticity of premium with respect to the price of basic, for example, is negative. This is what we should find since expanded basic is a component of premium cable (to get HBO, the customer must already be a basic cable subscriber). Thus, raising the price of basic eliminates premium consumption for some consumers altogether.

To check whether the micro-level data combined with the econometric corrections are important, we estimate the elasticity using the time series growth of satellite (to see if it is different from our estimates). The data indicate that the subscriber base in the year before our sample increased approximately 44%, from 5 million to 7.2 million. Over this time period, the price of a satellite dish fell from \$350 to \$266 with the programming costs remaining approximately constant. On an annualized flow basis, this reduced prices by about \$20-\$30, a 4 to 6 percent decrease.[28] This rough approximation gives an elasticity somewhere between -7 and -11, suggesting the micro data and the econometric corrections are important.

# 6 Welfare

For measuring the welfare gains from DBS, we will compute the compensating variation (CV).[29] The CV is the amount a consumer's income would need to change in

[28]For example, if the assumed life of the dish were 4 years and the discount rate were 10%, the \$84 change in the one-time cost would be a change in the annualized cost of \$20 per year.

[29]Hicks (1946) introduces a number of different cost-of-living indexes. Hause (1975) and Mishan (1977) provide helpful discussions.

order to maintain a level of utility associated with some reference basket of goods. This measure can accommodate the substitution effects brought about by changes in relative prices, making it well-suited to compute welfare gains due to new product introductions, since they can be viewed as a major reduction in the relative price of the new good from infinity (or at least from some very large number where demand is zero) to the actual price that exists in the market.

Our measure asks how much money a consumer would need to be given in order to voluntarily give up their satellite dish. Thus, we use the utility level when satellite is available in the choice set as the baseline and ask how much money it would take to restore this utility level if the satellite option is taken away. Using (1), we can write this compensating variation (CV) as the change in income that equates $V(\cdot)$ across the two environments considered, or

$$V_i(p^{Sat}, y_i) = V_i(p^{NoSat}, y_i + CV_i), \tag{8}$$

where $p^{Sat}$ is the price vector with satellite in the market and $p^{NoSat}$ is the price vector when it is not in the market.[30]

Given our framework, we can write compensating variation in an easy way by rescaling our utility index to the money metric. Doing so yields

$$CV_i = -\frac{V_{i1} - V_{i2}}{-\alpha_0 + \alpha_i},$$

where $V_{i1}$ is the maximum attainable utility when faced with all four choices, and $V_{i2}$ is the second highest utility.

Table 9 reports the welfare gains to satellite consumers from entry. Again, we stress the importance of using methods to control for endogeneity as we obtain upward sloping demand curves when we assume there are no unobserved quality differences across markets (i.e., using the OLS results). Columns 2-4 present the average welfare gains from the basic specification and also from the specification with a higher fixed cost of DBS (and with 83 instead of 60 markets). The higher fixed cost makes about

[30] We follow the standard assumption in the literature on demand analysis and take the supply characteristics as given. In future work we hope to examine the supply responses of cable companies to the introduction of satellite technology in the mid-1990s to see if cable companies endogenously altered their programming packages or their prices in response to the rise of DBS.

Table 9

**The Welfare Change**

Annual Compensating Variation for Satellite Purchasers

Evaluated at Prices with Satellites in Market

| | OLS | IV | IV | IV |
|---|---|---|---|---|
| Mean | Upward | \$110.76 | \$208.52 | \$203.84 |
| Std. Dev | Sloping | \$31.20 | \$23.40 | \$30.52 |
| % substituting to cable | Demands | 83.8 | 65.3 | 75.3 |
| Number of Markets | 60 or 83 | 60 | 60 | 83 |
| Annualized Fixed Cost | \$50 or \$100 | \$50 | \$100 | \$100 |

Notes: Welfare numbers for OLS not reported because of upward sloping demand estimates. IV is the generalized two-stage least squares that has weights accounting for the sampling variation in market shares. Annualized fixed cost is the amount consumers perceive they pay each year towards the cost of dish and installation. .

\$100 difference. The average consumer gain is estimated to be between \$100 and \$200 a year.[31] At the time of our sample, there were almost 10 million satellite users (FCC (2000)). This would put the aggregate surplus at around \$1-\$2 billion. In terms of substitution in the case of significant rises in the price of satellite, we find between 65%-80% of consumers would substitute to some form of cable television; antenna-only appears to be a poor substitute for satellite.

We close by considering other sources of welfare gains from new products. In the results above, we have shown that the estimated direct gains to satellite buyers from DBS are certainly positive but not enormous, once we properly estimate the demand system. We have assumed, though, that eliminating satellite would not change the incumbent price of expanded basic or of premium cable, in keeping with the findings of the U.S. General Accounting Office (2000). The standard practice in the literature is to take supply characteristics as given when estimating the demand system. It is

[31]This does not mean there do not exist people that would willingly pay much larger amounts for the satellite dish; they are just far from the average.

perfectly plausible, however, that the introduction of home satellites could reduce (or perhaps increase) the prices of cable television for the people who do not switch to the new technology. These welfare gains or losses are part of the proper social welfare gain from new products and Petrin (2001) and Hausman and Leonard (1998) show that (at least in the cases of minivans and toilet paper) these indirect welfare gains can be quite large.

We plan to take up the supply response of cable companies to the threat of satellite in future work. This subject is complicated by the fact that there are many potential margins of response in addition to price. To motivate such work, however, we note that if we regress the price charged by a cable company on its characteristics and then add the angle of satellite direction in the market as a measure of potential satellite competition, the coefficient on angle is significant and negative and suggests that every degree increase in the satellite angle (making reception more likely) reduces cable prices by about 0.5%. At this magnitude, the welfare gains from the impact of DBS on cable prices for cable subscribers would almost certainly outweigh the direct gains to the satellite buyers from buying DBS systems (if only because the cable share is so large).

# 7 Conclusions

In this paper we use an extensive micro data set to examine the welfare gains from the introduction of a new form of television, the Direct Broadcast Satellite, and to estimate the demand system for cable. Using a discrete choice model of consumer demand with controls for price endogeneity due to unobserved quality, our results suggest a modest welfare gain for the average consumer of about \$100 to \$200 per DBS consumer per year. We also show that naive estimates that do not correct for unobserved quality yield upward sloping demand curves.

The elasticities derived from the corrected demand estimates suggest that cable is not very price sensitive while DBS is more price sensitive. The low cable elasticities suggest the possibility of dynamic pricing considerations and/or real or perceived regulatory restrictions. Overall, our results indicate that for many consumers satellite is a reasonable substitute, and that there are also many for which it is not.

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Table A1

## Income Effect Parameters

Four Choices: Antenna Only, Expanded Basic, Premium, and Satellite

| Variable | Coefficient | Asymp. Std. Error |
|---|---|---|
| Income terms: | | |
| $\alpha_1$ ( \$27.5K - \$47.5K) | 0.0062 | 0.0070 |
| $\alpha_2$ ( \$47.5K - \$65K) | 0.0157 | 0.0072 |
| $\alpha_3$ ( \$65K-\$87.5K) | 0.0208 | 0.0071 |
| $\alpha_4$ ( \$87.5K+) | 0.0422 | 0.0071 |
| Log Likelihood | -15039 | |
| Observations | 15153 | |

Note: Specification is estimated using top 60 television markets and an annualized fixed cost of $50 for satellite.