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The Effects Of Competition On The Price For Cable Modem Internet Access[1]

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Abstract

An important issue in economics is how market structure affects prices. While the standard view is that competition lowers prices, Chen and Riordan (2006) argued that with product differentiation it is not exceptional for prices to be higher under duopoly than monopoly. This paper empirically investigates one implication from Chen and Riordan, namely, that prices are lower under duopoly when consumer preferences for the two products are similar, and they are more likely to be higher under duopoly if consumer preferences for the two products are more diverse. Focusing on the price for cable modem Internet access, with or without competition from a DSL provider, and using education dispersion and ethnic diversity as proxies for consumer preference diversity, we find empirical support for this implication. In markets where preference diversity is low, competition reduces prices. As preference becomes more diverse, the negative effect of competition on prices diminishes; and when preference diversity is high enough, competition increases prices.

Key words: competition, Internet, preference diversity, prices

JEL Classification: L1, L13, L96

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1. INTRODUCTION

How does market structure affect prices? The standard view is that competition lowers prices. Recently, however, Chen and Riordan (2006; hereafter, C-R) have argued that under product differentiation it is not exceptional for prices to be higher under duopoly competition than under monopoly. In a general discrete choice model of product differentiation, they find that the comparisons between duopoly and monopoly prices depend on the balance of two contrasting economic effects: the market share effect and the price sensitivity effect. The market share effect is that a reduced quantity per firm under duopoly motivates the firms to cut price below the monopoly level. The price sensitivity effect is that a steeper demand curve resulting from greater consumer choice under competition encourages the firms to raise price. The consumer value distributions for the two conceivable products determine the relative strength of these effects, and whether competition leads to a higher or lower price than monopoly.[2]

This paper conducts an empirical analysis of the effects of competition on the price for cable modem Internet access. We consider a data set that includes two market structures for high-speed Internet access, the monopoly market in which there is a single provider of Internet access through cable modem, and the differentiated duopoly market in which there is a cable modem and a digital subscriber line (DSL) provider. We develop an empirical model that examines the possibility that prices can be higher under duopoly than monopoly when consumer preferences for the two products are relatively diverse, an insight from the recent theoretical work of C-R. Using education dispersion,

[2] Other theoretical studies have also found that prices can be higher with more firms, but they tend to assume asymmetric information (e.g., Stiglitz, 1987; Schulz and Stahl, 1996; Janssen and Moraga-González, 2004), to rely on mixed strategies (e.g., Rosenthal, 1980), or to contain a spatial structure with perfect negative preference correlation (Perloff et. al., 2005; Chen and Riordan, 2007). In C-R's general discrete choice model, there is complete information and firms use pure strategies.

measured by the standard deviation of the population's number of years of schooling, as a proxy for consumer preference diversity, we find that in markets where education dispersion is low (at the 25th percentile), competition reduces monthly subscription prices by about $4. As education dispersion increases the negative effect of competition on prices diminishes; and when dispersion is high enough (at the 75th percentile), competition increases prices by about $2.55. This result is robust to the use of an alternative proxy for consumer preference diversity that measures the distribution of ethnicities among individuals within a given market population.

Other empirical studies have also found that competition sometimes increases prices. For example, Bresnahan and Reiss (1991) provide survey evidence that automobile tire prices are somewhat higher in local markets with two dealers rather than one; Perloff et. al. (2005) find that new entry raises prices in the anti-ulcer drug market; Ward et. al. (2002) present evidence that the entry of private labels raises prices of name-brand goods in the food industry; and Goolsbee and Syverson (2004) find that airlines raise route prices when Southwest opens new routes to the same destination from a nearby airport. Our paper contributes to this empirical literature by offering new evidence from the high-speed Internet access market. In particular, we show how price differences between monopoly and duopoly vary systematically with certain measures of consumer preference diversity.

The paper is organized as follows. Section 2 discusses the theoretical background underlying our empirical analysis and outlines the conditions whereby competition can, conceivably, lead to an increase in price. Section 3 describes the data and empirical model. Section 4 presents estimation results and Section 5 concludes.

2. THEORETICAL BACKGROUND

We are interested in the market for residential high-speed Internet access. This is a market with two potential differentiated products, cable modem and DSL. A consumer would purchase only one of the products, so a discrete choice model is appropriate.

As in C-R, we assume that the preferences of a consumer are described by reservation values for the two goods, (v_1, v_2), where $v_i \in [\underline{v}, \bar{v}]$ and $0 \leq \underline{v} < \bar{v} \leq \infty$. To connect with our empirical work closely, we focus on one class of consumer valuation distributions studied in C-R, the joint uniform distribution. Specifically, we assume that (v_1, v_2) are uniformly distributed on a rectangular area on the $v_1 - v_2$ space that is formed by segments of four lines with the following inequalities:

$$\begin{aligned} 2(1+a) \geq v_1 + v_2 \geq 2; \\ b \geq v_1 - v_2 \geq -b, \end{aligned} \qquad (1)$$

where $a \in [0, \infty]$ reflects the dispersion in consumer valuations for Internet access and $b \in [0, 1]$ reflects the diversity in consumer preferences for cable modem versus DSL products. This area defines the support for (v_1, v_2), Ω, and the joint probability density function is

$$\phi(v_1, v_2) = \frac{1}{2ab}, \; (v_1, v_2) \in \Omega \qquad (2)$$

Figure 1 illustrates Ω for representative values of a and $b = 1$. As explained in C-R, this particular model has the interesting property that it contains both the Bertrand and Hotelling duopoly model as limiting cases. When $b \to 0$, Ω converges to an upward sloping line and in the limit the model becomes the standard model of Bertrand competition with a downward sloping demand curve. On the other hand, when $a \to 0$, Ω converges to a downward sloping line and in the limit the model becomes one of Hotelling competition.

For this model, C-R shows that the variance and the correlation coefficient are, respectively:

$$Var(v_1) = \frac{1}{12}(a^2 + b^2) = Var(v_2),$$
$$\rho = \frac{(a-b)(a+b)}{a^2 + b^2};$$

and the difference between the monopoly price p^m and the symmetric duopoly price p^d is

$$p^d - p^m = \begin{cases} \dfrac{3b-a-2}{4} \ \ if \ \ 0 < a < b - \dfrac{2}{3} \\ \dfrac{4b-2}{3} - \dfrac{1}{6}\sqrt{24ab - 4b + b^2 + 4} \ \ if \ \ \max\{b - \dfrac{2}{3}, 0\} \le a < 1 + b \\ b - \dfrac{1+a}{2} \ \ if \ \ 1 + b \le a \end{cases} \tag{3}$$

It follows that $p^d > p^m$ if $0 < a < \frac{(3b-2)(7b-2)}{8b}$ and $b > \frac{2}{3}$, which holds if *a* is small enough relative to *b* and *b* is above a certain critical value, or if ρ is small and $Var(v_i)$ is high enough; otherwise $p^d \le p^m$. In other words, competition increases price if consumer preferences are sufficiently negatively correlated and diverse.[3] In these situations, the residual demand for each firm under duopoly is steeper than the demand curve under monopoly, and this price sensitivity effect dominates the market share effect under competition, resulting in an equilibrium duopoly price that is higher than the monopoly price.

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[3] C-R show more generally that consumer preferences need not be negatively correlated for price to be higher under duopoly than under monopoly, but preference diversity is always necessary for competition to increase price.

3. DATA AND EMPIRICAL MODEL

The contrasting effects highlighted by the theory suggest that competition in differentiated-product markets does not necessarily lower prices. The direction of the effect of competition on prices can depend crucially upon the heterogeneity of consumer preferences. Specifically, competition can increase prices when the diversity in consumer preferences for cable modem versus DSL products (b) is high relative to the dispersion in consumer valuations for Internet access (a). We do not test the theory directly as this would require measures of a and b, which are not available. Instead, we investigate the possibility that competition can increase prices with a reduced-form model that compares the duopoly and monopoly prices for cable modem Internet access, while controlling for cost and demand factors.[4] Model estimates are used to assess whether the difference between duopoly and monopoly prices is larger in markets with higher education dispersion, a proxy for diversity in consumer preferences.[5]

3.1 Sample data

The product market under investigation is residential high-speed Internet access. The product permits household consumers to use a high-speed connection to the Internet to obtain high-bandwidth information, music and video libraries, interactive gaming services, video-on demand, etc. High speed differs from dial-up Internet access with respect to two characteristics, always-on functionality and speed. Always on is a

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[4] We do not estimate the effects of competition on DSL prices. To the extent that Internet accesses through cable modem and DSL are horizontally differentiated products, we expect that DSL price can also be higher with competition from cable than without the competition, when preference is sufficiently diverse.
[5] While it is not possible to say that education dispersion, measured by the standard deviation of the population's number of years of schooling, would increase b more than a, it is reasonable to conjecture that it leads to more diversity in consumer preferences. The higher education dispersion is in the market the more likely it is that consumer preferences for cable Internet versus DSL are highly diverse. The empirical result that $p^d – p^m$ becomes higher, or positive, with higher education dispersion would be consistent with the key insight from the theory.

constant connection to the Internet whenever the computer is on; a telephone call is not required to establish connection. Speed, measured in megabytes per second (mbps), is the time it takes to send and receive information to and from the home computer. The FCC (2001) defines high-speed access as supporting, in both the Internet-to-household (downstream) and the household-to-Internet (upstream) directions, speeds greater than 0.2 mbps. This is about four times faster than dial-up access through a telephone line.

The differentiated products of interest are cable modem and DSL.[6] Cable modem access is provided by the local cable-television (TV) operator using hybrid coaxial-fiber architecture. Cable operators provide downstream Internet access over their own network and upstream access via a telephone line (i.e., one-way capability), or both upstream and downstream over the entire cable network (i.e., two-way capability). One-way access, however, is not really high-speed; the service is not always on, so subscribers must place a dial-up telephone call to upload data to the network; and the upstream speed is the same as dial-up Internet. While cable modem subscribers share the network with other active users they have a much higher bandwidth threshold relative to DSL because the cable system typically contains more fiber. Interestingly, many cable operators upgraded their systems with fiber and two-way capability in the mid- to late-1990s for the provision of digital, pay-per-view and video-on demand TV services.

DSL is provided by the local telephone company using copper telephone wires and a DSL access multiplexer.[7] DSL subscribers have a dedicated connection with the telephone company's central office, but the speed is lower than cable modem, and the

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[6] High-speed access is also available through fiber-to-the-home, satellite, fixed and mobile wireless, and power-line products. FCC (2006) data at December 31, 2005 show that cable modem (58 percent) and DSL (40 percent) comprise almost all residential high-speed access lines.

[7] The multiplexer separates voice and DSL traffic, routes multiple DSL subscribers to the Internet backbone through one connection, and provides engineering quality control functions.

quality of the connection degrades with distance from the central office. Connection quality is also affected by the presence of load coils between the household and the central office (i.e., local loop).[8] The provision of DSL can involve up to three separate entities, the telephone company, the DSL provider and the Internet service provider. By contrast, the cable modem product is typically a "one-stop shop" service.[9]

The geographic market of interest is the cable operator's service region or "city market." The unit of observation is cable modem brand $j = 1, 2, \ldots, J$ provided by the incumbent cable operator in Oregon city market $i = 1, 2, \ldots, n$. The decision to study Oregon markets is deliberate. Both the Oregon Public Utilities Commission (PUC) and Qwest, the regulated statewide local-exchange authority, publicly provide network data that can be used to instrument for competition in the empirical model. Table 1 shows that Oregon cable system characteristics compare reasonably well with the average for the 58 states, districts and territories of the U.S. at 2004.

Data on cable operator's location and ownership for 114 Oregon markets are sourced from Warren Publishing (2006). These data are matched with price, brand, infrastructure, demographic and regulatory information from both cable operator and telephone company web sites, Telcordia (2000), the Oregon PUC web site and the U.S. Census Bureau (2006). After eliminating markets with incomplete data the sample reduced to 93 markets, of which, 35 have cable modem access. 19 of these 35 markets

[8] In a traditional telephone network, load coils are placed intermittently along the local loop to prevent degradation of the quality of voice calls. While load coils boost the strength of voice calls, they do not permit DSL signals to pass through them easily, if at all.

[9] A freeway provides a useful analogy for comparing DSL versus cable modem access. In terms of performance, DSL provides a dedicated lane with a low speed limit, while cable modem users share the freeway with other users but have a much higher speed limit. Because DSL is a dedicated lane, some consumers may also believe that it is more safe or secure than cable.

are considered monopoly, i.e., they are served by a cable operator only, and 16 are duopoly[10], i.e., they are served by a cable operator and a telephone company.[11]

3.2 Two-step selection model

Selection into the restricted price sample results from cable operator's optimizing decisions that may not be independent of prices. For example, unobserved market conditions and/or firm characteristics may also affect prices so that the error terms in the two equations are correlated. To obtain consistent estimates, we first estimate the selection equation, compute the inverse Mills ratio, and include this in the cable modem price equation as an additional regressor.

Let the cable operator's decision to provide the cable modem product in market *i* be based on expected profits:

$$\pi_i^* = \boldsymbol{\gamma}'\mathbf{w}_i + \boldsymbol{\eta}'\mathbf{x}_i + u_i \qquad (4)$$

where $\mathbf{w}_i$ is a vector of market-specific cost and demand variables that affect variable profits and fixed costs, $\mathbf{x}_i$ is a vector of variables that measure consumer preferences and competition from telephone companies providing DSL, $\boldsymbol{\gamma}$ and $\boldsymbol{\eta}$ are vectors of parameters and u is an error. The exogenous variables in $\mathbf{w}$ are: 1,000 houses per square mile (*Density*); mean household income in $1,000 (*Income*); percentage of non-white population (*Non-white*); 1,000 houses (*Size*); and a qualitative variable that equals one when the cable system is two-way capable and zero otherwise (*Two-way*). Because they may behave differently to single-system operators, we also include a qualitative variable

[10] Four of the 16 duopoly markets are served by three companies. However, we do not consider the third company, which is a "service provider," to be a serious strategic player as it provides DSL through leased telephone infrastructure. Service providers also have very low market share. At December 31, 2005, they accounted for less then four percent of total U.S. DSL access lines (FCC, 2006).

[11] Data required to measure the market-specific provision of cable modem and DSL access were obtained from Warren Publishing and by using online reverse telephone books with broadband service locaters to obtain service plans by provider for a sample of household addresses within a market.

that equals one when the cable operator is a multiple-system operator and zero otherwise (*MSO*).[12] We also include a qualitative variable that equals one when the cable network is owned by a co-operative or municipality (*Co-op*). The vector $\mathbf{x}_i$ contains: average number of years of schooling for the population over 25 years of age (*Education*); standard deviation of the number of years of schooling for the population over 25 years of age (*Educ_dispersion*)[13]; and a qualitative variable that equals one when the local telephone company provides DSL and zero otherwise (*Duopoly*).

Although expected profits are not observable to the researcher, it is possible to observe when the cable operator provides cable modem access in market *i* when *Cable modem*$_i$ = 1 if $\pi_i^* > 0$ and *Cable modem*$_i$ = 0 if $\pi_i^* \leq 0$. The probability of providing cable modem Internet access is:

$$Prob(\pi_i^* > 0) = Prob(u_i < \boldsymbol{\gamma}'\mathbf{w}_i + \boldsymbol{\eta}'\mathbf{x}_i) = F(\boldsymbol{\gamma}'\mathbf{w}_i + \boldsymbol{\eta}'\mathbf{x}_i) \qquad (5)$$

where $F(\cdot)$ is the standard normal distribution function. Equation (5) implies the usual probit model for dichotomous choice under the assumption that the cable operator knows the random component and maximizes profits.

The equilibrium price for cable modem brand *j* in market *i* is:

$$P_{ij} = \boldsymbol{\beta}'\mathbf{x}_i + \boldsymbol{\delta}'\mathbf{z}_{ij} + \rho\sigma_\varepsilon\lambda(\boldsymbol{\gamma}'\mathbf{w}_i + \boldsymbol{\eta}'\mathbf{x}_i) + \varepsilon_{ij} \qquad (6)$$

[12] For example, Chipty (1995) argued that MSOs with a higher concentration of national cable-TV systems and subscribers obtain lower cost deals from program suppliers. Relatively large MSOs, considering the provision of cable TV and Internet access, may obtain similar deals from equipment suppliers, service contractors, advertising agencies, etc., and/or may have reputation advantages.

[13] Years of schooling for *Education* and *Educ_dispersion* are calculated from the distribution of the population over 25 years of age with: less than 9^{th} grade; 9^{th} to 12^{th} grade (no diploma); high school graduate; some college, no degree; associate degree, bachelor's degree; and graduate or professional degree.

where P is the monthly subscription price for cable modem access with self installation and own modem, $\mathbf{z}_{ij} = [\mathbf{z}_{1ij}, \mathbf{z}_{2i}]$, $\mathbf{z}_{1ij}$ is a vector of brand-specific characteristics, $\mathbf{z}_{2i}$ is a vector of market-specific cost and demand controls,

$$\lambda_i(\boldsymbol{\gamma}'\mathbf{w}_i + \boldsymbol{\eta}'\mathbf{x}_i) = f(\boldsymbol{\gamma}'\mathbf{w}_i + \boldsymbol{\eta}'\mathbf{x}_i)/F(\boldsymbol{\gamma}'\mathbf{w}_i + \boldsymbol{\eta}'\mathbf{x}_i)$$

is the inverse Mills ratio, $f(\cdot)$ is the standard normal density function, $\boldsymbol{\beta}$ and $\boldsymbol{\delta}$ are parameter vectors, ε is an error, ρ is the correlation between u and ε and σ_ε is the error standard deviation. The errors u and ε are assumed to be jointly normally distributed with $E(u) = E(\varepsilon) = 0$ and $Cov(u, \varepsilon) = \begin{bmatrix} 1 & \rho \\ \rho & \sigma_\varepsilon^2 \end{bmatrix}$. The vector of brand-specific characteristics $\mathbf{z}_{1ij}$ contains downstream cable-modem speed in mbps (*Speed*) and a qualitative variable that equals one when cable-modem access is offered to households with existing cable-TV service and zero otherwise (*Bundle*). The vector of market-specific cost and demand controls $\mathbf{z}_{2i}$ comprises *Density*, *Income*, *Non-white*, *Size* and *Co-op*. As additional controls, we also include dummy variables in $\mathbf{z}_{2i}$ for the five multiple-system operators in the price sample.[14]

Theory and previous studies guide *a priori* expectations for price equation estimates. Cable modem prices are expected to increase with *Speed*. Many cable operators provide existing cable-TV households with a discount for subscribing to cable modem access. A negative sign on *Bundle* would reflect this strategy. Because much of a cable operator's outside plant is shared among houses in a given geographic location, an inverse relationship exists between marginal costs and housing density. As such, a negative sign is expected for *Density*. Demand should be higher in higher-income

[14] Eleven different cable operators serve the 35 markets in the price sample. Five are multiple-system operators, Charter Communications, Comcast, Crestview Cable Communications, Millennium and Willamette Broadband, serving 29 markets.

markets, so a positive relationship is expected between *Income* and *Price*. Eisner and Waldon (2001) suggest household preferences for communications vary by race. While *Non-white* controls for this effect, its sign remains an empirical question. *Size* approximates the number of houses in the market. When demand is higher in markets of greater size, a positive relationship between *Size* and *Price* is expected. However, this effect could be dampened, or even reversed, when size conveys cost advantages.

3.3 The effects of competition on prices

Measuring preference diversity and/or how preferences for different products are correlated is difficult. Construction of the key variables of interest would require, for example, an appropriately sized sample of consumer's valuations for cable Internet and DSL products for each market. These measures could also conceivably be "backed out" from structural estimates of a differentiated-products model that permits unobserved preference heterogeneity to vary by product.[15] Unfortunately, cable companies do not provide their customer's valuations to the public, nor do they readily share the micro or aggregate market share data required to estimate a discrete choice model for Internet access with the appropriate specification of preference heterogeneity.

The alternative approach is to obtain an indicator for preference heterogeneity that is more easily observed and intuitively appealing. One such indicator is education attainment. Because consumers with different education backgrounds are likely to evaluate the relative merits of competing products differently, they should have different

[15] For example, Goolsbee and Petrin (2004) use micro data on consumers television choices to estimate a discrete choice demand model with a variance-covariance matrix that permits unobserved preference heterogeneity to vary by product and to be correlated between products.

preferences for cable modem versus DSL accesses to the Internet.[16] We thus use the within-market standard deviation of the population's number of years of schooling (i.e., *Educ_dispersion*) as an indicator of consumer preference dispersions.[17] The higher *Educ_dispersion* is in the market the more likely consumer preferences for cable Internet versus DSL products are highly diverse.

Because this is a first attempt to empirically examine a key insight from a new theory, we employ a reduced-form framework that utilizes variation in the market structure and education level of Oregon high-speed Internet markets. We control for cost, demand and *Education* and estimate several variants of the price equation (6) with additional controls, alternative specifications of the market structure vector $\mathbf{x}_i$ and with different methods of estimation. The economic effect of interest is $\partial P/\partial Duopoly = \beta_1 + \beta_2\, Educ\_dispersion$, where β_1 and β_2 are the parameters on *Duopoly* and *Duopoly*×*Educ_dispersion*, respectively. An estimate of $\beta_1 < 0$ (> 0) shows that competition, measured by a discrete change from monopoly to duopoly, decreases (increases) cable-modem prices. Estimates of $\beta_1 < 0$ and $\beta_2 > 0$ show that the effect of competition on prices becomes less negative, and possibly positive, for higher dispersion in the population's number of years of schooling. A finding of this nature is consistent with the implication outlined in the theoretical background.

[16] In this horizontal setting, consumers have preference differences for cable modem versus DSL products and we assume that the intensity of this preference diversity varies with education dispersion. For example, one could speculate that highly educated consumers have a strong preference for the performance or, security, of one product over another. Less educated consumers may simply have a strong historical preference for their cable provider over their telephone company, or, vice versa.

[17] For robustness, we also estimate the price equation with an alternative proxy for consumer preference diversity that measures the distribution of ethnicities among individuals within a given market population.

3.4 Summary statistics

A full description of the variables and data used to estimate the selection and price equations are provided in Table 2 and Table 3, respectively. For price equation (6), average market size and housing density are 12,982 houses and 719 houses per square mile, respectively. The average number of years of schooling for the sample population is about 13, and about 12 percent of the population are non-white. Mean household income is $43,992. The average cable modem brand has 2.70 mbps of downstream speed and a monthly subscription price of $41.01. Nearly 60 percent of cable modem brands provide a discount for existing cable-TV households.[18] 43 of the 84 cable modem brands are provided in monopoly markets with an average price of $40.87. The remaining brands are provided in duopoly markets with an average price of $41.16. A t-test ($t$ = 0.13; *P-val* = 0.90) does not reject the null that the $0.29 difference between duopoly and monopoly prices is equal to zero.

4. ESTIMATION RESULTS

4.1 Single-equation OLS and selection two-step estimates

The data and empirical model described in Section 3 are used to investigate the relationship between competition and cable Internet subscription prices. Single-equation OLS and selection two-step estimates of the price equation are presented in Table 4.

Column's two and three report estimates of the baseline model specification (i) without *Duopoly* and without dummy variables that control for the presence of multiple-system operators in the sample. Column two provides OLS estimates while column three accounts for selection by additionally including as a regressor the fitted value of the

[18] Some cable operators provide a price discount and additional downstream and upstream speed.

inverse Mills ratio, $\hat{\lambda}$, obtained from probit estimation of the first-step selection equation.[19] The estimated coefficient on $\hat{\lambda}$ is significant at the ten percent level and several of the coefficient estimates in the two-step model are quite different form their OLS counterparts. The two-step estimates suggest that cable Internet prices depend on *Speed* and *Bundle* only.

Model (ii) estimates, reported in column's four and five, include the five *MSO* dummy variables in the price equation as additional controls. The estimated coefficient on $\hat{\lambda}$ is not significant; after controlling for the observed MSO status of individual cable providers there is no correlation between the error in the equation determining the provision of cable Internet access and the error in the equation determining prices. Moreover, the OLS and two step models provide reasonably similar estimates of the price equation. Most of the estimated coefficients on the control variables have signs that follow *a priori* expectations. Cable modem prices increase with Internet *Speed* but the rate of increase diminishes for higher levels of this characteristic. Households with cable-TV service receive about a $10 discount per month when purchasing the cable modem product. Prices decrease with the cost proxy, *Density*, but these cost-related pricing advantages appear to moderate in markets with high housing density. Prices increase with household *Income*.

Model (iii) estimates, reported in column's six and seven, include *Duopoly* as an additional regressor in the price equation. Again, the estimated coefficient on $\hat{\lambda}$ is not significant and single-equation OLS and two-step estimates provide similar results. The

[19] Selection equation estimates for 93 markets are provided in Table 5. Results show that the local cable operator is more likely to provide cable modem Internet access in markets with relatively higher household density and in markets where the underlying cable-TV network is two-way operable.

control variables also have similar signs and magnitudes to those reported for model (ii). Estimates of $\partial P/\partial Duopoly = \beta_1$ show that the average cable modem price in duopoly markets is about \$0.99 (OLS) to \$0.37 (two-step) lower than the monopoly price, but these effects are not significantly different from zero.

4.2 IV estimates

The evidence presented in Table 4 suggests that selection is not an issue for estimating cable Internet subscription prices and that prices can be modeled separately by single-equation OLS. However, it is possible that the reported OLS estimate of $\partial P/\partial Duopoly$ reflects unobserved market conditions, such as advertising intensity, bandwidth availability, etc. that are correlated with competition and prices.[20] Model (iv) and model (v) account for the potential endogeneity of *Duopoly* with IV estimation of the price equation. Theory suggests that IV candidates should come from the telephone company's profit-maximizing decision to enter high-speed Internet markets and provide a DSL product. Our excluded instruments are *DSLAM* (equals one when the telephone company has installed a DSLAM in market *i* and zero otherwise) and *Deload* (equals one when load coils in the local loops for market *i* have been removed and zero otherwise). Installation of a DSLAM is a necessary but not sufficient condition for DSL service provision by the local telephone company, while *Deload* measures the attractiveness of telephone company's service areas in terms of expected market size, service quality and profits. Because they are sunk cost decisions for the telephone companies, *DSLAM* and *Deload* should not be correlated with cable Internet prices.

[20] The direction of these potential biases is not clear. For example, the cable operator's unobserved advertising intensity may have an entry-deterrence or market-expansion effect. A positive correlation between advertising and price, and a negative (positive) correlation between advertising and *Duopoly*, will bias the estimated coefficient on *Duopoly* down (up).

IV estimates of the price equation with *Duopoly*, model (iv), are reported in column two of Table 6. The *F* statistic of the first-stage reduced-form equation and the Hansen *J* statistic show that the excluded instruments, *DSLAM* and *Deload* are relevant and valid.[21] IV estimates are similar to the OLS estimates reported in column's six of Table 4. The average cable modem price in duopoly markets is about $1.06 lower than the monopoly price, but this effect is not significantly different from zero.

This analysis may mask differences in prices due to the combination of competition and the diversity in consumer preferences, as suggested by the theoretical model. Model (v) estimates, reported in column three of Table 6, evaluate the interaction effect by including *Duopoly*×*Educ_dispersion* in the price equation. Again, the *F* statistic of the first-stage reduced-form equation and the Hansen *J* statistic show that the excluded instruments, *DSLAM*, *Deload*, *DSLAM*×*Educ_dispersion* and *Deload*×*Educ_dispersion* are relevant and valid.[22] The IV estimates of the coefficients on *Duopoly* and *Duopoly*×*Educ_dispersion* are both statistically significant at the five percent level and result in $\partial P/\partial Duopoly = -37.0 + 12.77 Educ\_dispersion$. These estimates show the effect of competition on prices becomes less negative, and then positive, for higher diversity in consumer preferences, as measured by the within-market standard deviation of the number of years of schooling (*Educ_dispersion*). When evaluated at the 25th percentile for *Educ_dispersion* of 2.58 the average duopoly price is $4.04 below the monopoly price. When evaluated at the mean *Educ_dispersion* of 2.87

[21] The *F* statistic in the first-stage regression indicates that the excluded instruments are not weakly correlated with *Duopoly* ($F = 220$; $P\text{-}val = 0.00$). The partial R^2 of first-stage excluded instruments is 0.84. The *J*-statistic ($J = 2.93$; $P\text{-}val = 0.13$) suggests the instruments and price-equation errors are independent.

[22] The *F* statistics in the first-stage regressions indicate that the excluded instruments are not weakly correlated with *Duopoly* ($F = 138$; $P\text{-}val = 0.00$) and *Dispersion*× *Educ_dispersion* ($F = 95.5$; $P\text{-}val = 0.00$). The partial R^2's of first-stage excluded instruments for *Duopoly* and *Dispersion*× *Educ_dispersion*, respectively, are 0.59 and 0.56. The *J*-statistic ($J = 0.96$; $P\text{-}val = 0.62$) suggests the instruments and price-equation errors are independent.

the average duopoly price is \$0.32 below the monopoly price. When evaluated at the 75th percentile for *Educ_dispersion* of 3.10 the average duopoly price is \$2.54 above the monopoly price.

Column four of Table 6 provides IV estimates of the price equation (v) using a log-linear functional form. The coefficient estimates for *∂logP/∂Duopoly* and *∂logP/∂Duopoly*×*Educ_dispersion* are statistically significant and exhibit a qualitatively similar pattern to the linear estimates. When evaluated at the 25th percentile the duopoly price is \$5.12 below the monopoly price. When evaluated at the 75th percentile the average duopoly price is \$3.12 above the monopoly price.

For robustness, we also estimated linear and log-linear forms of the price equation with an alternative (horizontal) proxy for consumer preference diversity that measures the distribution of ethnicities among individuals within a given market population. *Ethnic_diversity* is Theil's entropy measure calculated for seven ethnic groups.[23] When one ethnic group comprises the entire population, entropy (*Ethnic_diversity*) equals zero. In this market, it is more likely that consumer preferences for cable Internet versus DSL are not that diverse. When all ethnic groups have an equal share of the population, entropy (*Ethnic_diversity*) equals its maximum positive value. Here, consumer preferences for cable Internet versus DSL are more likely to be highly diverse.

Model (vi) estimates using *Ethnic_diversity* as the proxy for consumer preference diversity are reported in columns' five and six of Table 6. In the linear model, IV estimates of the coefficients on *Duopoly* and *Duopoly*×*Ethnic_diversity* are both

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[23] For market *i*, entropy (*Ethnic_diversity*) is $-\sum_{k=1}^{K} s_k \log s_k$, where s_k is the ratio of ethnic group *k*'s population to the market's total population and *k* = white, black or African American, American Indian and Alaska native, Asian, Native Hawaiian and other Pacific Islander, some other race, and two or more races.

statistically significant at the five percent level and continue to show that the effect of competition on prices becomes less negative, and then positive, for higher values of *Ethnic_diversity*. When evaluated at the 25th percentile of *Ethnic_diversity* of 0.138 the duopoly price is $2.72 below the monopoly price. When evaluated at the mean *Ethnic_diversity* of 0.205 the duopoly price is $0.82 below the monopoly price. When evaluated at the 75th percentile for *Ethnic_diversity* of 0.246 the duopoly price is $0.35 above the monopoly price. Estimates from the log-linear model in column six show a qualitatively similar pattern. When evaluated at the 25th percentile the duopoly price is $3.57 below the monopoly price. When evaluated at the 75th percentile the duopoly and monopoly prices are almost the same.

5. CONCLUSION

This paper empirically examined the price effects of competition in the high-speed Internet access market. Our key finding is that the presence of a DSL provider in competition with a cable modem provider may or may not lower the cable provider's price, depending crucially on some measure of consumer preference diversity. Specifically, DSL competition lowers the cable modem Internet access price if consumer preference diversity is small, but raises the price if consumer preference diversity is large. This result is robust whether we use the population's education dispersion or ethnic diversity as the measure of preference diversity. Our finding, consistent with the theoretical work from C-R, sheds new light on the long-standing question in economics concerning how market structure affects prices.

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FIGURE 1
Ω IS AN ORIENTED RECTANGLE

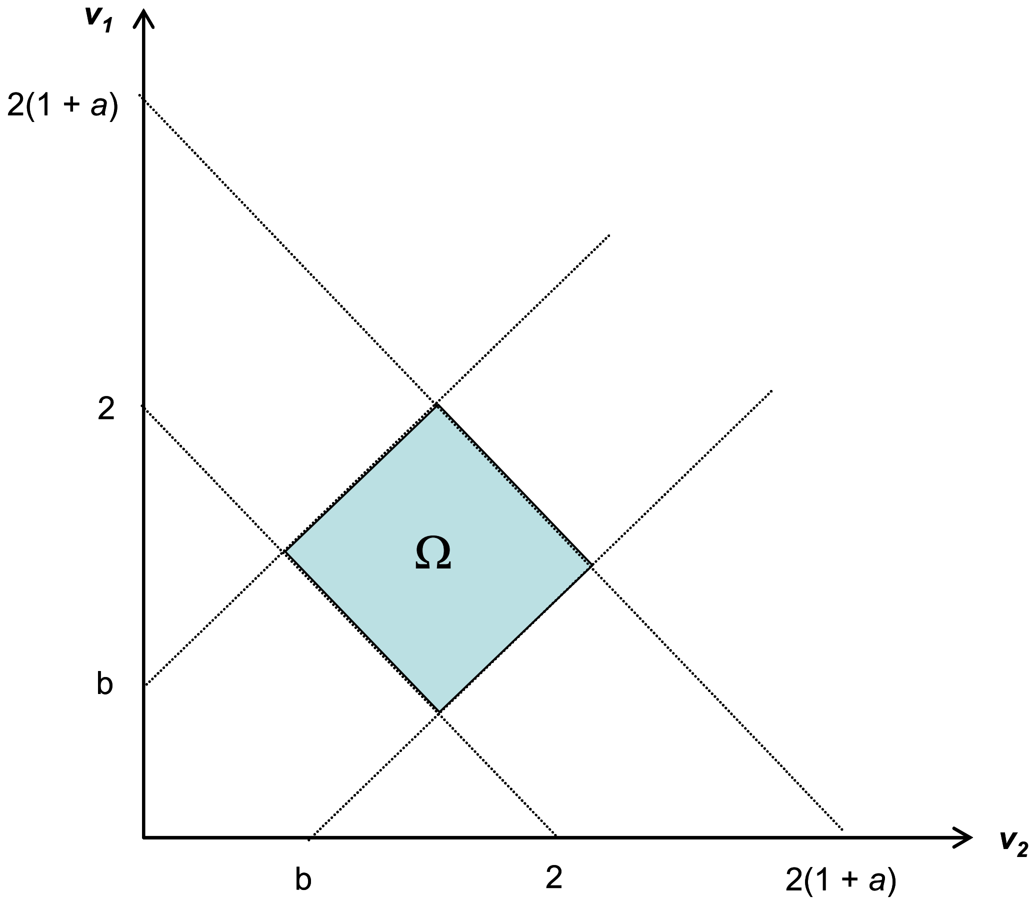

TABLE 1
CABLE OPERATOR CHARACTERISTICS 2004

Number of …	Total U.S.	State average	Oregon
States, districts, territories	58	n.a.	n.a.
Cable systems	8,409	145	107
Communities served	34,456	594	412
Basic-TV subscribers	65,296,014	1,125,793	759,744
Expanded-basic TV subscribers	29,980,818	516,911	464,496
Coaxial miles of plant	1,415,690	24,408	20,076
Homes passed by network	92,589,724	1,596,375	1,009,762

NOTES. State average is for 58 states, districts and territories. n.a. denotes not applicable.

Source. Warren Publishing (2004).

TABLE 2
SELECTION EQUATION VARIABLES

Variable	Description and data source	Mean (s.d.)
Cable modem	One when the cable operator provides cable modem Internet access, zero otherwise. Source: Warren Publishing (2006); company web sites; various online broadband service locators.	0.376 (0.487)
Density	1,000 houses per square mile. Source: U.S. Census Bureau (2006).	0.536 (0.431)
Income	Mean household income in $1,000. Source: U.S. Census Bureau (2006).	41.93 (8.813)
Education	Mean number of years of schooling for the population over 25 years of age. Source: U.S. Census Bureau (2006).	12.45 (0.853)
Educ_dispersion	Within-market standard deviation of the number of years of schooling for the population over 25 years of age. Source: U.S. Census Bureau (2006).	2.775 (0.493)
Non-white	Percentage of non-white population. Source: U.S. Census Bureau (2006).	11.17 (10.15)
Size	1,000 houses. Source: U.S. Census Bureau (2006).	12.98 (35.50)
MSO	One when the cable operator is a multiple-system operator, zero otherwise. Source: Warren Publishing Inc. (2006); company web sites; various online broadband service locators.	0.806 (0.397)
Co-op	One when the cable network is owned by a co-operative or municipality. Source: Warren Publishing Inc. (2006); company web sites; various online broadband service locators.	0.048 (0.214)
Two-way capability	One when the cable system is two-way capable, zero otherwise. Source: Warren Publishing Inc. (2006).	0.419 (0.496)

NOTES. s.d. is standard deviation. Number of observations is 93.

TABLE 3
PRICE EQUATION VARIABLES

Variable	Description and data source	Mean (s.d.)
P	Monthly subscription price for cable modem access with self installation and own modem ($). Source: Warren Publishing Inc. (2006); company web sites; various online broadband service locators.	41.01 (10.45)
Duopoly	One when the local telephone company provides DSL, zero otherwise. Source: Warren Publishing (2006); company web sites; various online broadband service locators.	0.488 (0.503)
Density	1,000 houses per square mile. Source: U.S. Census Bureau (2006).	0.719 (0.487)
Speed	Downstream cable modem speed in mbps. Warren Publishing (2006); company web sites; various online broadband service locators.	2.695 (1.696)
Bundle	One when cable modem access is offered to households with existing cable-TV service, zero otherwise. Warren Publishing (2006); company web sites; various online broadband service locators.	0.595 (0.494)
Income	Mean household income in $1,000. Source: U.S. Census Bureau (2006).	43.99 (6.736)
Education	Mean number of years of schooling for the population over 25 years of age. Source: U.S. Census Bureau (2006).	12.98 (0.928)
Educ_dispersion	Within-market standard deviation of the number of years of schooling for the population over 25 years of age. Source: U.S. Census Bureau (2006).	2.871 (0.411)
Non-white	Percentage of non-white population. Source: U.S. Census Bureau (2006).	12.60 (23.50)
Size	1,000 houses. Source: U.S. Census Bureau (2006).	0.719 (0.487)
Charter	One when the cable operator is Charter Communications (an MSO), zero otherwise. Source: Warren Publishing Inc. (2006); company web sites; various online broadband service locators.	0.310 (0.465)
Comcast	One when the cable operator is Comcast (an MSO), zero otherwise. Source: Warren Publishing Inc. (2006); company web sites; various online broadband service locators.	0.167 (0.375)
Crestview	One when the cable operator is Crestview Cable Communications (an MSO), zero otherwise. Source: Warren Publishing Inc. (2006); company web sites; various online broadband service locators.	0.107 (0.311)
Millennium	One when the cable operator is Millennium (an MSO), zero otherwise. Source: Warren Publishing Inc. (2006); company web sites; various online broadband service locators.	0.059 (0.238)
Willamette	One when the cable operator is Willamette Broadband (an MSO), zero otherwise. Source: Warren Publishing Inc. (2006); company web sites; various online broadband service locators.	0.095 (0.295)
Co-op	One when the cable network is owned by a co-operative or municipality. Source: Warren Publishing Inc. (2006); company web sites; various online broadband service locators.	0.048 (0.214)

TABLE 3
PRICE EQUATION VARIABLES

Variable	Description and data source	Mean (s.d.)
Deload	One when the load coils in the local loops have been removed and zero otherwise. Source: Source: Telcordia (2000); telephone company web sites; State PUC website.	0.214 (0.413)
DSLAM	One when the telephone company has installed a DSLAM, zero otherwise. Source: Telcordia (2000); telephone company web sites; State PUC website.	0.536 (0.502)
Ethnic_diversity	Within-market entropy measure calculated for seven ethnic groups: white; black or African American; American Indian and Alaska native; Asian, Native Hawaiian and other Pacific Islander; some other race; and two or more races. Source: U.S. Census Bureau (2006).	0.205 (0.099)

NOTE. s.d. is standard deviation. Number of observations is 84.

TABLE 4

OLS AND TWO-STEP SELECTION ESTIMATES OF CABLE INTERNET PRICES

	Without *MSO* dummies		With *MSO* dummies		With *MSO* dummies	
Independent variable	OLS	Two step	OLS	Two step	OLS	Two step
	Model (i)		Model (ii)		Model (iii)	
Constant	1.004	-4.386	41.80**	37.34**	40.11**	37.42**
	(20.84)	(24.70)	(16.43)	(18.37)	(17.07)	(18.19)
Duopoly					-0.992	-0.369
					(1.114)	(1.540)
Density	-9.858	-6.931	-10.92**	-9.737**	-10.24**	-9.487**
	(7.762)	(6.520)	(4.690)	(4.640)	(4.550)	(4.645)
Density^2	2.991	1.986	4.323*	4.005*	4.014	3.878*
	(3.427)	(3.203)	(2.473)	2.256	(2.485)	(2.259)
Speed	5.586***	6.324***	10.35***	10.23***	10.25***	10.19***
	(1.850)	(1.436)	(2.500)	(1.382)	(2.496)	(1.383)
Speed^2	-0.515*	-0.636***	-1.226***	-1.212***	-1.207***	-1.204***
	(0.261)	(0.230)	(0.326)	(0.208)	(0.326)	(0.209)
Bundle	-10.86***	-10.81***	-9.710***	-9.766***	-9.773***	-9.797***
	(1.793)	(1.576)	(1.137)	(1.099)	(1.135)	(1.098)
Income	0.012	0.037	0.278**	0.269**	0.243*	0.252*
	(0.140)	(0.146)	(0.129)	(0.132)	(0.141)	(0.139)
Education	1.638	1.792	-1.207	-0.997	-0.937	-0.908
	(1.381)	(1.554)	(1.028)	(1.195)	(1.176)	(1.215)
Educ_dispersion	7.195**	6.638	-1.109	-0.604	-0.994	-0.647
	(3.171)	(4.094)	(2.529)	(3.386)	(2.558)	(3.364)
Non-white	-0.114	-0.072	0.010	0.020	0.022	0.025
	(0.151)	(0.166)	(0.094)	(0.115)	(0.098)	(0.115)
Size	0.038**	0.032	0.002	0.002	0.006	0.003
	(0.015)	(0.026)	(0.008)	(0.018)	(0.009)	(0.019)
Co-op	6.392**	5.709	5.516**	5.987***	5.432***	5.303**
	(2.476)	(3.743)	(2.596)	(1.301)	(1.612)	(2.656)
$\hat{\lambda}\,(\boldsymbol{\gamma}'\mathbf{w}_i + \boldsymbol{\eta}'\mathbf{x}_i)$		3.684*		1.369		1.180
		(1.930)		(1.501)		(1.733)
R^2	0.593		0.817		0.818	
σ_ε	7.151	6.945	4.979	4.498	4.997	4.469

NOTES. Dependent variable is cable modem Internet subscription price. OLS is single-equation OLS estimates. Two-step is two-step selection estimates. ***significant at the 0.01 level; **significant at the 0.05 level; *significant at the 0.1 level. Standard errors in parentheses. Robust standard errors in OLS models. Heckman-corrected standard errors in two-step models. *MSO* estimates not reported for (ii) and (iii) . n = 84.

TABLE 5
PROBIT ESTIMATES OF SELECTION EQUATION

	Model (i)		Model (ii)		Model (iii)	
Independent variable	$\partial F/\partial$w	s.e.	$\partial F/\partial$w	s.e.	$\partial F/\partial$w	s.e.
Density	1.086**	0.480	1.057**	0.473	1.079**	0.465
Density²	-0.402	0.252	-0.400	0.250	-0.384	0.281
Income	0.002	0.009	0.005	0.010	0.006	0.010
Education	-0.058	0.113	-0.075	0.116	-0.106	0.133
Educ_dispersion	0.422*	0.220	0.401*	0.227	0.381	0.243
Non-white	-0.019	0.012	-0.021	0.013	-0.023*	0.013
Size	-0.002	0.002	-0.002	0.002	-0.002	0.002
Co-op	0.039	0.238	0.122	0.280	0.165	0.293
Two-way	0.820***	0.085	0.829***	0.084	0.829***	0.084
MSO			0.130	0.125	0.141	0.125
Duopoly					0.130	0.175
Log likelihood	-22.10		-21.83		-21.58	
Pseudo R^2	0.641		0.645		0.650	

NOTES. Dependent variable is *Cable modem*. ***significant at the 0.01 level; **significant at the 0.05 level; *significant at the 0.1 level. s.e. denotes robust standard errors. *Duopoly*. $\partial F/\partial$w shows the effect of a marginal change in w on the probability that the cable operator provides cable modem access. n = 93.

TABLE 6
IV ESTIMATES OF CABLE INTERNET PRICES

	Linear Model (iv)	Linear Model (v)	Log-linear Model (v)	Linear Model (vi)	Log-linear Model (vi)
Constant	39.99***	59.44***	4.527***	44.00***	3.840***
	(17.22)	(18.20)	(0.687)	(10.10)	(0.345)
Duopoly	-1.059	-37.01**	-1.131**	-6.632**	-0.198**
	(1.201)	(12.60)	(0.410)	(2.889)	(0.098)
Duopoly×Educ_dispersion		12.78**	0.390**		
		(4.492)	(0.145)		
Duopoly×Ethnic_diversity				28.37**	0.804*
				(13.82)	(0.449)
Density	-10.19**	-9.129**	-0.225*	-8.168**	-0.215
	(4.606)	(4.260)	(0.136)	(4.191)	(0.134)
Density^2	3.993	4.701*	0.122	3.897*	0.102
	(2.504)	(2.459)	(0.079)	(2.285)	(0.073)
Speed	10.24***	9.948***	0.257***	9.852***	0.251***
	(2.509)	(2.426)	(0.091)	(2.451)	(0.093)
Speed^2	-1.206***	-1.123***	-0.027**	-1.140***	-0.027**
	(0.328)	(0.317)	(0.012)	(0.320)	(0.012)
Bundle	-9.777***	-10.19***	-0.262***	-10.04***	-0.257***
	(1.137)	(1.143)	(0.039)	(1.140)	(0.039)
Income	0.241*	0.144	0.004	0.235*	0.006
	(0.142)	(0.135)	(0.004)	(0.139)	(0.004)
Education	-0.918	-1.608	-0.062	-1.099	-0.037
	(1.201)	(1.213)	(0.042)	(0.906)	(0.029)
Educ_dispersion	-0.986	-1.896	-0.105		
	(2.567)	(2.720)	(0.099)		
Ethnic_diversity				-19.96*	-0.572
				(11.56)	(0.362)
Non-white	0.023	-0.296*	-0.008*		
	(0.099)	(0.153)	(0.005)		
Size	0.006	-0.002	-0.000	-0.007	-0.000
	(0.009)	(0.009)	(0.000)	(0.010)	(0.000)
Co-op	5.299***	4.424***	0.135**	5.122***	0.154**
	(1.664)	(1.629)	(0.051)	(1.916)	(0.066)
R^2	0.818	0.820	0.727	0.822	0.728
σ_ε	4.429	4.409	0.161	4.938	0.181
F (*Duopoly*)	219.9***	138.2***	138.2***	125.3***	125.3***
F (*Duopoly×Educ_dispersion*)		95.47***	95.47***		
F (*Duopoly× Ethnic_diversity*)				37.87***	37.87***
Shea (*Duopoly*)	0.842	0.585	0.585	0.873	0.873
Shea (*Duopoly×Educ_dispersion*)		0.562	0.562		
Shea (*Duopoly×Ethnic_diversity*)				0.762	0.762
Hansen J	2.394	0.962	0.550	1.553	1.290

NOTES. Dependent variable is cable modem Internet subscription price. ***significant at the 0.01 level; **significant at the 0.05 level; *significant at the 0.1 level. Robust standard errors in parentheses. F tests the null that excluded instruments in the first stage are jointly equal to zero. Shea partial R^2 is for excluded instruments in the first stage. Hansen J tests the null of zero correlation between instruments and errors. *MSO* estimates not reported. *n* = 84.