USTELECOM
THE BROADBAND ASSOCIATION

April 19, 2013

<u>Ex Parte</u>

Ms. Marlene Dortch
Secretary
Federal Communications Commission
445 12th Street, SW
Washington, D.C. 20554

Re: USTelecom Petition for Forbearance From Certain Legacy Telecommunications Regulations, WC Docket 12-61

Dear Ms. Dortch:

In response to questions raised by Commission staff in connection with USTelecom's pending petition for forbearance, USTelecom is filing this ex parte letter and attachments in the record of the proceeding identified above.

The first three attached documents provide economic analysis of the impact of wireless services on pricing of wireline voice service, and the fourth is the most recent report of the Center for Disease Control on cut-the-cord households. These documents are: (1) Kevin W. Caves, *Quantifying Price-Driven Wireless Substitution in Telephony*, published at 35 Telecom Policy 984 (2011); (2) Richard N. Clarke, *The Case for Reforming Regulation of PSTN Voice Services*, published at Journal of Information Policy, Vol. 2, p. 287 (2012); (3) J. Macher, J. Mayo, O. Ukhaneva, G. Woroch, *Demand in a Portfolio-Choice Environment: The Evolution of Telecommunications* (Sept. 2012); and (4) *Wireless Substitution: Early Release of Estimates From the National Health Interview Survey, January-June 2012*, Center for Disease Control (rel. Dec. 19, 2012).

Pursuant to Commission rules, this ex parte letter and attachments are being filed in the above-referenced docket.

Sincerely,

Glenn Reynolds
Vice President, Policy

Attachments (4)
c: Eric Ralph
Bill Dever
Claudia Pabo
Jenny Prime

ATTACHMENT 1

Quantifying Price-Driven Wireless Substitution in Telephony

Kevin W. Caves†

For the better part of a decade, a steadily increasing share of US consumers have eschewed wireline telephony, relying instead on wireless voice service. Yet the existing empirical literature, which has largely utilized data from the turn of the millennium, provides scant evidence of economically significant intermodal cross-price effects (as competition authorities have observed). Using state level panel data from recent years, we estimate a demand system for wireless and wireline service. We estimate positive and economically significant cross-price elasticities, thereby corroborating econometrically a hypothesis that has long been suggested by academics, regulators, and the aggregate data.

† Associate Director, Navigant Economics, LLC.

I. INTRODUCTION

For the better part of a decade, a non-trivial and steadily increasing share of consumers nationwide have eschewed wireline telephony in the home, relying instead on wireless voice communications technology. The most recently available estimates indicate that nearly one in four US households was "wireless-only" as of 2009.[1]

Nevertheless, regulators and competition authorities have generally been reluctant to conclude that wireless voice service represents a meaningful economic substitute for traditional telephony. Instead, regulators have frequently focused on facilities-based providers of cable voice services as the only demonstrably viable competitors faced by incumbent wireline voice carriers. The US Department of Justice (DOJ) has summarized this view, stating that "[c]ompetition for residential consumers occurs primarily between the ILECs and cable companies," and that "the available evidence does not establish that mobile services currently represent an effective competitive constraint on landline access pricing."[2] The Federal Communications Commission (FCC) largely concurred with this assessment in a recent proceeding in Arizona, citing a lack of "evidence that would support a conclusion that mobile wireless service constrains the price of wireline service."[3]

When performing competition analysis in telecommunications, key empirical issues include the sign and magnitude of cross-price elasticities between intermodal alternatives. In the absence of reliable empirical analysis, even the sign of these parameters is an open question: The majority of US households continue to maintain both a landline connection and at least one wireless telephone, and it is unclear, *ex ante*, whether the two services are net substitutes or net complements. Thus, it is critical to identify consumer behavior at the margin. Absent reliable econometric estimates, one can make rough conjectures about these parameters by observing trends in aggregate data—which, as it happens, tend to support the hypothesis that wireless/wireline cross-price effects are both positive and economically significant. Specifically, the share of "wireless-only" households has risen substantially since the turn of the millennium, from a relatively trivial figure to a substantial segment of the voice communications market. Over the same time period, the number of residential landlines in service has steadily eroded, the price of wireless voice telephony has declined significantly, and wireline telephony rates have generally either fallen modestly or remained roughly constant, depending on the locality. In other words, as the relative price of wireless voice service has fallen, demand for wireless-only telephony in the home has surged.

But despite high-level evidence in support of economically significant cross-price effects, econometric evidence corroborating this hypothesis has proven

[1] Stephen Blumberg & Julian Luke, "Wireless Substitution: Early Release of Estimates From the National Health Interview Survey," Division of Health Interview Statistics, National Center for Health Statistics, Centers for Disease Control & Prevention (July – December 2009), at Table 1 [hereafter *CDC Report Jul-Dec 09*].

[2] US Department of Justice, *Voice, Video and Broadband: The Changing Competitive Landscape and Its Impact on Consumers*, (November 2008), at 87-88 [hereafter *Competitive Landscape Report*].

[3] Federal Communications Commission, *In the Matter of Petition of Qwest Corporation for Forbearance Pursuant to 47 U.S.C. § 160(c) in the Phoenix, Arizona Metropolitan Statistical Area, Memorandum Opinion and Order* (WC Docket No. 09-135, June 2010) [hereafter *Qwest Forbearance Decision*], ¶58.

elusive in empirical work, which has typically relied on rather dated data sets compiled at the turn of the millennium, when wireless substitution was still quite rare. As one recent survey of the empirical literature has observed, "we have very few quantitative analyses of the latest and arguably most dramatic developments [in the industry]."[4]

As a consequence, in justifying their current position, the DOJ and the FTC have highlighted the dearth of evidence on cross-price effects in the empirical literature.[5] At the same time, in light of the rapidly growing share of wireless-only households, regulators[6] and academics[7] alike have acknowledged the possibility that cross-price effects may well have increased over time in a manner not reflected in the empirical literature to date.

In this study, we employ state-level panel data to develop and estimate a demand system that permits us to evaluate the own-price, cross-price, and income elasticities of demand for wireless and wireline telephony. Our results provide evidence that wireline and wireless voice service are economic substitutes, and indicate that changes in relative prices drive economically significant intermodal substitution. Specifically, we estimate that a one percent decrease in the price of wireless service leads to a decline in the demand for traditional wireline service of approximately 1.22 - 1.28 percent. These figures substantially exceed prior econometric estimates of the wireline/wireless cross-price elasticity. Thus, our results corroborate econometrically a hypothesis that has long been suggested by academics, regulators, and the aggregate data (as well as casual observation and intuition).

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[4] Ingo Vogelsang, "The Relationship Between Mobile And Fixed-Line Communications: A Survey," *Information Economics and Policy* 22 (2010), at 4-17 [hereafter *Vogelsang 2010*].

[5] The DOJ concludes in the *Competitive Landscape Report* that "econometric analyses...have not shown that wireless and landline telephone services are in the same product market." *Competitive Landscape Report* at 66. See also *Qwest Forbearance Decision*, ¶58 ("[N]either Qwest nor any other commenter has submitted evidence that would support a conclusion that mobile wireless service constrains the price of wireline service. For example, Qwest has produced no econometric analyses that estimate the cross-elasticity of demand between mobile wireless and wireline access services.").

[6] See *Competitive Landscape Report* at 66 (noting that wireless and landline telephone services "may be getting close" to belonging in the same product market). See also *Qwest Forbearance Decision*, in which the FCC also emphasizes the possibility of increasing substitutability: "[W]e make no affirmative finding that mobile wireless services do not currently, or may not soon, belong in the same product market as residential wireline voice services. Nor are we suggesting that mobile wireless services must be a perfect substitute for residential wireline services for it to constrain the price of wireline service. In fact, we acknowledge that the increasing number of households that rely solely on mobile wireless services suggests that more consumers may view mobile wireless as a closer substitute for wireline voice service than in the past. We find only that there is insufficient data in the record to make such a determination here." *Qwest Forbearance Decision*, ¶60.

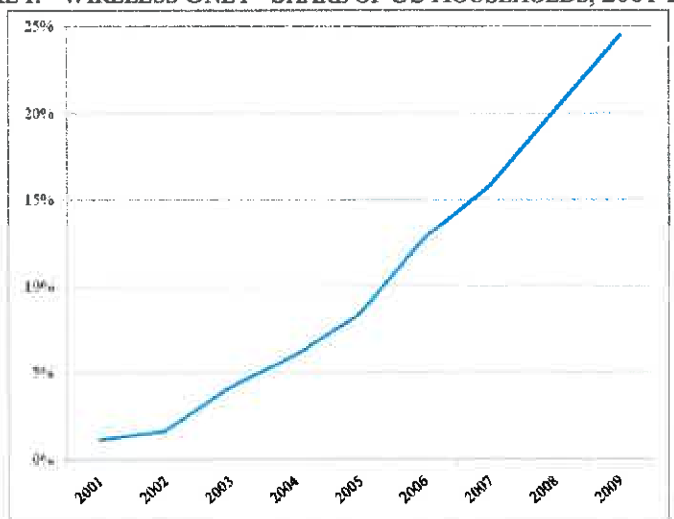
[7] See, e.g., Mark Rodini, Michael R. Ward, & Glenn A. Woroch, "Going Mobile: Substitutability Between Fixed And Mobile Access," *Telecommunications Policy* 27 (2003), 457–476 [hereafter *Rodini et. al.*]; see also *Vogelsang 2010*.

I. Aggregate Trends In Wireless Substitution

A. Trends Over Time

The share of households relying exclusively on wireless telephony has risen steadily in recent years, and now represents a substantial fraction of the voice communications market. The Centers for Disease Control and Prevention (CDC), through the National Health Interview Survey (NHIS), has collected detailed data on wireless substitution since the year 2003[8], and the FCC has reported similar data in earlier time periods.[9] The CDC survey results reflect biannual interviews of tens of thousands of households drawn from the civilian, non-institutionalized population. As seen in Figure I, the share of US households that use wireless voice service in lieu of a landline connection has risen from 1.1 percent to 24.5 percent from 2001 to 2009.

FIGURE I: "WIRELESS ONLY" SHARE OF US HOUSEHOLDS, 2001-2009[10]



In earlier years, wireless substitution was sometimes viewed as a "niche" phenomenon restricted to certain demographic groups.[11] In light of the fact that nearly one in four US households is now wireless-only, this characterization has become largely irrelevant. Although the data continue to indicate that the tendency to "cut the cord" varies significantly across several demographic

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[8] Many major survey research organizations, including the CDC's National Center for Health Statistics (NCHS), tend not to include wireless telephone numbers when conducting random-digit-dial telephone surveys. Because the omission of "wireless-only" households has the potential to distort health survey results, the CDC has taken an interest in tracking this phenomenon.

[9] Federal Communications Commission, *Trends in Telephone Service* (August 2008) [hereafter *Trends Report 2008*], at Table 7.4.

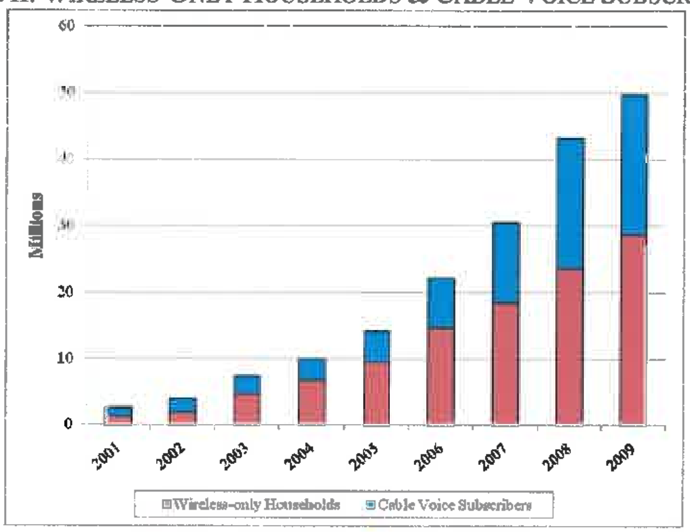
[10] Sources: Stephen Blumberg & Julian Luke, "Wireless Substitution: Early Release of Estimates From the National Health Interview Survey," Division of Health Interview Statistics, National Center for Health Statistics, Centers for Disease Control & Prevention (various years) [hereafter *CDC Reports*]. For data prior to 2003, see *Trends Report 2008* at Table 7.4.

[11] See, e.g., *Rodini et. al.* at 459 ("So far, the incidence of users who forgo fixed service entirely and depend completely on mobile, are few in number. The profile of the typical wireless-only user is young and single.").

characteristics, (such as race, age, income, and geographic region), it is also the case that, within essentially every demographic designation tracked by the CDC, the share of wireless-only households is greater than or equal to ten percent, and growing.[12]

As seen in Figure II below, the number of wireless-only households also exceeds the number of cable voice subscribers. As of 2009, the data indicate that there were approximately 28.7 million wireless-only households, compared with about 21.1 million cable voice customers. Although these data are informative, they are also likely to understate the degree to which wireless service has displaced traditional landline service. For example, some of the households that continue to maintain a wireline connection may view their wireless phones as suitable substitutes for, e.g., a second landline in a primary residence, or a landline that might otherwise be necessary in a vacation residence. On the other hand, because a given household is unlikely to subscribe to both cable telephony and traditional landline telephony, and because cable telephony is not portable across residences, it is less probable that the landline attrition due to substitution towards cable telephony is understated by cable subscriber counts.

FIGURE II: WIRELESS-ONLY HOUSEHOLDS & CABLE VOICE SUBSCRIBERS[13]



Given the rise in intermodal voice technologies, it is unsurprising that Local Exchange Carriers (LECs) have been losing landlines at non-trivial rates for some time. According to the FCC, the number of traditional landlines decreased by 29 percent from 2001 – 2008.[14] As seen in Figure III, over this same interval,

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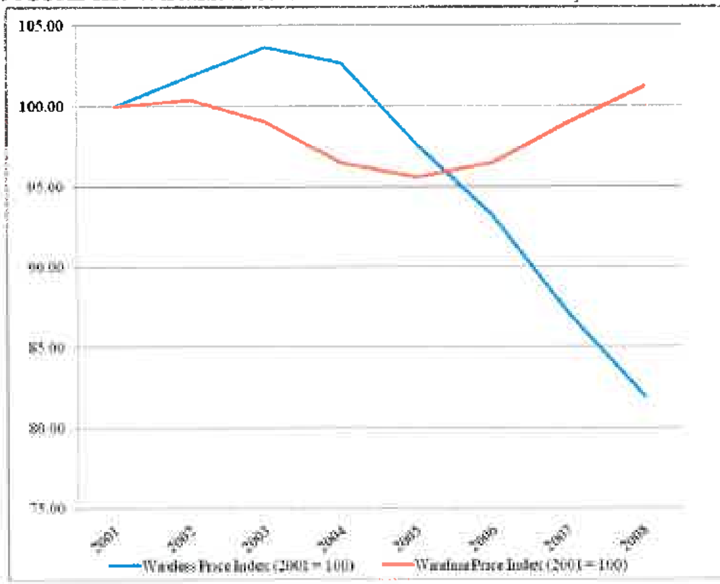
[12] The sole exception appears to be individuals aged 65 years or older, whose estimated cord-cutting percentage stands at 5.4 percent as of 2009 (a figure that has increased over time). The group with the highest cord-cutting propensity consists of households occupied by unrelated adults and no children. As of 2009, an estimated 68.5 percent of these households were wireless-only. See *CDC Report Jul-Dec 09.*

[13] Sources: U.S Census Bureau; *CDC Reports* (various years). Cable voice subscriber data obtained from SNL Kagan.

[14] FCC data indicate that the number of residential landlines fell from approximately 127.3 million in 2001 to approximately 89.9 million in 2008. For 2001 figure, *Trends Report 2008* at Table 7.4. For 2008 figure, see Federal Communications Commission, *Local Telephone Competition: Status as of December 31, 2008* (June 2010) [hereafter *Local Competition Report*], at Table 2. (Note: Two distinct reports are cited because, before 2005, the *Local Competition Report*

the price of wireless service declined substantially, both in absolute terms and relative to wireline rates.

FIGURE III: WIRELINE & WIRELESS PRICE INDICES, 2001-2008[15]



B. "Back of the Envelope" Cross-Price Effects

Given the observed trends in the aggregate prices and quantities of wireline and wireless voice services, it is possible to estimate the portion of the observed landline loss attributable to wireless substitution, and to use the resulting data to compute a "back of the envelope" proxy for the cross-price elasticity of wireline demand with respect to the relative price of wireless. Using this approach, Taylor and Ware (2008) have estimated that a one percent decrease in the price of wireless service relative to wireline is associated with a decline in the demand for landlines of approximately 1.4 percent.[16] This figure substantially exceeds prior econometric estimates of the wireline/wireless cross-price elasticity from the existing empirical literature (discussed in detail in Section III), which has relied on data from earlier time periods, when wireless substitution was quite rare. Thus, the aggregate data provide *prima facie* evidence of economically significant wireless-wireline substitutability. Yet such evidence is of limited value on its own, due to, e.g., the inability to control for factors such as shifts in

classified small business lines as residential, but from 2005 onward categorized them as business lines, and therefore excluded those lines from the residential totals. In contrast, Table 7.4 of *Trends Report 2008* does not include small business lines in any of its residential totals, but lacks data after the year 2006).

[15] Sources: Bureau of Labor Statistics, Consumer Price Index, Urban Consumer – Telephone Services; Federal Communications Commission, *Annual Report and Analysis of Competitive Market Conditions With Respect to Mobile Wireless, Including Commercial Mobile Services*, Fourteenth Report (May 2010) [hereafter *Fourteenth CMRS Report*], at Table 19 (Average Local Monthly Bill (excl. Data Revenues)).

[16] See William Taylor and Harold Ware, "The Effectiveness of Mobile Wireless Service as a Competitive Constraint on Landline Pricing: Was the DOJ Wrong?", NERA Economic Consulting Publication (December 2008).

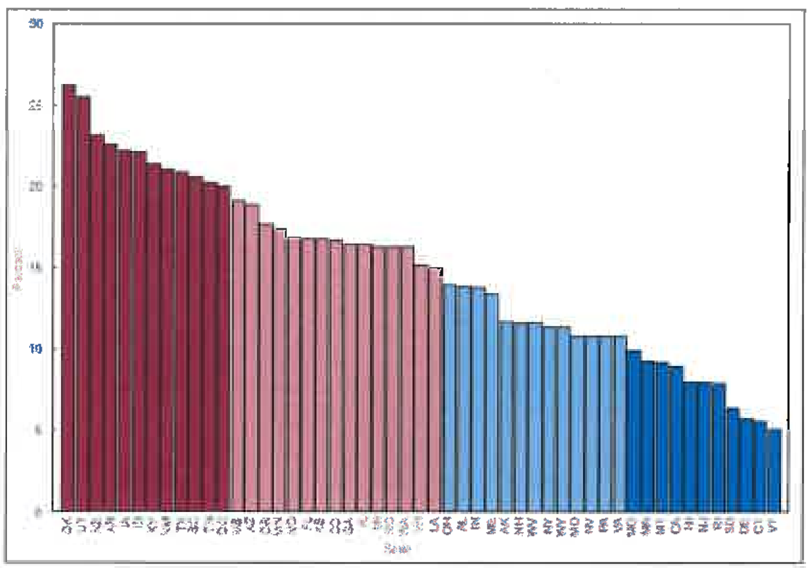
income and demographics, as well as the inability to conduct statistical analysis and hypothesis tests.

C. Geographic Variation

There is also evidence that wireless substitution varies substantially across geographic regions. Although earlier CDC surveys reported only national aggregates, the CDC recently released state-level estimates of wireless-only household shares, employing a methodology that exploits state-level demographics to predict rates of wireless substitution.[17]

As shown in Figure IV, there is significant cross-state variation in the point estimates of the wireless-only share, ranging from 5.1 percent (Vermont) to 26.2 percent (Oklahoma). However, the estimates are also characterized by relatively loose statistical precision. For example, the CDC reports that the "widest plausible interval" for the Oklahoma point estimate ranges from 12.9 percent to 38.8 percent.[18] This suggests that state-specific effects not captured by demographics may be important in determining the extent of wireless substitution.

FIGURE IV: STATE-LEVEL WIRELESS-ONLY SHARE ESTIMATES[19]



[17] Stephen Blumberg et. al., "Wireless Substitution: State-level Estimates From the National Health Interview Survey, January–December 2007," Division of Health Interview Statistics, National Center for Health Statistics, Centers for Disease Control & Prevention (March 2009) [hereafter *CDC State Level Estimates*].

[18] Blumberg et. al. compute the "widest plausible interval" for their point estimates by incorporating the upper and lower confidence bounds of both direct and synthetic estimates. See *CDC State Level Estimates* at 9-12.

[19] Source: *CDC State Level Estimates*, Figure 2.

III. EXISTING EMPIRICAL LITERATURE

The existing empirical literature on wireless substitution generally makes use of datasets compiled at the turn of the millennium, when wireless substitution was very limited.[20] Vogelsang (2010) provides a thorough survey of the literature, stressing the paucity of "quantitative analyses of the latest and arguably most dramatic developments [in the industry]."[21] Therefore, it is perhaps unsurprising that the body of empirical work to date provides scant econometric evidence of strong wireless/wireline intermodal substitutability (although empirical work has generally found wireless and wireline to be substitutes, rather than complements). Nevertheless, researchers have consistently recognized the likelihood that substitutability may be increasing with time.

Ward and Woroch (2004) focus on substitution at the margin of usage (minutes), as opposed to access substitution.[22] The authors use an Almost Ideal Demand System framework to model the share of minutes accounted for by wireless and wireline usage. Using household-level survey data spanning 1999-2001, the authors find evidence of modest cross-price elasticities of landline usage with respect to the mobile price per minute (between 0.13 and 0.33).[23] Ward and Woroch conclude that, although mobile service appears to be a "moderate" substitute for wireline usage, with substitutability is likely to increase over time, "[i]t would be premature…to infer from these estimates that mobile service currently constrains local telephone service market power to any economically significant degree."[24] In any case, as the DOJ has observed, usage substitution is less relevant than access substitution, in light of the fact that most residential customers purchase landline service on a flat-fee basis.[25]

In another study, Rodini, Ward, & Woroch (2003) use household survey data from 2000 - 2001 to investigate access substitution. The authors model the determinants of consumers' decisions to subscribe to second landlines and mobile service using logit regressions. They are unable to detect a statistically significant relationship between mobile prices and the demand for second landlines (although point estimates suggest moderate cross-price elasticities, ranging from 0.22 - 0.26).[26] In addition, because wireless-only households comprise such a small portion of their sample, the data do not allow the researchers to directly identify the determinants of consumer decisions to abandon fixed lines entirely. Thus, the authors invoke Slutsky symmetry to infer the sensitivity of the demand for *any* (first or second) landline with respect to the price of mobile service. The cross-price elasticities implied by this calculation are positive but small, ranging from 0.06 - 0.08.[27] Rodini et. al. conclude that wireless offerings represent a "moderate substitute" for landline telephony, but

[20] As seen in Figure I above, only about one percent of households were "wireless-only" as of 2001.

[21] *Vogelsang 2010* at 14.

[22] Michael R. Ward & Glenn A. Woroch, "Usage Substitution between Mobile Telephone and Fixed line in the U.S.", Center for Research on Telecommunications (May 2004) [hereafter *Ward & Woroch*].

[23] *Ward & Woroch* at 12.

[24] *Ward & Woroch* at 12-13.

[25] *Competitive Landscape Report* at 63.

[26] *Rodini et. al.* at 470.

[27] *Rodini et. al.* at 472

that "[e]volving usage patterns suggest that mobile and fixed service will become greater substitutes over time."[28]

Ingraham and Sidak (2004) employ household survey data from 1999 - 2001 to model the demand for wireless minutes as a function of the price per minute of wireless service, the price per minute of wireline long distance, and a series of demographic controls.[29] Although wireless substitution is not the primary focus of their study, the authors' econometric model indicates that wireless minutes are a weak substitute for wireline minutes. Specifically, a one percent increase in the price of wireline long distance is estimated to increase the demand for wireless minutes by approximately 0.02 percent.[30]

More recently, Ward and Woroch (2010) have utilized household survey data spanning 1999 - 2001 to estimate consumer demand for communications services by taking advantage of a natural experiment created by Lifeline Assistance telephony subsidies.[31] For households receiving the Lifeline subsidy, they estimate a cross-price elasticity of mobile demand with respect to the price of fixed line service ranging from 0.253 to 0.310. Due to data limitations, the authors are unable to directly estimate the elasticity of fixed-line demand with respect to the price of mobile. However, assuming that Slutsky symmetry holds, Ward and Woroch estimate that the elasticity ranges from 0.126 to 0.155, based on the fact that Lifeline subsidy recipients' expenditures on mobile services are about half as large as their expenditures on fixed line voice service.

IV. ECONOMETRIC ANALYSIS

A. *Panel Data Estimates: Single Equation Model*

To obtain updated econometric estimates of the cross-price elasticities between wireless and wireline telephony, we estimate the demand function for wireless telephony services using a panel data set of 38 states for the years 2001 - 2007. The basic demand relationship is specified in equation (0.1) below. Here, Q_{st}^{w} gives the demand for wireless service, measured by the quantity of wireless subscribers in state s in year t, as reported by the FCC.[32] Similarly, P_t^{w} gives the real price of wireless service, also reported by the FCC.[33] The observed price of wireless service does not vary by state. From a statistical standpoint, cross-state variation in wireless prices would obviously be desirable. Yet the reality is that geographic variation in wireless pricing has diminished substantially, given the rise in national calling plans and the increasingly obsolete distinction between "local" and "long distance" calling.[34] In any case, because there is still substantial

[28] *Rodini et. al.* at 475.

[29] Allan Ingraham & J. Gregory Sidak, "Do States Tax Wireless Services Inefficiently? Evidence on the Price Elasticity Of Demand," *Virginia Tax Review* 23 (2003), at 249-261 [hereafter *Ingraham & Sidak*].

[30] *Ingraham & Sidak* at 257-58.

[31] Michael Ward & Glenn Woroch, "The Effect Of Prices On Fixed And Mobile Telephone Penetration: Using Price Subsidies As Natural Experiments," *Information Economics and Policy* 22 (2010), 18-32.

[32] *Local Competition Report*, Table 14 (Mobile Wireless Telephone Subscribers).

[33] *Fourteenth CMRS Report*, Table 19 (Average Local Monthly Bill (excl. Data Revenues)).

[34] For example, according to a 2007 survey by the National Telecommunications Cooperative (NCTA), 72 percent of NCTA members offering wireless service provided free long distance

geographic variation in the price of landline service, the data do exhibit significant cross-state variation in the price of wireless service relative to wireline service.

The variable P^l_{st} denotes the real price of landline telephony service in state s in year t, as reported in the FCC's *Reference Book* of telephony rates.[35] The variable I_{st} denotes real median income by state and year, obtained from the Census Bureau. All price and income data are deflated by the Consumer Price Index (CPI). Lastly, X_{st} is a vector of demographic variables, obtained from the Census Bureau. These include variables capturing the racial distribution across states and over time, as well as median age and population density. Below, θ denotes a vector of parameters to be estimated:

$$Q^w_{st} = f(P^w_t, P^l_{st}, I_{st}, X_{st}; \theta) \qquad (0.1)$$

Summary statistics for each of the variables employed in the panel data analysis are displayed in Table I.[36]

calling. See Federal Communications Commission, *Annual Report and Analysis of Competitive Market Conditions With Respect to Commercial Mobile Services*, Thirteenth Report (January 2009) [hereafter *Thirteenth CMRS Report*], at 56.

[35] Federal Communications Commission, *Reference Book of Rates, Price Indices, and Household Expenditures for Telephone Service* (2008). The FCC's Wireline Competition Bureau conducts an annual survey of local telephone service rates in 95 US cities. Not all 50 states are covered in the survey, so we employ the available data to estimate the price of landline service in 38 of the lower 48 states. The FCC reports monthly residential telephone rates in the 95 sample cities for the years 1993 – 2007. Monthly charges reflect subscriber line charges, touch-tone service, surcharges, 911 charges, and taxes. Beginning in 2001, all rate data reflect charges for flat-rate service. Note also that the FCC frequently reports rates for multiple cities within a given state; in these instances, a population-weighted average across cities was employed to estimate statewide landline telephony prices.

[36] Note that Table I also contains the quantity of traditional wirelines by state, as reported by the FCC. These data are employed to estimate a demand system for both wireless and wireline services, as noted below.

TABLE I: SUMMARY STATISTICS FOR PANEL REGRESSION DATA, 2001-2007

38 US States, 2001 - 2007					
Variable	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
Wireless Quantity	264	4,266,512	4,413,591	291,429	30,203,858
Wireline Quantity	266	2,098,037	1,941,611	159,357	10,987,835
Real Wireless Price	266	50.34	5.25	40.88	55.13
Real Wireline Price	266	27.20	4.62	17.93	40.68
Real Median Income	266	48,656	7,958	34,579	68,080
Population Density	266	221	274	6	1,167
Median Age	266	36.4	2.2	27.3	41.6
White Pop	266	4,873,499	3,493,352	809,511	16,075,421
Black Pop	266	910,150	861,633	3,013	2,900,822
Asian Pop	266	290,510	675,748	4,839	4,377,304
Hispanic Pop	266	1,046,334	2,311,232	10,469	13,144,423
Other Pop	266	139,858	164,354	17,113	1,056,918

Notes:
(1) Price and income data expressed in 2007 dollars.
(2) Wireless subscriber data redacted for Montana in 2001 & 2004.

The results of the initial panel regressions are shown in Table II below. In the most basic specification, reported in column (1), we estimate the demand for wireless as a function of wireless prices, wireline prices, and income, using ordinary least squares (OLS), as shown in equation (0.2). Below, lower-case letters denote natural logs, and ε_{st} is a random error term, driven by unobserved demand shocks and/or measurement error in the dependent variable[37]:

$$q_{st}^{w} = \alpha_0 + \alpha_1 p_l^{w} + \alpha_2 p_{st}^{l} + \alpha_3 i_{st} + \varepsilon_{st} \qquad (0.2)$$

Note that the (Marshallian) own-price elasticity of demand for wireless is given by α_1, while the (Marshallian) cross-price elasticity of demand for wireline service is given by α_2; the income elasticity of demand is given by α_3:

$$\alpha_1 = \frac{\partial Q^w}{\partial P^w}\frac{P^w}{Q^w} = \frac{\partial q^w}{\partial p^w} \equiv \eta_{ww}^{M} \qquad (0.3)$$

[37] One potential source of measurement error in the wireless demand equation is the fact that the FCC's state-level wireless subscriber data does not distinguish between business and residential subscribers, and instead reports a single aggregate wireless subscriber figure by state and year.

$$\alpha_2 = \frac{\partial Q^w}{\partial P^l}\frac{P^l}{Q^w} = \frac{\partial q^w}{\partial p^l} \equiv \eta_{wl}^M \quad (0.4)$$

$$\alpha_3 = \frac{\partial Q^w}{\partial I}\frac{I}{Q^w} = \frac{\partial q^w}{\partial i} \equiv \eta_{wi} \quad (0.5)$$

As seen in Table II, the econometric results imply that both the price of wireless and the price of wireline are negatively and significantly related to the quantity of wireless services demanded. The estimated elasticity of demand for wireless service is -1.68. The estimated income elasticity implies that the demand for wireless service expands with household income. However, the results of the first specification also indicate that $\hat{\eta}_{wl}^M < 0$. Specifically, a one percent increase in the price of wireline service is associated with a 1.2 percent decrease in the demand for wireless, implying complementarily between the two services.

As shown in equation (0.6), in the next specification we add a series of demographic variables, X_{st}, including population density, median age, and race/ethnicity, to the OLS regression:

$$q_{st}^w = \alpha_0 + \alpha_1 p_t^w + \alpha_2 p_{st}^l + \alpha_3 i_{st} + \sum_{k=1}^{N} \lambda^k X_{st}^k + \varepsilon_{st} \quad (0.6)$$

The results of this regression, reported in column (2), suggest that income is not significantly related to wireless demand, nor is population density or median age. In contrast, many of the racial/ethnic variables are highly statistically significant.[38] The demographic variables are collectively significant, and add considerable explanatory power. However, the results in column (2) continue to indicate that wireless and wireline service are (weak) complements in demand.

[38] In addition to population density, the regressions in specifications (2) – (4) also control for overall population size, since the racial distribution variables sum to the total state-level population figures in each year. Allowing the population of each race to enter separately allows for the racial distribution of the population, as well as aggregate population size, to influence demand.

TABLE II: PANEL REGRESSION RESULTS, SINGLE EQUATION MODEL

	Dependent Variable: Natural Log of Wireless Subscribers			
	38 US States, 2001 - 2007			
Explanatory Variable	(1) OLS	(2) OLS	(3) OLS	(4) 2SLS
ln(Price of Wireless)	-1.676	-1.808	-0.222	-2.111
	(-3.7)	(-25.17)	(-2.22)	(-6.15)
ln(Price of Wireline)	-1.228	-0.124	-0.051	0.526
	(-4.13)	(-2.5)	(-0.58)	(3.28)
ln(Median Household Income)	1.733	-0.117	0.110	-1.708
	(5.54)	(-1.21)	(0.5)	(-3.88)
ln(Pop Density)		-0.022	0.535	-0.455
		(-1.48)	(0.72)	(-0.41)
Median Age		0.009	0.146	-0.043
		(1.94)	(5.53)	(-0.87)
ln(White)		0.503	-2.505	-1.033
		(17.69)	(-3.2)	(-0.88)
ln(Black)		0.1425	0.3954	0.4942
		(13.89)	(3.22)	(2.72)
ln(Asian)		0.126	1.326	0.708
		(4.89)	(5.32)	(1.86)
ln(Hispanic)		0.097	0.381	0.110
		(6.97)	(2.47)	(0.48)
ln(Other)		0.072	0.398	0.042
		(3.02)	(1.64)	(0.12)
Constant Term	6.780	10.416	16.911	42.802
	(1.68)	(8.53)	(1.63)	(2.69)
State Fixed Effects	No	No	Yes	Yes
Observations	264	264	264	264
R-Squared	0.2367	0.9828	0.9965	0.9899

Notes:
(1) T- and Z- statistics in parentheses.
(2) Wireless subscriber data redacted for Montana in 2001 & 2004.
(3) The price of wireless service is treated as endogenous in the 2SLS regression in column (4). An annual time trend is used to instrument for the price of wireless.

As noted above, the lack of precision in the CDC's state-level point estimates of wireless substitution highlight the potential importance of controlling for state-specific effects. The specification in column (3) adds state-level fixed effects to the OLS regression. In equation (0.7), D^j is equal to one if $j = s$, and zero otherwise (with the final state omitted to avoid singularity). Identification is therefore based on variation within states over time:

$$q^w_{st} = \alpha_0 + \alpha_1 p^w_t + \alpha_2 p^l_{st} + \alpha_3 i_{st} + \sum_{k=1}^{K} \lambda^k X^k_{st} + \sum_{j=1}^{J} \theta^j D^j + \varepsilon_{st} \qquad (0.7)$$

The results of the fixed effects specification using OLS are reported in column (3). The fixed effects coefficients (not reported in Table II) contribute significantly to the model's explanatory power. However, the own-price elasticity is now quite low. Moreover, the cross-price elasticity is both negative and insignificantly different from zero.

The results of the OLS regressions suggest that the coefficient estimates in these specifications may be biased, and that price endogeneity may be to blame. Because wireline rates are subject to regulation, they are unlikely to be correlated with unobserved demand shocks in ε_{st}.[39] However, the price of wireless service is not similarly constrained by regulation, and is thus more prone to be correlated with any shocks to demand not controlled for in our specifications. To address the potential endogeneity of the wireless price, in column (4) we estimate the model given in equation (0.7) via two-stage least squares (2SLS), using an annual time trend as an instrument for the price of wireless.

Before turning to the results in column (4) of Table II, we briefly discuss identification in the context of the 2SLS specification. The results of the first-stage regression are displayed in Table III. The exogenous variables collectively explain over 90 percent of the variation in the wireless price. Note also that the coefficient on the annual time trend is *negative* and statistically significant at the one percent level, indicating that, all else equal, the real price of wireless telephony declines by an average of approximately six percent per year over the sample period.

For the time trend instrument to be valid, it should capture shifts in supply over time, as opposed to demand. Given the industry and time period in question, wireless prices would be expected to fall over time due to supply-driven factors—such as increased competition among wireless providers, and technical progress causing cost curves to shift downward—as opposed to demand-side factors. Indeed, for demand-side factors to fully explain the downward trend in wireless prices, there would have to be unobserved, serially correlated, negative shocks to demand—yet the notion of a contraction in the demand for wireless service seems implausible. Instead, one would expect demand to have increased in response to improvements in the quality of wireless technology along several dimensions (e.g., handset size, battery life, sound quality, texting capability, photo/video sharing, etc.) All of these developments represent innovations on the supply side on the market, and imply a decline in the quality-adjusted price of wireless service. Thus, the observed decline in wireless prices is likely correlated with unobserved increases in quality over time. Stated differently, the time trend can be thought of as instrumenting for shifts in supply over time in the space of both quantity and quality.

To be concrete, the six percent annual decline in observed wireless prices likely implies a greater-than-six percent decline in quality-adjusted prices. Thus, if the model predicts that a decrease in the price of wireless service (relative to wireline) will constrain wireline demand by a given amount, this should be interpreted as the predicted effect, conditional on continued improvements in the quality of wireless service. Note that this does not necessarily have an adverse effect on the model's predictive power, given that there appears to be no reason to believe that the quality of wireless service will not continue to increase, as it has since its inception.[40] Nevertheless, it does represent a limitation on the ability of our state-level panel data to disentangle quality-adjusted price effects.[41]

[39] See, e.g., Laurits Christensen & William Greene, "Economies Of Scale In U.S. Electric Power Generation," *Journal of Political Economy* 84 (1976), 655–676 (exploiting the exogeneity of regulator-determined production levels to estimate a cost function for electric power generation).

[40] Wireless technologies have long been characterized by ongoing quality improvements, from the bulky analog "bag phones" of 1970s and 1980s to the second-generation digital voice technologies of the 1990s to the third- and fourth- generation networks being deployed and utilized in the present day.

[41] As noted below, in future research it would be useful to isolate these effects more precisely. This would likely require something akin to an updated version of the micro-level survey data that have been used in prior empirical work.

TABLE III: FIRST-STAGE REGRESSION RESULTS

	Dependent Variable: Natural Log of the Price of Wireless
	38 US States, 2001 - 2007
Explanatory Variable	(1) OLS
Time Trend	-0.061
	(-6.98)
ln(Price of Wireline)	0.249
	(4.86)
ln(Median Household Income)	-0.877
	(-7.19)
ln(Pop Density)	0.400
	(0.84)
Median Age	0.013
	(0.57)
ln(White)	-0.887
	(-1.66)
ln(Black)	0.0795
	(1.05)
ln(Asian)	0.255
	(1.47)
ln(Hispanic)	0.023
	(0.23)
ln(Other)	-0.047
	(-0.31)
Constant Term	19.973
	(3.13)
State Fixed Effects	Yes
Observations	264
R-Squared	0.9079

Notes:
(1) T-statistics in parentheses.
(2) Wireless subscriber data redacted for Montana in 2001 & 2004.

Turning back to column (4) of Table II, the two-stage least squares estimates yield economically plausible results. The own-price elasticity for wireless service is estimated at approximately -2.1. Interestingly, and consistent with the CDC's finding that wireless-only households are more likely to be near the poverty line[42], the coefficient on median income is now negative and statistically significant: A one percent decrease in median income causes wireless demand to increase by 1.7 percent. Most relevant for our purposes, the cross-price elasticity estimate is positive and highly statistically significant, implying that wireline and wireless service are substitutes in demand. Specifically, a one percent increase in the price of wireline service is associated with an expansion of wireless demand of about 0.53 percent.

B. Panel Data Estimates: Wireless/Wireline Demand System

By definition, cross-price elasticities are governed by multiple demand equations. To estimate the key parameters of interest more efficiently, we add the demand for wireline services to the model, and estimate the resulting system, expressed below in equations (0.8) and (0.9):

$$q_{st}^{w} = \alpha_0 + \alpha_1 p_t^{w} + \alpha_2 p_{st}^{l} + \alpha_3 i_{st} + \sum_{k=1}^{K} \lambda^k X_{st}^k + \sum_{j=1}^{J} \theta^j D^j + \varepsilon_{st} \qquad (0.8)$$

[42] *CDC Report Jul-Dec 09* at 9.

$$q_{st}^{l} = \beta_0 + \beta_1 p_{st}^{l} + \beta_2 p_t^{w} + \beta_3 i_{st} + \sum_{k=1}^{K} \gamma^k X_{st}^k + \sum_{j=1}^{J} \phi^j D^j + \mu_{st} \qquad (0.9)$$

Here, q_{st}^{l} is the natural log of the quantity of residential wirelines[43] in state s in year t, and μ_{st} is the random error term representing shocks to wireline demand and/or measurement error in the dependent variable.[44] As always, the own-price elasticity for wireless, the cross-price elasticity between wireless and wireline, and the income elasticity of wireless service are given by α_1, α_2, and α_3. The corresponding (Marshallian) own- and cross-price elasticities for wireline service, along with the wireline income elasticity, are defined symmetrically:

$$\beta_1 = \frac{\partial Q^l}{\partial P^l}\frac{P^l}{Q^l} = \frac{\partial q^l}{\partial p^l} \equiv \eta_{ll}^{M} \qquad (0.10)$$

$$\beta_2 = \frac{\partial Q^l}{\partial P^w}\frac{P^w}{Q^l} = \frac{\partial q^l}{\partial p^w} \equiv \eta_{lw}^{M} \qquad (0.11)$$

$$\beta_3 = \frac{\partial Q^l}{\partial I}\frac{I}{Q^l} = \frac{\partial q^l}{\partial i} \equiv \eta_{li} \qquad (0.12)$$

In addition, Slutsky symmetry implies certain cross-equation restrictions on the demand system. Below, s_w and s_l denote expenditure shares for wireless and wireline service, while η_{wl}^{H} and η_{lw}^{H} represent Hicksian cross-price elasticities:

$$\frac{s_w}{s_l}\eta_{wl}^{H} = \eta_{lw}^{H} \qquad (0.13)$$

Thus, the responsiveness of wireline demand to the price of wireless exceeds the responsiveness of wireless demand to the price of wireline, to the extent that expenditures on wireless exceed expenditures on wireline telephony.

The Hicksian cross-price elasticities are, in turn, related to the Marshallian cross-price elasticities η_{wl}^{M} and η_{lw}^{M}, along with the income elasticities η_{wi} and η_{li}, as follows:

[43] See Federal Communications Commission, *Residential Billable Access Lines by State*, ARMIS Report 43-01, Table II, Column (bb). Pursuant to Commission forbearance orders, the FCC's ARMIS data filing requirements were reduced significantly in 2008, and the requirement to file ARMIS Report 43-01 was eliminated. Thus, billable access line data by state are available only through the year 2007.

[44] One potential source of measurement error in the wireline demand equation would be deviations of the FCC's billable access line data—which capture residential ILEC lines only, and do not account for residential CLEC lines—from the true number of residential access lines. To the extent that this type of measurement error is non-random, it could bias the parameter estimates. However, as discussed in more detail below, the fact that Slutsky symmetry appears to hold for the demand system estimates in Table IV suggests that any such bias is small in magnitude.

$$\eta_{wl}^{H} = \eta_{wl}^{M} + s_l \eta_{wi} \tag{0.14}$$

$$\eta_{lw}^{H} = \eta_{lw}^{M} + s_w \eta_{li} \tag{0.15}$$

We estimate the demand system specified in (0.8) and (0.9) using iterated three-stage least squares (I-3SLS). As before, a time trend is used to instrument for the price of wireless service in each equation; identification therefore follows by the same logic discussed above. Instead of imposing Slutsky symmetry from the outset, we first estimate the unrestricted model, and then test the restrictions statistically. Table IV presents results for both unrestricted and restricted versions of the demand system. We use average expenditures on wireless and wireline services, along with median income data, to test the Slutsky symmetry restrictions given by (0.13), (0.14), and (0.15). We find that we are unable to reject the null hypothesis that the restrictions hold for our data set. Therefore, in the second set of restricted results in Table IV, we impose the cross-equation Slutsky restrictions *ex ante*. As seen below, the estimates in the unrestricted system are quite similar to those in the restricted system, reflecting the fact that the theoretical constraints on the demand system appear to be borne out in the actual relationships observed in the data.

In addition to being consistent with theoretical priors, the fact that the data support Slutsky symmetry is informative in other ways. For example, the parameter of greatest practical interest to policymakers is likely the elasticity of wireline demand with respect to the price of wireless (as opposed to the responsiveness of wireless demand to the price of wireline). This is due to the fact that the former effect is likely to be viewed as providing the most direct evidence that wireline pricing may be constrained by wireless offerings. Yet regulators control only the wireline price. It is therefore potentially helpful to provide empirical support for the theoretical proposition that an increase (decrease) in regulated wireline prices is equivalent to a decrease (increase) in wireless prices.[45]

[45] Moreover, as noted above, the dependent variable in equation (0.9), the (log) quantity of landlines, is based on the FCC's figures for billable access lines, which incorporate only ILEC lines (because state-level figures for residential CLEC lines are not published by the FCC). This type of measurement error, if non-random, could bias the estimates. Fortunately, the fact that the estimates obtained for equation (0.8) corroborate the cross-price elasticity estimated from equation (0.9) suggests that any such bias is minimal.

TABLE IV: ITERATED THREE-STAGE LEAST SQUARES ESTIMATES

	38 US States, 2001 - 2007	
First Demand Equation (Wireless)		
	Dependent Variable: Natural Log of Wireless Quantity	
Explanatory Variable	**(1) I-3SLS (Unrestricted)**	**(2) I-3SLS (Restricted)**
ln(Price of Wireless)	-2.111	-2.056
	(-6.15)	(-6.42)
ln(Price of Wireline)	0.526	0.464
	(3.28)	(4.6)
ln(Median Household Income)	-1.708	-1.662
	(-3.88)	(-3.93)
ln(Pop Density)	-0.455	-0.454
	(-0.41)	(-0.42)
Median Age	-0.043	-0.040
	(-0.87)	(-0.82)
ln(White)	-1.033	-1.085
	(-0.88)	(-0.94)
ln(Black)	0.494	0.499
	(2.72)	(2.8)
ln(Asian)	0.708	0.742
	(1.86)	(2.02)
ln(Hispanic)	0.110	0.111
	(0.48)	(0.49)
ln(Other Race)	0.042	0.047
	(0.12)	(0.13)
Constant Term	42.803	42.507
	(2.69)	(2.73)
State Fixed Effects	Yes	Yes
Observations	264	264
R-Squared	0.9905	0.9908
Second Demand Equation (Wireline)		
	Dependent Variable: Natural Log of Wireline Quantity	
Explanatory Variable	**(1) I-3SLS (Unrestricted)**	**(2) I-3SLS (Restricted)**
ln(Price of Wireline)	-0.351	-0.350
	(-2.53)	(-2.48)
ln(Price of Wireless)	1.224	1.283
	(4.12)	(4.58)
ln(Median Household Income)	0.807	0.867
	(2.12)	(2.35)
ln(Pop Density)	-1.017	-0.976
	(-1.06)	(-1)
Median Age	-0.091	-0.085
	(-2.12)	(-2.02)
ln(White)	1.601	1.561
	(1.57)	(1.51)
ln(Black)	0.002	-0.004
	(0.01)	(-0.03)
ln(Asian)	-0.274	-0.261
	(-0.83)	(-0.78)
ln(Hispanic)	0.121	0.132
	(0.61)	(0.65)
ln(Other Race)	0.445	0.458
	(1.42)	(1.44)
Constant Term	-16.786	-17.799
	(-1.22)	(-1.29)
State Fixed Effects	Yes	Yes
Observations	264	264
R-Squared	0.9927	0.9925

Notes:
(1) Z- statistics in parentheses.
(2) Wireless subscriber data redacted for Montana in 2001 & 2004.
(3) The price of wireless service is treated as endogenous in both equations. An annual time trend is used to instrument for the price of wireless.

The I-3SLS regressions, reported in Table IV, yield economically plausible parameter estimates. Each of the six price and income elasticities are statistically significant at the 5 percent level or better, and have economically intuitive signs. The demand for wireless services, as before, is significantly elastic ($|\hat{\eta}_{ww}| > 2$), while wireline demand, while not completely insensitive to price, is significantly inelastic ($|\hat{\eta}_{ll}| < 1$). As before, the results are consistent with the CDC's finding that low-income households are disproportionately likely to be wireless-only. Specifically, wireless telephony is found to be an inferior good ($\hat{\eta}_{wi} < 0$), whereas wireline telephony is found to be a normal good ($\hat{\eta}_{li} > 0$). (As before, the demographic variables, while sometimes individually insignificant, are collectively highly significant).

Most importantly for our purposes, the cross-price elasticity estimates are positive and statistically significant at the one percent level in each of the specifications in Table IV. Specifically, a one percent increase in the price of wireline service is estimated to increase the demand for wireless service by approximately 0.46 - 0.53 percent, while the cross-price elasticity of wireline demand with respect to the wireless price is estimated at 1.22 - 1.28 percent.[46] These are comparable in magnitude to Taylor and Ware's (2008) "back of the envelope" estimate of approximately 1.4. These estimates imply that the strength of cross-price effects have grown substantially since the turn of the millennium, when prior empirical studies were conducted, and wireless substitution was far less prevalent.

Our estimates also suggest that the degree of substitutability between wireless and wireline voice service is comparable to the cross-price effects between intermodal alternatives in other network industries, such as video programming: By way of comparison, the cross-price elasticity between the demand for cable television and the price of direct broadcast satellite (DBS) service and has been estimated in the range of 0.3 - 0.5.[47] Thus, the econometric results provide evidence that wireless telephony has evolved into a strong substitute for wireline service—even at current, regulated price levels for landline service.[48]

V. CONCLUSION

For the better part of a decade, a non-trivial and steadily increasing share of US consumers have come to rely exclusively on wireless technology for their voice communications needs, suggesting that the cross-price elasticity between wireless and wireline voice services is positive and economically significant. In contrast, the existing empirical literature provides scant evidence supporting this hypothesis, and competition authorities have generally found that there is

[46] Although the coefficients reported in Table IV represent Marshallian own- and cross-price elasticities, the corresponding Hicksian elasticities are quite similar in magnitude, given that expenditures on each technology represents a relatively small share of total household income.

[47] See Austan Goolsbee and Amil Petrin, "The Consumer Gains from Direct Broadcast Satellites and the Competition with Cable TV," *Econometrica* 72(2), 351-381 (March 2004) [hereafter *Goolsbee & Petrin*]. Goolsbee and Petrin's estimates imply cross-price elasticities between the price of DBS and the demand for cable television between 0.292 (for expanded basic cable) and 0.498 (for premium cable). See *Goolsbee & Petrin*, Table VIII.

[48] Of course, to the extent that wireline prices are currently kept below the competitive level by regulation, the cross-price elasticities at competitive prices may be even higher than those observed here. See Dennis Weisman, "A Principled Approach To The Design Of Telecommunications Policy," forthcoming, *Journal of Competition Law and Economics* (2010).

insufficient evidence available to conclude that wireless offerings constrain the price of wireline service. To date, empirical work has generally relied on datasets compiled at the turn of the millennium, when wireless substitution was quite limited. Using state-level panel data spanning 2001 - 2007, we have estimated a demand system for wireless and wireline service. The results yield positive and economically significant cross-price elasticities, thereby corroborating econometrically a hypothesis that has long been suggested by academics, regulators, and the aggregate data (not to mention casual observation and intuition).

In terms of a future research agenda, it would be useful to analyze wireless substitution using more detailed and disaggregated data from recent time periods. For example, as noted above, the state-level panel employed in our analysis is limited in its ability to disentangle quality-adjusted price effects. In future work, identification would clearly be aided by, e.g., cross-sectional and time-series variation in wireless prices and product characteristics. The household surveys upon which so much prior research has relied are now a decade old. Something akin to an updated version of these datasets could prove quite fruitful, and would presumably allow for the application of more sophisticated demand models and econometric techniques.

ATTACHMENT 2

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THE CASE FOR REFORMING REGULATION OF PSTN VOICE SERVICES

BY RICHARD N. CLARKE*

Have competitive conditions in the voice services market changed sufficiently to justify lifting most current economic and social regulation on the public switched telephone network (PSTN)? Yes, argues Richard Clarke, describing in detail the ongoing changes in the supply and demand structures of the voice market and their impact on reducing the economic power of the traditional incumbent local exchange carriers (ILECs). Based on this argument, and on evolving technology, Clarke notes that both the PSTN and the voice services it supports are "inexorably going away," to be replaced by new services and technologies, making current regulatory requirements superfluous.

INTRODUCTION

The public switched telephone network (PSTN) reaches virtually every home and business establishment in the United States. It is comprised of several hundred million copper wires plugged into several tens of thousands of local circuit switches – which are linked together by tens of millions of time division multiplex (TDM) interoffice trunks. This network, designed primarily to carry voice services, has now seen more than 130 birthdays. A wonder of the 19th and 20th centuries, it reached its technological apogee roughly twenty-five years ago and its commercial apogee only twelve years after that. Since the mid-1980s, there has been no significant innovative advance in its technology; and for the last dozen years, there has been no growth in its take-up and use. Indeed, both of these measures of its commercial acceptance have plummeted. Since 2000, the number of voice lines served by the PSTN has dropped 40% and the number of minutes it carries has dropped by over 60%. Declines in the PSTN operated by incumbent local exchange carriers (ILECs) have been even more dramatic.[1] Lines served by the ILEC PSTN have fallen nearly 50% and minutes used by 70%. The reason for these huge declines is, of course, quite clear. Communications have moved to wireless and broadband data networks. But while communications use and innovation have fled the PSTN over the last dozen years, government regulation has not. Rather, the voice services the PSTN offers have remained subject to nearly all of the same

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[1] Competitive local exchange carriers (CLECs) also comprise a portion of the PSTN. CLECs may offer circuit-switched voice services either through their own last-mile customer facilities, or by combining unbundled last-mile copper lines supplied by the ILEC with their own switching and transport facilities.

regulations as were applied when it was at its monopolistic and technical apogee. Indeed, in certain areas regulatory burdens on PSTN voice services have actually risen over this period.

This article examines whether current regulatory oversight of PSTN voice services should continue. It finds that because the voice services offered by the PSTN are now subject to very substantial market competition, no justification exists for continued economic regulation. Even regulation related to important social goals – such as universal service, disability access, and privacy – no longer makes sense if that regulation is focused exclusively on PSTN voice services, or especially just on ILEC PSTN services. This is because both the PSTN and the voice services it supports are inexorably going away, with many new services and technologies taking their place. Thus, it will not be possible to effectively address these social goals unless regulations are reformed to reflect this fact.

JURISDICTIONAL BACKGROUND

Voice services offered over the PSTN are regulated both by the Federal Communications Commission (FCC) and by state public utility commissions (PUCs).[2] In general, PUCs regulate so-called intrastate voice services while the FCC regulates interstate voice services. ILEC charges associated with PSTN intrastate voice service consist primarily of monthly local service rates, but also include various charges such as reciprocal compensation paid by competitive local exchange carriers (CLECs) for local call termination, intrastate access paid by long distance carriers, or charges to end-users for installation services, directory assistance, and other items. FCC-regulated charges for interstate PSTN voice services include both access charges imposed on long distance carriers as well as retail subscriber line charges (SLCs) paid by end users in conjunction with their purchase of monthly local voice service. In addition, it is possible that reciprocal compensation charges imposed on calls to/from Voice over Internet Protocol (VoIP) providers or dial-up Internet Service Providers (ISPs) may also be considered interstate services.[3]

Because of this dual regulatory framework, reduced FCC regulation of PSTN voice services, while highly salutary, will not automatically eliminate or suppress remaining PUC regulation of these services – unless this reduced FCC regulation also includes a preemption of parallel intrastate regulation of PSTN voice service. That said, any decision by the FCC to substantially reduce its regulation of interstate PSTN services will still be highly salutary – both in its own right and because any FCC action in this area may be impressionable upon PUCs addressing similar intrastate deregulation requests.

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[2] Telecommunications in the United States is quite unique in that it is subject to dual regulation by national and sub-national authorities.

[3] Federal Communications Commission, *In the Matter of Connect America Fund and Developing a Unified Intercarrier Compensation Regime, et al.,* WC Docket No. 10-90/CC Docket No. 01-92, et al., Nov. 18, 2011, accessed Nov. 30, 2012, http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-11-161A1.pdf, ¶¶ 933-975.

CRITERIA FOR FCC DECISION MAKING

Over the last twenty years, the FCC has followed at least four different sets of criteria for deciding whether regulation in particular markets may be reduced. In the early 1990s, the standard that the FCC developed was one of extant effective competition. This standard looked at market shares, the degree of current competitive presence, and ease and speed of further competitive expansion if the leading firm would attempt to exert any residual market power. It was on this basis that in 1995 legacy AT&T was declared nondominant in the long distance services business and was granted reduced regulation.[4] Similarly, it was on this same basis that mergers among the Regional Bell Operating Companies (RBOCs), operating in disjointed territories and not in competition with each other, were permitted by the FCC.[5]

In the late 1990s, the FCC advanced a somewhat different standard under section 271 of the 1996 Telecommunications Act for deciding whether regulations preventing the legacy RBOCs from entering in-region interLATA long distance markets could be relaxed. This standard was called the "irreversibly open to competition" standard.[6] Under this standard, an RBOC needed to demonstrate that there were no insurmountable barriers to competitive entry into local access markets and pledge, subject to verification by certain statistical metrics, that it would not discriminate against competing local or long distance companies in its provision of local access.

A few years later, the FCC adopted a set of criteria for determining whether it should grant increased flexibility for interstate special access pricing that were similar to its section 271 criteria in their prospective nature, but that differed in other respects.[7] In particular, these criteria were based on the proportion of central offices (COs) within a Metropolitan Statistical Area (MSA) where competitors had collocated their own special access equipment – along with the FCC's "predictive judgment" that the availability of this collocated equipment would provide an adequate competitive check on RBOC market power..

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[4] Federal Communications Commission, *In the Matter of Motion of AT&T Corp. to Be Reclassified as a Non-Dominant Carrier*, FCC No. 95-427, Oct. 23, 1995, accessed Nov. 30, 2012, http://transition.fcc.gov/Bureaus/Common_Carrier/Orders/1995/fcc95427.txt.

[5] Federal Communications Commission, *In the Matter of Application of AT&T, Inc. and BellSouth Corporation Application for Transfer of Control*, WC Docket No. 06-74, Mar. 26, 2007, accessed Nov. 30, 2012, http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-06-189A1.pdf, ¶¶ 3, 24, 88-112.

[6] Federal Communications Commission, *In the Matter of Application of Ameritech Michigan Pursuant to Section 271 of the Communications Act of 1934, as amended, To Provide In-Region, InterLATA Services in Michigan*, CC Docket No. 97-137, Aug. 19, 1997, accessed Nov. 30, 2012, http://transition.fcc.gov/Bureaus/Common_Carrier/Orders/1997/fcc97298.pdf; Federal Communications Commission, *In the Matter of Application by Bell Atlantic New York for Authorization Under Section 271 of the Communications Act to Provide In-Region, InterLATA Service in the State of New York*, CC Docket No. 99-295, Dec. 22, 1999, accessed in related document, Nov. 30, 2012, http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-07-44A1.pdf.

[7] Federal Communications Commission, *In the Matter of Access Charge Reform, Price Cap Performance Review for Local Exchange Carriers, Interexchange Carrier Purchases of Switched Access Services Offered by Competitive Local Exchange Carriers, Petition of U S West Communications, Inc. for Forbearance from Regulation as a Dominant Carrier in the Phoenix, Arizona MSA*, CC Docket No. 96-262, et al., Aug. 27, 1999, accessed Nov. 30, 2012, http://www.fcc.gov/Bureaus/Common_Carrier/Orders/1999/fcc99206.pdf.

Finally, in 2010 the FCC developed still a different set of criteria for deciding whether it should forbear completely from special access regulation. This standard was promulgated in the FCC's *Qwest-Phoenix* order.[8] In this order (which is currently being tested through court challenge) the sufficient standard adopted by the FCC appears to be one of perfect competition. That is, if it can be demonstrated that the market is currently perfectly competitive, forbearance shall be granted. If perfect competition cannot be demonstrated, the standard is ambiguous. While some view the FCC's language as suggesting that in this case forbearance shall not be granted, others believe that the order does not foreclose forbearance under possibly less onerous (but unstated) conditions.[9] But perhaps most important, the FCC has proposed that this *Qwest-Phoenix* standard replace all of its prior standards for indexing market competition and suitability for reduced or eliminated regulation.

Implicit in all of these standards is the concept of a market over which competition occurs. Historically, such market definitions have been relatively narrow with respect to communications function and broad with respect to geography. In the legacy AT&T nondominance proceeding, markets initially were defined as residence and small business long distance services, business 800 inbound long distance services, and other business services – primarily WATS and private line services. Further, because of the availability of "equal access" from the ILECs and rate averaging requirements, AT&T's retail markets were considered to be national. As regulations on some of AT&T's services were relaxed and it was recognized that physical long distance networks were largely fungible across multiple services, the market definition morphed into a single unseparated collection of interstate, domestic, interexchange services. In the section 271 proceedings focusing on competition at the local level, the market was defined as all exchange access services offered by an RBOC within a single state.[10] For special access pricing flexibility, markets were implicitly defined as either inter-CO channel mileage service within a MSA or as both channel terminations and channel mileage within a MSA. A similar definition is implicit in the *Qwest-Phoenix* proceeding.

While each of these market definitions may differ, one constant persists. PSTN voice markets have been viewed as *sui generis* – to be considered without regard to alternative communications services provided over wireless or data networks, and whose customers are deserving of the status quo (in terms of service character and pricing) without regard to the explicit costs this may generate to carriers, to customers of other telecommunications services or to society. To obtain PSTN voice service deregulation, it will be necessary both to convince regulators that wireless voice and data-based VoIP services are effective competitive alternatives (in both pricing and capabilities) to PSTN voice services – and that current levels of regulation over these competing services need no

[8] Federal Communications Commission, *In the Matter of Petition of Qwest Corporation for Forbearance Pursuant to 47 U.S.C. § 160(c) in the Phoenix, Arizona Metropolitan Statistical Area*, WC Docket No. 09-135, June 22, 2010, accessed Nov. 30, 2012, http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-10-113A1.pdf.

[9] George S. Ford and Lawrence J. Spiwak, "The Impossible Dream: Forbearance After the Phoenix Order," white paper no. 10-08, Phoenix Center for Advanced Legal & Economic Policy Studies, Dec. 16, 2010, accessed Nov. 30, 2012, http://www.phoenix-center.org/perspectives/Perspective10-08Final.pdf; Susan M. Gately, "FCC Denial of Qwest's Phoenix Forbearance Petition Highlights New Focus on Carrier Market Power," Economics and Technology, Inc., July 2010, accessed Nov. 30, 2012, http://www.econtech.com/newsletter/july2010/july2010a2.php.

[10] Aggregating local markets to the state level was economically logical because state PUCs generally enforce uniform regulations over an RBOC's operations and offerings within a state.

augmentation in order to afford customers equivalent protections to what they currently enjoy for PSTN voice services. This will require a threefold showing of: (a) technical equivalence; (b) economic equivalence; and (c) capacity of these alternatives to absorb PSTN voice traffic without significantly and adversely affecting their pricing or service quality.

In the alternative, rather than seeking simply to eliminate all PSTN voice regulations, it may be more appropriate to attempt to convince regulators that certain controls over PSTN voice services should be harmonized with controls over non-PSTN voice services. While in most cases this should be achieved by reducing PSTN voice regulation down to levels that apply to wireless voice or VoIP services, in certain cases this could be viewed as inappropriate and could present several obstacles. First, regulators may believe that market failures exist that require significant regulation of all providers. While the logical way of addressing such a concern is to extend the desired regulation directly to those providers that are currently exempt, this is not the only method that regulators have used. Rather, it is possible that some regulators may view continuing asymmetric regulation of PSTN voice as an indirect way of "regulating" other voice services. For example, regulations that keep PSTN voice prices low for high-cost customers have the effect of setting a competitive ceiling on non-PSTN voice prices. PSTN service quality regulation may have a similar impact by its high standard, forcing non-PSTN providers to elevate their own quality to stay competitive with PSTN services.

It is also possible that regulators believe they must offer customers the option of continuing to receive certain PSTN voice service features that they worry may not be supported by a competitive market. An example is network power. PSTN services are required to provide network-based power (both at network nodes and to the home) that generally enables continued operation even when commercial power grids fail. In contrast, wireless voice or VoIP services may have less robust power sources within the network, as well as less robust powering of home nodes. Thus, while regulators may be loath to require new technologies to provide the exact same level of operational reliability as the PSTN, they may also be loath to relax regulations that could result in customers being denied the option of maintaining the reliability levels they have come to expect from PSTN voice services.

SOURCES OF QUANTITATIVE INFORMATION ABOUT PSTN, WIRELESS AND DATA SERVICES

Available Facts and Data about PSTN Services

Public data currently available about PSTN voice services include the incumbent's market share of access lines down to the state level and the identity of major competitors (e.g. cable television [CATV], VoIP providers, large over-the-top [OTT] VoIP providers, mobile wireless providers, etc.).[11] The time series data contained within several of these reports may provide an indication of

[11] For example, see Federal Communications Commission, "Local Telephone Competition: Status as of December 31, 2010," white paper, Oct. 2011, accessed Nov. 30, 2012, http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-

timeframes for capacity expansion by these competitors, and tariff sheets and websites provide general terms and conditions under which these carriers provide service. More substantial public information as to volumes of different types of traffic (e.g. local, intrastate, or interstate) served by ILECs remains available in ARMIS reports filed up until 2000; and for interstate traffic served by ILECs in ARMIS reports filed up until 2007.[12] Additional public information may be available as to the cost structure for ILEC services.[13] Less specific or authoritative information may be available about the bundling practices and prices of the various carriers and about the actual traffic volumes their networks carry and the revenue they receive.[14]

Available Facts and Data about Wireless Services

CTIA publishes substantial industry-level information about volumes and revenues associated with wireless services.[15] Various investment houses also publish estimates of certain of these variables on a carrier-by-carrier basis.[16]

Available Facts and Data about Data Services

There is very little census-type information about data services – either of their traffic volumes or their prices. Perhaps the most widely used estimates of the size of this market are provided by Cisco's *Visual Networking Index*.[17] Nielson publishes certain estimates of the size of mobile data markets, as does Ericsson and CTIA.[18] AT&T also publishes some general information about the

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310264A1.pdf. See also various agency statistical reports at Federal Communications Commission, "Statistics of Communications Common Carriers," accessed Nov. 30, 2012, http://transition.fcc.gov/wcb/iatd/socc.html; and "Monitoring Reports," accessed Nov. 30, 2012, http://transition.fcc.gov/wcb/iatd/monitor.html.

[12] See Federal Communications Commission, Automated Reporting Management Information System (ARMIS), accessed Nov. 30, 2012, http://transition.fcc.gov/wcb/armis/.

[13] See Federal Communications Commission, Hybrid Cost Proxy Model (HCPM), accessed Nov. 30, 2012, http://transition.fcc.gov/wcb/tapd/hcpm/welcome.html.

[14] These reports from major investment banks are generally considered proprietary and available only to the investment banking clients of these institutions. For a public sampling of the type of data occasionally offered in these reports, see Craig C. Moffett, statements at "Workshops on the Telephone: Economic Rationales for PSTN Transition," Federal Communications Commission, Dec. 15, 2011 (video), accessed Nov. 30, 2012, http://www.fcc.gov/events/public-switched-telephone-network-transition-0.

[15] See CTIA, "CTIA Semi-Annual Wireless Industry Survey," accessed Nov. 30, 2012, http://www.ctia.org/advocacy/research/index.cfm/AID/10316.

[16] See the quarterly "Global Wireless Matrix" issued by Bank of American and Merrill Lynch.

[17] For example, see Cisco Systems, "Cisco Visual Networking Index: Forecast and Methodology, 2010-2016," white paper, June 1, 2011, accessed Nov. 30, 2012, http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-481360.pdf; Cisco Systems, "The Zettabyte Era," white paper, June 1, 2011, accessed Nov. 30, 2012, http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/VNI_Hyperconnectivity_WP.pdf; Cisco Systems, "Cisco Visual Networking Index: Forecast Update, 2011-2016," white paper, Feb. 14, 2010, accessed Nov. 30, 2012, http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.pdf.

[18] For example, see Ericsson, "Traffic and Market Data Report," white paper, Nov. 2011, accessed Nov. 30, 2012, http://hugin.info/1061/R/1561267/483187.pdf; Ericsson, "Traffic and Market Data Report: Interim Update," white paper, Feb. 2012, accessed Nov. 30, 2012, http://www.ericsson.com/res/docs/2012/tmd_report_feb_web.pdf; CTIA, "Semi-Annual Survey Shows Significant Demand by Americans for Wireless Broadband," press release, Apr. 13, 2012, accessed Nov. 30, 2012, http://www.ctia.org/media/press/body.cfm/prid/2171.

quantity of data traffic carried by its global networks.[19] Note that "data service" is a very broad concept and these different information sources may employ quite different definitions. Reported data traffic may, variously, include only "switched" data services such as those provided as IP, carrier Ethernet, VPN, or DDS. Further, these measurements may or may not include estimates of data transferred over fully dedicated services such as leased line DS1 or DS3.

THE SIZE OF THE PSTN MARKETS VS. THE SIZE OF WIRELESS OR DATA MARKETS

As with many things, "size" can be defined and measured in many ways. The following provides a discussion of several of the principal metrics often used to measure market size.

Volume of Traffic

Because PSTN voice traffic occupies reserved circuits of a consistent bandwidth, the traditional metric for PSTN traffic volumes is minutes of use. Similar metrics are used for 2G and 3G wireless voice services. The traditional measurement for data traffic would be in terms of bytes. But while all PSTN and 2G/3G wireless voice traffic passes through switches that afford the possibility of measurement, and all IP data traffic passes through routers capable of measuring byte volumes, substantial volumes of other data traffic pass through unmetered private lines or dedicated special access circuits.[20] There is likely to be substantial uncertainty in inferring the volume of this data traffic traversing dedicated circuits. Nevertheless, various entities have offered estimates of data traffic that attempt either to include or exclude those portions of data traffic that are unmetered. These include Cisco's *Visual Networking Index* measure of regional IP traffic, AT&T's *Big Petabyte* report, and CTIA's *Semi-Annual Wireless Industry Survey*.

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[19] This datum, sometimes called AT&T's *Big Petabyte* report, is updated only at irregular intervals and is available at http://www.att.com/gen/investor-relations?pid=5711.

[20] AT&T's *Big Petabyte* report assumes dedicated circuits to be 10% occupied with "data" over the course of an average business day.

Table 1: PSTN, VoIP, Wireless Voice, and Data Traffic Volumes (2011 Estimates)[21]

	ILEC PSTN	CLEC PSTN	VoIP	Wireless
Number of voice lines	93,000,000	22,000,000	33,000,000	300,000,000
Minutes/line/month	1,400	1,400	1,400	650
Total minutes/month	130,200,000,000	30,800,000,000	46,200,000,000	195,000,000,000
Total minutes/year	1,562,400,000,000	369,600,000,000	554,400,000,000	2,340,000,000,000
	Cisco VNI IP	**AT&T *Big Petabyte***	**CTIA U.S. Mobile-only**	
PB/day		30	2	
PB/month	8,952	810	69	
PB/year	107,424	9,720	826	

Note: PSTN and VoIP lines estimated from FCC *Local Telephone Competition* report. PSTN and VoIP minutes estimated by trending data from FCC *Statistics of Communications Common Carriers* and *Trends in Telephone Service*. Wireless data estimated from CTIA *Semi-Annual Survey* adjusted down for data-only connections

Next, we compare these data traffic volumes with voice traffic volumes. To do this, it is necessary to convert voice minutes into their data equivalents. The quantity of data bytes necessary to carry a minute of voice traffic depends on how the voice traffic is coded. Generally, PSTN voice traffic has been coded into "data" using a G.711 codec at 64 kbps.[22] This codec generates a higher quality signal than many of the lower speed G.729 codecs used for VoIP traffic.[23] Because of greater mobile bandwidth scarcity, most wireless voice traffic has been coded into "data" at rates of 13 kbps or less.[24]

[21] The VoIP statistics recorded by the FCC are restricted to "interconnected" VoIP services. These include both full-facilities VoIP services such as those provided by CATV companies and partial-facilities OTT VoIP services that are engineered to be PSTN-replacement services such as those provided by companies like Vonage. These statistics do not reflect software-only VoIP services such as those provided by companies like Skype. See Federal Communications Commission, "Consumer Advisory: VoIP and 911 Service," advisory document, Mar. 2, 2012, accessed Nov. 30, 2012, http://transition.fcc.gov/cgb/consumerfacts/voip911.pdf.
[22] For more information, see the "G.711" entry at Voip-Info, http://www.voip-info.org/wiki/view/ITU+G.711.
[23] For more information, see the "G.729" entry at Javvin, http://www.javvin.com/protocol/G729.html. Note, though, that advanced compression techniques may now permit lower speed codecs to generate voice qualities that are superior to those generated by uncompressed G.711 64 kbps codecs.
[24] For more information, see the "Full Rate" entry at Wikipedia, http://en.wikipedia.org/wiki/Full_Rate.

Table 2: Data "Equivalents" to PSTN, VoIP, and Wireless Voice Traffic Volumes

Voice traffic sources:	*Minutes/month*		*Lines*		
ILEC PSTN voice	130,200,000,000	32%	93,000,000	21%	
CLEC PSTN voice	30,800,000,000	8%	22,000,000	5%	
Total PSTN	161,000,000,000	40%	115,000,000	26%	
VoIP	46,200,000,000	11%	33,000,000	7%	
Wireless	195,000,000,000	48%	300,000,000	67%	
Total voice	402,200,000,000		448,000,000		
Voice quality assumptions:	*GSM Quality*		*Medium Quality*		*PSTN Quality*
VoIP transmit rate (kbps)	20		60		90
implied KB/minute	150		450		675
implied PB/minute	1.36424E-10		4.09273E-10		6.13909E-10
Implied voice data equivalents:					
ILEC PSTN PB/month	*18*		*53*		***80***
CLEC PSTN PB/month	*4*		*13*		***19***
Total PSTN PB/month	22		66		**99**
VoIP PB/month	6		**19**		28
Wireless PB/month	**27**		80		120
Total PB/month	55		165		247

Notes: Maintaining current PSTN voice quality would require an uncompressed VoIP encoding plus carriage overheads amounting to a transmit rate of roughly 90 kbps. Currently existing VoIP services are likely transmitted at no more than about 60 kbps. Current wireless service codecs plus overheads require closer to 20 kbps of throughput. The implied data loads associated with these different services are noted in **bold** in the above table.

Thus by any standard, the degree to which data networks would need to be incremented in order to carry all remaining PSTN voice traffic is minimal. PSTN PB (petabyte) equivalents amount to only slightly more than 1% of Cisco's figure for total United States IP traffic.[25]

Peak Traffic Capacity

No type of traffic – PSTN, wireless voice, or IP data – is offered uniformly across all hours of the day. Rather, each traffic type displays "peaks" that are significantly above 24-hour averages. Because networks must be sized to meet peak demands – and peak demand may be charged at rates that exceed those charged for off-peak demand – a more relevant measure of the "size" of voice and data markets may be their respective network throughput capacities. While relative total volumes of monthly voice and data traffic may be a suitable proxy for the relative peak capacity requirements of voice and data services, this is true only to the extent that PSTN voice, wireless voice, and data

[25] Note that the extent to which the Cisco *Visual Networking Index* IP data figures or the AT&T *Big Petabyte* figures include or do not include PSTN voice's implicit data loads is not completely clear.

traffic have similar peak-to-average profiles. There is substantial evidence suggesting that this is not true. In particular, while PSTN voice traffic historically has had peak demands that are roughly three times average demand, for data traffic this has varied over time.

Many years ago, data traffic was likely less peaked than voice. This was because substantial portions of data traffic were in support of non-real-time services. Data circuits were expensive and computer networks could and would queue their data traffic to send less time-critical traffic during off-peak periods in order to raise average utilization factors across these expensive networks. With the advent of the World Wide Web, real-time browsing greatly expanded its share of data network usage. Even more recently, video entertainment media streaming has exploded, with this real-time application now accounting for over one third of all Internet traffic – and focused disproportionately during the already-peak hours of the evening.[26] As a result, the ratio of peak-to-average traffic for data may be no less than for voice, and in residential areas may display a coincident busy time in the evening.[27]

Value of Traffic

Not all traffic has equal commercial value. This value is determined by the cost of its production, customer willingness to pay as well as availability of competitive substitutes. In general, customers have valued bytes associated with expensive-to-produce two-way communications greater than they have valued an equal number of bytes associated with one-way video or data communications. Further, the value of voice communications as a fraction of total communications value has been declining rapidly. As an example, Table 3 shows that AT&T reported its 2007 wireline voice revenues to be $41.630 billion, declining to $25.131 billion in 2011; and its 2007 wireline data revenues to be $24.075 billion, increasing to $29.606 billion in 2011. These changes have resulted in voice's share of total wireline service revenues dropping from 63% to 46%. Table 3 also shows that while AT&T's wireless voice revenues did increase from $31.718 billion in 2007 to $34.708 billion in 2011, over this same period its wireless data revenues more than tripled from about $6.960 billion in 2007 (practically all from low bandwidth text messages) to $22.018 billion in 2011.[28]

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[26] Cisco Systems, "The Zettabyte Era," 5-7.
[27] In any event, so long as voice peak-to-average ratios are no higher than those for data *and* so long as voice peaks are not perfectly coincident with data peaks, using total monthly traffic volumes for voice and data services to proxy any necessary augmentation to data networks to accommodate PSTN voice is a conservative assumption.
[28] See AT&T, *2007 Annual Report*, report, Feb. 8, 2008, accessed Nov. 30, 2012, http://www.att.com/Investor/ATT_Annual/downloads/07_ATTar_FullFinalAR.pdf; AT&T, "Quarterly Earnings: 4Q 2011," investor briefing, Jan. 26, 2012, accessed Nov. 30, 2012, http://www.att.com/gen/investor-relations?pid=262.

Table 3: AT&T Revenue and Traffic Shares for Voice and Data

	Wireline			Wireless	
	2007	2011		2007	2011
Voice revenue ($M)	$41,630	$25,131		$31,718	$34,708
Data revenue ($M)	$24,075	$29,606		$6,960	$22,018
Total revenue ($M)	$65,705	$54,737		$38,678	$56,726
Voice revenue share	63%	46%		82%	61%
Data revenue share	37%	54%		18%	39%
Voice traffic share	18%	5%		~100%	25-33%
Data traffic share	82%	95%		~0%	67-75%
Voice lines	64,025,500	41,287,500		65,550,000	88,194,000
Voice minutes/month	89,635,700,000	57,802,500,000		47,458,200,000	57,326,100,000
Voice revenue/minute	$0.0387	$0.0362		$0.0557	$0.0505

Note: Source for revenue data is *AT&T, Inc. 2007 Annual Report* and 4th Quarter 2011 AT&T Investor Briefing. Estimates for traffic shares based on AT&T's *Big Petabyte* report, Cisco's *Visual Network Index*, CTIA's *Semi-Annual Survey*, and Ericsson's *Traffic and Market Data* report. Traffic figures are estimated.

CAPABILITY OF WIRELESS AND DATA MARKETS TO ABSORB PSTN TRAFFIC

U.S. mobile networks have already shown themselves capable of accommodating significant inflows of formerly PSTN voice minutes. Over the course of the last decade, more than 30% of all U.S. households have "cut the cord" and converted their PSTN voice minutes into wireless voice minutes.[29] This suggests that over a quarter of the 195 billion voice minutes currently carried by U.S. mobile operators each month have migrated from the PSTN.[30] While the PSTN continues to carry roughly 161 billion minutes per month (down from over 400 billion minutes per month in 2000), wireless voice networks, which, over the last five years alone, have expanded their capacity by over 60 billion minutes per month, seem capable of continuing to absorb significant fractions of remaining PSTN usage. Indeed, past expansion of wireless networks to carry increased voice traffic is only the tip of the iceberg. Over the same period, wireless networks have expanded from having negligible capacity to handle data, to a data-carrying capacity that by early 2011 exceeded their voice capacity by a factor of two – and continues to rise at rates approaching 100% per year.[31] Given that

[29] Stephen J. Blumberg and Julian V. Luke, "Wireless Substitution: Early Release of Estimates from the National Health Interview Survey, January-June 2011," white paper, Centers for Disease Control, Dec. 21, 2011, accessed Nov. 30, 2012, http://www.cdc.gov/nchs/data/nhis/earlyrelease/wireless201112.pdf.

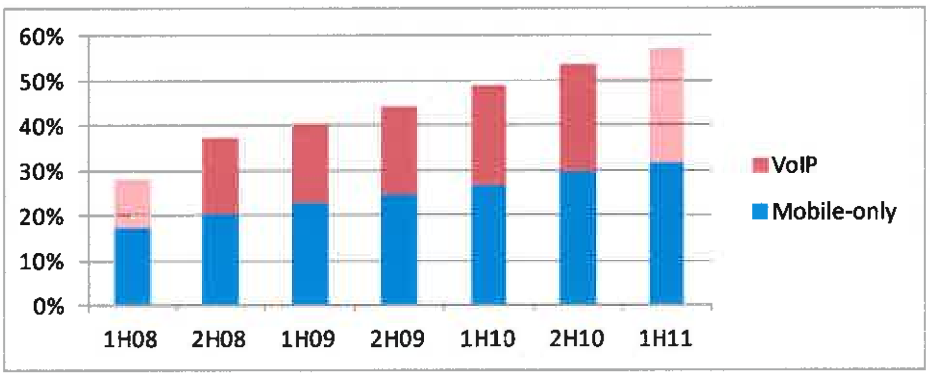
[30] This figure is developed by assuming that 35 million wireless-only households have each migrated 1400 minutes per month of formerly PSTN calling to mobile networks.

[31] Ericsson, "Traffic and Market Data Report: Interim Update;" CTIA, "CTIA Semi-Annual Wireless Industry Survey."

4G wireless networks are expected soon to carry voice as a data service application, this suggests an immense further increase in the capability of wireless networks to handle massive incremental amounts of voice traffic.

Similarly, data networks have also absorbed a large fraction of formerly PSTN services. By early 2011, about 33 million out of a total of about 148 million U.S. fixed voice lines were interconnected VoIP lines.[32] Given that about 28 million of these VoIP lines are residential, this suggests that in addition to the more than 30% of all U.S. residences abandoning PSTN services for wireless, an additional quarter of all residences have moved to VoIP. Thus, PSTN voice service is now absent from more than half of all U.S. households. See Figure 1.

Figure 1: Percentage of U.S. Households that are Either VoIP or Mobile-Only



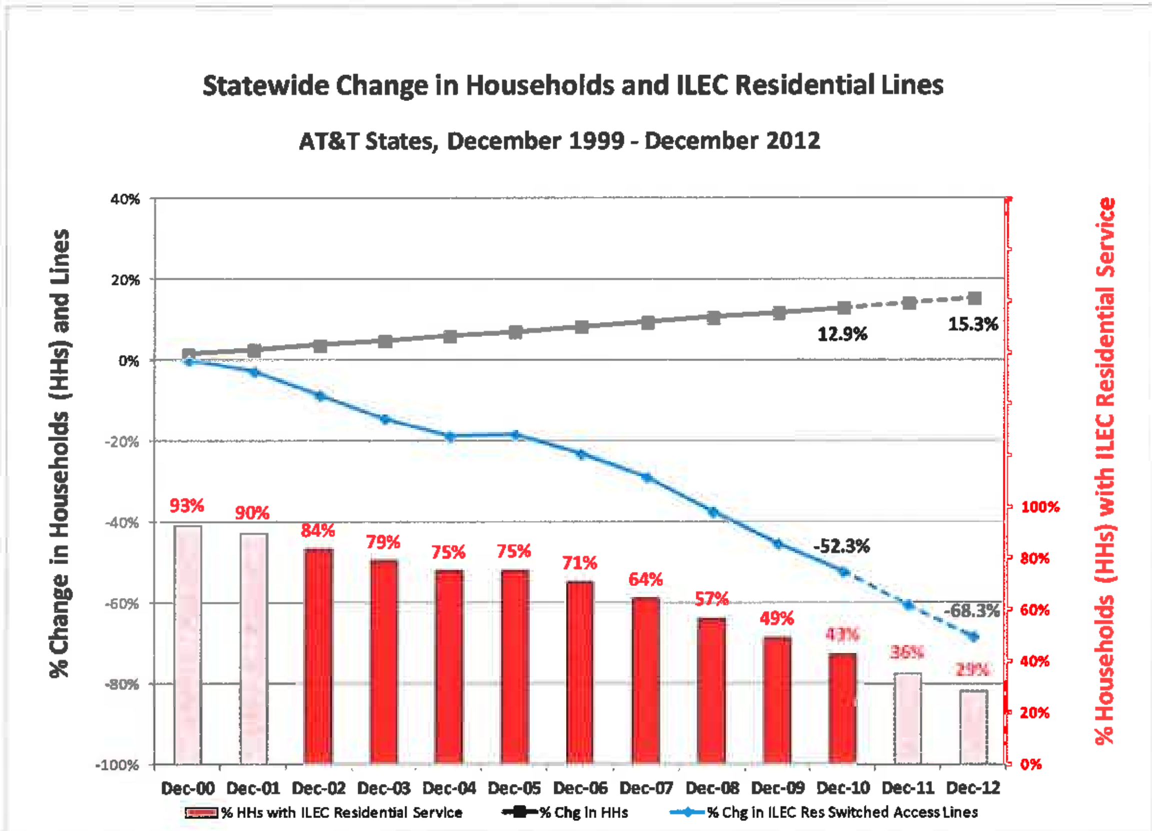
Note: Mobile-only data sourced from the Centers for Disease Control (CDC). VoIP data sourced from the FCC's *Local Telephone Competition Status* reports. Household counts from the FCC's *Telephone Subscribership* report. VoIP figures for 1H08 and 1H11 are estimates.

Note that Figure 1 shows only the extent to which U.S. households have abandoned PSTN voice services from any carrier – incumbent or new entrant. The decline in ILEC-provided PSTN services is even more dramatic. If AT&T's ILEC states are used as an example, since 2000, households in these states have grown by 15.3%, while the percentage of households served by ILECs has declined by over 61% (from 93% in 2000 to 36% in 2011) – with no more than 36% (and dropping) of all households continuing to contain an ILEC PSTN phone.[33]

32 Federal Communications Commission, "Local Telephone Competition: Status as of December 31, 2010." Note that these amounts do not include minutes or lines associated with non-interconnected VoIP services such as Skype.

33 Indeed, the situation is even more severe given that ILECs retain an obligation to serve all housing units in their territories. Over this same 2000-2011 time period, AT&T ILEC penetration on a housing unit basis has dropped to 34%.

Figure 2: Percentage of U.S. Households Served by ILEC PSTN Service



Note: Residential line count data sourced from the FCC's *Statistics of Communications Common Carriers* and *Local Telephone Competition Status* reports. Household counts from the FCC's *Telephone Subscribership* report. Line count figures for 2000-2001 and 2011-2012 are linearly-trended estimates.

Migration to VoIP is taking place in the rest of the world as well. For 2010, Cisco has estimated that 138 PB/month of the 12,528 PB/month of consumer Internet traffic carried over global IP networks each month is VoIP traffic.[34] Table 4 demonstrates that this implies that very large amounts of global voice traffic are already traversing IP networks.

[34] Cisco Systems, "Cisco Visual Networking Index: Forecast and Methodology, 2010-2016."

Table 4: Existing Global VoIP Traffic Volumes

Voice quality assumptions:	***GSM Quality***	***Medium Quality***	***PSTN Quality***
VoIP transmit rate (kbps)	20	60	90
implied Minutes/KB	0.00667	0.00222	0.00148
implied Minutes/PB	7,330,077,519	2,443,359,173	1,628,906,115
Implied voice data equivalents:			
Global VoIP PB/month	138	138	138
Implied VoIP minutes/month	1,011,550,697,554	337,183,565,851	224,789,043,901

Note: Cisco *Visual Network Index* plus calculations from Table 2.

ECONOMIC COMPARABILITY

Although wireless and data networks may have the technical capability quickly to absorb PSTN voice traffic, unless this can occur with incremental economics (to both customers and providers) that are at least as favorable as the incremental economics of this traffic remaining on the PSTN, customers and/or providers will not find this switch to be advantageous, and it may be blocked. Fortunately, the economics of voice service over alternative networks to the PSTN appear to be at least as favorable as continued use of the PSTN.

There are three points of view to examine. The first is from the consumer point of view. The second is from the point of view of interconnecting networks; and the third is from the point of view of hypothetically deregulated PSTN voice providers.

The Consumer View

While over the past five years large volumes of customers have voluntarily abandoned their PSTN voice services and have switched to wireless voice or VoIP, standard antitrust or competitive analysis would pose the question of whether still more consumers would find it advantageous to switch to VoIP or voice wireless service if regulations were relaxed on PSTN voice and its price started to rise.[35] Whether such continued substitution would occur is likely to depend on the price and quality of competing voice services *vis à vis* those offered by the PSTN.

As noted earlier, price/quality equivalence may be a different issue for the FCC than for customers – over 30% of whom have already decided that wireless services offer a more preferable price/quality profile than PSTN voice services – with nearly a further 25% deciding to replace former PSTN voice services with VoIP. Given these very large figures and their continuing growth in the face of *stable* PSTN voice prices and quality, it would be difficult to argue that significant numbers of

[35] United States Department of Justice and Federal Trade Commission, "Horizontal Merger Guidelines," advisory document, Aug. 19, 2010, accessed Nov. 30, 2012, http://www.justice.gov/atr/public/guidelines/hmg-2010.pdf, 8-13.

additional PSTN customers would be unwilling to convert to wireless voice or VoIP service if the price/quality proposition for PSTN service should hypothetically *worsen* relative to the price/quality proposition from wireless voice or VoIP service.

There may, however, be dwindling pockets of PSTN customers whose options for switching to wireless or VoIP voice services are constrained. These may be customers who cannot receive an adequate wireless signal in their house, or who are either not addressed by wireline broadband or who have no interest in subscribing to wireline broadband. While it is possible that marketing-driven rate averaging across customer aggregates, containing substantial numbers of customers who are willing and capable of switching providers, will be adequate to protect immovable customers from potential PSTN voice rate increases permitted by deregulation, even greater protection is assured if competitive forces of supply and demand are adequate to prevent any unreasonable rate increase/quality diminution for voice communications in the event of deregulation.

To evaluate these competitive forces requires a comparison of prices for the various alternative voice services. These pricing options are shown in Table 5.

Table 5: Voice Service Pricing Options (Illustrative Figures)

Service	Base	Taxes & fees	Total
PSTN local	$23.00	$5.00	$28.00
PSTN all-distance	$42.00	$10.00	$52.00
Wireless limited	$17.00	$3.00	$20.00
Wireless all-distance	$30.00	$5.00	$35.00
CATV VoIP local	$35.00	$5.00	$40.00
CATV VoIP all-distance	$45.00	$6.00	$51.00
OTT VoIP limited	$12.00	$2.00	$14.00
OTT VoIP all-distance	$25.00	$3.00	$28.00
Non-I/C VoIP all-distance	$3.00	$0.00	$3.00
Wireline DSL	$38.00	$3.00	$41.00
Wireline cable modem	$45.00	$3.00	$48.00
Wireline DSL + VoIP	$63.00	$6.00	$69.00
Wireline cable modem + VoIP	$70.00	$6.00	$76.00

Note: Sample PSTN rates are from the FCC *Trends in Telephone Service* and AT&T. Wireless rates are from Tracfone and Tracfone StraightTalk. CATV VoIP and cable modem rates are from Comcast. OTT VoIP rates are from Vonage. Non-I/C VoIP rates are from Skype. Wireline DSL rates are from AT&T.

Whether a PSTN customer will be protected against price increases may depend on the particular PSTN voice service they are seeking to replace and whether they have wireless options in addition to VoIP-based options. In general, PSTN all-distance customers will always find non-PSTN options to be at least as favorably priced as all-distance PSTN service. For local-only PSTN customers, the choices may be more challenging. While wireless limited service is likely to be priced less than local PSTN service, it may only offer monthly usage volumes of about 375 minutes – which is less than PSTN average usage that may approach 1400 minutes per month.[36] On the other hand, the minutes that wireless offers are all-distance minutes rather than local-only minutes – which could equalize the value proposition. If a customer already purchases wireline broadband from a CATV provider, he/she should be able to procure a VoIP service add-on that is more economical than either local-only or all-distance PSTN service. But the very few PSTN customers who have no wireless option and who have no use for, or prior purchase of, either broadband or CATV may face price increases if they attempt to substitute away from PSTN voice.[37] For these customers to obtain an alternative voice service, they would need to purchase broadband or CATV in addition to VoIP, or pay the standalone VoIP price from the wireline broadband carrier. While this may not result in much of a price increase for previous PSTN all-distance subscribers, it may cause an increase for high-usage local-only subscribers – although these subscribers may now be receiving significant extra value from the broadband service and/or long distance calling included with their replacement VoIP or wireless service.

The Interconnecting Network View

Despite (or actually, because) IP interconnection is unregulated, prices for terminating voice calls are much cheaper when these calls are carried as data bytes over IP networks rather than as TDM traffic over the regulated PSTN. Carried over the PSTN, the rock-bottom price for interconnection is $0.0007 per minute (which many claim is below the relevant "cost". [38] This entitles the interconnecting carrier to receive voice call termination within a local service area.[39] In contrast, over IP networks, interconnection generally is either compensated on a paid transit basis, or on a settlement-free bill-and-keep peering basis. Let's consider the more expensive paid transit circumstance that requires no complicating *quid pro quo* in the form of reciprocal traffic termination duties.

The purchase of transit from an interconnecting IP carrier requires that carrier to ensure that the received bytes are transported and terminated to any IP address in the world. Thus, the scope of

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36 This assumes the purchase of a 1500-minute annual Tracfone airtime card for $200 with a handset that entitles the user to a tripling of the face value number of minutes.

37 Note, however, that the reason why many current PSTN voice customers might face a price increase by switching to wireless or VoIP is because their current PSTN service is being subsidized by one or more of the various so-called universal service subsidy plans. Indeed, it is not uncommon for subsidized PSTN customers in so-called "high cost" areas to actually be paying retail PSTN voice rates that are less than the rates paid by a customer in a medium- or low-cost area. To the extent that the unavailability of current PSTN voice-only subsidies may generate an apparent rate increase for customers shifting to wireless voice or VoIP, the appropriate policy is to transfer the current PSTN voice subsidy to these alternative services.

38 James Bradford Ramsay, *Notice of Oral Ex Parte Contact, re: WC Docket No. 10-90 et al.*, July 14, 2011, accessed Nov. 30, 2012, http://apps.fcc.gov/ecfs/document/view?id=7021692221.

39 While reciprocal compensation by PSTN carriers at $0.0007 per minute has provided call termination within a local service area (i.e. areas generally not larger than a Metropolitan Statistical Area [MSA]), new rules promulgated in the FCC's *In the Matter of Connect America Fund and Developing a Unified Intercarrier Compensation Regime; et al.* will now require this fee to purchase PSTN termination throughout an entire Local Access And Transport Area (LATA) – which may be up to a full state in size.

service offered by IP transit is much, much broader than the scope of reciprocal compensation or terminating switched access that requires the receiving carrier only to terminate calls within a local service area or LATA. But now consider the price attached to IP transit. In the United States, large purchasers of IP transit are currently paying rates that are below $2 per mbps of capacity.[40] Smaller or more remotely located purchasers may pay somewhat higher rates. This pricing is due strictly to the competitive market for such services, and is not enforced by any government regulation.[41] If, using conventional traffic management and quality assumptions, representative IP transit rates are converted into costs per minute for terminating VoIP calls, the answer is stunning. Using IP transit to complete calls anywhere in the world is no more than a tenth as expensive as the already rock-bottom $0.0007 per minute that U.S. PSTN carriers are paid to complete calls within a local service area or LATA. See Table 6.

Table 6: Cost of Using IP Transit to Terminate VoIP

Voice quality assumptions:	*GSM Quality*	*Medium Quality*	*PSTN Quality*
VoIP transmit rate (kbps)	20	60	90
PSTN voice equivalents:			
VoIP circuits/mbps	51.2	17.1	11.4
Monthly minutes/circuit	20,000	15,000	10,000
Monthly minutes/mbps	1,024,000	256,000	113,778
IP transit price/mbps	$2	$4	$6
VoIP cost/minute	**$0.000008**	**$0.000031**	**$0.000070**
Percent relative to $0.0007	1%	4%	10%

Note: The presented figures for monthly minutes of carrying capacity per VoIP "circuit" assume that VoIP traffic is carried on IP capacity that is dedicated to voice and at a service quality level that is consistent with standard PSTN traffic engineering assumptions. To the extent that VoIP traffic is carried as prioritized traffic within far larger IP networks, the number of monthly minutes capable of being carried on a "circuit" could reasonably approach a theoretic limit of 43,000. Under this latter assumption, VoIP cost per minute would be only $0.000004, $0.000011, and $0.000016, respectively for the three quality assumptions.

The Incumbent PSTN View

While over the past five to ten years, many PSTN voice customers have voluntarily abandoned PSTN voice services and switched to wireless or VoIP services, standard antitrust or competitive

[40] Dennis Weller and Bill Woodcock, "Internet Traffic Exchange Market Developments and Policy Challenges," white paper No. 207, Organisation for Economic Co-operation and Development, Oct. 17, 2012, accessed Nov. 30, 2012, www.oecd-ilibrary.org/internet-traffic-exchange_5k918gpt130q.pdf;jsessionid=16fdxejcmg5na.x-oecd-live-02?contentType=/ns/WorkingPaper&itemId=/content/workingpaper.
[41] Weller and Woodcock; Bill Woodcock and Vijay Adhikari, "Survey of Characteristics of Internet Carrier Interconnection Agreements," white paper, Packet Clearing House, May 2, 2011, accessed Nov. 30, 2012, http://www.pch.net/docs/papers/peering-survey/PCH-Peering-Survey-2011.pdf, 2-3.

analysis would pose the forward-looking question of whether PSTN providers would find it profitable to raise prices or reduce service quality once they were granted deregulation. Unless current PSTN consumers continue to find it advantageous to switch to wireless or VoIP voice service if PSTN prices rise or quality falls, then such a price increase by PSTN voice providers (assuming that it is profitable) may demonstrate that market power remains, and deregulation could raise questions about potential harm to customer welfare.

Whether a deregulated PSTN voice provider would find a hypothetical price rise profitable or unprofitable depends on three key elements. The first is the PSTN's customer demand structure, the second is its cost structure, and the third is the competitive supply reaction of alternative voice service providers.[42] This is illustrated in the following equation:

$$\pi = p \cdot x(p) - c\big(x(p)\big) \qquad (1)$$

The PSTN's profits are π, its price is p, its output quantity is $x(p)$, and its total costs are $c(\cdot)$. Customer demand is represented in Equation (1) by the demand curve $x(p)$. The PSTN's cost structure is given by its cost function $c(x(p))$. The influence of the alternative voice carriers' competitive supply reaction is reflected in the induced demand function $x(p)$ for the PSTN's output.

Whether the PSTN voice provider earns more from raising its price than lowering its price depends on the elasticity of its profit with respect to price. This elasticity, represented by E, is defined as:

$$E = \frac{p}{\pi}\frac{\partial \pi}{\partial p} \qquad (2)$$

The PSTN voice provider will earn more from raising (lowering) its price if the sign of this elasticity E is positive (negative). Substituting the profit function from Equation (1) into Equation (2) and taking derivatives with respect to p yields the following expanded form for E (omitting symbols for functional dependency):

$$E = \frac{p}{\pi}\left[x + p\frac{\partial x}{\partial p} - \frac{\partial c}{\partial x}\frac{\partial x}{\partial p}\right]$$
$$= \frac{R}{\pi}\left[1 + \varepsilon \cdot \left(1 - \tau\frac{C}{R}\right)\right], \qquad (3)$$

where R represents the PSTN's revenue [$R = p \cdot x(p)$], C represents the PSTN's total cost [$C = c(x(p))$], ε is the PSTN's price elasticity of demand [$\varepsilon = (p/x) \cdot (\partial x/\partial p)$], and τ is the PSTN's quantity elasticity of cost [$\tau = (x/c) \cdot (\partial c/\partial x)$].

Assuming that the PSTN's revenue R and profit π are non-negative, the sign of elasticity E is the same as the sign of the expression in brackets in Equation (3). Because ε is a negative number and C/R is a positive number less than 1 (assuming $\pi > 0$) and τ is a number between 0 and 1 (if there

[42] William M. Landes and Richard A. Posner, "Market Power in Antitrust Cases," *Harvard Law Review* 94, no. 5 (1981): 937-966.

are no diseconomies of scale), the sign of E is ambiguous. It depends crucially on the numerical values of ε, τ, and C/R. The more elastic is demand for the PSTN's voice services, the more likely it is that the sign of E will be negative and that a price rise will be unprofitable.[43] Similarly, the more "fixed" are the PSTN's costs (smaller values of τ) and the more currently profitable is PSTN service (low C/R), the more likely it is that the sign of E will be negative and that a price rise will be unprofitable.

Of these three variables, τ and C/R are the easiest to identify through direct data analysis, which will be done in the next subsection below. The PSTN's own price elasticity of demand ε may be much harder to estimate directly. An alternative method for calculating ε in a homogeneous market has been proposed by Stigler and reemphasized by Landes and Posner.[44] This method suggests that if the total market price elasticity of demand is known along with the supply elasticity of the alternative competing voice firms, a residual firm's (i.e. the PSTN's) own price elasticity of demand can be calculated.

Let s be the PSTN's share of the total market for voice services and let $(1-s)$ be the share of the other voice firms competing in this market. It is easy to show that the total market price elasticity of demand ε_m is the share-weighted average of the PSTN's own price elasticity of demand ε and the alternative voice competitors' price elasticity of supply σ:

$$\varepsilon_m = s \cdot \varepsilon + (1-s) \cdot \sigma . \tag{4}$$

Solving for ε yields:

$$\varepsilon = \frac{1}{s}\, \varepsilon_m - \frac{(1-s)}{s}\, \sigma . \tag{5}$$

Thus, if the PSTN's own price elasticity of demand ε cannot be estimated directly from appropriate data on PSTN and alternative voice carriers' price and quantity movements, its value may be inferred using knowledge of total voice market demand elasticity, the PSTN's share of this market, and the elasticity of supply from the alternative voice carriers. This synthetic value for ε may then be substituted into Equation (3) to determine whether a price increase would increase the PSTN's profits.

Empirical Analyses

As noted in the *Criteria for FCC Decision Making* section above, the FCC has considered the geographical extent of local service switched telecommunications markets to be statewide. While this may suggest that an empirical analysis of potential PSTN voice service market power should be

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43 Note that for all normal goods, $\varepsilon < 0$. That is, as prices increase, quantity demanded falls. By convention, when we refer to ε being "large" or "small," we are referring to $|\varepsilon|$ being "large" or "small."

44 George J. Stigler, "Notes on the Theory of Duopoly," *Journal of Political Economy* 48, no. 4 (1940): 521; Landes and Posner.

performed on a state-by-state basis, there are several reasons why this is not necessary. The first is that the focus of this analysis is on federally-imposed regulation – which is nationally uniform. The second is that the competitive pressures facing PSTN voice services are remarkably similar in all geographic areas of the U.S. The FCC noted that in 2010, 99.8% of the U.S. population lives in census blocks served by at least one wireless voice provider. Further, 99.2% were served by at least two wireless voice providers and 97.2% were served by at least three.[45] Similarly, the FCC has noted that as of the end of 2010, more than 93% of all U.S. ZIP Codes had at least one CLEC or non-ILEC interconnected VoIP provider.[46] In addition, competitive pressure is not restricted to just metropolitan areas. The Centers for Disease Control (CDC) finds that wireless-only households are nearly as prevalent in non-metropolitan areas as in metropolitan areas – and are substantially more prevalent in the less-densely populated Midwest, South, and West regions of the U.S. than in the more-densely populated Northeast.[47] CLEC PSTN voice services and VoIP subscriptions are also robust across all states.[48] Because of this national uniformity in competitive circumstance and the greater availability of national data, the following empirical analysis will assume a national market for PSTN voice services. We do not anticipate that an analysis based on more geographically granular state-by-state data is likely to show appreciable competitive differences.

To estimate empirically the sign of E, which indicates whether a deregulated PSTN voice provider will have the incentive to increase prices ($E > 0$) or to reduce prices ($E < 0$), we need to evaluate Equation (5) and the bracketed expression in Equation (3). Let's start with the bracketed expression in Equation (3). Its undetermined elements are ε, τ, and C/R. As noted earlier, the PSTN's profitability determines C/R. Presumably this ratio should be less than one because the PSTN's voice revenues continue to exceed its costs. Examining ILEC ARMIS records for 2005-2010 suggests the value for C/R is in the 0.85 to 0.90 range. The cost structure for the current PSTN determines the sensitivity of its total costs to its output, τ. Because the PSTN was installed using very long-lived equipment years ago, and it is currently operating at less than half of its capacity, its variable capital costs (with respect either to lines or minutes) are virtually nil. Indeed, total variable costs likely consist only of certain billing, maintenance, and operating expenses – and even many of these would not vary with counts of PSTN voice lines or minutes assuming customers continue to take DSL broadband from the PSTN provider.[49] Thus, these variable costs would certainly amount to something less than 40% of total costs, and quite likely less than 25% of total costs. As a result, if we assume $\frac{C}{R} < 0.90$, the expression $\tau\frac{C}{R}$ will be less than 0.36, and quite possibly less than 0.225. This assures that $1 - \tau\frac{C}{R}$ will exceed 0.64, and possibly exceed 0.775. Therefore, the sign of E will depend on whether $|\varepsilon|$ is greater or less than a number no higher than 1.5625 (= 1/0.64), and

45 See Federal Communications Commission, *Annual Report and Analysis of Competitive Market Conditions with Respect to Mobile Wireless, Including Commercial Mobile Services*, WT Docket No. 10-133, June 27, 2011, accessed Nov. 30, 2012, http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-11-103A1.pdf, 6.

46 Federal Communications Commission, "Local Telephone Competition: Status as of December 31, 2010," table 18.

47 Blumberg and Luke, table 2.

48 Federal Communications Commission, "Local Telephone Competition: Status as of December 31, 2010," table 11.

49 Note, though, that there should be significant savings in fixed capital once PSTN voice services are completely discontinued, e.g. CO switches can be completely turned off and dismantled, and the expensive real estate that housed them can be repurposed.

possibly a number smaller than 1.29 (= 1/0.775).[50] In particular, values of $|\varepsilon|$ less than these critical figures will suggest that a PSTN price increase would be profitable, while greater values suggest that a PSTN price increase would be unprofitable.

Note that ε is the price elasticity of demand for PSTN voice services, and that Equation (5) demonstrates that the PSTN-specific elasticity is always larger (in absolute value) than ε_m, the total voice market price elasticity of demand.[51]

Historically, $|\varepsilon_m|$ has been viewed to be a very small number: around 0.022 or less.[52] Note, however, that these measurements date from an era when there were few alternatives to voice services for real time or near-real time communications. Over the past twenty years, numerous alternatives have arisen. These include e-mail, instant messaging, and SMS texting. Thus, it is reasonable to expect that the market demand for voice services has become a bit more elastic in recent years. As a result, let's assume that $|\varepsilon_m|$ now equals 0.10 – five to ten times higher than it was in 2000. Turn now to σ, the price elasticity of supply from non-PSTN voice competitors. Simply stated, this figure is the percentage change in output from these competitors in response to a given percentage change in the price they receive. Over the past five years, the total percent growth in wireless lines has been about 45% and the total percent growth in wireless minutes has been 50%. Meanwhile, total growth in VoIP lines over just the last two years has been nearly 50%.[53] Thus it is safe to say that total percentage growth in non-PSTN services has exceeded 45% over the past five years. Over this same time span, nominal prices for telephone service increased by 7.9% and real prices declined by 3.4%.[54] Therefore, σ exceeds 5.7 (= 45%/7.9%) on a nominal basis and is undefined (but presumed in actuality to be even larger) on a real basis because these providers increased their output even in the face of price declines.

Given these parameter values for ε_m and σ, and a PSTN share of the voice market s that is only 40% on a lines basis and 26% on a minutes basis, Equation (5) suggests that $|\varepsilon|$ ranges between 8.8 and 16.6. Note that both of these figures are comfortably above the critical figures of 1.5625 to 1.29 necessary to ensure that the sign of E is negative, thus deregulated PSTN voice providers have no profit incentive to raise their prices.

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[50] If we assumed, less favorably, that $\frac{C}{R} < 1.00$, then the critical figures for $|\varepsilon|$ would be 1.67 (assuming $\tau < 0.40$) or 1.33 (assuming $\tau < 0.25$).

[51] The logic of this is clear. If the price of PSTN voice services rises, customers will shift to non-PSTN voice services before they abandon voice services completely. Thus, demand for voice services from the PSTN segment of the voice services industry will always be more elastic than demand for voice services from the market as a whole.

[52] Garbacz and Thompson find local telephone demand elasticity to be 0.006 to 0.011. Christopher Garbacz, and Herbert G. Thompson, Jr. "Estimating Telephone Demand with State Decennial Census Data from 1970-1990: Update with 2000 Data," *Journal of Regulatory Economics* 24, no. 3 (2003): 373-378. Ackerberg et al. find this elasticity to be between 0.016 and 0.0219 using data from the 2000 vintage for low-income subscribers. Daniel A. Ackerberg, Michael H. Riordan, Gregory L. Rosston, and Bradley S. Wimmer, "Low-Income Demand for Local Telephone Service: Effects of Lifeline and Linkup," white paper, May 2011, accessed Nov. 30, 2012, http://www.columbia.edu/~mhr21/papers/ARRW.pdf.

[53] Note that this excludes VoIP growth related to non-interconnected services such as Skype.

[54] United States Department of Labor, Bureau of Labor Statistics, "How the Consumer Price Index Measures Price Change for Telephone Services," June 19, 2012, accessed Nov. 30, 2012, http://www.bls.gov/cpi/cpifactc.htm.

WHAT REGULATIONS SHOULD REMAIN?

Given that competitive forces seem to be well capable of governing the economic conditions under which voice services are provided, the question remains as to whether there are other regulatory obligations that currently pertain only to PSTN voice services (particularly ILEC-provided PSTN voice services) that also should be reformed. Such reforms could either be in the form of complete elimination, or of widening the applicability of these regulations to all forms of voice services – thus making these regulations more technology-neutral. Whether and how a particular regulation should be reformed will depend on whether its purpose is obviated (or, perhaps, exacerbated) by economic competition. To make this evaluation, it is useful to classify nonprice-related regulations into several buckets.

Pricing and Financial Accounting

Incumbent PSTN voice carriers are required to follow specific protocols for developing and limiting their pricing. These may include regulations defining their cost accounting processes (Part 32), regulations separating costs between state/interstate political and regulated/nonregulated jurisdictions (Parts 36 and 64), and regulations defining allowed returns and prices (Part 61, Part 69, and Section 254 rate-averaging).[55] These regulations are imposed on no other providers of voice services. Given that no economic market power remains for PSTN voice services, let alone incumbent-provided PSTN voice services, it appears that all of these regulations can be retired.

Customer Service and Transparency

The FCC imposes a substantial number of regulations addressing how PSTN voice service shall be structured and presented to customers. Examples include specifications for how services are described, marketed, and billed (e.g. slamming, cramming, directory assistance, pay-per-call, disclosure of rates, terms and conditions, handling of customer complaints, do-not-call lists, use of customer proprietary network information [CPNI], etc.). While some of these regulations may also apply to competing wireless or VoIP voice services, many do not. Further, certain of these requirements (e.g. those concerning primary interexchange carrier [PIC] changes/freezes, win-back or retention marketing, and CPNI) seem inimical with competitive markets. Thus, it would be beneficial if such requirements were jettisoned and if the remaining regulations (to the extent they are viewed as necessary to protect customers from inappropriate actions by voice carriers) were applied uniformly across all providers of voice services.

Network Operations, Numbering, and Reliability

How voice networks are deployed and operated is the subject of a variety of FCC directives. Examples include the establishment of demarcations between carrier networks and customer-provided equipment (CPE), requirements to allow and price attachments to poles, access to multi-

[55] While certain of these regulations have been relaxed on certain classes of PSTN voice carriers, all of the mentioned regulations remain intact for at least a subset of PSTN carriers. See Code of Federal Regulations, 47 CFR §§ 32, 36, 54, 61, 64, 69.

tenant buildings, and LATA boundaries for interconnection. There are also regulations specifying how telephone numbers are allocated and used, and regulations covering standards for the provision of network power, disruption, and reliability reporting. Of these different types of requirements, only those related to numbering are generally applied uniformly. Regulations associated with network operations and reliability are mixed in their application to non-PSTN voice carriers. As with regulations associated with customer service and transparency, non-uniformly applied network regulations should be jettisoned if competitive markets render them inappropriate (e.g. access to facilities, demarcation, LATA, etc.) or applied uniformly if their need is believed to remain without regard to the competitive status of the market (e.g. numbering, cybersecurity standards, or reporting).

Public Safety

These requirements relate to items like E911 access, adherence to the Communications Assistance to Law Enforcement Act (CALEA), etc. Such requirements are generally applied without regard to the competitive or technological status of the voice provider, thus no changes would be indicated.

Universal Service and Disability Access

There are three sides to universal service regulation: being required to offer it, being required to fund it, and being allowed to receive funds from it. Historically, only PSTN voice carriers have been required to offer universal service and/or to be uncompensated carriers-of-last-resort (COLRs). Such discriminatory requirements are not appropriate in a competitive voice market and should be lifted from PSTN carriers, possibly to be replaced by compensated nondiscriminatory obligations on all voice service providers. While certain types of carriers historically have been prohibited from receiving such universal service support, the FCC is already in the process of lifting these restrictions.[56] Although these new rules appear to be somewhat nondiscriminatory in requiring funding from most (but not all) voice carriers, it is increasingly evident that voice service revenues should not be the sole source of funding support for these obligations. Similarly with disability access obligations: generally these are applied to most but not all providers.

Financial and Operational Reporting

PSTN voice carriers, and in particular incumbent PSTN carriers, face a myriad of reporting requirements relative to their finances and operating performance. These may include reports describing their revenues, their costs, and their operational performance. While non-incumbent voice providers are required to report their revenues and line counts (Forms 499 and 477), they generally face no further burdens. Incumbent PSTN providers should face no greater reporting obligations.

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[56] See Federal Communications Commission, *In the Matter of Connect America Fund and Developing a Unified Intercarrier Compensation Regime; et al.*, ¶¶ 62-63.

Competitive Access and Interconnection

Incumbent PSTN carriers have uniquely strong regulatory obligations to provide interconnection and competitive access to their voice networks. While all PSTN carriers are required to interconnect and allow resale of their services, only incumbents must also follow strict rules regarding the pricing of interconnection and resale, and in addition must allow competitors to purchase on an unbundled basis individual elements of their voice networks and to collocate equipment in their central offices. Further, incumbents are also required to provide competitors with advance notice of any changes to their networks and to ensure dialing parity. Given that unregulated IP networks appear to provide reasonable opportunities to interconnect on a commercial basis and that PSTN voice providers have no significant remaining market power, all of these types of requirements now appear to be superfluous.

Establishment and Withdrawal of Service

PSTN voice providers generally must receive advance regulatory approval to establish service as well as to withdraw service.[57] Given the variety of alternative providers generally competing to offer voice services to customers, none of these regulations appear necessary to promote public welfare.

The new touchstone upon which regulators should determine whether there is a continuing need for regulation should be whether there is some market failure or information impactedness that prevents customers from adequately expressing their preferences or whether there is an overriding government interest in requiring the industry to address its concerns over their customers' concerns. Unless a regulation meets one of these criteria, it should be eliminated; and if it does meet one of these criteria, it should be applied universally – and not selectively – to particular voice providers or technologies.

CONCLUSION

The foregoing analysis suggests that current supply and demand structures in voice services are such that PSTN voice providers retain no economic market power that would give them an incentive to impose a general price increase if they obtained further deregulation. To the extent that certain dwindling pockets of customers might have fewer alternative sources of voice service supply, policymakers need to consider whether their past regulatory practices have impeded competition to serve these customers. But regardless of the cause, it is almost certain that the most efficient way to address these customers' needs is directly through mechanisms such as universal service subsidies or relaxation of prior regulatory practices – rather than by maintaining current levels of PSTN voice regulation.

[57] Such requirements remain at the federal level in the U.S. There are, however, several states such as Alabama, Arkansas, Florida, Georgia, Mississippi, and North Carolina that have eliminated state requirements for ILEC suspension of service.

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ATTACHMENT 3

Demand in a Portfolio-Choice Environment: The Evolution of Telecommunications

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Abstract

We explore the pattern and evolution of the rapidly changing landscape of consumers' wired and wireless telecommunications choices with a model that extends the traditional (node-to-node) demand structure. We then empirically estimate a consumer choice model using household-level observations from 2003-2010. Households that are more affiliated with their domicile are more prone toward wireline services while more "on the go" households are more attracted to wireless telephony. The estimations indicate that subscription to wireline and wireless telephony are substitutes rather than complements. Finally, the quality convergence in wireless and wireline services has contributed significantly to shifts in consumers' telephone portfolios.

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1 Introduction

The emergence and rapid proliferation of wireless telephony and broadband service have introduced the most dramatic transformations in the telecommunication industry since the invention of the telephone in 1876. When Ameritech first introduced cellular service in the United States in 1983, however, few would have imagined its explosive growth potential. After all, the first wireless phones were large, weighing over two pounds each, and airtime prices were nearly $1 per minute.[1] Yet by 2012, the technology had improved significantly and the prices of wireless handsets and subscription services had fallen dramatically. The result: over 300 million wireless subscribers in the U.S. alone and roughly 6 billion wireless subscribers worldwide.[2] Over 30 percent of all U.S. households today are wireless-only.[3]

The rapid pace of consumer demand, technology and public policy changes in this industry has raised a number of important questions that economists have only recently begun to address. Prominent among these questions is how the presence of wireless telephony affects households' choices as they seek to have their communications needs met. Insights into this question promise, in turn, to shed light on a number of current economic policy questions, including whether wireline and wireless services are better described as complements or substitutes, whether traditional public policy efforts to promote wireline subscription to the public switched network are necessary in light of the rapid wireless services adoption, and whether competition between wireline and wireless platforms is sufficient to warrant a "light-handed" approach to industry regulation. Additionally, the emergence of wireless technologies also raises broader questions regarding the potential for improved efficiencies in specific industries, such as health care, education, insurance, agriculture and fishing, as well as to the broader economy.[4]

Two threads of economic research have emerged which provide some assistance in addressing the issue of household telephony choices in an environment that includes wireline and wireless options. The first is a rich literature on the demand for wireline telecommunications.[5] The second is a more recent literature on the diffusion of wireless telephony.[6] While both research threads are informative, neither captures the rich evolution of consumers' decisions regarding their telecommunications portfolios over the past decade. In particular, given the dramatic evolution of wireline and wireless services, natural questions arise regarding the economic motivations driving adoption when consumers now have multiple options to satisfy their communications needs, including wireline service only, wireless service only, both wireline and wireless services, and neither wireline nor wireless service.

[1] Mayo and Woroch (2010).

[2] International Telecommunication Union (2012).

[3] See Blumberg and Luke (2011). Following their terminology, we refer to "wireless" as what alternatively is termed "mobile", "cell", or "cellular" service.

[4] For industry-based studies of the impact of advanced telecommunications, see, e.g., Brown and Goolsbee (2002), Jensen (2007) and Aker (2010). See Röller and Waverman (2001) for a study of the macroeconomic consequences of the deployment of advanced telecommunications.

[5] For a detailed review, see Taylor (2002).

[6] Vogelsang (2010) provides a thorough review of the diffusion of wireless telephony, including studies using microdata from the early 2000s that seek to estimate evidence of consumer substitution across fixed (wired) and mobile (wireless) services. See, e.g., Rodini, Ward and Woroch (2003) and Ward and Woroch (2010). For a literature survey of economic issues related to the wireless telephone industry, see Gans, King and Wright (2005).

In this paper, we take a step toward understanding the evolution of telecommunications demand in the context of an environment in which consumers face a portfolio-choice. We do so by first developing a simple model of household choice for alternative platforms that satisfy their communications needs. One alternative is a high quality wireline platform that provides telecommunications services between wired nodes, but is incapable of providing communications for consumers who are not physically located at such nodes. Another choice is (initially) a lower quality wireless platform, but offers consumers the ability to communicate while away from the wired nodes. Other household choices include the selection of both platforms or neither platform. Our model provides insights into the household and network characteristics that are likely to arise as key determinants of the choices that households make regarding how to satisfy their communications needs. We also explore conceptually the implications and interpretations of consumer patterns of substitution across platforms in the face of alternative prices. This approach allows us to frame an empirical analysis that explores both non-price and price determinants of demand, including the substitutability or complementarity of wireline and wireless services.

Given this model, we then draw upon a large and unique survey of household-level communications platform choices over 2003-2010 to empirically model households' decisions to adopt wireline services, wireless services, both services, or neither service. The estimations provide consistent support for the conceptual framework. In particular, households whose characteristics indicate spatial mobility of household members are significantly more likely to gravitate toward portfolio choices that include wireless telephone service. And conversely, households whose characteristics signify greater attached to their homes are more attracted to wireline telephone service. Our empirical analysis also provides strong evidence that wireless telephony has become a close substitute for wireline telephony over the 2003-2010 period.

2 A Model of Consumer Choice in a Wired and Wireless Environment

2.1 Substitution Patterns: Nonprice Considerations

Consumers' demand for telecommunications services is a consequence of the desire both to be able to transfer information (i.e., voice, data or video) to others and to be able to receive information from others when sufficiently spatially separated to make direct communications difficult. Historically, telecommunications has been available only at fixed (wireline) nodes, so telephone calls from one consumer to another were characterized by exact physical locations. Within this context, models of telephony demand emerged in the 1970s. Over time these models have sought, for example, to capture the essence of network externalities [e.g., Rohlfs (1974)], to model consumer demand in the presence of multiple nonlinear pricing options [e.g., Train, McFadden and Ben-Akiva (1987)], and to model the role that local and long-distance service boundaries and pricing play on telecommunications demand [e.g., Martins-Filho and Mayo (1993)].

While advancing understanding of the demand for traditional telephone services, these models have not typically allowed for consumer preferences to reflect a desire (or an ability) to communicate away from fixed nodes. That is, communications demand was driven by the utility of a consumer i, located at node N_i, to communicate with another consumer j, $j = 1 \ldots m$, located at N_j, by either making or receiving telephone calls between i and j.[7] The emergence of wireless telephony, however, provides the opportunity for a broader description of consumer demand. In particular, while consumers may retain the demand for N_i to N_j communications, they may also gain utility from being able to reach other consumers who are not at a wireline node. Similarly, a consumer i may also gain utility from the ability of another consumer j to reach her while she is away from her node.[8]

Thus, if we let N_iN_j represent calls (or the prospect of calls) between consumers i and j that originate at N_i, the utility of i in a wireline-only world can be fully characterized by:

$$u_i = \sum_{j=1}^{m} u(N_iN_j) + \sum_{j=1}^{m} u(N_jN_i). \tag{1}$$

Allowing for the possibility of wireless communications, we can now represent a consumer i's utility from telecommunications services more fully by:

$$u_i = \sum_{j=1}^{m} u(N_iN_j) + \sum_{j=1}^{m} u(N_jN_i) + \sum_{j=1}^{m} u(N_iW_j) + \sum_{j=1}^{m} u(W_iN_j) + \sum_{j=1}^{m} u(W_iW_j)$$

$$+ \sum_{j=1}^{m} u(N_jW_i) + \sum_{j=1}^{m} u(W_jN_i) + \sum_{j=1}^{m} u(W_jW_i)^{9} \tag{2}$$

where the Ws represent communication using wireless technologies.

Two features of wireless services point toward a more nuanced specification of eq. (2). First, while in theory wireless telephony may provide ubiquitous calling, in practice wireless networks may not be sufficiently developed to provide communications services throughout a consumer's relevant region.[10] Thus, if we let λ, $0 \leq \lambda \leq 1$, represent the proportion of a region served by wireless providers, we can more accurately represent eq. (2) by discounting the utility afforded from wireless calling to and from areas in which wireless coverage does not exist. Second, provided that coverage does exist, the wireless transmission quality may be lower than that of wireline telephony. This lower quality may be due to either inadequate infrastructure development in a nascent (or even mature) wireless network or physical challenges caused by manmade or natural topography. Such reduced transmission quality may

[7] Of course, households also may place value on the option to make or receive calls between nodes.

[8] It is also possible that wireless service may not only afford mobility, but also enhance communications services breadth. This would happen, for instance, if wireline broadband service was unavailable while broadband service was available via wireless technologies.

[9] We follow the convention first established by Rohlfs (1974, p. 20) in assuming that interrelationships between the demand for telecommunications services and other non-communications services purchased by consumers can be ignored. Similarly, we eschew (for the moment) a discussion of the effects of pricing on consumption patterns. We return to this below, however, in Section 2.2.

[10] The size of the relevant region depends on the geographic scope of a consumer's calling patterns. In some cases, virtually all of a consumer's desired calling is within a small geographic area. In other cases, however, it may be quite large. The potential lack of ubiquity regarding wireless networks holds regardless.

be in the form of increased dropped calls, slower data transmission, or the like. Thus, letting δ, $0 \leq \delta \leq 1$, be the quality discount of wireless service relative to wireline service, we then specify:

$$W_i^* = (1-\lambda)(1-\delta)W_i \text{ and}$$

$$W_j^* = (1-\lambda)(1-\delta)W_j \tag{3}$$

where W_i^* and W_j^* represent the ubiquity- and quality-adjusted level of wireless services available to consumers i and j, respectively. Substituting eq.(3) into eq. (2) gives:

$$u_i = \sum_{j=1}^{m} u(N_iN_j) + \sum_{j=1}^{m} u(N_jN_i) + \sum_{j=1}^{m} u(N_iW_j^*) + \sum_{j=1}^{m} u(W_i^*N_j) + \sum_{j=1}^{m} u(W_i^*W_j^*)$$

$$+ \sum_{j=1}^{m} u(N_jW_i^*) + \sum_{j=1}^{m} u(W_j^*N_i) + \sum_{j=1}^{m} u(W_j^*W_i^*) \tag{4}$$

For consumer i, the incremental utility associated with subscribing to wireless service depends on: (a) whether consumer i has a demand to communicate with other consumers ($j = 1 \ldots m$) while i is away from his node; (b) the probability of consumer i being at his node at the time that i to j communications is desired;[11] (c) the ubiquity of wireless coverage; (d) the quality of wireless service relative to wireline service; and (e) the utility to consumer i of being reachable by the other consumers j when i is away from his node.

2.2 Substitution Patterns: Price Considerations

Turning to the effects of pricing on consumer substitution, our goal is to determine the economic relationship between wireline services and wireless services. In particular, we seek to determine whether access to wireless service serves as a complement to, or substitute for, access to wireline service. As such, the central questions are ones of consumers' responsiveness to pricing changes in nodal wireline services (N) and wireless services (W). Wireline telephone service is typically priced as a lump-sum monthly payment with a zero marginal price per minute of use.[12] Similarly, wireless telephone service pricing plans most typically

[11] We abstract away from the potential for households to gain utility from asynchronous communications such as voicemail, email, video and file transmissions that are not received simultaneously. We also implicitly assume that the wireless device is "turned on" while individuals are away from their nodes rather than receiving a message and subsequently returning the call at a later time. Incorporating these considerations would involve discounting the utility from fully contemporaneous communications without any harm to the basic approach we adopt here. We also abstract away from the distinction between the called party being at her node from the called party being at any wired node. In our empirical analysis, however, we account separately for these possibilities.

[12] We set aside here the rather *de minimis* portion of consumers who subscribe to local wireline telephone service on a usage basis.

incorporate allowances for a number of minutes that have a zero marginal price as long as the consumer's usage does not exceed the allowance. In these circumstance, the consumer's subscription will depend on a comparison of the monthly subscription fees of wireline and wireless services to the amount of consumer surplus enjoyed from wireline and wireless usage, after consumers have paid their respective monthly fixed charges.[13]

Across the various options for consumers to satisfy their telecommunications needs, let P_{i,Ψ_k} represent the monthly access price paid by consumer i for consumption bundle Ψ_k, $k = 0 \ldots 3$. With the introduction of a wireless service option, consumers face a portfolio choice:

(1) The household chooses to not subscribe to either wireline or wireless service - Ψ_0;

(2) The household chooses to subscribe to only wireline service - Ψ_1;

(3) The household chooses to subscribe to both wireline and wireless service - Ψ_2; or

(4) The household chooses to subscribe to only wireless service - Ψ_3.

Consumer decisions among these choices will be driven by a consideration of the utility associated with these four mutually exclusive options and the relative prices imposed by each. If we let M_i represent household income, individual consumers can be seen to choose Ψ_k over alternatives Ψ_z ($\Psi_z \neq \Psi_k$) whenever:

$$u_i(\Psi_k; M - P_{i,\Psi_k}) > u_i(\Psi_z; M - P_{i,\Psi_z}), \text{for all } z. \tag{5}$$

Normalizing consumers' utility by the "outside good" ("off-the grid") option, and letting utility depend both on a deterministic component μ and unobservable variations in utilities ν_N and ν_W that vary across decision-making units, we can specify:

$$\begin{aligned} &u_0 = 0, \text{the utility derived when the household chooses to remain "off the grid";} \\ &u_N = \mu_N + \nu_N = X_N\beta_N - \alpha P_N + \nu_N, \text{the utility from wireline-only subscription;} \\ &u_W = \mu_W + \nu_W = X_W\beta_W - \alpha P_W + \nu_W, \text{the utility from wireless-only subscription;} \\ &u_{NW} = u_N + u_W + \Gamma = \mu_N + \mu_W + \nu_N + \nu_W + \Gamma, \text{the utility from wireline and} \\ &\text{and wireless subscription;} \end{aligned} \tag{6}$$

where X is a standard set of explanatory variables, α and β are vectors of parameters to be estimated and Γ is the incremental utility from consuming both services rather than either one separately. Following Gentzkow (2007), we specify:

$$\Gamma = (u_{NW} - u_W) - (u_N - u_0) \tag{7}$$

which measures the extent to which the consumer enjoys added utility of nodal wireline service if wireless service is also consumed. In this model, the utility associated with subscribing to both services is therefore not the simple sum of utility for each one. When $\Gamma > 0$, there is a "bonus" utility from subscribing to both services, and so indicates a complementarity from

[13]See Taylor (2002).

joint consumption. When $\Gamma < 0$, some utility is lost relative to the simple sum. Provided there is still a net gain from adding the second service, it is consistent with substitutability of the services. For these reasons, we follow Gentzkow (2007) and state that wireline service is a *substitute* for mobile service if and only if $\Gamma < 0$. Similarly, wireline service is a *complement* to wireless service if and only if $\Gamma > 0$. If $\Gamma = 0$, the services are independent.[14]

For any given decision-making unit, let π_j, $j = N, W$ represent the probability of choosing either nodal wireline service N but not wireless service or choosing wireless service W but not nodal wireline service, and let π_{NW} be the probability of choosing both wireline and wireless service. The probability of choosing no service π_0 is linearly dependent and can be determined by examination of the other probabilities. Assuming that consumers maximize utility, the probability that a consumer will choose one of the four options is:

$$\pi_j = \int_{\vec{\nu}} \mathbf{I}\{u_j > u_0, u_j > u_k, u_j > u_{NW}\} dF(\vec{\nu}) - \text{the probability of the } j^{th} \text{ service alone}$$

$$\text{where} j \neq k,$$

$$\pi_{NW} = \int_{\vec{\nu}} \mathbf{I}\{u_{NW} > u_0, u_{NW} > u_N, u_{NW} > u_W\} dF(\vec{\nu}) - \text{the probability of both services,}$$

$$\pi_0 = \int_{\vec{\nu}} \mathbf{I}\{u_0 > u_N, u_0 > u_W, u_0 > u_{NW}\} dF(\vec{\nu}) - \text{the probability of neither service.} \quad (8)$$

To generate insights into the degree of substitutability or complementarity of consumers' demand for wireline and wireless services we explore how the probabilities in equation (8) are affected by variation in the prices of wireline and wireless services. In this regard, we focus on the (subscription-based) quantities of wireline services ($Q_N = \pi_N + \pi_{NW}$) and wireless services ($Q_W = \pi_W + \pi_{NW}$). We can then define the economic relationship between nodal wireline and wireless services as:

$$\frac{\partial Q_W}{\partial P_N} = 0 - \text{Wireline and wireless services are independent,}$$

$$\frac{\partial Q_W}{\partial P_N} > 0 - \text{Wireline and wireless services are substitutes,}$$

$$\frac{\partial Q_W}{\partial P_N} < 0 - \text{Wireline and wireless services are complements.} \quad (9)$$

Figure 1 shows this relationship visually and demonstrates the critical role played by Γ. This figure depicts the demands for wireline and wireless services in utility space.[15] As driven by the utilities depicted in eq. (6), consumers choose among the four depicted portfolio choices. Consider panel (a), which depicts the situation in which wireline and wireless services are independent. In this case, an increase in wireline service price will cause a marginal consumer (shown as j) to switch from purchasing the NW bundle to purchase

[14]For a formal proof, see Gentzkow (2007).

[15]Figure 1 is an adaptation of Gentzkow (2007) to the case of nodal wireline and wireless services.

Wonly.[16] It also results in some marginal consumers (shown as k) to switch from N only to the outside option of no telephone service. Notice, however, that the change in the price of N has no effect on the demand for (i.e., subscription to) W, hence the independence of the services.

Next consider panel (b), which depicts the situation in which wireline and wireless services are complements ($\Gamma > 0$). Given equation (6), the boundaries between consumers' portfolio choices are shown as heavier-shaded lines. Given a price increase in N, marginal customers designated by j and k react as described previously. But there are now other marginal consumers designated as o for whom an increase in the price of N is met with a switch from consuming both services to consuming neither service. In this case, the decrease in π_{NW} exceeds the gain in π_W. Thus, $\frac{\partial Q_W}{\partial P_N} < 0$ and $\Gamma > 0$ keynotes complementarity between N and W.

Finally, consider panel (c), which depicts the situation in which wireline and wireless services are substitutes ($\Gamma < 0$). In this case, a price increase in N leads to three sorts of switching. Some consumers of N, such as k, shift to consume neither N or W. Other consumers of N, such as j, who previously consumed both services now consume W only. Still other consumers of N, such as o, who previously consumed only N switch to W only. In this case, the decrease in π_{NW} will be smaller than the increase in π_W, so $\frac{\partial Q_W}{\partial P_N} > 0$ and the services are considered substitutes.

3 Empirical Setting and Data

To estimate consumer decisions regarding their portfolio of telecommunications choices, we begin with a unique micro-level database assembled by the National Center for Health Statistics (NCHS), which operates as part of the Centers for Disease Control (CDC). NCHS administers the National Health Interview Survey (NHIS) annually as the principal source of information on the health of the U.S. civilian non-institutionalized population. Interviewers visit 35,000-40,000 households and collect data on roughly 75,000-100,000 individuals annually.[17] Our data are over the 2003-2010 period, with nearly 25,000 households surveyed each year. As shown in Appendix A, NHIS-surveyed households generally track U.S. population demographic characteristics closely.[18] Households are queried in this survey regarding their subscription to wireline and wireless telephone services. Of particular interest are questions about whether the household has no telephone, a wireline telephone only, a wireless telephone only, or a wireline telephone and (one or more) wireless telephones.

While the public use portion of the data are helpful, the specific locations of surveyed households remain confidential. By application to and approval from the NCHS, we gained access to the confidential household data maintained at a secure facility in Hyattsville, Maryland. Using household-level geocodes, we are able to link the NHIS survey data to

[16]We consider here the case of a price change for wireline service. A similar construction for wireless price changes is straightforward and, therefore, omitted.

[17]For a detailed overview, see *http://www.cdc.gov/nchs/nhis/about_nhis.htm*.

[18]To provide additional assurance that our empirical analysis is not unduly affected by the sampling methods of the NCHS, we employ the sampling weights established by CDC as a robustness check to the estimations we report in Section 4. The results we report are substantively unchanged by the application of the sample weights.

location-specific data from several public data sources, including the Federal Communications Commission, the United States Census Bureau, the United States Bureau of Labor Statistics and the United States Department of Agriculture. We describe these other data sources below.

3.1 Data Overview and Summary Statistics

The combined dataset for empirical analysis includes 189,616 observations over the 2003-2010 period. Table 1 provides summary statistics on households' subscription to wireline and wireless services, while Figure 2 shows the evolution of households' portfolio choices over time.[19] Several characteristics of households' portfolio choices are noteworthy. First, the proportion of households not subscribed to any telephony service is small (about one percent) and remains so throughout the sample period. Second, the proportion of households subscribed exclusively to wireline service decreased dramatically from roughly 49 percent in 2003 to just over 12 percent in 2010. Third, the corresponding share of households subscribing exclusively to wireless telephony grew over the sample period from roughly four percent in 2003 to approximately 31 percent in 2010. Finally, households subscribing to both services grew at the beginning of the sample period from 46 percent to a peak of 61 percent in 2007 and has subsequently declined to 55 percent in 2010.

The data also reveal important subscription pattern differences by household income. Figure 3 shows the evolution of telephone portfolio choices for households that are below the poverty thresholds in each year. By 2010, the share of poor households subscribing to wireless services only (around 44 percent) was significantly higher than the share of all households subscribing to wireless services only (around 31 percent). Similarly, by 2010 poor households subscribed in larger proportions to wireline service only (roughly 20 percent) in comparison to all households (roughly 12 percent).

Finally, the data point to important changes in telephone portfolio choices by household age. Figure 4 shows that the movement to wireless-only consumption has been particularly dramatic for young households (household members less than 31 years old) over the 2003-2010 period. In 2003, nearly 13 percent of young households subscribed exclusively to wireless services and over 85 percent subscribed to either wireline service only or both wireline and wireless services. But by 2010, over 70 percent of young households subscribed only to wireless service, while the share subscribing to wireline only had fallen to under four percent and the share subscribing to both services had fallen to roughly 23 percent.

3.2 Variables

Our effort to capture variations in observed household telephone portfolio choices focuses on four categories of variables. First, based on the Section 2.1 discussion, we include variables that are designed to capture the degree to which household members are affiliated more closely with their domicile (node), or alternatively are considered more mobile. Second, we incorporate measures of the respective prices of wireline and wireless telephone service, along with measures of household income. Third, we include measures that seek to capture

[19]The data shown in Figure 2 are unweighted. Weighted observations yield essential the same pattern as what is reported here.

the wireless telecommunications quality relative to the wireline network. Finally, we include measures to account for demographic characteristics of households. We provide a general overview of these variables below, but a more detailed set of variable definitions and sources is provided in Appendix B.

Nodal Variables Several variables are included to capture the degree to which household members are more (less) closely affiliated with their nodal domicile. Because older households typically spend a greater proportion of their time at home,[20] we include several age-related variables. We first account for whether the household includes a retired individual (*Retired Household*).[21] We next account for whether the household consists solely of individuals under age 31 (*Young Household*), between ages 31 and 45 (*Young-Middle Household*), between ages 45 and 64 (*Older-Middle Household*), or over age 64 (*Older Household*). We expect that older or retired households will be more closely affiliated with their node and will therefore be more prone to subscribe to wireline service than wireless service. Conversely, we expect that younger households will be attracted in greater proportions to wireless service, as it enhances their abilities to communicate while being "on the go". While more mobile lifestyles among younger households may be thought to create greater attraction to wireless telephony than older households, it is also possible that older consumers are leary of "new" technologies, and will remain loyal to wireline telephony longer than younger households. To account for this potential, we also account for whether an older household is also wealthy (*Wealthy Retired Household*). We expect that wealthier elderly households will be more mobile and less intimidated by new technologies, thereby enhancing wireless telephony subscription.

We also account for household nodal demographics by including measures of whether the household has children (*Children*) and whether any children are students (*Student*). Our expectation is that parents place high priority on "anywhere, anytime" communications with children and students, and will accordingly have enhanced demand for wireless services relative to households without children and students. At the same time, children and students create greater attachment to the family domicile, so we also expect that children and students will create a greater propensity for the household to subscribe to wireline service.

A unique feature of our data is that it includes measures of the health of household members. To take advantage of this information, we account for potential health-related impacts on households' telephone portfolio choices. In particular, we account for households that have a health-impaired youth (*Limited Youth*) or health-impaired adult (*Limited Adult*). Our expectation for the former is that such households have a greater demand for "anywhere, anytime" communication and will therefore be more inclined to include wireless telephony in their portfolio, while our expectation for the latter is that such households have a stronger nodal presence and corresponding need for wireline service.

We also account for the working status of the household via several variables. We first account for the ratio of household members employed outside the home (*Ratio Working*). We suggest that work-related matters take household members away from their domicile, making nodal wireline service less attractive and wireless service more attractive. We also

[20] Bureau of Labor Statistics (2011).

[21] We alternatively substituted this variable with one that accounted for whether the surveyed household included a member that draws Social Security benefits. There was virtually no change in the subsequent empirical results.

account for whether any household member is employed part-time *(Part-time Employed)*. Given the mobile nature of such households, we expect that part-time employment will be associated with an enhanced propensity to subscribe to wireless service. But a household member that is only employed part-time signals greater attachment to the domicile, and therefore likely enhances wireline service demand. We also account for whether a member of the household has self-identified as a housewife (*Housewife*) to examine whether this creates a greater nodal presence and, hence, attraction to wireline services.

Given the efficiency gains from the wider reach [c.f., Jensen(2007)] and the security benefits of mobile telephony in rural areas, we include a measure of the degree to which the household is located in more sparsely populated areas. In particular, we include a variable to capture the population density of the county within which the household resides (*Population Density*). We expect that for a given wireless infrastructure quality level, the propensity of rural households to subscribe to wireless telephony will be enhanced.

Finally, we account for domicile ownership using an indicator variable that differentiates between households that own their home versus rent (*Own House*). Our expectation is that ownership signals greater nodal attachment, with a corresponding increase in the propensity toward wireline telephony services.

Price and Income Variables Prices are at the heart of demand theory. Accordingly, we include measures of the individual prices of wireline and wireless services. To capture variations in wireline service prices, we begin with 2002 data on the basic flat monthly charges by wire center throughout the U.S.[22] Because the areas served by wire centers are not typically contiguous with county boundaries, we use population weights within individual wire centers to construct a weighted price by county for residential landline service throughout the U.S. To update these data for the larger sample period, we utilize the Federal Communication Commission's (FCC) "Reference Book of Rates, Price Indices, and Household Expenditures for Telephone Service" (Reference Book). In particular, the Reference Book reports the results of an annual survey of local monthly fixed telephone rates for 95 cities located throughout the U.S. The year-to-year values of Pearson correlations for prices in these cities are very high, averaging .96 across for the relevant time period, indicating that the principal source of wireline rate variation is captured by our spatial disaggregation of prices at the sample period beginning. Accordingly, *Wireline Price* is updated by the values of Consumer Price Index (CPI) for local exchange service for the 2003-2010 period.[23]

We also include the price of wireless telephone service subscription. While numerous wireless subscription plans exist, they most generally entail a flat rate charge for a "bucket" of minutes. For consumers whose usage levels remain within the purchased bucket, the price can be taken as the average monthly expenditure for the service. Data on the average monthly

[22]These data were graciously provided to us by Greg Rosston, Scott Savage and Bradley Wimmer. See Rosston, Savage and Wimmer (2008) for a detailed description of these data. While many local telephone companies offer local measured service in which customers pay a smaller monthly subscription charge and (after a call or minute allowance) pay a marginal charge per minute or call, industry sources report that the percentage of customers who avail themselves of this option is *de minimus*. Accordingly, we focus on consumers' choices based on variations in flat monthly rates. For a detailed study of the economics of such optional calling plans, see Miravete (2002).

[23]Robustness checks of our estimations that employed alternative price measures, such as measures of annual telephone CPI variations or CPI ratios for local and wireless telephone service, gave results that are very similar to those reported below.

revenue per user (including roaming charges and long distance toll calling) were provided to us by the Cellular Telephone and Internet Association (CTIA). We rely upon *Wireless Industry Indices*, a semi-annual survey conducted by CTIA of its member companies. In the survey, data were received by companies representing over 95 percent of all U.S. wireless subscribers, and are provided for the 2003-2010 period. While wireless prices are typically geographically invariant, state and local taxes impose spatial variations in the prices paid by consumers in different locales. To capture these variations, we incorporate state and local tax data provided by the Committee on State Taxation (COST). The data are derived from a series of studies conducted by COST, beginning in 1999 and repeated thereafter every three years (i.e., 2001, 2004, 2007 and 2010),[24] which report the prevailing state sales tax rate inclusive of general sales taxes. Local tax rates for each state were taken to be the average between those imposed in the largest city and the capital city. Federal taxes were reported separately. Any flat fees (e.g., 911, Universal Service Fund) were converted to percentages based on average monthly residential bills. In the first two reports, a single tax rate was provided that blended the state and local taxes applied to wireline local and long distance service, and mobile service. In later reports, taxes levied specifically on wireless service were reported separately. After incorporating state and local taxation variations, our measure of *Wireless Price* entails both spatial and inter-temporal dimensions over the relevant period.[25]

As is common in modern demand estimation, we consider the potential endogeneity of prices which in our case may most directly be thought to arise either from omission of relevant exogenous variables (or product characteristics) or from a causal feedback from observed demand on prices. In the case at hand, however, potential endogeneity concerns are tempered somewhat by two considerations. First, while a common source of endogeneity bias arises from the omission of relevant independent variables our model includes a wide-ranging and substantial number of explanatory variables that may reasonably be thought to collectively mitigate this source of endogeneity bias. Second, in our case feedback from observed demand on prices is mitigated by the particular price-setting mechanisms in the telecommunications industry. Specifically, wireline prices are determined by the regulatory process, which in large part is driven by supply-side (cost) considerations. This is most obviously true for traditional rate-base/rate-of-return regulation. It is also true, however, for price cap regulated firms, whose initial prices under price cap regulation were most often set by existing rates that were established under rate-of-return regulation. Subsequent price changes under price cap regulation have most typically been driven by changes in measures of general inflation (e.g., the CPI) and productivity changes, neither of which tends to be driven by market demand. Similarly, geographic variations in the price of wireless telephony are captured by variations in state and local tax differences, which are, again, not driven in any obvious way by market demand and are exogenous to the carriers. While these considerations ameliorate endogeneity concerns, as described below we nonetheless incorporate econometric methods based on Rivers and Vuong (1988) and Petrin and Train (2010) to assure the integrity of the parameter estimates and their corresponding statistics.

Drawing on the NHIS survey data, we also include measures of household income. Household income is categorized relative to an annual poverty threshold using four dichotomous

[24] See COST (2002, 2005) and Mackey (2008, 2011).

[25] We examined alternative constructions of the wireless price variable in the estimations reported below with essentially no substantive differences from those reported here.

variables. Household income below the poverty threshold (*Income1*), between one and two times the poverty threshold (*Income2*), between two and four times the poverty threshold (*Income3*), and more than four times the poverty threshold (*Income4*) are relevant categories.

Quality Variables Consistent with Section 2, we seek to capture both intertemporal and geographic variations in the relative quality of wireline and wireless services. Given that wireline service has been engineered to very high levels with *de minimis* blocking rates over our sample timeframe, we principally focus our efforts on quality variations in wireless services. Wireless service quality is affected by both topographical characteristics of the local calling area and the extent of infrastructure build out. We accordingly gathered data from the United States Geological Survey (USGS) on the extent to which the hilliness or mountainous nature of the local terrain may impair wireless communications quality. *Mountainous* is coded on a 21 point scale ranging from flat plains (1), to open low hills (13), and to high mountains (21). We also account for the provisional challenges of high quality wireless service poised by large bodies of water, and accordingly gathered data from the United States Department of Agriculture (USDA) to account for the percentage of the household's county that is water (*Water*).

As noted in Section 2, the quality of wireless services may suffer either from lack of geographic coverage or from insufficient capacity relative to demand (leading to dropped calls). Wireless industry infrastructure grew significantly over the 2003-2010 period, with corresponding increases in the ubiquity of coverage and call quality. To capture this variation, we include a measure of the number of cellsites deployed over time (*Cellsites*).[26]

Finally technological changes over the past decade have brought notable changes to the versatility (quality) of wireline telephony. Specifically, during the first decade of the 2000s, wireline broadband was increasingly deployed across the United States. Concurrent with the deployment of wireline broadband, providers of both telephone service and cable television began to introduce bundled offerings of these services with high-speed internet access.[27] To account for the potential demand effects of this increased versatility of the wired connections into households, we introduce *Wireline Broadband* which measures the proportion of households within a state over time that subscribe to wireline broadband services.[28]

[26]In the initial years of cellular telephony, cell sites were typically large stand-alone towers. Over time, providers have deployed quality and capacity enhancing antennae on large buildings, utility poles, water towers, etc., so that "towers" are no longer the most accurate measure of wireless capacity. We therefore draw upon a broader measure of cell sites made available by CTIA, which includes repeaters and other cell-extending devices but excludes microwave hops. Because the specific cell site locations are proprietary, we are unable to account for their geographic distribution. More recent deployments of wireless repeaters and antennae have greater coverage and capacity-enhancing characteristics than earlier vintage deployments. Also, wireless network capacity depends upon the "back-haul" capacity of cell sites which carry wireless traffic to the landline network. Increasingly, such "back-haul" is provided by high-capacity fiber which dramatically increases the ability of specific cell sites to handle larger volumes of voice, data and video traffic. Accordingly, our count of cell sites may underestimates the actual wireless capacity and quality increases over time.

[27]See Prince and Greenstein(2011)

[28]As a robustness check, we also drew directly on state-level data collected by the FCC over the 2008-2010 period on households that explicitly subscribed to wireline telephony as part of a bundled offering. The results of this alternative estimation are substantively invariant to those reported in Section 4 below, but involve sacrificing approximately 100,000 observations over the 2003-2007 period. Acordingly, we report our the estimations using *Wireline Broadband* in Section 4 below. In addition to our measure of wireline broad-

Demographic Variables Finally, the existing literature has identified a number of demographic characteristics that affect the likelihood that households subscribe to the "telephone" network. Riordan (2002) surveys this literature, and also independently verifies several demographic factors as contributing to households' propensities to subscribe to wireline service. We accordingly account for households' racial composition (*White, Black, Hispanic, Asian, Indian,* and *Chinese*), gender composition (*Female Household* and *Male Household*), and marital status (*Divorced*) as controls.

4 Estimation and Results

To provide a better understanding of consumer selection of a portfolio of available telecommunications services, we first report correlations between household's subscription to wireline and wireless telephone services. The second column of Table 2 reports tetrachoric correlations for households' decisions to adopt wireless and wireline services, respectively.[29] These estimates represent simple correlations between households' decisions to adopt wireline services with their decisions to adopt wireless services (1 if "yes", 0 if "no"). The pattern of correlations is consistently negative: households that adopt wireless telephony are less likely to adopt wireline telephony ($\rho = -.53$). The observed correlation is statistically significantly different from zero at the .01 level. As seen in Table 2, moreover, this pattern of negative correlations holds not only for the entire sample of surveyed households but also within each sample year and across all income levels, with the largest negative correlations occurring in the lowest income households. These negative correlations point toward the substitutability of wireline and wireless services.

We also report the partial correlation coefficients between wireline and wireless consumption, after controlling for a number of variables, including price, income, demographic variables (*Female/Male Household, Black, Divorced*), nodal variables (*Young Household, Young-Middle Household, Older-Middle Household, Children, Student, Own House, Ratio Working, Part-Time Employed, Retired Household, Wealthy Retired Household, Housewife, Limited Youth, Limited Adult, Unrelated Adults, Population Density)*, and wireless telephony quality variables (*Cellsites, Water, Mountainous, Wireline Broadband*). As seen in Column 3 of Table 2, the relationship between wireline and wireless consumption remains negative ($\rho = -.37$) and is highly statistically significant (even after controlling for several other correlates). The negative correlations again hold not only for the entire sample, but also for each year (with the exception of 2003) and income level. Again, the highest (negative) correlations observed are at the lowest income levels.

To parametrically investigate the empirical relationship between wireline and wireless subscriptions, we employ several discrete choice models. In any discrete choice analysis, the first step is to identify the available choice set. For our purposes, we assume that both wireline and wireless services are in the choice set, as is the option to not subscribe to any telephone service. As described in Section 2, we seek to understand the decisions of

band, we also sought to incorporate the potential demand effects of the emergence of wireless broadband. Unfortunately both the novelty of this phenomenon and inconsistent data collection methodologies by the FCC prohibited our use of such a measure in the estimations.

[29]Tetrachoric correlations are developed for two normally distributed variables that are both expressed as dichotomous. See Greene (2012), p. 741.

households to adopt (or not) either wireline or wireless service.

4.1 Bivariate Probit Model

We begin with a simple specification of household decisions to adopt (or not) wireline service and, potentially independently, adopt (or not) wireless service. The results of two probit regressions are reported in Model (a) of Table 3. The first regression estimates households' decisions to adopt wireline service, and the second regression estimates households' decisions to adopt wireless service. The key assumption underlying these probit estimations is that the decisions to adopt wireline service and wireless service are unrelated. To test this proposition, we allow for the possibility that the error structures across these equations are related.[30] We subsequently estimate a bivariate probit model which yokes the decision to adopt (or not) wireline and wireless, respectively, by accounting for common correlation (ρ) between the error structure in the two equations.[31] The estimation results are shown in Model (b) of Table 3, and reveal a strong negative correlation ($\rho = -.52$) in the error structure from the two equations that is significantly different from zero ($p = .01$). The hypothesis of independence of these decisions is therefore strongly rejected. The negative and statistically significant correlation indicates that positive random errors to the wireless subscription equation are associated with negative random errors to the wireline subscription equation. Because this association is, by construction, through the error structure no causality can be inferred. The results nevertheless strongly reject the hypothesis that these decisions are made independently by households and are suggestive of the wireline and wireless service substitutability.

To address the endogeneity issues mentioned above we implement Rivers and Vuong's (1988) two-stage conditional maximum likelihood (2SCML) estimation of the probit and bivariate probit models. In our case, the models are estimated using the following system of equations:

$$y_{it} = \sum_{j=N,W} \beta_j Price_{ijt} + \gamma_k X_{it} + \gamma_m Z_{ijt} + \epsilon_{it}, \tag{10}$$

$$\tilde{y}_{it} = \sum_{j=N,W} \kappa_j Price_{ijt} + \xi_k X_{it} + \xi_m Z_{ijt} + \tilde{\epsilon}_{it}, \tag{11}$$

where y_{it} and $\tilde{y}_{it}$ are dummy variables which equal to 1 if a household is subscribed to wireline (respectively, wireless) service at time t. $Price_{ijt}$ is the price faced by household i for service j at time t, X_{it} is an $k \times 1$ vector of demographic and nodal characteristics of household i in year t; Z_{ijt} is an $m \times 1$ vector of quality variables for household i for telephone option j ($j = N, W$) in year t and ϵ_{it} and $\tilde{\epsilon}_{it}$ are error terms.

Allowing for the potential endogeneity of $Price_{ijt}$, we first estimate

[30] See Greene (2012), p. 738.

[31] For an earlier application of the bivariate approach, see Augereau, Greenstein, Rysman (2006) who model Internet Service Providers' propensities to offer 56K service by utilizing an "X2" modem, a Flex modem, both or neither.

$$Price_{ijt} = \tau_k X_{it} + \tau_m Z'_{ijt} + v_{ijt}, \tag{12}$$

and recover the estimated residuals $\hat{v}_{ijt}$ from equation (12). This in turn allows us to estimate

$$y^{\star}_{it} = \sum_{j=N,W} \beta_j Price_{ijt} + \gamma_k X_{it} + \gamma_m Z_{ijt} + \sum_{j=N,W} \omega_j \hat{v}_{ijt} + \epsilon'_{it}, \tag{13}$$

$$\tilde{y}^{\star}_{it} = \sum_{j=N,W} \kappa_j Price_{ijt} + \xi_k X_{it} + \xi_m Z_{ijt} + \sum_{j=N,W} \theta_j \hat{v}_{ijt} + \tilde{\epsilon}'_{it}, \tag{14}$$

where Z'_{ijt} is an $(m+2) \times 1$ matrix which includes Z_{ijt} and two exclusion restrictions (*Telecommunications Wages, Mobile Penetration*).[32] Here $\beta_j, \omega_j, \kappa_j, \theta_j$, $j = N, W$ are parameters to be estimated, and τ_k, τ_m, γ_k, γ_m, ξ_k and ξ_m are vectors of parameters to be estimated. We assume that both (X_{it}, Z'_{ijt}, ϵ'_{it}, v_{ijt}) and (X_{it}, Z'_{ijt}, $\tilde{\epsilon}'_{it}$, v_{ijt}) are i.i.d; (v_{ijt}, ϵ'_{it}) and (v_{ijt}, $\tilde{\epsilon}'_{it}$) conditional on X_{it} and Z'_{ijt} have joint normal distributions with mean zero and finite positive definite covariance matrices.

In this case

$$y_{it} = \begin{cases} 1, & \text{if } y^{\star}_{it} > c, \\ 0, & \text{otherwise,} \end{cases} \tag{15}$$

and

$$\tilde{y}_{it} = \begin{cases} 1, & \text{if } \tilde{y}_{it}^{\star} > \tilde{c}, \\ 0, & \text{otherwise,} \end{cases} \tag{16}$$

where c and $\tilde{c}$ represent critical cutoff values that trigger household decisions to subscribe to wireline or wireless service, respectively.

For the bivariate probit model we allow correlation between ϵ'_{it} and $\tilde{\epsilon}'_{it}$ in the second step. That is,

$$\left(\begin{matrix} \epsilon'_{it} \\ \tilde{\epsilon}'_{it} \end{matrix} | Price_{ijt}, X_{it}, Z'_{ijt} \right) \sim N \left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix} \right]. \tag{17}$$

[32]Our exclusion restrictions seek to capture observable variables that may drive prices but which are not drawn from the demand side. Accordingly, we draw upon measures designed to capture cost variations (and hence indirectly prices) including a measure of telecommunications wages that varies by state and year and a measure of the density of mobile penetration by Economic Area which also varies by year.

where ρ captures the correlation in the errors across equations (13) and (14). The resulting estimates are consistent and asymptotically normally distributed. Our asymptotic covariance matrix of the 2SCML estimator is based on Rivers and Vuong (1988).[33]

After incorporating the interdependence of the wireline and wireless service subscription choice and accounting for endogeneity, the bivariate probit model provides considerable confidence regarding the overall model shown in Table 3, Model (b). A comparison of the portfolio choices predicted by the model and those actually chosen suggests a good fit. The model correctly predicts 68 and 97 percent of households' portfolio decisions in the wireline and wireless equations, respectively. The specific parameter estimates also provide insight into the determinants of households' portfolio choices for telephony service. The nodal variables provide strong support for the concepts advanced in Section 2 above. In particular, households that are more closely attached to their domicile (node) are more likely to subscribe to wireline service and less likely to subscribe to wireless service. For example, households with a retired household member are significantly more likely to subscribe to wireline service and significantly less likely to subscribe to a wireless service. Other age-related variables that characterize household members (e.g., *Young Household* and *Young-Middle Household*) similarly reflect the greater propensity of younger and more mobile households to subscribe to wireless service, and the corresponding decrease in the propensity of these households to subscribe to wireline telephone service.

Households with different levels of work-related attachments to their node are found to be attracted differentially to wireline and wireless services. In particular, *Ratio Working* increases the propensity to subscribe to wireless telephony and decreases the propensity to subscribe to wireline telephony. Households in which a member works part-time (*Part-Time Employed*) are more likely to subscribe to both wireline and wireless service, in comparison to other households. Households with a self-reported *Housewife* appear more more likely to subscribe to wireline service and less likely to subscribe to wireless service, though these results are statistically insignificant.

Households with a health-limited youth (*Limited Youth*) are no different than other households in their propensity to subscribe to wireline service, but as anticipated are significantly more likely to subscribe to wireless service than other households. By contrast, households with a health-limited adult *Limited Adult* are more likely to subscribe to wireline services and less likely to subscribe to wireless services than other households. Households with students (*Student*) have significantly higher propensities to subscribe to wireless telephony, while having significantly lower propensities to subscribe to wireline service. The estimations also reveal that, *ceteris paribus*, households in more rural areas have higher demands for wireless services in comparison to households in more urban areas. Finally, the estimations indicate that home ownership (*Own House*) is strongly associated with subscription to both wireline service and wireless service.

The price and income parameters are also revealing. Consistent with standard demand theory, *Wireline Price* and *Wireless Price* negatively [and statistically significantly *(p = .01)*] impact the demand for wireline and wireless service, respectively. Beyond the own-

[33]See, in particular, Rivers and Vuong (1988) equations 4.7 and 4.11. Matrices incompatibility prohibits computation of the covariance matrix for recursive bivariate probit model, discussed below, which includes an additional explanatory variable. Nevertheless we provided estimation results from the second step and these are largely consistent with those obtained in the other estimations.

price impact, however, the estimations also reveal that the cross-price effects are positive and highly statistically significant. Changes in the price of wireline service positively impact the demand for wireless service, while changes in the price of wireless services positively affect the propensity to subscribe to wireline service. The estimations indicate that consumers view wireline and wireless telephone subscriptions as substitutes. While the nonlinear nature of the estimations prevents simple interpretations of marginal effects (ME), they are estimable.[34] Specifically, recalling that $Q_n = \pi_N + \pi_{NW}$ and $Q_n = \pi_N + \pi_{NW}$, we estimate the marginal price effects $\frac{\partial Q_N}{\partial P_N}$, $\frac{\partial Q_W}{\partial P_W}$, $\frac{\partial Q_N}{\partial P_W}$ and $\frac{\partial Q_W}{\partial P_N}$. The results are presented in Table 4, and indicate that the own-marginal effects are both negative and statistically significant *(p=.01)*, while the cross-partial derivatives are both positive and highly significant *(p=.01)*. From equation (9), this latter result again indicates that wireline and wireless services display substitutable rather than complementary characteristics over the 2003-2010 period.

We also find (See Table 4) that *Income* is an important determinant to wireline and wireless subscription. In each case, income increments for those below the poverty threshold to higher levels increase subscription to both wireline and wireless services. The marginal effect of an income shift from the lowest to the highest category results in about a six percent increase in the likelihood of wireline service subscription *(p=.01)* and about a 26 percent increase in the likelihood of wireless service subscription *(p=.01)*.

The quality and diffusion of wireless service are also found to affect consumers' telephony portfolio decisions. *Cellsites* is positive and highly significant *(p=.01)*, indicating as expected that quality improvements associated with greater coverage increases wireless telephony subscription. Similarly, the diffusion of wireline broadband is seen to have enhanced the propensity to retain wireline telephone service and stem the move to wireless service. Finally, areas with more challenging topographies, such as mountains or large bodies of water, which reduce wireless service quality are found to reduce wireless subscription.

Among the most substantial changes in households' telephony portfolio over the 2003-2010 period, the shift away from "wireline-only" is perhaps the most dramatic. As Figure 2 indicates, approximately 50 percent of all U.S. households subscribed exclusively to wireline telephony in 2003. That percentage had fallen to 12 percent by 2010. To explore this phenomena in more detail, we bifurcate the sample into an early period (2003-2006) and a later period (2007-2010).[35] Specifically, we decompose the aggregate marginal effects: $-\frac{\partial \pi_N}{\partial P_N} = \frac{\partial \pi_W}{\partial P_N} + \frac{\partial \pi_{NW}}{\partial P_N} + \frac{\partial \pi_0}{\partial P_N}$. This decomposition permits us to see how the marginal reaction of consumers to relative prices has evolved over time. Table 5 shows the decomposition results of the total marginal substitution effect associated with a change in the price of wireline service. In the 2003-2006 period, there is relatively moderate substitution directly away from wireline services. During this period, only about one-half of the marginal substitution from wireline-only customers was the result of households becoming wireless-only, with the other half seemingly trying out wireless telephony but not dropping their wireline service. By the 2007-2010 period, however, the marginal impact on wireline only households was largely toward a wireless-only portfolio choice. That is, the dominant marginal effect to any elevation of wireline prices in the most recent period has been for households to "cut the

[34] In nonlinear models with single-index form conditional means, marginal effects are calculated using the formula $ME_j = \frac{\partial \pi_i}{\partial x_j} \times \beta_j$. In our case, marginal effects are calculated at mean values of independent variables. For the bivariate probit model, we calculate marginal effects for the following probabilities: $\pi_N, \pi_W, \pi_{NW}, \pi_0, \pi_{W|N}, \pi_{N|W}, \pi_N + \pi_{NW}, \pi_W + \pi_{NW}$. (Cameron and Trivedi (2010)).

[35] We find similar patterns emerge if alternative years are chosen for this bifurcation.

cord" and go wireless-only.

4.2 Robustness: Alternative Model Specifications

Recursive Bivariate Probit Model. Given the highly negative correlation across equations in the bivariate probit estimation, a natural extension is to model households' decisions jointly by explicitly conditioning wireline service decisions on wireless service decisions. To do so, we include *Wireless*, a variable indicating that the household has adopted at least one wireless telephone, as an independent variable in the *Wireline* equation. The resulting model is recursive and, thereby, does not suffer from the typical problems associated with incorporating a dependent variable as an explanatory variable in a multi-equation discrete choice model.[36] Model (c) of Table 3 provides the results, which indicate households that have chosen wireless service are significantly less likely ($p = .01$) to adopt wireline service. Moreover, the marginal impact of wireless service on the probability of wireline service subscription is large. In particular, wireless service subscription reduces the probability of wireline service subscription by 13.9 percent.[37] Even after accounting for the direct negative impact of wireless service subscription on the likelihood of wireline subscription, the recursive bivariate probit estimates yield the same substantive implications as those in the bivariate model presented in Model (b) of Table 3.

Alternative Specific Conditional Logit (ASC Logit) Model. To this point, we have permitted households' decisions to adopt wireless and wireline telephony to be related, but not part of a single household decision-making process. To allow for this possibility, we estimate an alternative specific conditional logit model.[38] This model is distinguished by two features. First, it envisions households making single decisions across the full portfolio of service alternatives. In particular, households choose simultaneously to have no service, wireline service, wireless service or both services. Second, unlike a simple multinomial logit model with measured variation in the characteristics across the decision-making units (viz., households), the ASC Logit model also incorporates measured variations in alternatives themselves. In our case, the ASC Logit model incorporates variations in household characteristics (e.g., age, income, mobility) as well as variations in specific telephone alternative characteristics from which households may choose (e.g., quality).

This estimation requires construction of a price array that households face as they consider the entire telephony portfolio. The price facing households that choose no telephone is zero, while the price facing households that subscribe to wireline only or to wireless only is the local wireline price and wireless price, respectively. Households considering subscription to both services face a price equal to the sum of the wireline and wireless services prices.[39]

To estimate telecommunications demand when the consumer simultaneously chooses across multiple options and where the endogeneity of prices may create inconsistent parameter estimates, we employ the control function approach devised by Petrin and Train

[36]See Greene (2012), p. 745.

[37]For purposes of this calculation, we evaluate the right-hand side variables at their mean values.

[38]See Cameron and Trivedi (2010).

[39]We cannot account for any discounts afforded through bundling of wireline and wireless prices, as these data are unavailable.

(2010). In particular, we assume that the utility obtained by household i from service j (j = "*No Phone*," "*Wireline Only*," "*Wireless Only*," or "*Both*") is specified by:

$$u_{ijt} = \alpha Price_{ijt} + \psi_k X_{it} + \psi_m Z_{ijt} + \epsilon_{1ijt} + \epsilon_{2ijt}, \tag{18}$$

where all variables have the same notation as described above in the Bivariate Probit Model section, α is a parameter to be estimated, ψ_k is $1 \times k$ vector of parameters to be estimated and ψ_m is $1 \times m$ vector of parameters to be estimated. The terms ϵ_{1ijt} and ϵ_{2ijt} represent the decomposition of the traditional error term into a control function (ϵ_{1ijt}) and a component (ϵ_{2ijt}) that is independent of $Price_{ijt}$. As with our bivariate probit estimations, we account for the potential endogeneity problem that arises with correlation between price and ϵ_{1ikt}. We do this in two steps. First, as in Rivers and Vuong (1988), we estimate an equation for the endogenous independent variable using ordinary least squares:

$$Price_{ijt} = \tau_k X_{it} + \tau_m Z'_{ijt} + v_{ijt}. \tag{19}$$

We assume that v_{ijt} and ϵ_{1ijt} are jointly normal and ϵ_{2ijt} is i.i.d. extreme value for all j. Residuals ($\hat{v}_{ijt}$) from the first stage are the used to estimate the control function in the second stage. Incorporating the control function, the utility function is:

$$u_{ijt} = \alpha Price_{ijt} + \psi_k X_{it} + \psi_m Z_{ijt} + \sum_{j=N,W} \lambda_j \hat{v}_{ijt} + \epsilon_{2ijt}, \tag{20}$$

where the λ_j are parameters to be estimated. The probability that household i chooses alternative j at time t is given by:

$$Pr(y_{it} = j) = \int \mathrm{I}(u_{ijt} > u_{ist}, \forall s \neq j) f(\epsilon_{2it}) d\epsilon_{2it}, \tag{21}$$

where y_{it} represents the choice of household i, $f(\cdot)$ is the density of ϵ_{2it} and $\mathrm{I}(\cdot)$ is the indicator function. We estimate this choice model using alternative specific logit estimation.[40]

Table 6 provides the results of the ASC Logit model, which are similar to those provided in the Bivariate Probit estimation of Table 3. The importance of both the household's nodal propensities as well as price and income are confirmed. The price that households face for their respective portfolio choice is negative and highly statistically significant, indicating that consumers are price sensitive across the various options as they consider their portfolio of telephone services. Similarly, the nodal variable parameter estimates from the ASC Logit model are quite similar in nature to those generated in the Bivariate Probit model, providing reassuring robustness.[41]

[40]Because the second stage of this estimation employs estimated residuals, we must account for this extra variation in the development of the asymptotic sampling variance. We do so by implementing the bootstrap, as in Petrin and Train (2010).

[41]Given the reliance of the ASC Logit model on the assumption of the independence from irrelevant alternatives, we also estimated a Multinomial Probit model. Parameters from this estimation failed to reveal any notable differences in the interpretations suggested by our other model estimates.

5 Conclusion

The introduction of new products or services with new technologies and characteristics presents a number of challenges to traditional demand analysis. Faced with this situation, consumers may replace or augment their existing consumption portfolios. In particular, the new product or service may serve as either a substitute or complement to the existing product or service. In this regard, the advent and diffusion of wireless telecommunications has radically altered traditional consumption patterns among consumers, creating a natural opportunity to consider telecommunications demand with a portfolio choice lens.

In this paper, we develop an economic framework capable of capturing the pattern and evolution of telecommunications consumers' portfolio consumption choices. In doing so, we provide several contributions that may serve as a platform for subsequent research. First, we formulate a portfolio choice framework for how households satisfy their communications needs. Second, within that portfolio choice model, we develop a theory of why (non-price) characteristics of households, especially related to their "nodal tendencies", affect their subsequent telephony portfolio choices. Third, the portfolio choice framework sheds considerable light on the "substitutes versus complements" issue that underpins competition and regulatory policies toward the telecommunications industry. Fourth, given the window of our data from 2003-2010, we are able to observe empirically how variations in the quality and ubiquity of the "new service" affects consumers' portfolio choices.

The empirical results provide considerable support for the approach that we have adopted. In particular, we find that variations in household's nodal characteristics serve as important drivers of households' portfolio choices of telephone service. Households that are more closely attached to their domiciles are more attracted toward wireline service, while households with more mobile lifestyles are more attracted to wireless telephony. The results also consistently and robustly reveal that wireline and wireless services have become substitutes. Finally, variations in the quality and ubiquity of wireless telephony are found to be important determinants of wireless telephony subscription growth relative to wireline telephony over the 2003-2010 period.

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ATTACHMENT 4

Wireless Substitution: Early Release of Estimates From the National Health Interview Survey, January–June 2012

by Stephen J. Blumberg, Ph.D., and Julian V. Luke
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Overview

Preliminary results from the January–June 2012 National Health Interview Survey (NHIS) indicate that the number of American homes with only wireless telephones continues to grow. More than one-third of American homes (35.8%) had only wireless telephones (also known as cellular telephones, cell phones, or mobile phones) during the first half of 2012—an increase of 1.8 percentage points since the second half of 2011. In addition, nearly one of every six American homes (15.9%) received all or almost all calls on wireless telephones despite also having a landline telephone. This report presents the most up-to-date estimates available from the federal government concerning the size and characteristics of these populations.

NHIS Early Release Program

This report is published as part of the NHIS Early Release Program. Twice each year, the Centers for Disease Control and Prevention's (CDC) National Center for Health Statistics (NCHS) releases selected estimates of telephone coverage for the civilian noninstitutionalized U.S. population based on data from NHIS, along with comparable estimates from NHIS for the previous 3 years. The estimates are based on in-person interviews that NHIS conducts continuously throughout the year to collect information on health status, health-related behaviors, and health care access and utilization. The survey also includes information about household telephones and whether anyone in the household has a wireless telephone.

Two additional reports are published regularly as part of the NHIS Early Release Program. *Early Release of Selected Estimates Based on Data From the National Health Interview Survey* is published quarterly and provides estimates for 15 selected measures of health. *Health Insurance Coverage: Early Release of Estimates From the National Health Interview Survey* is also published quarterly and provides additional estimates regarding health insurance coverage. Other Early Release Program products are released as needed.

Methods

For many years, NHIS has asked respondents to provide residential telephone numbers, to permit the recontacting of survey participants. Starting in 2003, additional questions were asked to determine whether a family had a landline telephone. NHIS families were considered to have landline telephone service if the survey respondent for each family reported that there was "at least one phone inside your home that is currently working and is not a cell phone." (To avoid possible confusion with cordless landline telephones, the word "wireless" was not used in the survey.)

An NHIS "family" can be an individual or a group of two or more related persons living together in the same housing unit (a "household"). Thus, a family can consist of only one person, and more than one family can live in a household (including, for example, a household where there are multiple single-person families, as when unrelated roommates are living together).

The survey respondent for each family was also asked whether "anyone in your family has a working cellular telephone." Families are identified as

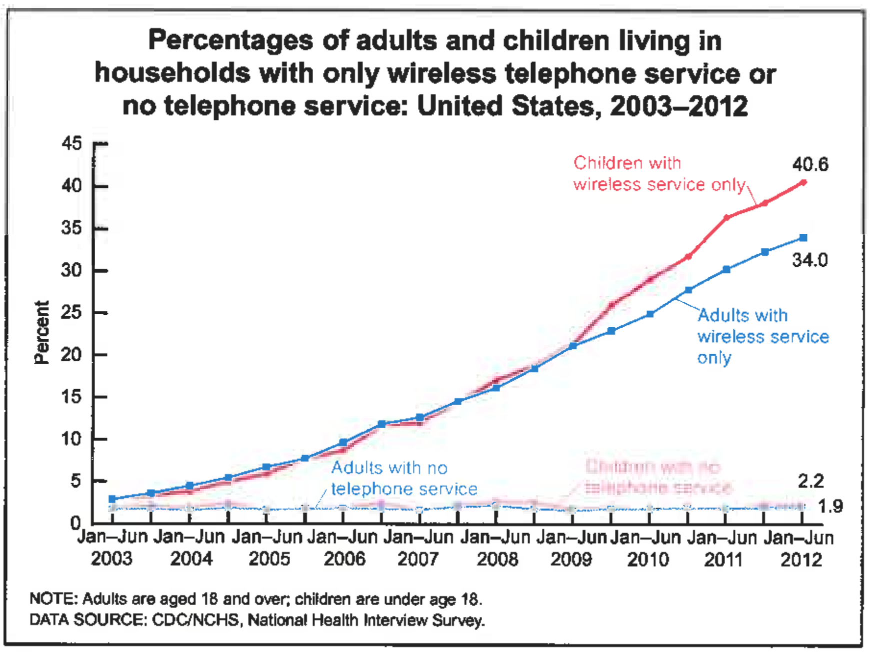

Figure 1

"wireless families" if respondents reported that someone in the family had a working cell phone at the time of interview. This person (or persons) could be a civilian adult, a member of the military, or a child.

Households are identified as "wireless-only" if they include at least one wireless family and if there are no working landline telephones inside the household. Persons are identified as wireless-only if they live in a wireless-only household. A similar approach is used to identify adults living in households with no telephone service (neither wireless nor landline). Household telephone status (rather than family telephone status) is used in this report because most telephone surveys do not attempt to distinguish between families when more than one family lives in the same household.

From January through June 2012, information on household telephone status was obtained for 20,608 households that included at least one civilian adult or child. These households included 38,896 civilian adults aged 18 and over, and 13,905 children under age 18. Analyses of telephone status are presented separately for households, adults, and children in **Table 1**.

Analyses of demographic characteristics are based on data from the NHIS Person and Household files. Demographic data for all civilian adults living in interviewed households were used in these analyses. "Household income" is the sum of the family incomes in the household. Estimates stratified by household poverty status are based on reported income only because imputed income values are not available until a few months after the annual release of NHIS microdata. Household poverty status was unknown for 20.2% of adults in these analyses.

Analyses of selected health measures are based on data from the NHIS Sample Adult file. Health-related data for one civilian adult randomly selected from each family were used in these analyses. From January through June 2012, data on household telephone status and selected health measures were collected from 16,891 randomly selected adults.

Because NHIS is conducted throughout the year and the sample is designed to yield a nationally representative sample each week, data can be analyzed quarterly. Weights are created for each calendar quarter of the NHIS sample. NHIS data weighting procedures are described in more detail in a previous NCHS report (**Botman et al., 2000**). To provide access to the most recent information from NHIS, estimates using the January–June 2012 data are being released prior to final data editing and final weighting. These estimates should be considered preliminary. If estimates are produced using the final data files, the estimates may differ slightly from those presented here.

Point estimates and 95% confidence intervals were calculated using SUDAAN software to account for the complex sample design of NHIS. Differences between percentages were evaluated using two-sided significance tests at the 0.05 level. Terms such as "more likely" and "less likely" indicate a statistically significant difference. Lack of comment regarding the difference between any two estimates does not necessarily mean that the difference was tested and found to be not significant. Because of small sample sizes, estimates based on less than 1 year of data may have large variances, and caution should be used in interpreting such estimates.

Telephone Status

In the first 6 months of 2012, more than one of every three households (35.8%) did not have a landline telephone but did have at least one wireless telephone (**Table 1**). Approximately 34.0% of all adults (about 80 million adults) lived in households with only wireless telephones; 40.6% of all children (approximately 30 million children) lived in households with only wireless telephones.

The percentage of households that are wireless-only has been steadily increasing. However, the 1.8-percentage-point increase from the second 6 months of 2011 through the first 6 months of 2012 is the smallest increase observed for any 6-month period dating back to January 2008. The percentage of adults and children living in wireless-only households has also been increasing steadily (**Figure 1**).

The percentages of adults and children living without any telephone service have remained relatively unchanged over the past 3 years. Approximately 2.1% of households had no telephone service (neither wireless nor landline). Nearly 4.5 million adults (1.9%) and 1.6 million children (2.2%) lived in these households.

Demographic Differences

The percentage of U.S. civilian noninstitutionalized adults living in wireless-only households is shown by selected demographic characteristics and by survey time period in **Table 2**. For the period January–June 2012, there are four demographic groups in which the majority live in households with only wireless telephones: adults aged 25–34, adults living only with unrelated adult roommates, adults renting their home, and adults living in poverty.

- Six in 10 adults aged 25–29 (60.1%) lived in households with only wireless telephones. This rate is greater than the rates for adults aged 18–24 (49.5%) or 30–34 (55.1%). The percentage of adults living in households with only wireless telephones decreased as age increased beyond 35 years: 39.1% for those aged 35–44; 25.8% for those aged 45–64; and 10.5% for those aged 65 and over.
- More than three in four adults living only with unrelated adult roommates (75.9%) were in households with only wireless telephones. This rate is higher than the rate for adults living alone (43.0%) and the rate for adults living only with spouses or other adult family members (27.0%).
- More than half of all adults renting their home (58.2%) had only wireless telephones. This rate is more than twice as large as the rate

for adults owning their home (23.2%).

- Adults living in poverty (51.8%) were more likely than adults living near poverty (42.3%) and higher income adults (30.7%) to be living in households with only wireless telephones.

Other demographic differences exist:

- Men (35.2%) were more likely than women (32.9%) to be living in households with only wireless telephones.
- Adults living in the Midwest (37.5%), South (37.2%), and West (34.0%) were more likely than adults living in the Northeast (23.1%) to be living in households with only wireless telephones.
- Hispanic adults (46.5%) were more likely than non-Hispanic white adults (30.4%) or non-Hispanic black adults (37.7%) to be living in households with only wireless telephones.

Demographic Distributions

The demographic differences noted in the previous section are based on the distribution of household telephone status within each demographic group. When examining the population of wireless-only adults, some readers may instead wish to consider the distribution of various demographic characteristics within the wireless-only adult population.

Table 3 gives the percent distribution of selected demographic characteristics for adults living in households with only wireless telephones, by survey time period. The estimates in this table reveal that the distributions of selected demographic characteristics changed little over the 3-year period shown. The exceptions were related to sex, age, employment status, and household structure. From the second 6 months of 2008 to the first 6 months of 2012,

- The proportion of women among all wireless-only adults increased from 47.6% to 50.2%.
- Among all wireless-only adults, the proportion aged 35 and over has increased steadily. In the first 6 months of 2012, more than one-half of wireless-only adults (51.7%) were aged 35 and over, up from 41.9% in the second 6 months of 2008.
- The proportion of employed adults among all wireless-only adults has decreased from 74.5% to 69.3%. Over the same time period, the proportion of adults with an employment status other than working, keeping house, or going to school increased. These adults (largely unemployed or retired) made up 20.2% of wireless-only adults in the first 6 months of 2012, up from 15.4% in the second 6 months of 2008.
- Among all wireless-only adults, the proportion living with children has increased. In the first 6 months of 2012, 40.4% of wireless-only adults were living with children, up from 34.3% in the second 6 months of 2008.

Selected Health Measures by Household Telephone Status

Many health surveys, political polls, and other research are conducted using random-digit-dial (RDD) telephone surveys. Until recently, these surveys did not include wireless telephone numbers in their samples. Now, despite operational challenges, most major survey research organizations are including wireless telephone numbers when conducting RDD surveys. If they did not, the exclusion of households with only wireless telephones (along with the small proportion of households that have no telephone service) could bias results. This bias—known as coverage bias—could exist if there are differences between persons with and without landline telephones for the substantive variables of interest.

The NHIS Early Release Program updates and releases estimates for 15 key health indicators every 3 months. Table 4 presents estimates by household telephone status (landline, wireless-only, or phoneless) for all but two of these measures. ("Pneumococcal vaccination" and "personal care needs" were not included because these indicators are limited to older adults aged 65 and over.) For the period January–June 2012,

- The prevalence of having five or more alcoholic drinks in 1 day during the past year among wireless-only adults (30.5%) was substantially higher than the prevalence among adults living in landline households (17.5%). Wireless-only adults were also more likely to be current smokers than were adults living in landline households.
- Compared with adults living in landline households, wireless-only adults were more likely to engage in regular leisure-time physical activity and less likely to have ever been diagnosed with diabetes.
- The percentage without health insurance coverage at the time of interview among wireless-only adults under age 65 (27.9%) was greater than the percentage among adults in that age group living in landline households (15.1%).
- Compared with adults living in landline households, wireless-only adults were more likely to have experienced financial barriers to obtaining needed health care, and they were less likely to have a usual place to go for medical care. Wireless-only adults were also less likely to have received an influenza vaccination during the previous year.
- Wireless-only adults (42.4%) were more likely than adults living in landline households (29.7%) to have ever been tested for human immunodeficiency virus, known as HIV, the virus that causes AIDS.

The potential for bias due to undercoverage remains a real threat to surveys conducted only on landline telephones.

Wireless-mostly Households

The potential for bias due to undercoverage is not the only threat to surveys conducted only on landline telephones. Researchers are also concerned that some people living in households with landlines cannot be reached on those landlines because they rely on wireless telephones for all or almost all of their calls.

In 2007, a question was added to NHIS for persons living in families with both landline and cellular telephones. The respondent for the family was asked to consider all of the telephone calls his or her family receives and to report whether "all or almost all calls are received on cell phones, some are received on cell phones and some on regular phones, or very few or none are received on cell phones." This question permits the identification of persons living in "wireless-mostly" households—defined as households with both landline and cellular telephones in which all families receive all or almost all calls on cell phones.

Among households with both landline and wireless telephones, 29.9% received all or almost all calls on the wireless telephones, based on data for the period January–June 2012. These wireless-mostly households make up 15.9% of all households.

During the first 6 months of 2012, approximately 41 million adults (17.6%) lived in wireless-mostly households. This prevalence estimate was greater than the estimate for the second 6 months of 2008 (15.4%) but has remained largely unchanged since January 2010.

Table 5 gives the percentage of adults living in wireless-mostly households, by selected demographic characteristics and by survey time period. For the period January–June 2012,

- Adults working at a job or business (20.6%) were more likely to be living in wireless-mostly households than were adults keeping house (15.5%) or with another employment status such as retired or unemployed (10.8%).
- Adults with college degrees (21.0%) were more likely to be living in wireless-mostly households than were high school graduates (15.5%) or adults with less education (11.9%).
- Adults living with children (22.4%) were more likely than adults living alone (10.2%) or with only adult relatives (16.2%) to be living in wireless-mostly households.
- Adults living in poverty (10.8%) and adults living near poverty (11.1%) were less likely than higher-income adults (21.5%) to be living in wireless-mostly households.
- Adults renting their home (12.7%) were less likely to be living in wireless-mostly households than were adults owning their home (19.9%).

Research by **Boyle, Lewis, and Tefft (2009)** suggests that the majority of adults living in wireless-mostly households are reachable using their landline telephone number. NHIS data cannot be used to estimate the proportion of wireless-mostly adults who are unreachable or to estimate the potential for bias due to their exclusion from landline surveys.

References and Other Sources of Information

For more information about the potential implications for health surveys that are based on landline telephone interviews, see

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When including wireless telephone numbers in RDD surveys, researchers have many methodological, statistical, operational, legal, and ethical issues to consider. These issues have been described in a report from a task force of the American Association for Public Opinion Research (AAPOR). That task force included staff from CDC, and its report is available online:

- AAPOR Cell Phone Task Force. New considerations for survey researchers when planning and conducting RDD telephone surveys in the U.S. with respondents reached via cell phone numbers. Deerfield, IL: American Association for Public Opinion Research (AAPOR). 2010. Available from: http://aapor.org/cell_phone_task_force.htm.

The potential for bias may differ from one state to another because the prevalence of wireless-only households varies substantially across states. For more information about prevalence estimates at the state and local level, see

- Blumberg SJ, Luke JV, Ganesh N, et al. Wireless substitution: State-level estimates from the National Health Interview Survey, 2010-2011. National health statistics reports; no 61. Hyattsville, MD: National Center for Health Statistics. 2012. Available from: http://www.cdc.gov/nchs/data/nhsr/nhsr061.pdf.

For more information about NHIS and the NHIS Early Release Program, or to find other Early Release Program products, see

- NHIS home page at http://www.cdc.gov/nchs/nhis.htm.
- Early Release home page at http://www.cdc.gov/nchs/nhis/releases.htm.
- Botman SL, Moore TF, Moriarity CL, Parsons VL. Design and estimation for the National Health Interview Survey, 1995–2004. National Center for Health Statistics. Vital Health Stat 2(130). 2000. Available from: http://www.cdc.gov/nchs/data/series/sr_02/sr02_130.pdf.

Suggested Citation

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Table 1. Percent distribution of household telephone status for households, adults, and children, by date of interview: United States, July 2008–June 2012

Date of interview		Household telephone status						
		Landline with wireless	Landline without wireless	Landline with unknown wireless	Nonlandline with unknown wireless	Wireless-only	Phoneless	Total
	Number of households (unweighted)	Percent of households						
Jul–Dec 2008	12,597	59.6	17.4	0.9	0.0	20.2	1.9	100.0
Jan–Jun 2009	12,447	59.4	15.5	0.4	0.0	22.7	1.9	100.0
Jul–Dec 2009	21,375	58.2	14.9	0.4	0.0	24.5	2.0	100.0
Jan–Jun 2010	17,619	58.1	12.9	0.3	0.0	26.6	2.0	100.0
Jul–Dec 2010	16,676	55.0	12.9	0.3	0.1	29.7	2.0	100.0
Jan–Jun 2011	20,133	55.0	11.2	0.2	0.1	31.6	2.0	100.0
Jul–Dec 2011	19,311	53.4	10.2	0.2	0.0	34.0	2.2	100.0
Jan–Jun 2012	20,608	52.5	9.4	0.2	0.0	35.8	2.1	100.0
95% confidence interval[1]		51.21–53.70	8.87–9.99	0.13–0.27	0.01–0.06	34.70–37.00	1.84–2.35	…
	Number of adults (unweighted)	Percent of adults						
Jul–Dec 2008	23,726	63.7	15.1	1.0	0.0	18.4	1.7	100.0
Jan–Jun 2009	23,632	63.5	13.4	0.4	0.0	21.1	1.5	100.0
Jul–Dec 2009	40,619	62.5	12.6	0.3	0.0	22.9	1.7	100.0
Jan–Jun 2010	33,780	62.2	10.9	0.3	0.0	24.9	1.7	100.0
Jul–Dec 2010	31,791	59.4	10.7	0.3	0.1	27.8	1.8	100.0
Jan–Jun 2011	38,104	58.8	9.0	0.2	0.0	30.2	1.8	100.0
Jul–Dec 2011	36,564	57.3	8.3	0.2	0.0	32.3	1.9	100.0
Jan–Jun 2012	38,896	56.1	7.8	0.2	0.0	34.0	1.9	100.0
95% confidence interval[1]		54.90–57.34	7.29–8.36	0.12–0.26	0.01–0.06	32.84–35.10	1.68–2.16	…

See footnotes at end of table.

Table 1. Percent distribution of household telephone status for households, adults, and children, by date of interview: United States, July 2008–June 2012—Con.

Date of interview	Number of children (unweighted)	Landline with wireless	Landline without wireless	Landline with unknown wireless	Nonlandline with unknown wireless	Wireless-only	Phoneless	Total
		Percent of children						
Jul–Dec 2008	8,635	67.1	11.1	0.7	0.0	18.7	2.4	100.0
Jan–Jun 2009	8,818	67.6	9.1	0.3	0.0	21.3	1.7	100.0
Jul–Dec 2009	14,984	63.4	8.5	0.2	0.0	25.9	1.9	100.0
Jan–Jun 2010	12,234	62.8	6.4	0.1	–	29.0	1.7	100.0
Jul–Dec 2010	11,815	59.8	6.2	0.1	0.1	31.8	2.0	100.0
Jan–Jun 2011	13,753	56.7	5.1	0.1	0.0	36.4	1.7	100.0
Jul–Dec 2011	13,028	54.7	4.8	0.1	0.0	38.1	2.2	100.0
Jan–Jun 2012	13,905	52.7	4.5	0.1	–	40.6	2.2	100.0
95% confidence interval[1]		51.00–54.31	3.86–5.15	0.03–0.15	…	39.05–42.25	1.78–2.67	…

0.0 Quantity more than zero but less than 0.05.

… Category not applicable.

– Quantity zero.

[1]Refers to the time period January–June 2012.

NOTE: Data are based on household interviews of a sample of the civilian noninstitutionalized population.

DATA SOURCE: CDC/NCHS, National Health Interview Survey, July 2008–June 2012.

Table 2. Percentage of adults living in wireless-only households, by selected demographic characteristics and calendar half-years: United States, July 2008–June 2012

Demographic characteristic	Calendar half-year								95% confidence interval[1]
	Jul–Dec 2008	Jan–Jun 2009	Jul–Dec 2009	Jan–Jun 2010	Jul–Dec 2010	Jan–Jun 2011	Jul–Dec 2011	Jan–Jun 2012	
	Percent								
Race/ethnicity									
Hispanic or Latino, any race(s)	25.0	28.2	30.4	34.7	38.4	40.8	43.3	46.5	44.40 – 48.61
Non-Hispanic white, single race	16.6	19.7	21.0	22.7	25.0	27.6	29.0	30.4	28.99 – 31.76
Non-Hispanic black, single race	21.4	21.3	25.0	28.5	31.1	32.5	36.8	37.7	35.65 – 39.79
Non-Hispanic Asian, single race	17.8	18.0	20.6	18.8	27.0	27.7	31.6	33.4	30.12 – 36.93
Non-Hispanic other, single race	17.3	20.6	26.5	*16.1	31.9	33.8	44.1	43.4	34.17 – 53.02
Non-Hispanic multiple race	22.5	28.7	26.9	36.0	36.1	39.3	36.7	40.2	34.71 – 46.01
Age									
18–24 years	33.1	37.6	37.8	39.9	45.5	46.8	48.6	49.5	46.96 – 52.10
25–29 years	41.5	45.8	48.6	51.3	53.5	58.1	59.6	60.1	57.41 – 62.63
30–34 years	30.4	33.5	37.2	40.4	43.8	46.2	50.9	55.1	52.63 – 57.50
35–44 years	17.5	21.5	23.9	27.0	30.9	34.3	36.8	39.1	37.38 – 40.77
45–64 years	11.6	12.8	14.9	16.9	18.8	21.6	23.8	25.8	24.67 – 27.04
65 years and over	3.3	5.4	5.2	5.4	7.7	7.9	8.5	10.5	9.58 – 11.56
Sex									
Male	20.0	22.5	24.5	26.2	29.0	31.4	33.7	35.2	33.94 – 36.40
Female	17.0	19.8	21.3	23.7	26.8	29.1	30.9	32.9	31.71 – 34.01
Education									
Some high school or less	18.8	22.2	24.7	28.6	29.2	32.1	34.7	36.4	34.55 – 38.33
High school graduate or GED[2]	17.8	20.8	22.9	23.6	27.6	30.8	32.7	33.9	32.47 – 35.38
Some post-high school, no degree	20.1	23.6	25.0	26.5	30.9	31.8	35.1	36.7	35.03 – 38.38
4-year college degree or higher	17.7	18.2	19.5	22.7	24.3	26.9	27.8	30.1	28.51 – 31.69
Employment status last week									
Working at a job or business	21.5	24.3	26.0	28.5	31.5	34.2	36.8	38.4	37.09 – 39.72
Keeping house	16.0	16.6	20.5	22.7	25.8	31.2	32.7	34.0	31.48 – 36.71
Going to school	23.5	29.7	29.2	33.2	38.6	35.3	40.8	41.9	37.76 – 46.15
Something else (incl. unemployed)	11.0	14.0	15.9	16.8	19.2	21.0	22.3	23.6	22.42 – 24.79

See footnotes at end of table.

Table 2. Percentage of adults living in wireless-only households, by selected demographic characteristics and calendar half-years: United States, July 2008–June 2012—Con.

Demographic characteristic	Calendar half-year								95% confidence interval[1]
	Jul–Dec 2008	Jan–Jun 2009	Jul–Dec 2009	Jan–Jun 2010	Jul–Dec 2010	Jan–Jun 2011	Jul–Dec 2011	Jan–Jun 2012	
	Percent								
Household structure									
Adult living alone	28.1	30.8	32.9	33.5	36.8	38.0	41.3	43.0	41.02 – 45.05
Unrelated adults, no children	60.6	68.5	62.9	69.4	69.7	71.3	77.5	75.9	69.17 – 81.60
Related adults, no children	14.7	16.8	17.1	19.1	22.1	23.2	25.1	27.0	25.57 – 28.41
Adult(s) with children	17.2	20.4	24.1	26.9	29.4	33.6	35.4	37.2	35.72 – 38.64
Household poverty status[3]									
Poor	30.9	33.0	36.3	39.3	42.8	46.8	51.4	51.8	49.09 – 54.47
Near poor	23.8	26.5	29.0	32.9	35.2	38.1	39.6	42.3	39.95 – 44.68
Not poor	16.0	18.9	19.6	21.7	24.1	27.7	28.9	30.7	29.39 – 32.05
Geographic region[4]									
Northeast	11.4	14.6	15.1	15.8	17.2	18.8	20.6	23.1	20.71 – 25.61
Midwest	20.8	21.9	25.6	26.6	30.0	33.5	35.2	37.5	35.01 – 39.96
South	21.3	25.0	25.4	29.3	31.1	33.6	35.9	37.2	35.38 – 39.09
West	17.2	19.0	22.2	23.5	28.7	30.3	33.0	34.0	31.68 – 36.42
Metropolitan statistical area status									
Metropolitan	19.7	22.4	24.2	26.5	29.1	31.4	33.6	35.7	34.43 – 36.97
Not metropolitan	13.5	16.5	17.9	19.3	22.9	25.6	27.2	27.1	25.06 – 29.25
Home ownership status[5]									
Owned or being bought	9.9	12.8	14.0	15.5	17.7	20.6	21.2	23.2	22.09 – 24.33
Renting	39.2	40.9	43.1	47.1	50.3	52.5	56.0	58.2	56.58 – 59.87
Other arrangement	17.7	33.6	33.8	34.9	35.1	38.4	40.7	37.7	32.27 – 43.53
Number of wireless-only adults in survey sample (unweighted)	4,426	5,078	9,401	8,659	9,228	11,872	12,350	13,724	...

* Estimate has a relative standard error greater than 30% and does not meet National Center for Health Statistics (NCHS) standards for reliability.

… Category not applicable.

[1]Refers to the time period January–June 2012.

[2]GED is General Educational Development high school equivalency diploma.

[3]Based on household income and household size using the U.S. Census Bureau's poverty thresholds. "Poor" persons are defined as those below the poverty threshold. "Near poor" persons have incomes of 100% to less than 200% of the poverty threshold. "Not poor" persons have incomes of 200% of the poverty threshold or greater. Early Release estimates stratified by poverty status are based on reported income only and may differ from similar estimates produced later that are based on both reported and imputed income. NCHS imputes income when income is unknown, but the imputed income file is not available until a few months after the annual release of National Health Interview Survey microdata. For households with multiple families, household income and household size were calculated as the sum of the multiple measures of family income and family size.

[4]In the geographic classification of the U.S. population, states are grouped into the following four regions used by the U.S. Census Bureau: *Northeast* includes Maine, Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, and Pennsylvania. *Midwest* includes Ohio, Illinois, Indiana, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Kansas, and Nebraska. *South* includes Delaware, Maryland, District of Columbia, West Virginia, Virginia, Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Oklahoma, Arkansas, and Texas. *West* includes Washington, Oregon, California, Nevada, New Mexico, Arizona, Idaho, Utah, Colorado, Montana, Wyoming, Alaska, and Hawaii.

[5]For households with multiple families, home ownership status was determined by considering the reported home ownership status for each family. If any family reported owning the home, then the household-level variable was classified as "Owned or being bought" for all persons living in the household. If one family reported renting the home and another family reported "other arrangement," then the household-level variable was classified as "Other arrangement" for all persons living in the household.

NOTE: Data are based on household interviews of a sample of the civilian noninstitutionalized population.

DATA SOURCE: CDC/NCHS, National Health Interview Survey, July 2008–June 2012.

Table 3. Percent distribution of selected demographic characteristics for adults living in wireless-only households, by date of interview: United States, July 2008–June 2012

Demographic characteristic	Calendar half-year								95% confidence interval[1]
	Jul–Dec 2008	Jan–Jun 2009	Jul–Dec 2009	Jan–Jun 2010	Jul–Dec 2010	Jan–Jun 2011	Jul–Dec 2011	Jan–Jun 2012	
	Percent distribution								
Race/ethnicity									
Hispanic or Latino, any race(s)	18.5	18.4	18.5	19.4	19.5	19.0	19.1	20.3	18.66 – 22.03
Non-Hispanic white, single race	61.9	63.8	62.5	61.6	61.0	61.8	61.0	59.6	57.72 – 61.38
Non-Hispanic black, single race	13.3	11.7	12.7	13.3	13.0	12.5	13.1	12.7	11.67 – 13.90
Non-Hispanic Asian, single race	4.4	3.9	4.1	3.5	4.5	4.3	4.7	5.1	4.39 – 5.80
Non-Hispanic other, single race	0.6	0.7	1.0	0.6	0.7	0.8	0.9	0.8	0.59 – 1.09
Non-Hispanic multiple race	1.2	1.5	1.3	1.6	1.3	1.6	1.3	1.5	1.31 – 1.82
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	…
Age									
18–24 years	23.1	22.9	21.2	20.7	21.1	20.0	19.4	18.9	17.57 – 20.32
25–29 years	21.0	19.9	19.6	19.1	17.7	17.6	17.0	15.5	14.64 – 16.42
30–34 years	14.0	13.6	14.0	13.9	13.7	13.3	14.0	14.0	13.11 – 14.85
35–44 years	17.4	18.4	18.6	18.9	19.3	19.5	19.2	19.5	18.57 – 20.45
45–64 years	21.6	21.0	22.8	23.7	23.6	25.0	25.8	26.7	25.65 – 27.68
65 years and over	2.9	4.3	3.8	3.7	4.7	4.5	4.6	5.5	4.95 – 6.07
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	…
Sex									
Male	52.4	51.4	51.8	50.9	50.3	50.4	50.7	49.8	49.05 – 50.57
Female	47.6	48.6	48.2	49.1	49.7	49.6	49.3	50.2	49.43 – 50.95
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	…
Education									
Some high school or less	15.8	15.5	16.0	16.6	15.4	15.6	15.2	15.2	14.20 – 16.22
High school graduate or GED[2]	27.2	27.7	28.9	26.7	28.1	27.8	28.2	27.1	25.97 – 28.23
Some post-high school, no degree	31.7	33.3	32.9	32.0	32.7	32.2	32.7	33.3	31.90 – 34.64
4-year college degree or higher	25.3	23.5	22.3	24.7	23.9	24.3	23.9	24.5	23.19 – 25.81
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	…

See footnotes at end of table.

Table 3. Percent distribution of selected demographic characteristics for adults living in wireless-only households, by date of interview: United States, July 2008–June 2012—Con.

Demographic characteristic	Calendar half-year								95% confidence interval[1]
	Jul–Dec 2008	Jan–Jun 2009	Jul–Dec 2009	Jan–Jun 2010	Jul–Dec 2010	Jan–Jun 2011	Jul–Dec 2011	Jan–Jun 2012	
	Percent distribution								
Employment status last week									
Working at a job or business	74.5	71.1	69.1	69.7	68.8	68.5	69.0	69.3	68.23 – 70.29
Keeping house	5.3	4.5	5.3	5.3	5.5	5.9	5.6	5.3	4.93 – 5.78
Going to school	3.7	4.6	4.4	4.3	4.7	4.2	4.0	4.3	3.73 – 4.96
Something else (incl. unemployed)	15.4	18.7	20.2	19.5	20.0	20.3	20.6	20.2	19.27 – 21.16
Unknown, not reported	*1.1	1.1	1.1	1.3	1.1	1.0	0.7	0.9	0.64 – 1.23
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	…
Household structure									
Adult living alone	23.6	22.1	21.9	19.9	20.0	18.7	19.8	18.9	17.73 – 20.10
Unrelated adults, no children	5.2	5.4	4.1	4.1	4.0	4.3	4.0	3.8	3.09 – 4.61
Related adults, no children	36.9	36.0	34.0	35.1	36.0	35.3	35.8	36.9	35.40 – 38.42
Adult(s) with children	34.3	36.4	40.0	40.9	40.0	41.7	40.5	40.4	38.78 – 42.11
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	…
Household poverty status[3]									
Poor	15.5	15.5	16.4	16.5	17.4	15.6	15.9	15.0	13.83 – 16.22
Near poor	16.8	17.9	18.5	19.8	18.6	17.7	18.2	17.7	16.68 – 18.86
Not poor	53.3	56.7	53.0	53.2	52.3	47.8	46.2	47.1	45.27 – 48.87
Unknown, not reported	14.4	10.0	12.2	10.6	11.7	18.8	19.8	20.2	18.87 – 21.62
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	…
Geographic region[4]									
Northeast	11.3	12.2	12.1	11.4	11.0	11.1	11.7	12.4	11.16 – 13.75
Midwest	26.0	23.9	26.0	24.0	24.7	24.9	25.2	24.5	22.49 – 26.61
South	41.1	43.8	39.5	42.3	40.2	40.5	39.9	40.4	38.31 – 42.43
West	21.6	20.1	22.4	22.3	24.1	23.5	23.3	22.8	21.16 – 24.44
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	…

See footnotes at end of table.

Table 3. Percent distribution of selected demographic characteristics for adults living in wireless-only households, by date of interview: United States, July 2008–June 2012—Con.

Demographic characteristic	Calendar half-year								
	Jul–Dec 2008	Jan–Jun 2009	Jul–Dec 2009	Jan–Jun 2010	Jul–Dec 2010	Jan–Jun 2011	Jul–Dec 2011	Jan–Jun 2012	95% confidence interval[1]
	Percent distribution								
Metropolitan statistical area status									
Metropolitan	85.1	83.3	83.7	83.2	82.7	82.8	82.3	83.9	81.88 – 85.81
Not metropolitan	14.9	16.7	16.3	16.8	17.3	17.2	17.7	16.1	14.19 – 18.12
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	…
Home ownership status[5]									
Owned or being bought	37.1	42.1	42.3	43.7	43.3	47.0	44.2	46.5	44.50 – 48.51
Renting	61.1	55.0	54.3	53.5	54.2	49.9	53.3	51.2	49.20 – 53.21
Other arrangement	1.8	2.9	3.3	2.8	2.5	3.0	2.5	2.3	1.90 – 2.78
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	…
Number of wireless-only adults in survey sample (unweighted)	4,426	5,078	9,401	8,659	9,228	11,872	12,350	13,724	…

… Category not applicable.

* Estimate has a relative standard error greater than 30% and does not meet National Center for Health Statistics (NCHS) standards for reliability.

[1]Refers to the time period January–June 2012.

[2]GED is General Educational Development high school equivalency diploma.

[3]Based on household income and household size using the U.S. Census Bureau's poverty thresholds. "Poor" persons are defined as those below the poverty threshold. "Near poor" persons have incomes of 100% to less than 200% of the poverty threshold. "Not poor" persons have incomes of 200% of the poverty threshold or greater. Early Release estimates stratified by poverty status are based on reported income only and may differ from similar estimates produced later that are based on both reported and imputed income. NCHS imputes income when income is unknown, but the imputed income file is not available until a few months after the annual release of National Health Interview Survey microdata. For households with multiple families, household income and household size were calculated as the sum of the multiple measures of family income and family size.

[4]In the geographic classification of the U.S. population, states are grouped into the following four regions used by the U.S. Census Bureau: *Northeast* includes Maine, Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, and Pennsylvania. *Midwest* includes Ohio, Illinois, Indiana, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Kansas, and Nebraska. *South* includes Delaware, Maryland, District of Columbia, West Virginia, Virginia, Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Oklahoma, Arkansas, and Texas. *West* includes Washington, Oregon, California, Nevada, New Mexico, Arizona, Idaho, Utah, Colorado, Montana, Wyoming, Alaska, and Hawaii.

[5]For households with multiple families, home ownership status was determined by considering the reported home ownership status for each family. If any family reported owning the home, then the household-level variable was classified as "Owned or being bought" for all persons living in the household. If one family reported renting the home and another family reported "other arrangement," then the household-level variable was classified as "Other arrangement" for all persons living in the household.

NOTE: Data are based on household interviews of a sample of the civilian noninstitutionalized population.

DATA SOURCE: CDC/NCHS, National Health Interview Survey, July 2008–June 2012.

Table 4. Prevalence rates (and 95% confidence intervals) for selected measures of health-related behaviors, health status, health care service use, and health care access for adults aged 18 and over, by household telephone status: United States, January–June 2012

Measure	Household telephone status		
	Landline[1]	Wireless-only	Phoneless
	Percent (95% confidence interval)		
Health-related behaviors			
Five or more alcoholic drinks in 1 day at least once in past year[2]	17.5 (16.41 – 18.54)	30.5 (28.85 – 32.14)	24.5 (19.17 – 30.65)
Current smoker[3]	14.5 (13.48 – 15.51)	24.3 (22.80 – 25.81)	20.8 (15.58 – 27.20)
Engaged in regular leisure-time physical activity[4]	35.7 (34.23 – 37.11)	40.1 (38.31 – 41.93)	41.9 (35.30 – 48.88)
Health status			
Health status described as excellent or very good[5]	59.3 (57.89 – 60.75)	62.2 (60.63 – 63.80)	65.0 (58.43 – 70.96)
Experienced serious psychological distress in past 30 days[6]	2.8 (2.34 – 3.25)	3.5 (2.97 – 4.14)	*3.0 (1.65 – 5.38)
Obese (adults aged 20 and over)[7]	28.6 (27.31 – 29.93)	29.3 (27.77 – 30.95)	21.8 (16.68 – 27.90)
Asthma episode in past year[8]	4.3 (3.77 – 4.86)	4.6 (3.88 – 5.36)	*4.1 (2.07 – 8.15)
Ever diagnosed with diabetes[9]	10.8 (10.06 – 11.56)	6.4 (5.69 – 7.19)	6.1 (3.53 – 10.33)
Health care service use			
Received influenza vaccine during past year[10]	44.4 (43.09 – 45.82)	27.6 (26.01 – 29.16)	31.3 (24.98 – 38.37)
Ever been tested for HIV[11]	29.7 (28.53 – 30.93)	42.4 (40.75 – 44.16)	40.9 (34.17 – 47.95)
Health care access			
Has a usual place to go for medical care[12]	88.0 (87.05 – 88.98)	72.4 (70.86 – 73.97)	70.3 (64.48 – 75.61)
Failed to obtain needed medical care in past year due to financial barriers[13]	6.0 (5.44 – 6.62)	12.2 (11.22 – 13.25)	8.4 (5.69 – 12.36)
Currently uninsured (adults aged 18–64)[14]	15.1 (13.95 – 16.36)	27.9 (26.03 – 29.80)	31.7 (25.02 – 39.15)
Number of adults in survey sample (unweighted)	9,984	6,546	361

* Estimate has a relative standard error greater than 30% and does not meet National Center for Health Statistics (NCHS) standards for reliability.

[1]Includes households that also have wireless telephone service.

[2]A year is defined as the 12 months prior to interview. The analyses excluded adults with unknown alcohol consumption (about 2% of respondents each year).

[3]A person who had smoked more than 100 cigarettes in his or her lifetime and now smokes every day or some days. The analyses excluded persons with unknown smoking status (about 1% of respondents each year).

[4]Regular leisure-time physical activity is defined as engaging in light-moderate leisure-time physical activity for greater than or equal to 30 minutes at a frequency greater than or equal to five times per week, or engaging in vigorous leisure-time physical activity for greater than or equal to 20 minutes at a frequency greater than or equal to three times per week. Persons who were known to have not met the frequency recommendations are classified as "not regular," regardless of duration. The analyses excluded persons with unknown physical activity participation (about 3% of respondents each year).

[5]Health status data were obtained by asking respondents to assess their own health and that of family members living in the same household as excellent, very good, good, fair, or poor. The analyses excluded persons with unknown health status (about 0.5% of respondents each year).

[6]Six psychological distress questions are included in the National Health Interview Survey. These questions ask how often during the past 30 days a respondent experienced certain symptoms of psychological distress (feeling so sad that nothing could cheer you up, nervous, restless or fidgety, hopeless, worthless, that everything was an effort). The response codes (0–4) of the six items for each person were equally weighted and summed. A value of 13 or more for this scale indicates that at least one symptom was experienced "most of the time" or "all of the time" and is used here to define serious psychological distress.

[7]Obesity is defined as a body mass index (BMI) of 30 kg/m^2 or more. The measure is based on self-reported height and weight. The analyses excluded people with unknown height or weight (about 4% of respondents each year). Estimates of obesity are presented for adults aged 20 and over because the Healthy People 2020 objectives (http://www.healthypeople.gov) for healthy weight among adults define adults as persons aged 20 and over.

[8]Information on an episode of asthma or an asthma attack during the past year is self-reported by adults aged 18 and over. A year is defined as the 12 months prior to interview. The analyses excluded people with unknown asthma episode status (about 0.3% of respondents each year).

[9]Prevalence of diagnosed diabetes is based on self-report of ever having been diagnosed with diabetes by a doctor or other health professional. Persons reporting "borderline" diabetes status and women reporting diabetes only during pregnancy were not coded as having diabetes in the analyses. The analyses excluded persons with unknown diabetes status (about 0.1% of respondents each year).

[10]Receipt of flu shots and receipt of nasal spray flu vaccinations were included in the calculation of flu vaccination estimates. Responses to these two flu vaccination questions do not indicate when the subject received the flu vaccination during the 12 months preceding the interview. In addition, estimates are subject to recall error, which will vary depending on when the question is asked because the receipt of a flu vaccination is seasonal. The analyses excluded those with unknown flu vaccination status (about 1% of respondents each year).

[11]Individuals who received human immunodeficiency virus (HIV) testing solely as a result of blood donation were considered not to have been tested for HIV. The analyses excluded those with unknown HIV test status (about 4% of respondents each year).

[12]Does not include a hospital emergency room. The analyses excluded persons with an unknown usual place to go for medical care (about 0.6% of respondents each year).

[13]A year is defined as the 12 months prior to interview. The analyses excluded persons with unknown responses to the question on failure to obtain needed medical care due to cost (about 0.5% of respondents each year).

[14]A person was defined as uninsured if he or she did not have any private health insurance, Medicare, Medicaid, Children's Health Insurance Program (CHIP), state-sponsored or other government-sponsored health plan, or military plan at the time of interview. A person was also defined as uninsured if he or she had only Indian Health Service coverage or had only a private plan that paid for one type of service, such as accidents or dental care. The data on health insurance status were edited using an automated system based on logic checks and keyword searches. The analyses excluded persons with unknown health insurance status (about 1% of respondents each year).

NOTE: Data are based on household interviews of a sample of the civilian noninstitutionalized population.

DATA SOURCE: CDC/NCHS, National Health Interview Survey, January–June 2012.

Table 5. Percentage of adults living in wireless-mostly households, by selected demographic characteristics and calendar half-years: United States, July 2008–June 2012

Demographic characteristic	Calendar half-year								95% confidence interval[1]
	Jul–Dec 2008	Jan–Jun 2009	Jul–Dec 2009	Jan–Jun 2010	Jul–Dec 2010	Jan–Jun 2011	Jul–Dec 2011	Jan–Jun 2012	
	Percent								
Total	15.4	16.2	16.3	17.7	17.4	18.2	17.8	17.6	16.75 – 18.41
Race/ethnicity									
Hispanic or Latino, any race(s)	15.9	18.0	16.9	19.7	17.2	16.3	17.0	16.1	14.65 – 17.63
Non-Hispanic white, single race	14.9	15.6	16.1	17.2	17.2	18.4	17.9	17.6	16.54 – 18.68
Non-Hispanic black, single race	14.7	15.0	16.2	17.5	16.2	18.4	17.1	17.6	15.91 – 19.42
Non-Hispanic Asian, single race	20.3	19.6	18.5	20.8	22.5	21.0	20.3	21.5	18.76 – 24.43
Non-Hispanic other, single race	15.5	22.9	*16.1	*12.3	23.8	17.6	15.6	15.1	10.49 – 21.28
Non-Hispanic multiple race	24.2	22.5	18.2	21.0	20.7	16.1	21.7	18.7	14.61 – 23.57
Age									
18–24 years	18.8	20.0	19.9	21.4	18.7	20.1	18.9	20.1	18.42 – 21.94
25–29 years	18.3	17.7	16.4	17.4	16.8	16.3	15.8	15.0	13.25 – 16.93
30–44 years	19.0	20.3	19.5	21.2	21.6	21.9	21.2	20.7	19.46 – 22.09
45–64 years	15.4	16.5	17.5	19.0	18.9	19.8	19.9	19.3	18.31 – 20.33
65 years and over	4.9	5.3	6.3	7.0	7.1	8.9	8.9	8.9	7.93 – 10.00
Sex									
Male	15.4	16.2	16.5	18.1	17.8	18.5	18.3	17.9	16.94 – 18.89
Female	15.2	16.1	16.2	17.4	17.1	17.9	17.3	17.3	16.48 – 18.06
Education									
Some high school or less	9.8	12.1	11.5	12.0	12.1	12.9	11.7	11.9	10.77 – 13.16
High school graduate or GED[2]	13.2	13.7	14.2	16.0	15.3	16.6	15.7	15.5	14.42 – 16.62
Some post-high school, no degree	18.6	17.7	18.1	20.1	18.9	20.0	19.4	19.1	17.90 – 20.36
4-year college degree or higher	18.0	19.7	19.7	20.3	21.3	21.1	21.4	21.0	19.70 – 22.38
Employment status last week									
Working at a job or business	18.4	19.5	19.7	20.8	20.5	21.6	20.9	20.6	19.59 – 21.74
Keeping house	11.9	12.7	15.1	14.5	16.7	14.9	16.6	15.5	13.76 – 17.38
Going to school	21.5	21.1	21.7	23.5	24.4	23.5	20.0	23.7	20.66 – 26.93
Something else (incl. unemployed)	7.8	9.0	9.0	11.5	10.2	11.3	11.4	10.8	10.03 – 11.64

See footnotes at end of table.

Table 5. Percentage of adults living in wireless-mostly households, by selected demographic characteristics and calendar half-years: United States, July 2008–June 2012—Con.

Demographic characteristic	Calendar half-year								95% confidence interval[1]
	Jul–Dec 2008	Jan–Jun 2009	Jul–Dec 2009	Jan–Jun 2010	Jul–Dec 2010	Jan–Jun 2011	Jul–Dec 2011	Jan–Jun 2012	
	Percent								
Household structure									
Adult living alone	12.2	10.0	10.6	10.1	9.5	10.2	10.1	10.2	9.18 – 11.36
Unrelated adults, no children	21.3	13.9	15.5	13.4	13.4	*15.6	10.3	13.0	8.08 – 20.14
Related adults, no children	13.2	14.7	15.0	15.7	15.8	17.2	16.9	16.2	15.18 – 17.35
Adult(s) with children	19.2	20.5	20.2	23.3	22.7	22.8	22.5	22.4	21.20 – 23.67
Household poverty status[3]									
Poor	9.5	11.0	10.0	11.0	10.2	10.5	8.8	10.8	9.07 – 12.71
Near poor	11.3	12.0	12.7	12.6	13.8	13.3	13.5	11.1	9.90 – 12.52
Not poor	18.2	18.8	19.2	20.8	20.4	21.6	21.9	21.5	20.36 – 22.60
Geographic region[4]									
Northeast	12.0	15.3	14.9	17.1	18.5	19.5	17.9	18.9	17.01 – 20.97
Midwest	13.2	14.6	14.7	17.5	16.3	17.7	16.6	15.5	13.88 – 17.33
South	16.2	16.7	17.3	18.1	17.2	18.0	17.7	17.3	15.83 – 18.84
West	18.7	17.7	17.7	17.8	18.0	18.1	19.1	18.9	17.59 – 20.31
Metropolitan statistical area status									
Metropolitan	15.8	16.9	16.8	18.0	17.8	18.4	18.2	17.9	17.01 – 18.74
Not metropolitan	13.4	13.5	14.5	16.5	16.1	17.3	16.4	16.4	14.16 – 18.88
Home ownership status[5]									
Owned or being bought	15.9	17.2	17.5	19.6	19.4	20.0	19.9	19.9	18.82 – 20.96
Renting	13.0	13.9	13.6	13.9	13.0	13.9	13.5	12.7	11.64 – 13.73
Other arrangement	24.6	13.8	15.8	10.8	15.6	20.0	11.7	13.8	10.50 – 17.88
Number of adults in survey sample who live in landline households with wireless telephones (unweighted)	14,816	14,886	24,904	20,610	18,357	21,626	20,184	21,100	…

* Estimate has a relative standard error greater than 30% and does not meet National Center for Health Statistics (NCHS) standards for reliability.

… Category not applicable.

[1]Refers to the time period January–June 2012.

[2]GED is General Educational Development high school equivalency diploma.

[3]Based on household income and household size using the U.S. Census Bureau's poverty thresholds. "Poor" persons are defined as those below the poverty threshold. "Near poor" persons have incomes of 100% to less than 200% of the poverty threshold. "Not poor" persons have incomes of 200% of the poverty threshold or greater. Early Release estimates stratified by poverty status are based on reported income only and may differ from similar estimates produced later that are based on both reported and imputed income. NCHS imputes income when income is unknown, but the imputed income file is not available until a few months after the annual release of National Health Interview Survey microdata. For households with multiple families, household income and household size were calculated as the sum of the multiple measures of family income and family size.

[4]In the geographic classification of the U.S. population, states are grouped into the following four regions used by the U.S. Census Bureau: *Northeast* includes Maine, Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, and Pennsylvania. *Midwest* includes Ohio, Illinois, Indiana, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Kansas, and Nebraska. *South* includes Delaware, Maryland, District of Columbia, West Virginia, Virginia, Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Oklahoma, Arkansas, and Texas. *West* includes Washington, Oregon, California, Nevada, New Mexico, Arizona, Idaho, Utah, Colorado, Montana, Wyoming, Alaska, and Hawaii.

[5]For households with multiple families, home ownership status was determined by considering the reported home ownership status for each family. If any family reported owning the home, then the household-level variable was classified as "Owned or being bought" for all persons living in the household. If one family reported renting the home and another family reported "other arrangement," then the household-level variable was classified as "Other arrangement" for all persons living in the household.

NOTE: Data are based on household interviews of a sample of the civilian noninstitutionalized population.

DATA SOURCE: CDC/NCHS, National Health Interview Survey, July 2008–June 2012.