**Before the**
**FEDERAL COMMUNICATIONS COMMISSION**
**Washington, D.C. 20554**

| | | |
|---|---|---|
| In the Matter of | ) | |
| | ) | |
| Petition of USTelecom for Declaratory Ruling | ) | WC Docket No. 13-3 |
| That Incumbent Local Exchange Carriers Are | ) | |
| Non-Dominant in the Provision of Switched | ) | |
| Access Services | ) | |
| | ) | |

**COMMENTS OF**
**THE UNITED STATES TELECOM ASSOCIATION**

The United States Telecom Association (USTelecom) submits these comments in response to the Wireline Competition Bureau's Public Notice seeking to refresh the record on USTelecom's petition for declaratory ruling (Petition) that incumbent local exchange carriers (ILECs) are non-dominant in the provision of switched access services.[1]

## I. INTRODUCTION

In passing the Telecommunications Act of 1996 twenty years ago, Congress set out to "promote competition and reduce regulation in order to secure lower prices and higher quality services for American telecommunications consumers and encourage the rapid deployment of new telecommunications technologies."[2] Twenty years later, opinions differ on whether the Commission's implementation of the 1996 Act, in all respects, has been a success or failure. But one thing is indisputable: the core local market-opening goals of the 1996 Act have been

[1] *Wireline Competition Bureau Seeks Comment to Refresh the Record on United States Telecom Association Petition for Declaratory Ruling That Incumbent Local Exchange Carriers are Nondominant in the Provision of Switched Access Services*, WC Docket No. 13-3, DA 16-79 (rel. Jan. 21, 2016) (*Public Notice*); Petition of USTelecom for Declaratory Ruling that Incumbent Local Exchange Carriers are Non-Dominant in the Provision of Switched Access Services, WC Docket No. 13-3 (filed Dec. 19, 2012) (*Petition*).

[2] Preamble to the Telecommunications Act of 1996, Pub. L. No. 104-104, 110 Stat. 56 (1996).

achieved, as evidenced by the overwhelming migration of consumers from traditional home-bound, wired, Bell-provided switched access telephone service to multiple other options for their basic and advanced communications needs. There is rigorous competition across traditional industry boundaries – wired, fixed and mobile wireless, Internet-based, satellite – and the worlds of computing and communications have essentially converged into one inseparable, interdependent ecosystem. The reality is that ILECs long ago lost their stronghold in the switched access market, largely because the policies and regulations that grew out of the 1996 Act did what they were intended to do. And as Chairman Wheeler observed: "the elimination of circuit-switched monopoly markets certainly obviates the need for old monopoly-based regulation of that technology."[3]

The relevant question here, then, is whether ILECs currently dominate the marketplace for switched access services; that is, whether they possess sufficient market power to control prices regardless of market forces.[4] We have consistently demonstrated to the Commission over the past three years that the answer to that question is a resounding "no." For example, USTelecom presented evidence in the *Modernization Forbearance Petition* that "'ILECs' aggregate market share [of switched access lines] fell from 60.5 percent to 18.5 percent' from 2000 to 2012, and ILEC fixed access lines accounted for *less than 18 percent* of the voice market as of mid-2013."[5] These market shares are far below any threshold used by the Commission and

[3] Tom Wheeler, *Net Effects: The Past, Present and Future Impact of our Networks*, at 20 (Nov. 26, 2013), *available at* https://transition.fcc.gov/net-effects-2013/NET_EFFECTS_The-Past-Present-and-Future-Impact-of-Our-Networks.pdf.

[4] *See Petition* at 13 (citations omitted).

[5] *Petition of USTelecom for Forbearance Pursuant to 47 U.S.C. § 160(c) from Enforcement of Obsolete ILEC Legacy Regulations That Inhibit Deployment of Next-Generation Networks*, WC Docket No. 14-192, at 11-12 (filed Oct. 6, 2014) (emphasis in original) (*Modernization Forbearance Petition*) (citing Declaration of Dr. Kevin Caves ¶ 12 (Oct. 6, 2014) (Caves Decl.),

other antitrust agencies to assess market dominance.[6] The Commission has a clear opportunity here to take long-awaited action consistent with the data-driven, forward-looking, deregulatory policies it has long espoused by granting this Petition.

## II. ILECS HAVE NOT DOMINATED THE SWITCHED ACCESS VOICE MARKET FOR YEARS.

There already is ample evidence in the record for treating ILECs as non-dominant in the provision of switched access voice services. When we filed this Petition, USTelecom projected that by the end of 2012, 40 percent of households would have "cut the cord" in favor of wireless only service.[7] That projection was spot on; in fact the trend has continued as shown on the Chart below, with 43 percent of households going wireless only by the end of 2013, 30 percent using landline other than ILEC switched access, and a mere 27 percent of households using traditional ILEC voice service.[8] Based on the same reliable marketplace observations and evidence, we now project that as of the end of 2015, ILECs provided switched access voice service to fewer than 20 percent of households nationwide.[9] Even if you attribute the entire CLEC residential

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attached to the *Modernization Forbearance Petition* as Appendix B, and attached hereto as Appendix B).

[6] *See, e.g.*, *Motion of AT&T Corp. to be Reclassified as a Non-Dominant Carrier*, Order, 11 FCC Rcd 3271, 3307 ¶ 67 (1995) (declaring AT&T to be non-dominant in the provision of long distance services based, in part, on its finding that between 1984 and 1994, "AT&T's market share [ ] fell from approximately 90 percent to 55.2 and 58.6 percent in terms of revenues and minutes respectively").

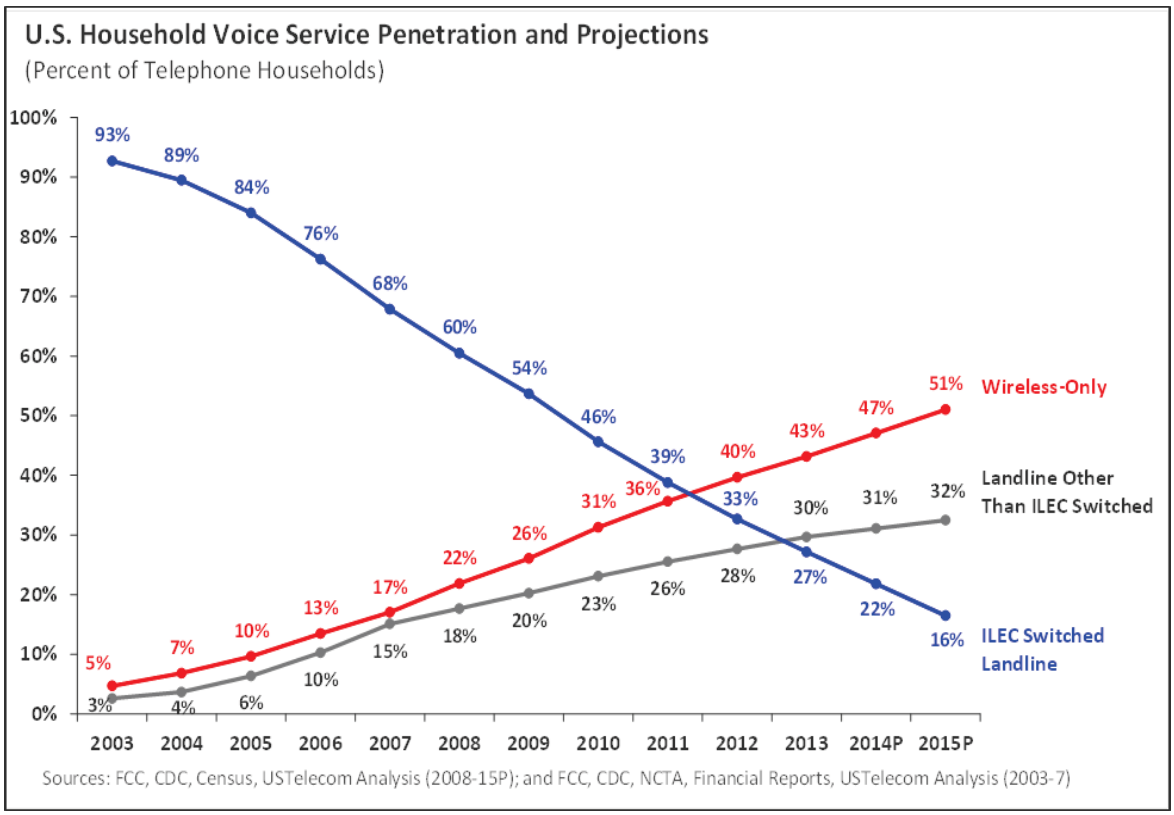
[7] *Petition* at 31.

[8] *See also* Brogan, Patrick, Vice President of Industry Analysis, USTelecom, *Voice Competition Data Support Regulatory Modernization*, at 1 (*USTelecom Voice Competition Research*), available at http://www.ustelecom.org/sites/default/files/documents/National%20Voice%20Competition%202014_0.pdf.

[9] *Id.; see also* Ex Parte of USTelecom, WC Docket No. 14-192 (filed Nov. 4, 2015) ("Given the current market dynamics, with 'incumbent' LECs providing voice service to roughly 20% of households ..., competition and consumers would be served best by removing the legacy

switched voice share of the market to ILECs (assuming that ILECs provide either wholesale or last mile facilities for those CLEC services), the result would increase ILEC share by only 0.9 percent, still a trivial amount by antitrust standards.[10] The Commission itself acknowledges that "almost 75 percent" of residential customers no longer get voice service over traditional ILEC facilities.[11]

**Chart: ILEC Switched vs. Wireless-Only and Interconnected VoIP Households**

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regulatory handicaps identified in our forbearance petition."). The current projection at year-end 2015 for ILEC switched households is 16%. *See* Chart.

[10] *See infra* pp. 6-7, quantifying the scope of CLEC-provided switched access services at the end of 2013 (citing *USTelecom Voice Competition Research*, Appendix A).

[11] *Petition of USTelecom for Forbearance Pursuant to 47 U.S.C. § 160(c) from Enforcement of Obsolete ILEC Legacy Regulations That Inhibit Deployment of Next-Generation Networks, et al.*, WC Docket Nos. 14-192, 11-42, 10-90, Memorandum Opinion and Order, FCC 15-166, at ¶ 6 (rel. Dec. 28, 2015) (*Modernization Forbearance MO&O*) (citation omitted).

Despite this overwhelming and indisputable evidence of dramatic ILEC decline in market share, ILEC competitors tell a different story. They continue to make familiar yet unsubstantiated and untrue claims that ILECs remain the dominant providers of fixed voice services in all or virtually all regions of the country. This persistent refrain about ILEC dominance is not credible, and serves only to keep one segment of the market mired in the past, while other incumbents (cable providers) and competitors that have proven they can compete in an unregulated or lightly-regulated environment (CLEC, wireless and Internet-based over-the-top voice providers) get a regulatory free pass. This outcome is directly contrary to Congress's intent to "promote competition and reduce regulation."

## III. WIRELESS SERVICE COMPETES HEAD-TO-HEAD WITH WIRELINE SERVICE.

The rise of mobile communicating has greatly impacted the state of the switched access voice services marketplace. In our petition for forbearance relief from obsolete ILEC regulatory obligations, USTelecom made the case that the ubiquitous presence of wireless service and the "cut-the-cord phenomenon" have completely reshaped the competitive landscape.[12] In light of this, the Commission can no longer credibly discount the presence of wireless service in determining what market power, if any, ILECs continue to have in the switched access voice marketplace.

Wireless services unquestionably are a competitive alternative to wireline services, and they "present a substantive, viable and economically constraining influence on the behavior of wireline telephone providers."[13] In fact, "ILEC wireline voice prices are disciplined by a range

[12] *Modernization Forbearance Petition* at 11-12.

[13] *Modernization Forbearance Petition* at 12-13 (citing Declaration of Professor John Mayo ¶ 36 (Oct. 6, 2014) (Mayo Decl.), attached to the *Modernization Forbearance Petition* as Appendix C, and attached hereto as Appendix A).

of competitive alternatives, including wireless telephony, cable voice, over-the-top VoIP, and offerings from [CLECs]."[14] The Commission has already recognized and acted upon this power shift by granting ILECs significant forbearance relief from burdensome, legacy regulations that serve no meaningful purpose in the current competitive landscape.[15] Dominant carrier status and the regulations that come with it are prime examples of "old monopoly-based regulation"[16] that has long outlived its usefulness, and thus should be eliminated.

## IV. SWITCHED ACCESS VOICE SERVICES ARE SUBJECT TO EVEN MORE COMPETITION THAN CABLE VIDEO PROGRAMMING SERVICES.

USTelecom has previously suggested that the Commission could credibly establish a presumption that ILECs are no longer dominant in the same manner that it essentially found that cable operators no longer dominate the multichannel video programming distributor (MVPD) services marketplace.[17] The Commission summarily dismissed that proposal in a footnote, finding it to be "inapposite because, *despite the relatively similar degrees of market share*, the DBS providers do not rely on incumbent cable operators to provide their products to customers whereas competitive LECs rely on the networks and services of incumbent LECs."[18]

As an initial matter, that statement is only partially true, and in fact suggests much more than what the facts show. Although some CLECs continue to rely on ILEC wholesale and UNEs to provide business services, that is rarely the case for residential switched access voice services. For example, USTelecom concludes that at the end of 2013 only a negligible 0.9 percent of

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[14] *Modernization Forbearance Petition* at 13 (citing Caves Decl. ¶ 2).

[15] *See generally Modernization Forbearance MO&O*.

[16] *Supra* note 3 and accompanying text.

[17] *See* Ex Parte of USTelecom, GN Docket No. 13-5, WC Docket No. 05-25 (filed Jun. 24, 2015).

[18] *Technology Transitions, et al.*, 30 FCC Rcd 9372, 9445 n.457 (2015) (emphasis added) (*Technology Transitions Order*).

households were using CLEC-provided switched access voice services that may have relied on ILEC wholesale (resale), UNEs, or other last-mile facilities.[19] This hardly reflects a CLEC reliance on the networks and services of ILECs that justifies treating the CLEC-ILEC relationship differently than the DBS-cable relationship. Thus, the Commission's justification for finding the "effective competition" determination to be inapposite in this context on the basis that some CLEC competitors rely on ILEC services and facilities to compete is simply not persuasive.

The Commission further noted that the specific tests for "effective competition" in the MVPD services marketplace do not apply in the context of competition between ILECs and CLECs.[20] This observation entirely misses the point for at least two reasons. First, competition in the switched access voice service marketplace is not only between ILECs and CLECs; mobile, cable, and VoIP and other over-the-top providers vigorously compete in this space as well. Second, USTelecom did not and does not now advocate that the same "effective competition" tests be used to determine whether ILECs remain dominant in the provision of switched access voice services. The Commission, in its discretion, could nevertheless apply the same standards by analogy, since the underlying regulatory and public policy goals of MVPD "effective competition" and voice services competition spring from the same Communications Act. It would be disingenuous to argue that they do not at least warrant comparable treatment given the similar impact that competition has had in each market.

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[19] *USTelecom Voice Competition Research*, Appendix A. This number excludes both cable and wireless services.

[20] *Technology Transitions Order*, 30 FCC Rcd at 9445 n.457. *See also Amendment to the Commission's Rules Concerning Effective Competition, Implementation of Section 111 of the STELA Reauthorization Act*, 30 FCC Rcd 6574 (2015) (*Effective Competition Order*).

The value of evaluating the switched access voice services market in a similar fashion is obvious; both cable operators and ILECs once enjoyed the advantages (and attendant burdens) of incumbency, but now hold no such sway over their respective markets. The loss of significant market share, in both instances (and far more in the case of ILECs), justifies similar regulatory treatment because competitors have changed the balance of power through their capture of market share. Not fully analyzing these similarities in the *Technology Transitions Order* is understandable, but the Commission should make a full, fair, and reasoned assessment in *this* proceeding of whether the demonstrated lack of market power of both cable operators in the MVPD marketplace and ILECs in the switched access voice service marketplace warrants similar regulatory treatment.[21] If after careful examination the Commission still thinks that ILECs, after losing over 75 percent of switched access voice market share to competitors, should retain "dominant" status while at the same time incumbent cable operators that have lost less than 34 percent of the MVPD market share to DBS providers should get regulatory relief, it should provide a more reasoned explanation for that conclusion than it provided in footnote 457 of the *Technology Transitions Order*.

## V. DECLARATORY RELIEF IS APPROPRIATE HERE.

Granting the declaratory relief sought by USTelecom on behalf of its member companies is appropriate and consistent with the broad discretion of the Commission to implement the 1996 Act's central goals of promoting competition and reducing regulatory burdens. To be clear, we

[21] Indeed, the Commission's goals in both proceedings should be the same: to update its rules to reflect the current marketplace, to reduce regulatory burdens on all providers, and to efficiently allocate the Commission's resources. *See Effective Competition Order*, 30 FCC Rcd at 6575, ¶ 1 (explaining that with this action the Commission "update[s its] Effective Competition rules, for the first time in over 20 years, to reflect the current MVPD marketplace, reduce[s] the regulatory burden on all cable operators, especially small operators, and more efficiently allocate[s] the Commission's resources") (citations omitted).

do not seek blanket deregulation of ILEC switched access voice services; rather, we seek a narrow scope of relief that would result in the consistent treatment of all providers in this highly competitive marketplace as "non-dominant" providers.

There is no question that some relief here is warranted, and declaring ILECs to be non-dominant would be the cleanest approach. To the extent the Commission is concerned that such a ruling might have unintended consequences such as the elimination of a regulation or requirement that might ultimately harm consumers, it has broad discretion to carve out or retain such requirements to the extent they are in the public interest. For example, if the Commission believes that price cap ILECs, once they are considered non-dominant, could raise subscriber line charges associated with their switched access services above the current cap (even though there is no evidence that they would have sufficient market power to do so), it could continue to apply the cap once they no longer are considered dominant. Thus, the remote possibility of unforeseen or unintended consequences need not deter the Commission from granting this petition.

## VI. CONCLUSION

Continued dominant regulation of ILECs is simply not warranted by the record or by the current state of the marketplace for switched access voice services. For the reasons discussed herein, we again ask for a declaration that ILECs are no longer subject to dominant carrier regulation under the Commission's rules.

Respectfully submitted,

By: _____

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Attachments

Dated: February 22, 2016

# APPENDIX A

**REDACTED – FOR PUBLIC INSPECTION**

**Before the**
**Federal Communications Commission**
**Washington, D.C. 20554**

| | |
|---|---|
| In the Matter of | |
| | ) |
| Petition of USTelecom for Forbearance | ) |
| Pursuant to 47 U.S.C. § 160(c) from Obsolete | ) |
| ILEC Regulatory Obligations that Inhibit | ) |
| Deployment of Next-Generation Networks | ) |

# Expert Declaration of John Mayo, PhD

October 6, 2014

# I. INTRODUCTION

## Qualifications

1. I am a Professor of Economics, Business and Public Policy in the McDonough School of Business at Georgetown University. I am also the Executive Director of the Georgetown Center for Business and Public Policy. I previously have served as Dean of the McDonough School at Georgetown University and have served as a Visiting Scholar at both the University of California, Berkeley and Stanford University. Since 2000, I am also a Zaeslin Fellow in Law and Economics at the University of Basel in Switzerland. My business address is Georgetown University, McDonough School of Business, 37th and O Streets, N.W., Washington, D.C., 20057.

2. I hold a Ph.D. in economics from Washington University in St. Louis (1982), with a principal field of concentration in industrial organization, which includes the analysis of antitrust and regulation. I also hold both an M.A. (Washington University in St. Louis, 1979) and a B.A. (Hendrix College, Conway, Arkansas, 1977) in economics. I have taught both undergraduate and graduate economics, business and public policy courses at Georgetown University, Washington University, the University of Tennessee and Virginia Tech.

3. I have actively studied the telecommunications industry for thirty years and have authored numerous peer-reviewed articles, research monographs, and a number of specialized articles related to the industry. These have appeared in academic journals such as the *RAND Journal of Economics, Journal of Law and Economics, Journal of Industrial Economics, International Journal of Industrial Organization, Review of Network Economics, Review of Industrial Organization, Journal of Regulatory Economics* and *Yale Journal on Regulation.* I

have also written a comprehensive text entitled *Government and Business: The Economics of Antitrust and Regulation*. In addition, I have served as President of the Transportation and Public Utilities Group and am currently serving in editorial capacities for the *Journal of Regulatory Economics*, *Economic Inquiry* and the *Review of Industrial Organization*.

4. Additionally, I have been an economic advisor for, and consultant to, both public agencies and private companies, including the Antitrust Division of the United States Department of Justice, the Federal Trade Commission, AT&T, Sprint, UPS and AmerenUE. A more detailed accounting of my education, publications and employment history is contained in Exhibit 1.

**Assignment**

5. I have been asked by US Telecom to provide a description of my ongoing research on the transition that the telecommunication industry is currently undergoing, and in particular the substantial shift by consumers to wireless telephony from wireline telephony. This shift is part a larger industry dynamic that now enables consumers who once faced a single monopoly provider of telephony to use a variety of alternatives including not only wireless telephony but also cable telephony, over-the-top VoIP, and offerings from Competitive Local Exchange Carriers ("CLECs"). While the economic impact of these alternatives is certainly relevant for the appropriate design of regulatory policy, I will focus here solely on the wireline-to-wireless shift.

**Summary of Conclusions**

6. The past ten years have witnessed a complete dismantling of one-hundred years of loyalty by Americans to wireline voice telephone service. I am aware that in its past

consideration of the role of wireless service the Federal Communications Commission (hereafter, Commission) was reticent to conclude that residential consumers' subscriptions to wireless service are a competitive alternative for traditional wireline access.[1] This reticence appeared to stem from several observations. First, the Commission noted that while the number of wireless-only households had grown from 2006-2009, the proportion of households continuing to subscribe to both wireline and wireless services "has not substantially changed since the first half of 2006."[2] The facts have now changed. As shown in Figure 1 below the percentage of households subscribing to both wireline and wireless service has fallen sharply since the Commission made this observation. From 2009 to 2014, the percentage of households subscribing to both services fell from 59 to 47 percent. It is altogether clear from the data that this trend is driven by the corollary decisions by households to simply subscribe to wireless telephony. In particular, over the 2009-2014 period, the share of wireless-only household grew from 24 percent to over 42 percent. Moreover, as discussed below, these trends are robust across virtually all demographic groups that may be worthy of special public policy attention.

7. Second, the Commission noted that econometric evidence was absent on the economic relationship between wireless and wireline services. In particular, the Commission noted an absence of econometric evidence supporting the proposition that consumer shifts from wireline to wireless services were sufficiently strong that wireline service providers would be constrained in raising the price of wireline service were they to have pricing flexibility.[3] Again, this situation has changed. Both clear descriptive statistics and modern econometric

[1] *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 22, 2010).
[2] *Ibid*, para.55. The Commission also refers to a report by the Department of Justice which notes that at the time of its 2007 inquiry "less than 20 percent of consumers have 'cut the cord'."
[3] *Ibid*, para. 58.

evidence exists today which point clearly to the competitive role of wireless service. Beyond my own research, other econometric studies, too, provide support for this intuitive proposition.[4]

8. Third, while acknowledging the growing number of wireless-only customers in the United States, the Commission suggested that the choices to rely exclusively on wireless services may be "driven more by differences in consumers' age, household structure, and underlying preferences than by relative price differentials."[5] While the Commission correctly notes differences in the degree of wireline-wireless substitutability across different demographic categories, it is now clear that the sensitivity of consumers to price differentials exists after accounting for these demographic effects. The shift to wireless cannot at this point simply be dismissed as a phenomenon embraced only by the young and tech-savvy.

9. In sum, in its prior assessment the Commission was cautious. While eschewing an "affirmative finding" in 2010 that wireless and wireline services "do not currently, or may not soon, belong in the same product market as residential wireline voice services," its own language recognized the potential for the emerging pattern of consumer behavior to move that passiveness to a more "affirmative finding." The rapid evolution of consumer behavior now warrants the affirmative finding that wireless services presents a substantive, viable and economically constraining influence on the behavior of wireline telephone providers.

## II. BACKGROUND

[4] See, e.g., the Declaration of Kevin W. Caves in this proceeding.

[5] *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 22, 2010), p. 33.

10. Wireline telephony has been regulated by state and federal authorities since the early 20th century. The reasons for this public oversight were manifold, ranging from the public's goal to ensure universal service to the desire to assure reasonable prices. Over the years, the combination of private sector investments in the telephone network and public oversight have produced a modern telecommunications network that is in many respects the envy of the world.

11. While both the public oversight and industry itself evolved slowly during the bulk of the 20th century,[6] the combination of emerging technology and a national embrace of competition for the industry has now radically unsettled the industry. On the technological front, the single technological platform for wireline voice communications has in relatively short order given way to a plethora of largely Internet-enabled technological options for wireline – or wireless – voice, video and data communications. The consequence is that consumers can, and do, routinely avail themselves of the option to communicate in ways that would have been unthinkable only a few short years ago. A loved one may telephonically send a photograph from the top of a mountain on her cellphone to her spouse. A son walking on the streets of a city may forward an informative video to his father. A businessperson may communicate with colleagues who are travelling in a car to provide an update to the day's schedule. These, and countless other examples provide incontrovertible, and profound, testimony to a new and substantially more vibrant set of telecommunications options for consumers than even a few short years ago.

12. The embrace of competition as a viable option to regulation has also dramatically changed the industry. In particular, the 1996 Telecommunications Act embraced a "pro-

[6] The divestiture of AT&T in 1984 and the passage of the Telecommunications Act of 1996 provide two notable exceptions.

competitive, de-regulatory national policy framework"[7] for the governance of the industry. This embrace, in turn, set in motion a series of policies to reduce barriers to entry that have substantially enhanced the portfolio of consumers' telecommunications choices. And while few in the early post-Telecommunications Act period may have envisioned today's sources of competitive pressure for incumbent local exchange carriers, it is by this point clear that the combination of cable telephony, wireless telephony, over-the-top VoIP, and offerings from Competitive Local Exchange Carriers ("CLECs") have substantially enhanced consumers' choices for satisfying their telecommunications needs.

13. Substantial portions of modern regulation were historically justified in an industry characterized by a single local wireline provider of essentially all communications. The vibrant emergence of a larger portfolio of communications choices for consumers, however, provides a clear call for the evolution of regulation, and in particular a review of existing regulations that may no longer be warranted in an industry that is radically different today. A critical part of this review should turn on the revealed willingness and propensity of consumers to shift away from wireline telephony. This shift (together with other discipline brought about by the emergence of cable-telephony, VOIP and CLEC services) can properly provide policymakers with confidence that the disciplinary forces of consumer choices will more efficiently govern the marketplace than traditional monopoly regulation of the industry. Whether, however, consumers do in fact treat wireline and wireless telecommunications offerings as economic substitutes or economic complements is an empirical question. It is this question that has been the focus of my research which I will now describe.

## III. CONSUMERS' SHIFT TO WIRELESS FROM WIRELINE TELEPHONY

[7] Conference Report, Telecommunications Act of 1996, House of Representatives, 104th Congress, 2d Session, H.Rept. 104-458, at p. 1.

14. When commercially introduced in 1983, few would have imagined the inroads that wireless telephony would have made by 2014. In 1983, the price of a wireless handset was over $4000 and airtime was over $1 per minute.[8] Additionally, the lack of infrastructure meant that even while nominally "mobile," dead-zones and dropped calls made wireless telephony less ubiquitous than the name "mobile" implied and a distinctly inferior option to traditional wireline service. As is well-documented, the years have seen both the price of wireless services fall and investments in wireless-enabling infrastructure explode.[9] Additionally, the rapid introduction and proliferation of smart-phones, which are capable of sending and receiving Internet-based data, voice, and video communications, have dramatically enhanced the versatility of wireless telephony.

15. It is apparent to even casual observers that consumers have responded dramatically to the emergence of affordable, ubiquitous and versatile wireless telephony. My research with colleagues provides data-based documentation of this shift.[10] For instance, Figure 1 depicts the evolving portfolio of consumer choices for the 2003-2013 decade. In particular, Figure 1 depicts the revealed choices of American households, who have chosen to satisfy their telecommunications needs by the use of: (1) a wireline telephone; (2) both a wireline and wireless telephones; (3) only wireless telephones, or (4) no telephone of any sort.

**FIGURE 1**

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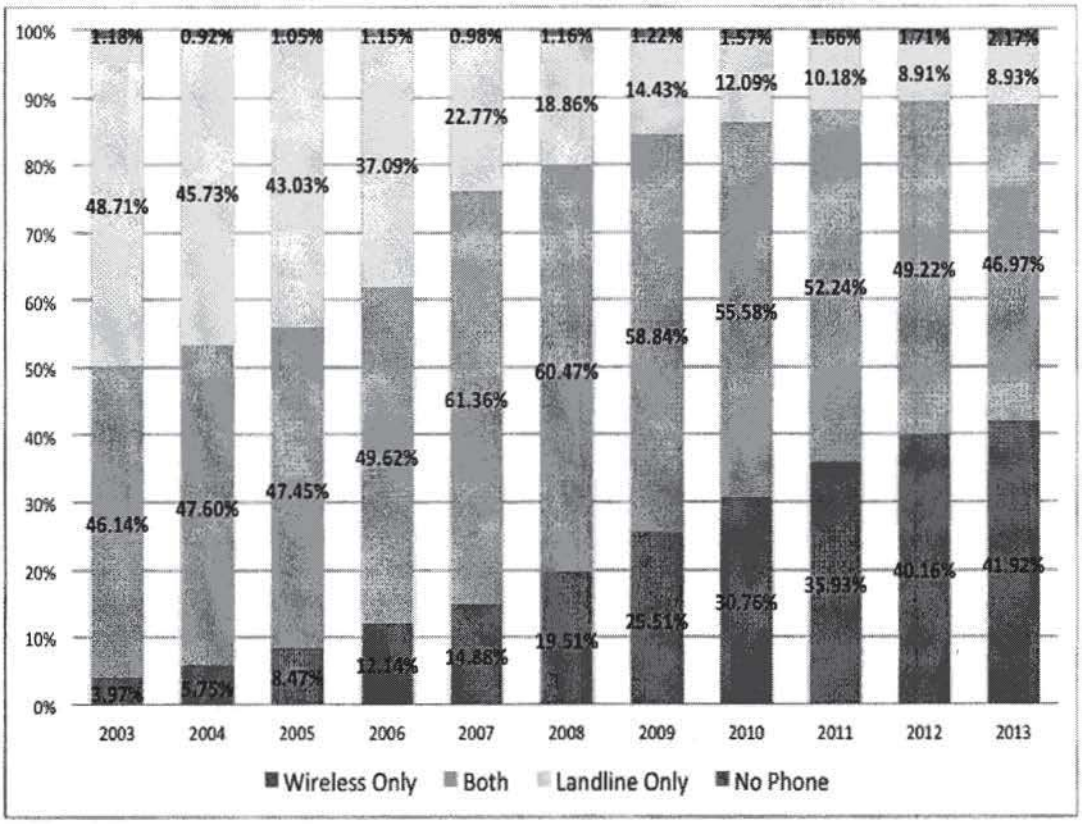
[8] John W. Mayo and Glenn Woroch, "Wireless Technologies," Information Economics and Policy, Vol. 22, March 2010, pp. 1-3.

[9] *Annual Report and Analysis of Competitive Market Conditions With Respect to Mobile Wireless*, Including Commercial Mobile Services, WT Docket No. 11-186 (Terminated) Sixteenth Report, March 21, 2013.

[10] The data for our research stem from several sources, including the National Center for Health Statistics of the Center for Disease Control (Health Interview Survey), the Federal Communications Commission, the United States Census Bureau, the United States Bureau of Labor Statistics, the Cellular Telecommunications and Internet Association and the United States Department of Agriculture. These data are described in greater detail in Jeffrey T. Macher, John W. Mayo, Olga Ukhaneva and Glenn A. Woroch "Demand in a Portfolio Choice Environment: the Evolution of Telecommunications" July 15, 2014, hereafter, Macher, at al. (2014) which is appended as Exhibit 2.

**HOUSEHOLDS WITH WIRELINE, WIRELESS, BOTH OR NEITHER**

**2003-2013**




16. Several features of Figure 1 are especially noteworthy. First, while the decade began with nearly half of American households subscribing to wireline service exclusively, that number had fallen to under 9 percent by 2013. Second, the proportion of American households that have abandoned their landline telephone service, becoming "wireless only" has grown from under four percent in 2003 to almost 42 percent by 2013. This is a *dramatic* shift away from Americans' reliance on wireline telephony. Third, while the first part of the last decade saw the percentage of households subscribing to both wireline and wireless services grow, this percentage peaked in 2007 and has declined precipitously since then. This reduction is driven in considerable measure by the introduction of extremely consumer-friendly and powerful

smartphones that have massively enhanced the versatility of wireless devices for consumers.[11] This falling percentage of households subscribing to both wireline and wireless and the growing number of households that are "wireless only" suggests that households have grown to see mobile telephone subscriptions as sufficient to satisfy all their voice telecommunications needs.

17. While this substantial shift between wireline and wireless-base subscriptions is both easily visible and substantial, a natural set of questions arise regarding the ability and willingness of historically vulnerable groups to make the wireline-wireless change. For instance, policymakers may legitimately seek to assure themselves that poor households and elderly households are able to substitute away from any unwarranted price increases by their incumbent local exchange providers. In particular, two concerns may arise. First, considering the rapidly evolving shift of households generally from wireline to wireless, if the poor and elderly are unwilling to shift away from unwarranted price increases by a deregulated local exchange carrier, effectively becoming the "residual" consumers, then such price increases may become more attractive to incumbent local exchange carriers.[12] Second, if these customers are less able and willing to shift from wireline to wireless services in the face of an attempt by a price-deregulated local exchange provider to raise rates, then these groups may bear a disproportionate amount of the burden associated with any price increase.

18. Fortunately, these concerns appear to have little substantive merit. Consider Figure 2, which displays the evolution of telephone portfolio choices of below-poverty households.

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[11] The Apple iPhone was introduced in 2007 touching off a substantial innovation-based competition among device manufacturers and mobile service providers that has robustly continued. The most recent, but surely not the last, round of this innovation-based competition is centered on the recent introduction of the Apple iPhone 6.0.

[12] In the language of more formal economics, the concern is that more price-elastic consumers have already fled the wireline network and that the remaining consumers are less price elastic, thereby raising the desired price-cost margin of the suppliers of wireline service.

There we see that the shift away from wireline telephony over the past decade has been substantially *more pronounced* among poor households than those with incomes above the poverty level. For instance, while the dependency of poor households on "landline only" telephone subscriptions was substantially higher than other households (68.7 percent versus 48.7 percent) in 2003, the share of poor households that rely exclusively on wireline telephony has fallen very sharply to under 13 percent today. Even more dramatically, the share of poor households that have "cut the cord", becoming wireless only, grew from 6 percent in 2003 to over 57 percent by 2013. Undoubtedly, poor households have demonstrated both the ability and the propensity to avail themselves of the wireless alternatives to traditional wireline telephony. Importantly, this observed propensity to switch has occurred in an environment with little price-based incentives to switch away from wireline service.[13] This suggests that the propensity of poor household to switch away from landline service would be especially pronounced in the event of an unwarranted price increase by their current local exchange provider.

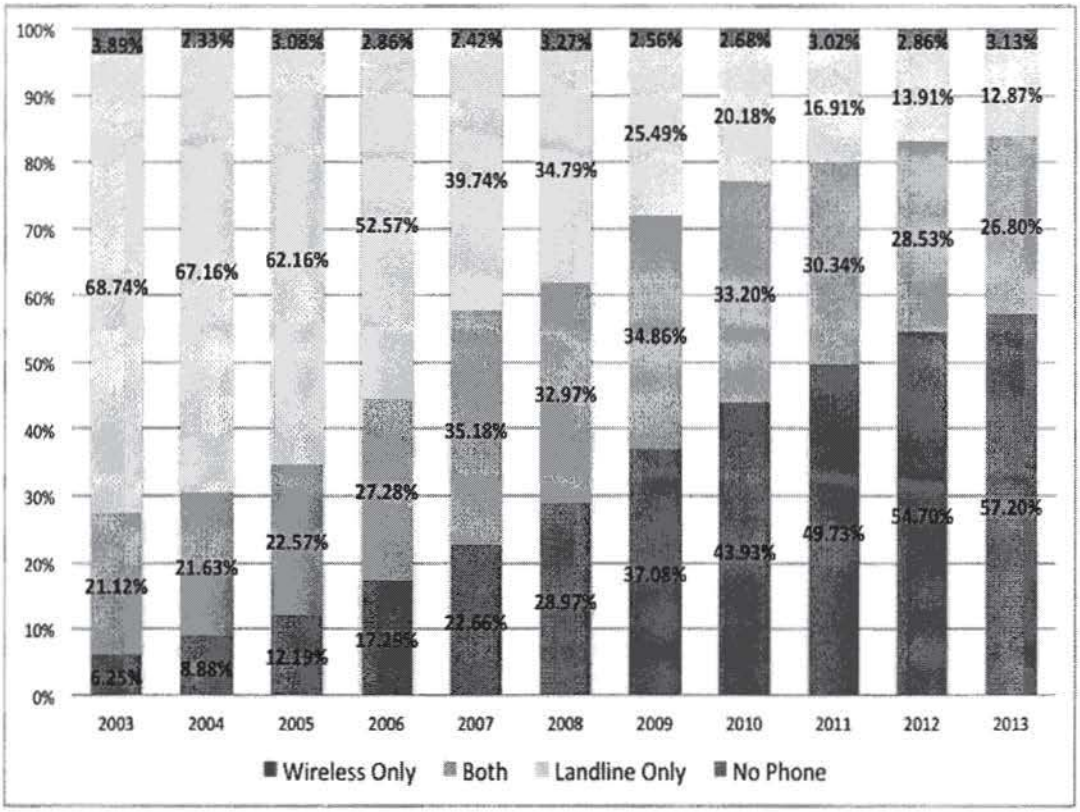
**FIGURE 2**

**HOUSEHOLDS WITH WIRELINE, WIRELESS, BOTH OR NEITHER**

**AMONG HOUSEHOLDS BELOW POVERTY THRESHOLD**

**2003-2013**

[13] Landline telephone service prices have virtually mirrored changes in the aggregate Consumer Price Index over the December 2009-July 2013 period, indicating no inflation-adjusted price increase over this period. See Table 4.3 of the Universal Service Monitoring Report 2013, Federal Communication Commission. Over the same time period, the breadth and versatility of services offered via wireless telephony have increased with the proliferation of smart-phones.




19. Another "but what about" issue that naturally surfaces in discussions of relaxing regulatory constraints on local exchange carriers is the potential impact of any regulatory reform on the elderly. Of particular concern is the fear that this demographic segment will not participate in the transformation to a "wireless economy" to the same extent as other demographic segments. That is, might the elderly be disadvantaged due to their inabilities or unwillingness for change, technological anxieties, limited wireless telephony options, or some other reason? While these concerns are substantive, policy ought not to be based merely on fears. In particular, two important questions must be addressed before concerns about the ability of the elderly to make the transition to wireless telephony is allowed to slow otherwise

needed regulatory reform. First, do the elderly have telephony choices? And second, are the elderly taking advantage of these telephony choices?

20. As part of my larger research effort, my colleagues and I have investigated the evolution of telephone demand among the U.S. elderly population over the 2003-2013 period.[14] The results—both at a cursory level and a more econometrically refined level—are telling: while younger households have moved more quickly to embrace the wireless revolution, older households are rapidly transitioning to wireless services. In short, elderly households are not "stuck in the past" or "stuck in their ways" but are instead demonstrably nimble adopters of modern wireless technologies and the ever-increasing platform of communications options that this new technology brings.

21. Consider Figure 3 which shows the portfolio of elderly households' telephone choices over the 2003 through 2013 period. As with Figures 1 and 2, each household is categorized as being in one of four mutually exclusive and exhaustive categories: "none," "landline," "wireless," or "both".

**FIGURE 3**
**HOUSEHOLDS WITH WIRELINE, WIRELESS, BOTH OR NEITHER**
**AMONG HOUSEHOLDS WITH HEAD OF HOUSEHOLD OVER 50 YEARS OLD**
**2003-2013**

[14] See, e.g., Jeffrey T. Macher and John W. Mayo "The Wireless Revolution: Are the Elderly Keeping Up?" Economic Policy Vignette 2012-5-29, Georgetown Center for Business and Public Policy, McDonough School of Business, Georgetown University, May 2012.

# APPENDIX B

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# Quantifying price-driven wireless substitution in telephony

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ABSTRACT

For the better part of a decade, a non-trivial and steadily increasing share of households in the United States has come to rely exclusively on wireless technology for their voice communications needs. Aggregate data show clearly (1) that the share of wireless-only households has risen steadily in recent years; while (2) the price of wireless service has fallen substantially relative to traditional landline service. The aggregate data are therefore consistent with the hypothesis that wireless/wireline cross-price elasticities are positive and economically significant. However, econometric corroboration of this conjecture has proven elusive in the existing empirical literature, which has relied on datasets compiled at the turn of the millennium, when wireless substitution was very limited. Partly in response to this dearth of econometric evidence, regulators and competition authorities in the US have generally been reluctant to conclude that wireless voice service represents a meaningful economic substitute for traditional wireline telephony. In the absence of reliable econometric estimates, even the sign of the relevant cross-price elasticities is an open question: The majority of US households maintain both a landline and at least one wireless connection, so it is unclear, ex ante, whether the two services are substitutes or complements. Thus, it is critical to identify consumer behavior at the margin. Using state-level panel data from a relatively recent time period (2001–2007), this study develops and estimates a demand system that permits evaluation of the own-price, cross-price, and income elasticities of demand for wireless and wireline telephony in the United States. A one percent decrease in the price of wireless service is estimated to decrease the demand for fixed-line service by approximately 1.2–1.3%, and the parameter estimates imply that the Slutsky symmetry holds for the demand system. These results substantially exceed prior econometric estimates from the existing empirical literature, and provide evidence that wireless voice service has evolved into a strong economic substitute for traditional landline service. The parameter estimates from the demand system suggest that roughly two thirds of observed landline attrition in the United States over the sample period is attributable to the observed decline in the relative price of wireless service.



## 1. Introduction

For the better part of a decade, a non-trivial and steadily increasing share of consumers in the United States has eschewed wireline telephony in the home, relying instead on wireless voice communications technology. The most recently available estimates indicate that approximately one in four US households was wireless-only as of early 2010.[1] Nevertheless, regulators and competition authorities in the United States have generally been reluctant to conclude that

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[1] Blumberg and Luke (2010) identify a household as wireless-only if (1) there is no functioning landline inside the household; and (2) at least one family member living in the household possesses a functioning wireless telephone.

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wireless voice service represents a meaningful economic substitute for traditional telephony. Instead, regulators have generally focused on facilities-based providers of cable voice services as the only demonstrably viable competitors faced by incumbent wireline voice carriers.

When performing competition analysis in telecommunications, key empirical issues include the sign and magnitude of cross-price elasticities between intermodal alternatives. Regulators attempting to determine whether price caps for Incumbent Local Exchange Carriers (ILECs) should be relaxed must assess the degree of market power that a deregulated local service provider would be able to exercise. This depends on the extent to which consumers view intermodal alternatives – such cable voice, voice over internet protocol (VoIP), and wireless telephony – as economic substitutes for traditional landline service. The greater the degree of substitutability that exists between landline service and the aggregate suite of intermodal alternatives, the less likely it is that a price increase above competitive levels would be profitable for the incumbent landline carrier. In this context, the sign of the cross-price effect between wireless and wireline is a first-order concern, because a wireline incumbent attempting to increase prices above competitive levels will lose customers to wireless competitors if and only if the cross-price elasticity is positive. If the cross-price elasticity is zero or negative, wireless services are not properly included in the set of products that constrain the price of wireline. The magnitude of the cross-price effect is also highly relevant, because wireless substitution will contribute little to intermodal price discipline if the cross-price elasticity is positive yet economically insignificant (Brennan, 2008).

In the absence of reliable cross-price elasticity estimates, 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 substitutes or 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 the aggregate data—which, as it happens, tend to support the hypothesis that wireless/wireline cross-price effects are both positive and economically significant. But despite these high-level trends, econometric evidence corroborating this hypothesis has proven elusive in empirical work, which has typically relied on rather dated datasets compiled at the turn of the millennium, when wireless substitution was still quite rare: A recent survey of the literature summarized the state of existing empirical work by stressing the paucity of "quantitative analyses of the latest and arguably most dramatic developments [in the industry]" (Vogelsang, 2010, p. 14).

Partly in response to this dearth of empirical evidence, US competition authorities such as the U.S. Department of Justice (DOJ) and the Federal Communications Commission (FCC) have generally been skeptical of the proposition that mobile telephony should be included in the suite of intermodal alternatives that potentially constrain the price of wireline telephony. The 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" (DOJ, 2008, p. 88). The 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" (FCC, 2010a, p. 32). At the same time, in light of the rapidly growing share of wireless-only households, regulators and academics alike have acknowledged the possibility that the true magnitude of cross-price effects might not be reflected in the empirical literature to date.

In this study, a state-level panel dataset from a relatively recent timeframe (2001–2007) is employed to develop and estimate a demand system that permits evaluation of the own-price, cross-price, and income elasticities of demand for wireless and wireline telephony in the United States. The results provide evidence that wireline and wireless voice service are strong economic substitutes, and indicate that changes in relative prices drive economically significant intermodal substitution. Specifically, it is estimated that a one percent decrease in the price of wireless service leads to a decline in the demand for traditional wireline service of approximately 1.2–1.3%. These results substantially exceed prior econometric estimates from the existing empirical literature, and suggest that roughly two thirds of observed landline attrition in the United States over the sample period is attributable to observed declines in the relative price of wireless service.

## 2. Trends in aggregate US data

The share of US 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, have collected detailed data on wireless substitution since the year 2003 (Blumberg & Luke, 2006), and the FCC has reported similar data in earlier time periods. (FCC, 2008a). The CDC survey results reflect biannual interviews of tens of thousands of households drawn from the civilian, non-institutionalized population.[2] As seen in Fig. 1, the share of US households that use wireless voice service in lieu of a landline connection has risen from 1.1% to 26.6% from 2001 to 2010, respectively.[3]

[2] Note that the CDC implemented changes to its questionnaire in 2007. In prior years, respondents were asked whether "the family's phone number" was a cellular telephone number. If so, the respondent was then asked whether there was at least one functioning telephone in the home that was not a cell phone. Starting in 2007, instead of a being asked two-part question, respondents were simply asked whether there was "at least one phone inside your home that is currently working and is not a cell phone" (Blumberg & Luke, 2009a).

[3] Although nationwide statistics on the share of wireless-only households provide useful high-level evidence of wireless substitution, note that these data are not well-suited to econometric analysis, and are not employed to estimate the econometric model developed here. See Section 4.1.

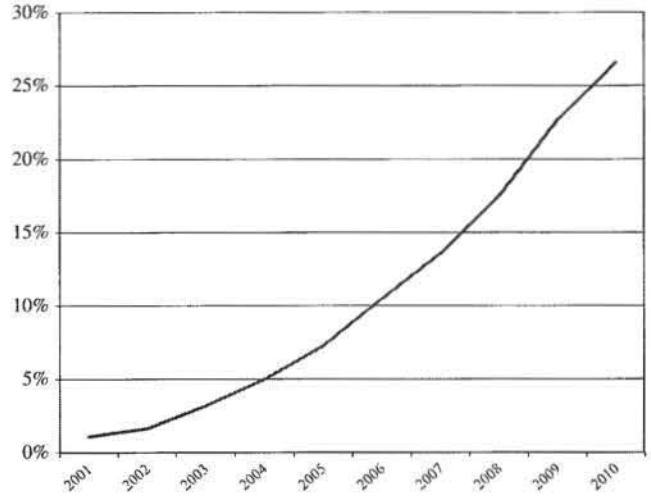


**Fig. 1.** Wireless-only share of US households, 2001–2010.
*Source*: Data for 2001–2002 from FCC (2008a). Data for 2003 forward from Blumberg and Luke (2006, 2007a, 2007b, 2008a, 2008b, 2009a, 2009b, 2010).

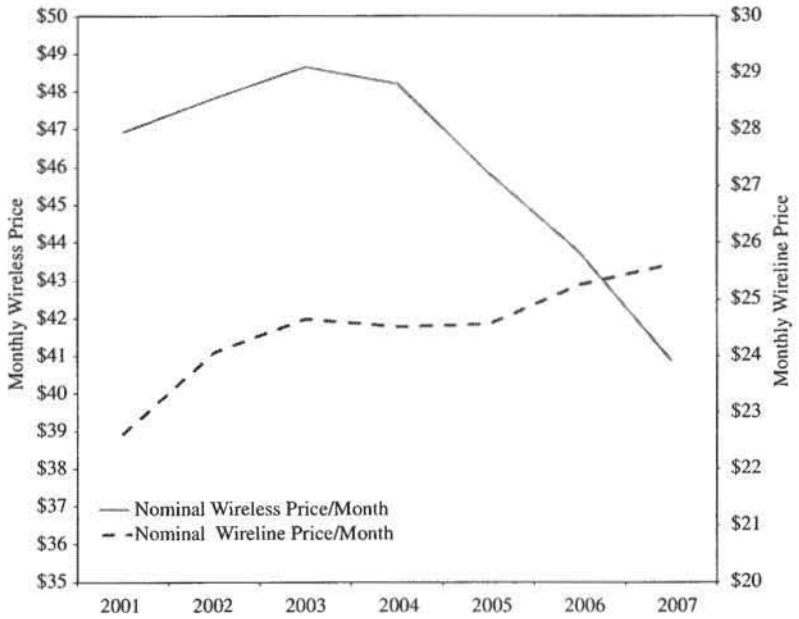


**Fig. 2.** US wireless and wireline prices, 2001–2007.
*Sources*: Wireless prices based on average monthly local wireless bills for voice service (excluding data revenues), derived from a survey of wireless carriers, reported in FCC (2010c). Wireline prices also based on average monthly local rates, derived from a separate survey of wireline carriers, reported in FCC (2008b).

In earlier years, wireless substitution was sometimes viewed as a niche phenomenon restricted to certain narrow demographic groups (Rodini, Ward, & Woroch, 2003). In light of the fact that approximately one in four US households is now wireless-only, this characterization has become increasingly obsolete. Indeed, the data show that cord-cutting has become widespread across a range of demographic categories (Blumberg & Luke, 2010). There is also evidence that wireless substitution varies substantially across geographic regions in the United States, although the available data on state-level variation are more limited.[4]

Given the rise in wireless telephony and other intermodal voice technologies, it is perhaps unsurprising that ILECs have been losing landlines at non-trivial rates for some time. According to the FCC, incumbent fixed lines decreased by more

[4] Although most of the CDC's wireless substitution surveys report only national aggregates, the CDC has also released a cross-section of state-level wireless-only estimates. However, the CDC's state-level estimates should be interpreted with caution, as they rely on a methodology that exploits state-level demographics to predict rates of wireless substitution, and are characterized by relatively loose statistical precision. For example, the widest plausible interval for the Oklahoma point estimate ranges from 12.9% to 38.8% (Blumberg et al., 2009).

than 40% over the past decade (FCC, 2010b). Industry analysts estimate that wireless substitution has been the most important factor behind the erosion of the market for traditional fixed line service, with current trends projected to continue unabated in future years (Olgeirson & Rondeli, 2011).

During this timeframe, the price of wireless voice telephony has declined significantly, while average wireline telephony prices have increased. Fig. 2 displays the nominal price of wireless and wireline services over time, based on trends in average monthly prices for local voice service. From 2001–2007, the price of wireless service dropped by approximately 12.9%. Meanwhile, although the price of wireline service remained significantly below the price of wireless, it is also the case that average wireline rates increased by approximately 13.3% during this timeframe. Adjusting for inflation, real wireless prices declined by about 25.6%, while real landline prices declined much more modestly (by about 3.3%). Thus, the data show clearly that wireless prices in the U.S. have declined significantly relative to the price of fixed line service over the sample period.

In summary, trends in the aggregate US data appear to support the hypothesis of significant economic substitutability between wireless and wireline telephony: As the relative price of wireless voice service has fallen, the share of wireless-only households has surged, while demand for traditional fixed-line service has declined steeply. Thus, the aggregate data provide prima facie evidence of positive and economically significant cross-price effects. Yet such evidence is of limited value on its own, due to the inability to control for non-price factors that may influence the relative demand for wireless versus wireline – such as improvements/expansions in cellular network coverage, etc. – as well as the inability to conduct formal statistical analysis and hypothesis tests.

## 3. Existing empirical literature

The existing empirical literature on substitution between wireline and wireless telephony generally makes use of datasets compiled at the turn of the millennium, when wireless substitution was very limited.[5] Vogelsang (2010, p. 14) provides a thorough survey of the literature, stressing the paucity of "quantitative analyses of the latest and arguably most dramatic developments [in the industry]." Therefore, it is perhaps unsurprising that the body of empirical work to date provides scant econometric evidence of strong wireless/wireline intermodal substitution (although empirical work has generally found wireless and wireline to be substitutes, rather than complements). Nevertheless, researchers have recognized the possibility that substitutability might become more evident in more recent time periods.

Broadly speaking, the existing empirical literature can be divided into studies focusing on usage substitution and research focused on access substitution. Perhaps not surprisingly, empirical estimates of the wireline/wireless cross-price elasticity are generally positive when substitution is defined in terms of usage, while the evidence is more mixed when substitution is defined in terms of access. Although both strands of the literature are reviewed here, it bears emphasis that regulators are likely to view access substitution as more economically relevant than usage substitution, since regulated Local Exchange Carriers generally provide local wireline service on a flat-fee basis (DOJ, 2008).

### 3.1. Empirical evidence: usage substitution

Using survey data for over 7000 British consumers spanning 1999–2001, Horváth and Maldoom (2002) employ an endogenous switching model to estimate the effect of mobile subscribership on fixed-line usage. After controlling for potentially confounding self-selection effects, the authors estimate that mobile telephone usage significantly depresses fixed-line usage, a finding consistent with the hypothesis that wireless usage is a substitute for wireline usage. The study does not yield direct estimates of cross-price elasticities, since the analysis relies on quantity comparisons, and does not examine price responsiveness directly. The evidence of substitution is strongest in the later years of the sample. However, the results must be interpreted with some care, as the data are self-reported, and only ranges of consumption (as opposed to precise quantities) are reported in the surveys.

Yoon and Song (2003) analyze a monthly traffic and revenue dataset from South Korea for the years 1997–2002 to study substitution between fixed and mobile usage. The authors estimate a demand system for calls originating in both mobile and fixed networks, focusing on the demand for (1) fixed-to-fixed calls (FF); (2) fixed-to-mobile calls (FM); and (3) calls originating in mobile networks. The empirical estimates provide evidence of fixed-mobile usage substitutability, with the cross-elasticity of demand for FF calls with respect to mobile prices estimated at approximately 0.6. The corresponding cross-elasticity for FM calls is not statistically significant, although it is unclear precisely what this would imply for usage substitution, since FM calls, by definition, reflect usage of both wireline and wireless services.

Briglauer, Schwarz, and Zulehner (2009) analyze a monthly Austrian dataset for the time period from 2002–2007 to estimate the demand response of fixed-line domestic calling to changes in the price of mobile service. The authors use an instrumental variables approach to account for the endogeneity of output and prices; the instruments include fixed and mobile termination charges, as well as variables related to scale and scope economies, such as the quantity of fixed network access lines and the number of broadband and voice over broadband subscribers. The econometric estimates suggest a long-run cross-price elasticity of 0.50, although the short-run elasticity estimates are smaller and sometimes statistically insignificant.

[5] See Fig. 1. Note also that the literature on mobile telephony diffusion provides evidence that wireless substitution is less likely to be observed early in the technology life cycle, when mobile penetration is low (Grajec & Kretschmer, 2009).

Ward and Woroch (2004) employ an Almost Ideal Demand System framework to model the share of minutes accounted for by wireless and wireline usage. Using US 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 0.22 and 0.33. Ward and Woroch (2004, p. 12) conclude that, although mobile service appears to be a moderate substitute for wireline usage, "[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".

Although fewer studies have estimated the elasticity of wireless usage with respect to the price of wireline, the available evidence points to smaller (but still positive) values. Ingraham and Sidak (2004) employ US household survey data from 1999 to 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. 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%. Using the same bill-harvesting dataset, Rodini (2009) estimates a structural model of mobile telephony demand, derived from a quadratic utility function. The econometric estimates again imply small but statistically significant elasticities of wireless minutes with respect to wireline prices.

### 3.2. *Empirical evidence: access substitution*

Empirical studies of the wireless/wireline cross-price elasticity have produced more ambiguous evidence when substitution is defined in terms of access, rather than usage, with some studies finding complementarity rather than substitutability. In one relatively early study, Ahn and Lee (1999) analyze a cross-section of 64 countries in order to study the determinants of the demand for mobile subscriptions. The probability of subscribing to mobile telecommunications is found to be positively and significantly correlated with the number of fixed lines per capita, a finding consistent with complementarity. However, because the authors do not include the price of fixed lines in their estimating equations, they do not obtain a direct estimate of the cross-price elasticity.

Garbacz and Thompson (2005) estimate fixed and mobile demand equations using panel data for developed and developing countries for the time period from 1996 to 2001. Many of their cross-price elasticity estimates are negative, leading the authors to conclude that their results are "generally suggestive of...complementary relationships" (Garbacz & Thompson, 2005, p. 495). The authors also note that sign of the relationship appears to change towards the end of their sample, particularly for developing countries, suggesting a possible transition away from complementarity. In a subsequent study, using a panel of developing country data spanning 1996–2003, Garbacz and Thompson (2007) present evidence of asymmetries in the sign of the cross-price elasticity. Specifically, their results suggest that, although the cross-price elasticity of wireless demand with respect to the price of wireline is positive, the cross-price elasticity of wireline demand with respect to wireless prices is negative. Both effects are relatively modest in magnitude: Estimates of the cross-price elasticity of wireline demand with respect to the monthly price of wireless fall in the range of $-0.1$, while the cross-price elasticity of wireless demand with respect to the monthly price of wireline is estimated to fall in the range of 0.05.

Narayana (2010) estimates a binary logit model of mobile and fixed-line demand using 2003 survey data from India. The survey variables allow the author to control for various non-price demographic factors. However, a lack of variation in mobile price data across survey respondents complicates the interpretation of the cross-price effects, which are not separately identified from own-price effects. Instead, in the econometric specifications, fixed and mobile prices are combined into a single composite variable. Specifically, the mobile demand equation in Narayana (2010) allows the probability of subscribing to mobile service to vary with a composite price variable equal to the difference between the mobile price and the fixed-line price. Similarly, the probability of subscribing to fixed-line service is estimated as a function of the ratio of the fixed-line price to the mobile price. Nevertheless, the econometric estimates are consistent with substitutability, and suggest that the probability of subscribing to mobile (fixed-line) telephony increases significantly with the fixed-line price (mobile price).

Rodini et al. (2003) employ US bill-harvesting household survey data from 2000 to 2001 to investigate access substitution. The authors model the determinants of consumers' decisions to subscribe to second landlines and mobile service using logit regressions. The cross-price elasticity of mobile access with respect to the wireline price is positive and statistically significant, ranging from 0.13 to 0.18.[6] However, the authors 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 to 0.26). Moreover, because wireless-only households comprise only a very small share of their sample, the data do not allow the researchers to directly identify the determinants of consumer decisions to abandon first *and* second landlines, making it impractical to directly estimate the elasticity of total fixed-line demand with respect to the price of wireless. Instead, the authors invoke Slutsky symmetry to infer the value of this parameter. The cross-price elasticities implied by this calculation are small, ranging from 0.06 to 0.08. The authors conclude that wireless offerings represent a "moderate substitute" for landline telephony, but that "[e]volving usage patterns suggest that mobile and fixed service will become greater substitutes over time" (Rodini et al., 2003, p. 475).

[6] Rodini (2009) obtains a similar estimate (0.22) using a similar dataset for the years 1999–2001.

Using the same US bill-harvesting data from a similar time period (1999–2001), Ward and Woroch (2010) estimate consumer demand for communications services by taking advantage of a natural experiment created by Lifeline Assistance telephony subsidies, which injects additional variation into the effective wireline prices faced by low-income consumers that qualify for the subsidy. 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. Because Lifeline does not subsidize mobile service during the sample period, the data do not give rise to a parallel natural experiment that would allow for a direct estimate the elasticity of fixed-line demand with respect to the price of wireless. However, assuming that the Slutsky symmetry holds, the authors estimate that this elasticity ranges from 0.126 to 0.155, based on the fact that Lifeline subsidy recipients' expenditures on mobile services are estimated to be about half as large as their expenditures on fixed-line voice service.

## 4. Econometric model

### 4.1. Methodology and data

To obtain a more current empirical assessment of the economic substitutability between wireless and wireline telephony, this study develops and estimates a demand system that permits evaluation of the own-price, cross-price, and income elasticities of demand for wireless and wireline telephony in the United States, using state-level panel data from a relatively recent time period (2001–2007). Demand is defined in terms of access (rather than usage), given that regulators generally view access substitution as more economically relevant than usage substitution (DOJ, 2008). Note that the econometric model developed here does not rely on estimates of wireless-only households. Although such statistics provide useful high-level evidence of wireless substitution, these estimates are typically nationwide aggregates, leaving insufficient cross-sectional variation for econometric analysis.[7] Moreover, the key parameter of interest – the cross-price elasticity between wireless and wireline service – is not actually defined in terms of wireless-only households, since households may have multiple landlines (Rodini et al., 2003), and subscription decisions may also take place at the level of the individual. Therefore, consistent with the definition of the cross-price elasticity, the econometric model developed below relies on state-level panel data to measure the responsiveness of the demand for wireless (wireline) subscriptions to changes in the price of wireline (wireless) telephony.

A standard, aggregated linear approach is used to estimate the demand system, rather than aggregated discrete choice methods, which have become quite prevalent in demand estimation (Berry, Levinsohn, & Pakes, 1995). A key advantage of discrete choice models is their ability to account for unobserved consumer heterogeneity, even when only aggregate data are available; another advantage they convey is the fact that the number of parameters to be estimated does not grow with the number of equations in the demand system, making it statistically feasible to incorporate a large number of products into the system, and to estimate a potentially large matrix of cross-price elasticities. Unfortunately, most discrete choice frameworks also impose strong ex ante assumptions regarding substitutability between products in the demand system, rather than allowing the data to identify whether products are substitutes or complements.[8] For present purposes, this is a clear disadvantage: The majority of households maintain both a landline and at least one wireless telephone, and the two services could, in theory, be either substitutes or complements. (As noted in Section 3, this ambiguity is borne out in the existing empirical literature, which has found evidence of both substitutability and complementarity). Therefore, it is clearly preferable to allow the data to identify the sign of the cross-price elasticity. This can be accomplished by applying a standard, aggregated linear demand framework, which allows the cross-price elasticity to vary freely. Moreover, because here the focus is on the demand for just two products (wireless and fixed-line voice service), the number of parameters to be estimated within this framework is quite manageable.

The basic demand relationship for wireless telephony is given in Eq. (1.1) below

$$Q_{st}^{w} = f(P_{st}^{w}, P_{st}^{l}, I_{st}, X_{st}; \Theta) \tag{1.1}$$

Here, $Q_{st}^{w}$ gives the demand for wireless voice service, measured by the quantity of wireless subscribers in state $s$ in year $t$, as reported by the FCC (FCC, 2008d). Similarly, $P_{st}^{w}$ gives the price of wireless service, also reported by the FCC.[9] Consistent with the increased prevalence of national calling plans and the increasingly obsolete distinction between local and long distance calling, the FCC's wireless price data do not vary by state. However, there is considerable cross-state variation in

[7] Note also that the state-level estimates produced by the CDC are characterized by relatively loose statistical precision. See Section 2.

[8] For example, Berry et al. (1995) and Hendel (1999) both impose ex ante substitutability among all products in the demand system, and therefore do not allow for complementarity. Augereau, Greenstein, and Rysman (2006) restrict all goods to be independent in demand, and therefore do not allow for substitutability or complementarity. The exception is Gentzkow (2007), who develops a discrete choice framework specifically designed to identify whether the products in the demand system are substitutes or complements. Unfortunately, the data requirements of this approach fall well outside the scope of what is available here: Applied in the current context, the Gentzkow (2007) framework would require that the data set contain, among other things, information on the number of consumers purchasing both wireless and wireline service. In contrast, in the data set employed here, only the aggregate quantity of wireless connections and the aggregate quantity of wirelines (and not the overlap between the two) are observed. Furthermore, implementation of the full Gentzkow (2007) model requires micro-level data on consumer behavior, which is also unavailable here.

[9] The wireless price data reflect average local monthly wireless bills for voice service, derived from a survey of wireless carriers (FCC, 2010c). Data revenues, toll revenues, and roaming revenues are excluded. In this way, comparability is maintained between the wireless and wireline price series, which is also based on local calling rates. As noted above, the wireless price series is adjusted to reflect variation in state taxes on wireless service.

**Table 1**
Summary statistics for panel regression data.

| 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 | 49.64 | 5.38 | 37.47 | 57.90 |
| Real Wireline Price | 266 | 27.20 | 4.62 | 17.93 | 40.68 |
| Real Median Income | 266 | 48,656 | 7958 | 34,579 | 68,080 |
| Population Density | 266 | 221 | 274 | 6 | 1167 |
| Cell Tower Density | 266 | 0.35 | 0.19 | 0.06 | 0.81 |
| Commute Time | 266 | 23.65 | 3.13 | 16.28 | 31.50 |
| White Pop | 266 | 4,873,499 | 3,493,352 | 809,511 | 16,075,421 |
| Black Pop | 266 | 910,150 | 861,633 | 3013 | 2,900,822 |
| Asian Pop | 266 | 290,510 | 675,748 | 4839 | 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 |

*Note*: Wireless subscriber data redacted for one state (Montana) in 2001 and 2004.

the tax rates on wireless service in the United States. Therefore, $P_{st}^{w}$ is adjusted to reflect this variation using a panel of state-specific wireless tax data. (Council On State Taxation, 2002, 2005; Mackey, 2004, 2008, 2011). The variable $P_{st}^{l}$ denotes the price of landline telephony service in state $s$ in year $t$, as reported by the FCC. The landline price variable, like $P_{st}^{w}$, is inclusive of taxes.[10] The variable $I_{st}$ denotes real median income by state and year. All price and income data are deflated by the Consumer Price Index (CPI).

Lastly, $X_{st}$ is a vector of demand shifters, including demographic controls such as state population densities and populations by race/ethnicity across states and over time. Another control variable in $X_{st}$ is the average commute time, which may affect demand for mobile communications. Finally, over the sample period, wireless coverage throughout the US improved significantly, as mobile carriers built out and upgraded their network infrastructures (FCC, 2010c). To capture this effect, $X_{st}$ includes a cellular tower density variable, defined as the number of FCC-registered cellular antennae per 1000 inhabitants in a given state in a given year (FCC, 2008c). Finally, the variable $\Theta$ in Eq. (1.1) denotes the vector of parameters to be estimated. Table 1 displays summary statistics for each of the variables employed in the panel data analysis.

### 4.2. Single-equation model

In the most basic model, the demand for wireless is expressed as a function of wireless prices, wireline prices, and income, as shown in Eq. (1.2). Below, lower-case letters denote natural logs, and $\varepsilon_{st}$ is a random error term, driven by unobserved demand shocks and/or measurement error in the dependent variable:

$$q_{st}^{w} = \alpha_0 + \alpha_1 p_{st}^{w} + \alpha_2 p_{st}^{l} + \alpha_3 i_{st} + \varepsilon_{st} \tag{1.2}$$

Note that the (Marshallian) own-price elasticity of demand for wireless service is given by $\alpha_1$, while the (Marshallian) cross-price elasticity of demand for wireless service with respect to the price of wireline is given by $\alpha_2$. The income elasticity of demand is given by $\alpha_3$:

$$\alpha_1 = \frac{\partial Q^w}{\partial P^w}\frac{P^w}{Q^w} = \frac{\partial q^w}{\partial p^w} \equiv \eta_w^M \tag{1.3}$$

$$\alpha_2 = \frac{\partial Q^w}{\partial P^l}\frac{P^l}{Q^w} = \frac{\partial q^w}{\partial p^l} \equiv \eta_{wl}^M \tag{1.4}$$

$$\alpha_3 = \frac{\partial Q^w}{\partial I}\frac{I}{Q^w} = \frac{\partial q^w}{\partial i} \equiv \eta_{wi} \tag{1.5}$$

In the next specification, shown in Eq. (1.6), the vector of demand shifter, $X_{st}$, is added to the OLS regression:

$$q_{st}^{w} = \alpha_0 + \alpha_1 p_{st}^{w} + \alpha_2 p_{st}^{l} + \alpha_3 i_{st} + \sum_{k=1}^{N} \lambda^k X_{st}^k + \varepsilon_{st} \tag{1.6}$$

[10] Like the wireless price data, the wireline price data reflect the average monthly rates for local service, derived from a separate survey of wireline carriers (FCC, 2008b). Wireline prices include subscriber line charges, touch-tone service, surcharges, 911 charges, and taxes (including state-specific taxes).

Next, in Eq. (1.7), state-level fixed effects are added, with $D_s^j = 1$ if $j = s$, and $D_s^j = 0$ otherwise. Thus, the model controls for all state-specific factors that are invariant over time. (To avoid singularity, one state is omitted.)

$$q_{st}^w = \alpha_0 + \alpha_1 p_t^w + \alpha_2 p_{st}^l + \alpha_3 i_{st} + \sum_{k=1}^{K} \lambda^k X_{st}^k + \sum_{j=1}^{J} \theta^j D_s^j + \varepsilon_{st} \tag{1.7}$$

Note that both $p_{st}^w$ and $p_{st}^l$ are potentially correlated with unobserved demand shocks in $\varepsilon_{st}$. With respect to wireless prices, over the sample period there have been significant advances in the quality and versatility of wireless technology along several dimensions (handset size, battery life, sound quality, etc.). As a consequence, there have likely been positive unobserved shocks to wireless demand. These shifts in demand are potentially correlated with wireless prices, which are unregulated in the US.

Although landline prices in the US remain partly constrained by regulation, which may help to mitigate endogeneity problems (Christensen & Greene, 1976), it is also the case that several states have begun to deregulate wireline prices, or at least to allow for additional upward pricing flexibility. Moreover, regulation typically does not prevent wireline incumbents from *lowering* prices (either in real or nominal terms) in response to *negative* demand shocks. Given the advent and expansion of cable telephony, VoIP, and, of course, mobile telephony, it is likely that unobserved negative shocks to wireline demand have occurred during the sample period. These shocks are likely correlated with unobserved shifts in wireless demand, implying that $p_{st}^l$ is likely to be correlated with $\varepsilon_{st}$.[11]

To ensure that the estimated own- and cross-price elasticities reflect the responsiveness of demand to prices alone, holding non-price factors constant, it is important to address this potential for simultaneity bias. Therefore, the model in Eq. (1.7) is also estimated via two-stage least squares (2SLS), treating both $p_{st}^w$ and $p_{st}^l$ as endogenous. Instruments and identification are discussed in Section 5.

### 4.3. *Full model: wireless/wireline demand system*

By definition, cross-price elasticities are governed by multiple demand equations. Although it is not necessary to model every equation in the demand system in order to obtain consistent parameter estimates, it is nonetheless desirable to include multiple equations in the econometric model in order to estimate the key parameters of interest more efficiently. Therefore, an equation is added to model the demand for fixed lines.[12] The resulting system is expressed below in Eqs. (1.8) and (1.9)

$$q_{st}^w = \alpha_0 + \alpha_1 p_t^w + \alpha_2 p_{st}^l + \alpha_3 i_{st} + \sum_{k=1}^{K} \lambda^k X_{st}^k + \sum_{j=1}^{J} \theta^j D_s^j + \varepsilon_{st} \tag{1.8}$$

$$q_{st}^l = \beta_0 + \beta_1 p_{st}^l + \beta_2 p_{st}^w + \beta_3 i_{st} + \sum_{k=1}^{K} \gamma^k X_{st}^k + \sum_{j=1}^{J} \phi^j D_s^j + \mu_{st} \tag{1.9}$$

Here, $q_{st}^l$ is the natural log of the quantity of wirelines in state $s$ in year $t$ (FCC, 2007), and $\mu_{st}$ is a random error term representing shocks to wireline demand and/or measurement error in the dependent variable. State fixed effects are included in each equation, as indicated by the $D_s^j$ terms. As discussed above, both $p_{st}^w$ and $p_{st}^l$ are potentially endogenous to Eq. (1.8).[13] Moreover, if the demand curves for wireless and wireline are interrelated, then $\varepsilon_{st}$ is likely to be correlated with $\mu_{st}$. (For example, an unobserved improvement in the quality of wireless service is likely to affect demand for both services.) This implies that $p_{st}^w$ and $p_{st}^l$ are also potentially endogenous to Eq. (1.9). Therefore, the model is estimated via iterated three-stage least squares (I-3SLS), treating both wireless and wireline prices as endogenous to the demand system. Instruments and identification are discussed in Section 5.

As before, the (Marshallian) own-price elasticity for wireless, the (Marshallian) cross-price elasticity between wireless and wireline, and the income elasticity of wireless service are given by $\alpha_1$, $\alpha_2$, and $\alpha_3$. The corresponding (Marshallian) own- and cross-price elasticities for wireline service, along with the wireline income elasticity, are defined symmetrically:

$$\beta_1 = \frac{\partial Q^l}{\partial P^l}\frac{P^l}{Q^l} = \frac{\partial q^l}{\partial p^l} \equiv \eta_l^M \tag{1.10}$$

[11] If wireless and wireline are substitutes, unobserved positive shocks to wireless demand will generally be correlated with unobserved negative shocks to wireline demand. For example, an improvement in the sound quality of wireless calls would be expected to increase the demand for wireless service, while decreasing fixed-line demand.

[12] All else equal, it would of course be informative to estimate a complete demand system for voice telephony, including equations for wireline telephony, wireless telephony, cable voice telephony, and VoIP. Due to constraints on data availability, this approach is infeasible here. (Indeed, it appears that no study in the existing empirical literature has estimated a complete demand system, presumably due to similar data constraints). Note, however, that it is not necessary to estimate a complete demand system to obtain consistent parameter estimates. In particular, the own-and cross-price elasticities for wireless and wireline service are estimated consistently as long as the instruments for wireless and wireline prices are uncorrelated with unobserved demand shocks. Note also that the key parameters of interest – the cross-price elasticities between wireless and wireline – appear only in the wireless and wireline equations.

[13] Note that Eq. (1.8) is equivalent to Eq. (1.7).

$$\beta_2 = \frac{\partial Q^l}{\partial P^w}\frac{P^w}{Q^l} = \frac{\partial q^l}{\partial p^w} \equiv \eta_{lw}^M \tag{1.11}$$

$$\beta_3 = \frac{\partial Q^l}{\partial I}\frac{I}{Q^l} = \frac{\partial q^l}{\partial i} \equiv \eta_{li} \tag{1.12}$$

In addition, the 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 $\eta_{wl}^H$ and $\eta_{lw}^H$ represent the Hicksian cross-price elasticities:

$$\frac{s_w}{s_l}\eta_{wl}^H = \eta_{lw}^H \tag{1.13}$$

Therefore, the percentage response 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 $\eta_{wl}^M$ and $\eta_{lw}^M$, along with the income elasticities $\eta_{wi}$ and $\eta_{li}$, as follows:

$$\eta_{wl}^H = \eta_{wl}^M + s_l\eta_{wi} \tag{1.14}$$

$$\eta_{lw}^H = \eta_{lw}^M + s_w\eta_{li} \tag{1.15}$$

Finally, note also that the Hicksian own-price elasticities, $\eta_w^H$ and $\eta_l^H$, are related to the Marshallian own-price elasticities and the corresponding income elasticities as follows:

$$\eta_w^H = \eta_w^M + s_w\eta_{wi} \tag{1.16}$$

$$\eta_l^H = \eta_l^M + s_l\eta_{li} \tag{1.17}$$

## 5. Empirical results and interpretation

### 5.1. Econometric estimates: single-equation model

The results of the single-equation estimates of the wireless demand function are reported in Table 2. Column (1) reports the estimates corresponding to specification (1.2). Given the demand specification, the coefficients on prices and incomes are properly interpreted as elasticities. These initial results indicate that the wireless own-price elasticity is inelastic, while the estimated income elasticity implies that the demand for wireless service expands with household income. 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 1.3% decrease in the demand for wireless, implying complementarity, rather than substitutability, between the two services.

Column (2) reports the estimates corresponding to specification (1.6), which adds demographic controls to the initial specification. The results of this regression indicate that the own-price elasticity of wireless demand is greater than one in absolute value. Cellular tower density and commute times are both positively and significantly associated with wireless demand; in addition, many of the demographic variables are statistically significant. However, the results in column (2) no longer yield a statistically significant cross-price elasticity between wireless and wireline. Moreover, when state-level fixed effects are added to the OLS regression, in column (3) (which estimates specification (1.7)), the cross-price elasticity is even smaller in absolute value, and again insignificantly different from zero. In addition, the absolute value of the own-price elasticity decreases substantially, and becomes inelastic.

As discussed above, both wireless and wireline prices are potentially endogenous to the demand equation. If this is the case, then the parameter estimates reported for the OLS regressions in columns (1)–(3) of Table 2 are biased and inconsistent. To address this potential for simultaneity bias, the model is estimated via two-stage least squares in column (4), treating both $p_{st}^w$ and $p_{st}^l$ as endogenous. The instruments include state-specific taxes on wireless and wireline service, which provide exogenous price variation across states and over time. In addition, because the wireless industry has undergone significant technical change, an index of wireless telecommunications productivity is included to capture shifts in the industry cost curve over time (BLS, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008). Standard $F$-tests applied to the first-stage regressions reject the null hypothesis of weak instruments at high levels of significance, as do tests based on the minimum eigenvalue of the $F$-statistic's matrix analog (Stock & Yogo, 2005).

The 2SLS estimates yield economically plausible results. The demand for wireless service is found to be significantly elastic, with the own-price elasticity estimated at approximately $-1.76$. Most relevant for present purposes, the cross-price elasticity estimate is positive and 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 approximately 0.69 percent.

**Table 2**
Panel regression results, single-equation model.

| Explanatory variable | Dependent variable: Natural log of wireless subscribers | | | |
|---|---|---|---|---|
| | Panel of US States, 2001–2007 | | | |
| | (1) OLS | (2) OLS | (3) OLS | (4) 2SLS |
| *ln(Price of Wireless)* | −0.916 | −1.611 | −0.303 | −1.756 |
| | (−2.06) | (−21.06) | (−3.00) | (−6.55) |
| ***ln(Price of Wireline)*** | −1.315 | −0.062 | 0.010 | **0.687** |
| | (−4.36) | (−1.19) | (0.11) | **(3.25)** |
| *ln(Median Household Income)* | 1.749 | 0.009 | 0.182 | −1.182 |
| | (5.49) | (0.08) | (0.76) | (−3.17) |
| *Population Density* | | 0.0001 | −0.007 | 0.002 |
| | | (1.34) | (−3.39) | (0.6) |
| *Cellular Tower Density* | | 0.484 | 0.016 | 0.760 |
| | | (4.59) | (0.06) | (2.11) |
| *Commute Time* | | 0.020 | 0.031 | −0.001 |
| | | (3.59) | (1.94) | (−0.06) |
| *ln(White Pop )* | | 0.592 | −2.965 | −1.126 |
| | | (17.32) | (−7.13) | (−1.84) |
| *ln(Black Pop)* | | 0.0916 | 0.5727 | 0.4655 |
| | | (7.66) | (4.95) | (3.11) |
| *ln(Asian Pop)* | | 0.073 | 1.840 | 0.761 |
| | | (2.4) | (8.04) | (2.24) |
| *ln(Hispanic Pop)* | | 0.145 | 0.294 | 0.068 |
| | | (9.79) | (1.91) | (0.34) |
| *ln(Other Pop)* | | 0.088 | 0.940 | −0.069 |
| | | (3.53) | (3.65) | (−0.19) |
| *Constant Term* | 3.908 | 6.750 | 19.438 | 33.715 |
| | (0.96) | (4.32) | (3.19) | (4.08) |
| State Fixed Effects | No | No | Yes | Yes |
| Observations | 264 | 264 | 264 | 264 |
| R-Squared | 0.2095 | 0.9821 | 0.9963 | 0.9925 |

*Note*: *t* and *z* statistics in parentheses.

A comparison of columns (3) and (4) of Table 2 suggests the importance of controlling for price endogeneity in estimation. In particular, note that the estimated cross-price elasticity increases substantially when prices are treated as endogenous, which is consistent with the notion that wireline prices are negatively correlated with unobserved shocks to wireless demand: If unobserved factors have increased the attractiveness of wireless offerings relative to landline offerings, and if this has forced wireline prices lower than they would have been otherwise, then failure to control for the endogeneity of $p_{st}^{l}$ would lead to downward bias in the estimated cross-price elasticity. Similarly, note that the absolute value of the estimated own-price elasticity increases substantially when the model is estimated via 2SLS. This is consistent with the notion that wireless prices are positively correlated with unobserved shocks to wireless demand: If unobserved factors have increased the demand for wireless offerings, and if this has caused wireless prices to be higher than they would have been otherwise, then failure to control for the endogeneity of $p_{st}^{w}$ would lead to downward bias in the (absolute value of) the estimated own-price elasticity of demand for wireless service.

### 5.2. Econometric estimates: wireless/wireline demand system

Table 3 presents the econometric estimates for the full wireless/wireline demand system specified in Eqs. (1.8) and (1.9). The system is estimated using iterated three-stage least squares. As before, both $p_{st}^{w}$ and $p_{st}^{l}$ are treated as endogenous, using the same tax and productivity instruments noted above. (Since the first stage of 2SLS is identical to the first stage of I-3SLS, the null hypothesis of weak instruments continues to be rejected).

As before, the estimated coefficients for the price and income variables are properly interpreted as elasticities. The I-3SLS regressions yield economically plausible parameter estimates. Each of the own-price elasticities is statistically significant at the 1% level or better, and each has an economically intuitive interpretation. The demand for wireless services is significantly elastic ($|\hat{\eta}_{w}^{M}| > 1$), while wireline demand, although not completely insensitive to price, is significantly inelastic ($|\hat{\eta}_{l}^{M}| < 1$). Interestingly, the coefficient on median income is negative and statistically significant in the wireless demand equation: An increase in income is associated with a decrease in the demand for wireless. In contrast, the coefficient on median income is positive and significant in the wireline demand equation. Stated differently, wireless telephony is found to be an inferior good ($\hat{\eta}_{wi} < 0$), whereas wireline telephony is found to be a normal good ($\hat{\eta}_{li} > 0$). These results are consistent with the CDC's finding that households near the poverty line are consistently more likely to be wireless-only (Blumberg & Luke, 2010).

**Table 3**
Iterated three-stage least squares results, full demand system.

| **Panel of US States, 2001–2007** | | |
|---|---|---|
| **Explanatory variable** | **Dependent variable: Natural log of wireless quantity** | |
| | **(1) I-3SLS (Unrestricted)** | **(2) I-3SLS (Restricted)** |
| **First Demand Equation (Wireless)** | | |
| *ln(Price of Wireless)* | −1.756 | −1.630 |
| | (−6.55) | (−7.02) |
| ***ln(Price of Wireline)*** | **0.687** | **0.475** |
| | **(3.25)** | **(5.00)** |
| *ln(Median Household Income)* | −1.182 | −1.099 |
| | (−3.17) | (−3.16) |
| *Population Density* | 0.002 | 0.002 |
| | (0.6) | (0.67) |
| *Cellular Tower Density* | 0.760 | 0.748 |
| | (2.11) | (2.18) |
| *Commute Time* | −0.001 | −0.001 |
| | (−0.06) | (−0.04) |
| *ln(White Pop)* | −1.126 | −1.344 |
| | (−1.84) | (−2.43) |
| *ln(Black Pop)* | 0.465 | 0.496 |
| | (3.11) | (3.55) |
| *ln(Asian Pop)* | 0.761 | 0.858 |
| | (2.24) | (2.74) |
| *ln(Hispanic Pop)* | 0.068 | 0.072 |
| | (0.34) | (0.38) |
| *ln(Other Pop)* | −0.069 | −0.062 |
| | (−0.19) | (−0.18) |
| *Constant Term* | 33.715 | 34.873 |
| | (4.08) | (4.48) |
| State Fixed Effects | Yes | Yes |
| Observations | 264 | 264 |
| R-Squared | 0.9925 | 0.9932 |
| | **Dependent variable: Natural log of wireline quantity** | |
| **Second Demand Equation (Wireline)** | | |
| *ln(Price of Wireline)* | −0.575 | −0.544 |
| | (−2.71) | (−2.55) |
| ***ln(Price of Wireless)*** | **1.249** | **1.324** |
| | **(4.65)** | **(5.00)** |
| *ln(Median Household Income)* | 0.761 | 0.849 |
| | (2.03) | (2.28) |
| *Population Density* | −0.001 | −0.002 |
| | (−0.44) | (−0.73) |
| *Cellular Tower Density* | −0.163 | −0.224 |
| | (−0.45) | (−0.62) |
| *Commute Time* | −0.013 | −0.011 |
| | (−0.63) | (−0.5) |
| *ln(White Pop)* | 1.518 | 1.449 |
| | (2.47) | (2.34) |
| *ln(Black Pop)* | −0.206 | −0.210 |
| | (−1.37) | (−1.38) |
| *ln(Asian Pop)* | −0.509 | −0.454 |
| | (−1.49) | (−1.33) |
| *ln(Hispanic Pop)* | 0.084 | 0.102 |
| | (0.42) | (0.5) |
| *ln(Other Pop)* | 0.194 | 0.281 |
| | (0.52) | (0.76) |
| *Constant Term* | −14.546 | −16.336 |
| | (−1.76) | (−1.98) |
| State Fixed Effects | Yes | Yes |
| Observations | 264 | 264 |
| R-Squared | 0.9923 | 0.9921 |

*Notes*: $z$ statistics in parentheses. Standard errors calculated according to the standard I-3SLS formula: $[\widehat{Z}'(\widehat{\Sigma}^{-1} \otimes I)\widehat{Z}]^{-1}$, where $\widehat{Z}$ denotes the predicted values of the independent variables, and $\widehat{\Sigma}$ denotes the estimated variance-covariance matrix for the error term vector from the two equations.

**Table 4**
Marshallian and Hicksian elasticity estimates.
*Source*: Author's calculations based on demand system parameter estimates.

| | Unrestricted | Restricted |
|---|---|---|
| **Marshallian** | | |
| $\widehat{\eta}_{ww}^{M}$ | −1.756 | −1.630 |
| $\widehat{\eta}_{ll}^{M}$ | −0.575 | −0.544 |
| $\widehat{\eta}_{wl}^{M}$ | 0.687 | 0.475 |
| $\widehat{\eta}_{lw}^{M}$ | 1.249 | 1.324 |
| **Hicksian** | | |
| $\widehat{\eta}_{ww}^{H}$ | −1.777 | −1.650 |
| $\widehat{\eta}_{ll}^{H}$ | −0.570 | −0.539 |
| $\widehat{\eta}_{wl}^{H}$ | 0.679 | 0.468 |
| $\widehat{\eta}_{lw}^{H}$ | 1.263 | 1.339 |

Wireless demand is also positively and significantly related to cellular tower density, indicating that demand for mobile telephony has expanded as wireless carriers have upgraded and expanded their networks. Although the commute duration variable is not statistically significant, this result is not particularly surprising, given that commute times exhibit mostly cross-sectional variation, and relatively little time series variation, while the econometric model controls for any state-specific effects that are fixed over time. The demographic variables, while sometimes individually insignificant, are collectively highly significant.

The most relevant result for present purposes is that the cross-price elasticity estimates in Table 3 are all positive and statistically significant at the 1% level or better. Specifically, a one percent increase in the price of wireline service is estimated to increase the demand for wireless service by approximately 0.48–0.69%, while the cross-price elasticity of wireline demand with respect to the wireless price is estimated to fall between 1.25% and 1.32%.

Table 3 displays both restricted and unrestricted estimates of the demand system: Rather than imposing the Slutsky symmetry from the outset, the model is first estimated without any cross-equation restrictions. Next, expenditures on wireless and wireline services, along with the household income data, are used to construct budget shares and to statistically test the Slutsky restrictions given by Eqs. (1.13)–(1.15). The test results indicate that the null hypothesis that the restrictions are valid cannot be rejected. Therefore, in the second column of Table 3, the Slutsky restrictions are imposed ex ante. The estimates of the unrestricted system are quite similar to those of 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.

Although the price elasticity estimates reported in Table 3 are Marshallian own- and cross-price elasticities, the corresponding Hicksian elasticities are quite similar in magnitude, given that expenditures on each technology represent a relatively small share of household income. Table 4 summarizes the Marshallian and Hicksian own- and cross-price elasticity estimates, with and without the imposition of the Slutsky symmetry restrictions on the demand system. The Marshallian own- and cross-price elasticity estimates reported in Table 4 are simply equal to the corresponding coefficient estimates reported in Table 3. The Hicksian own- and cross-price elasticities are computed according to Eqs. (1.14)–(1.17). The estimated Hicksian elasticities are quite close to the corresponding Marshallian elasticities. For instance, the Hicksian cross-price elasticity of wireless demand with respect to the wireline price, $\hat{\eta}_{wl}^{H}$, ranges from 0.468 to 0.679, while $\hat{\eta}_{wl}^{M}$ ranges from 0.475 to 0.687.

### 5.3. Relationship to prior empirical work

The cross-price elasticity estimates obtained here substantially exceed prior estimates from the existing literature, which has found only weak evidence of substitutability, particularly when substitution is defined in terms of access (as it is here). As noted above, the existing empirical literature has relied almost exclusively on older datasets compiled at the turn of the millennium, and has sometimes found evidence of complementarity, rather than substitutability. Those studies that have found positive cross-price elasticities have typically produced small and/or statistically insignificant estimates. In contrast, the results obtained here, using data from a relatively recent time period, provide evidence that wireless voice service has evolved into a strong economic substitute for landline service.

The most comparable estimates in the prior literature are those obtained by Ward and Woroch (2010). Using household survey data from the years 1999–2001, they estimate $\widehat{\eta}_{wl}^{M}$ in the range of 0.253–0.310. These cross-price elasticity estimates are somewhat close to the low end of the estimates of $\widehat{\eta}_{wl}^{M}$ reported in Table 4 (which range from 0.475 to 0.687). However, while the estimates in Table 4 imply that $\widehat{\eta}_{lw}^{M} > \widehat{\eta}_{wl}^{M}$, Ward and Woroch (2010) reach the opposite conclusion. As a consequence, their estimates of $\widehat{\eta}_{lw}^{M}$ (ranging from 0.126 to 0.155), are substantially smaller than the estimates of

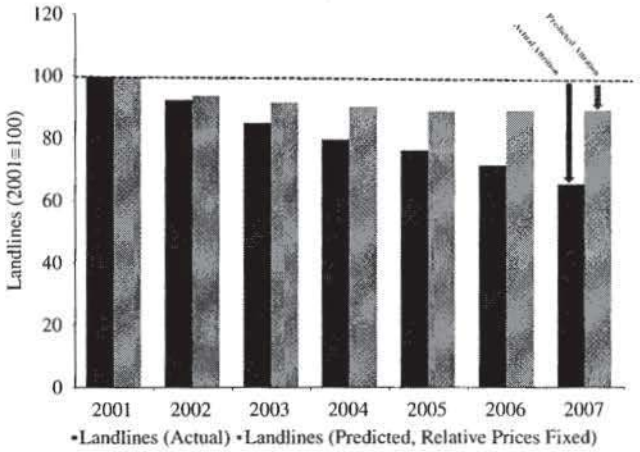


**Fig. 3.** Actual and predicted landline attrition, 2001–2007.
*Source*: Author's calculations based on demand system data and parameters.

$\widehat{\eta}^M_{lw}$ obtained here (ranging from 1.249 to 1.324). Recall that Ward and Woroch (2010) obtained $\widehat{\eta}^M_{lw}$ only indirectly, by imposing the Slutsky symmetry; thus, their result is driven by the fact that the households in their data set had higher expenditures on wireline than on wireless service. In contrast, the present approach allows the data to identify $\widehat{\eta}^M_{lw}$ directly. The fact that the statistical tests accept the null hypothesis of the Slutsky symmetry reflects the tendency for expenditures on wireless voice services to significantly exceed wireline expenditures during the sample period.

In addition to being consistent with theoretical priors, the fact that the data support the Slutsky symmetry is informative in other, more practical ways. For instance, the parameter of greatest interest to policymakers is almost certainly the elasticity of wireline demand with respect to the price of wireless, or $\eta^M_{lw}$, as opposed to $\eta^M_{wl}$, since the former effect is likely to be viewed as providing the most direct evidence that ILEC pricing is constrained by wireless offerings. Yet regulators control only the wireline price, which is defined in terms of $\eta^M_{wl}$, and not directly in terms of $\eta^M_{lw}$. It is therefore informative to provide empirical support for the theoretical proposition that an increase (decrease) in wireline prices, which the regulator controls, is equivalent to a decrease (increase) in wireless prices, which the regulator does not control. Stated differently, a finding of the Slutsky symmetry in the demand system indicates that regulators can influence wireless substitution directly, despite the fact that they directly control only one component of the price ratio.

Finally, the cross-price elasticity estimates in Table 4 also suggest that the degree of substitutability between wireless and wireline voice service is comparable to or greater than 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. (Goolsbee & Petrin, 2004). In other words, the evidence suggests that consumers view wireless telephony to be at least as interchangeable with wireline telephony as cable television service is with DBS service.

### 5.4. *Quantifying price-driven wireless substitution*

As noted previously, the price of wireless voice service has fallen significantly relative to the price of fixed-line service over the sample period, and during this same interval, there has been very substantial landline attrition. A natural question that arises is the extent to which the former can explain the latter. Given the parameter estimates from the demand system, it is possible to assess this question empirically. In particular, it is possible to estimate the equilibrium landline quantity that would have been observed at the end of the sample period if the relative price of wireless had not decreased. Because wireless and wireline telephony are substitutes, the demand system will tend to predict a higher equilibrium quantity of landlines at the end of the sample period when relative prices are constrained in this way. This in turn yields an estimate of the share of observed landline attrition attributable to the observed decline in the relative price of wireless over the sample period.

Specifically, the parameter estimates from the demand system are used to estimate the equilibrium quantity of landlines under the counterfactual scenario in which both the real wireless price and the real wireline price are held fixed at their initial observed values for the duration of the sample period. This counterfactual is illustrated in Fig. 3, which shows that the model predicts a much more gradual decline in the equilibrium quantity of landlines when relative prices are held constant. In particular, the parameter estimates imply that landline losses over the sample period would have been only about one third as large if relative prices had remained unaltered. Thus, approximately two thirds of observed landline attrition can be attributed to the observed decline in the relative price of wireless service over the sample period.

Although the wireless/wireline price ratio remains fixed under the counterfactual, all other demand shifters in the model are permitted to evolve over time according to their observed values in the dataset, which implies that the difference between the real world and the counterfactual world in Fig. 3 is driven by the estimated cross-price elasticity. By definition, the cross-price elasticity measures the extent to which landline attrition is driven by decreases in the relative price of wireless, holding constant other factors, such as improvements in the quality/versatility of wireless technology, or general (non-price) diffusion effects. To the extent that these factors are not captured by the control variables already included in the model (such as cellular tower density), they would appear in the error terms of the demand equations. Therefore, the counterfactual contemplated in Fig. 3 isolates the effect of relative prices on wireline attrition as long as the instruments used to obtain the I-3SLS cross-price elasticity estimates are uncorrelated with unobserved demand shifters. This should be the case here, since the instruments (wireless taxes, wireline taxes, and wireless industry productivity), are exogenous to the demand system.

## 6. Conclusion

For the better part of a decade, a non-trivial and steadily increasing share of US households has chosen to rely exclusively on wireless technology for their voice communications needs, while demand for traditional wireline telephony has declined steeply. At the same time, the price of wireless service has fallen significantly relative to the price of fixed-line service, suggesting that the cross-price elasticity between wireless and wireline voice services is positive and economically significant. However, econometric corroboration of this conjecture has proven elusive in the existing empirical literature, which has found only weak evidence of substitutability. To date, the empirical literature on wireless substitution has relied almost exclusively on rather dated datasets, compiled when wireless substitution was quite limited. In particular, the bill-harvesting household survey datasets upon which so much prior empirical work has relied in the US are now a decade old, and therefore capture time periods when only a very small fraction of households were wireless-only, and the relative price of wireless service was significantly higher. Partly in response to the dearth of econometric evidence in the literature, regulators and competition authorities in the United States have generally been reluctant to conclude that wireless voice service represents a meaningful economic substitute for traditional telephony.

To obtain a more current empirical assessment of the economic substitutability between wireless and wireline telephony, this study develops and estimates a demand system whose parameters include the own-price, cross-price, and income elasticities of demand for wireless and wireline telephony in the United States, using state-level panel data from a relatively recent time period (2001–2007). The econometric estimates yield positive and economically significant cross-price elasticities: A one percent decrease in the price of wireless service is estimated to decrease the demand for fixed-line service by approximately 1.2–1.3%, and the parameter estimates imply that the Slutsky symmetry holds for the demand system. These results substantially exceed prior cross-price elasticity estimates from the existing empirical literature, and suggest that roughly two thirds of observed landline attrition in the United States over the sample period is attributable to observed declines in the relative price of wireless service. Therefore, the econometric results provide evidence that wireless telephony has evolved into a strong substitute for traditional landline service—even at existing fixed-line price levels, whose levels were largely regulated during the sample period.

Because a wireline incumbent attempting to increase prices above competitive levels will lose customers to wireless competitors at a non-trivial rate if and only if the cross-price elasticity is positive and economically significant, these results support the view that regulators should take wireless competition into account when assessing the degree of market power that wireline incumbents would be able to exercise, absent regulatory pricing constraints. Specifically, the empirical results suggest that wireless offerings should be included among the set of intermodal alternatives capable of imposing price discipline on wireline incumbents, and that wireless substitution contributes substantially to the aggregate price-disciplining effect imposed by the full suite of intermodal alternatives to landline telephony. The continued erosion of the landline business since the time period analyzed here, combined with increasing rates of wireless substitution, lend additional credence to this perspective.

## References


Ahn, H., & Lee, M. (1999). An econometric analysis of the demand for access to mobile telephone networks. *Information Economics and Policy, 11*, 297–305.

Augereau, A., Greenstein, S., & Rysman, M. (2006). Coordination versus differentiation in a standards war: 56k modems. *RAND Journal of Economics, 37*, 887–909.

Berry, S., Levinsohn, J., & Pakes, A. (1995). Automobile prices in market equilibrium. *Econometrica, 63*, 841–890.

Blumberg, S. & Luke, J. (2006). *Wireless substitution: Early release of estimates based on data from the national health interview survey, July–December 2006.* Division of Health Interview Statistics, National Center for Health Statistics, Centers for Disease Control & Prevention. Atlanta, GA. Retrieved from ⟨http://www.cdc.gov/nchs/nhis/releases.htm⟩.

Blumberg, S. & Luke, J. (2007a). *Wireless substitution: Early release of estimates from the national health interview survey, January–June 2007.* Division of Health Interview Statistics, National Center for Health Statistics, Centers for Disease Control & Prevention. Atlanta, GA. Retrieved from ⟨http://www.cdc.gov/nchs/nhis/releases.htm⟩.

Blumberg, S. & Luke, J. (2007b). *Wireless substitution: Early release of estimates from the national health interview survey, July–December 2007.* Division of Health Interview Statistics, National Center for Health Statistics, Centers for Disease Control & Prevention. Atlanta, GA. Retrieved from ⟨http://www.cdc.gov/nchs/nhis/releases.htm⟩.

Blumberg, S. & Luke, J. (2008a). *Wireless substitution: Early release of estimates from the national health interview survey, January–June 2008.* Division of Health Interview Statistics, National Center for Health Statistics, Centers for Disease Control & Prevention. Atlanta, GA. Retrieved from ⟨http://www.cdc.gov/nchs/nhis/releases.htm⟩.

Blumberg, S. & Luke, J. (2008b). *Wireless substitution: Early release of estimates from the national health interview survey, July–December 2008.* Division of Health Interview Statistics, National Center for Health Statistics, Centers for Disease Control & Prevention. Atlanta, GA. Retrieved from ⟨http://www.cdc.gov/nchs/nhis/releases.htm⟩.

Blumberg, S. & Luke, J. (2009a). *Wireless substitution: Early release of estimates from the national health interview survey, January–June 2009.* Division of Health Interview Statistics, National Center for Health Statistics, Centers for Disease Control & Prevention. Atlanta, GA. Retrieved from ⟨http://www.cdc.gov/nchs/nhis/releases.htm⟩.

Blumberg, S. & Luke, J. (2009b). *Wireless substitution: Early release of estimates from the national health interview survey, July–December 2009.* Division of Health Interview Statistics, National Center for Health Statistics, Centers for Disease Control & Prevention. Atlanta, GA. Retrieved from ⟨http://www.cdc.gov/nchs/nhis/releases.htm⟩.

Blumberg, S. & Luke, J. (2010). *Wireless substitution: Early release of estimates from the national health interview survey, January–June 2010.* Division of Health Interview Statistics, National Center for Health Statistics, Centers for Disease Control & Prevention. Atlanta, GA. Retrieved from ⟨http://www.cdc.gov/nchs/nhis/releases.htm⟩.

Blumberg, S., Luke, J., Davidson, G., Davern, M., Yu, T., & Soderberg, K. (2009). *Wireless substitution: State-level estimates from the national health interview survey, January–December 2007.* National Health Statistics Reports, Division of Health Interview Statistics, National Center for Health Statistics, Centers for Disease Control & Prevention. Atlanta, GA. Retrieved from ⟨http://www.cdc.gov/nchs/data/nhsr/nhsr014.htm⟩.

Brennan, T. (2008). Applying "merger guidelines" market definition to (de)regulatory policy: pros and cons. *Telecommunications Policy, 32,* 388–398.

Briglauer, W., Schwarz, A., & Zulehner, C. (2009). *Is fixed-mobile substitution strong enough to de-regulate fixed voice telephony? Evidence from the Austrian markets.* Working Paper, Vienna, Austria: Research Institute for Regulatory Economics, Forschungsinstitut für Regulierungsökonomie, University of Economics and Business.

BLS. (2001). *Productivity and costs by industry, 2001.* Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics Retrieved from.

BLS. (2002). *Productivity and costs in selected service-providing and mining industries, 2002.* Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics Retrieved from.

BLS. (2003). *Productivity and costs by industry, 2003.* Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics Retrieved from.

BLS. (2004). *Productivity and costs by industry: selected service-providing and mining industries, 2004.* Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics Retrieved from.

BLS. (2005). *Productivity and costs by industry: selected service-providing and mining industries, 2005.* Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics Retrieved from.

BLS. (2006). *Productivity and costs by industry: selected service-providing and mining industries, 2006.* Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics Retrieved from.

BLS. (2007). *Productivity and costs by industry: selected service-providing and mining industries, 2007.* Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics Retrieved from.

BLS. (2008). *Productivity and costs by industry: manufacturing, mining, and selected service-providing industries, 2008.* Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics Retrieved from.

Christensen, L., & Greene, W. (1976). Economies of scale in U.S. electric power generation. *Journal of Political Economy, 84,* 655–676.

Council On State Taxation. (2002). *Special report: 2001 state study and report on telecommunications taxation.* Tax Management Multistate Tax Report, 9, 1–175.

Council On State Taxation. (2005). *2004 state study and report on telecommunications taxation.* Washington, DC. Retrieved from ⟨http://www.cost.org/StateTaxLibrary.aspx?id=17768⟩.

DOJ. (2008). *Voice, video and broadband: the changing competitive landscape and its impact on consumers.* Washington, DC: United States Department of Justice Retrieved from.

FCC. (2007). *Residential billable access lines by state.* ARMIS report 43-01. Federal Communications Commission, Washington, DC. Retrieved from ⟨http://www.fcc.gov⟩.

FCC. (2008a). *Trends in telephone service.* Washington, DC: Federal Communications Commission Retrieved from.

FCC. (2008b). *Reference book of rates, price indices, and household expenditures for telephone service.* Federal Communications Commission, Washington, DC. Retrieved from ⟨http://www.fcc.gov⟩.

FCC. (2008c). *Geographic information systems database (cellular tower locations).* Washington, DC: Federal Communications Commission Retrieved from.

FCC. (2008d). *Local telephone competition: status as of December 31, 2007.* Washington, DC: Federal Communications Commission Retrieved from.

FCC. (2010a). *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). Federal Communications Commission, Washington, DC. Retrieved from ⟨http://www.fcc.gov⟩.

FCC. (2010b). *Local telephone competition: Status as of December 31, 2009.* Washington, DC: Federal Communications Commission Retrieved from.

FCC. (2010c). *Annual report and analysis of competitive market conditions with respect to mobile wireless, including commercial mobile services.* Fourteenth report. Federal Communications Commission, Washington, DC. Retrieved from ⟨http://www.fcc.gov⟩.

Garbacz, C., & Thompson, H. (2005). Universal telecommunication service: a world perspective. *Information Economics and Policy, 17,* 495–512.

Garbacz, C., & Thompson, H. (2007). Demand for telecommunication services in developing countries. *Telecommunications Policy, 31,* 276–289.

Gentzkow, M. (2007). Valuing new goods in a model with complementarity: online newspapers. *American Economic Review, 97,* 713–744.

Goolsbee, A., & Petrin, A. (2004). The consumer gains from direct broadcast satellites and the competition with cable TV. *Econometrica, 72,* 351–381.

Grajec, M., & Kretschmer, T. (2009). Usage and diffusion of cellular telephony, 1998–2004. *International Journal of Industrial Organization, 27,* 238–249.

Hendel, I. (1999). Estimating multiple-discrete choice models: an application to computerization returns. *Review of Economic Studies, 66,* 423–446.

Horváth, R. & Maldoom, D. (2002). *Fixed-mobile substitution: a simultaneous equation model with qualitative and limited dependent variables.* DotEcon DP No. 02/02, London, United Kingdom. Retrieved from ⟨http://userpage.fu-berlin.de/~jmueller/its/conf/Madrid02/abstracts/Horvath.pdf⟩.

Ingraham, A., & Sidak, G. (2004). Do states tax wireless services inefficiently? Evidence on the price elasticity of demand. *Virginia Tax Review, 24,* 249–261.

Mackey, S. (2004). The excessive state and local tax burden on wireless telecommunications service. *State Tax Notes, 33,* 181–194.

Mackey, S. (2008). Excessive taxes and fees on wireless service: recent trends. *State Tax Notes, 47,* 519–531.

Mackey, S. (2011). A growing burden: taxes and fees on wireless service. *State Tax Notes, 59,* 475–486.

Narayana, M. (2010). Substitutability between mobile and fixed telephones: evidence and implications for India. *Review of Urban & Regional Development Studies, 22,* 1–21.

Olgeirson, I., & Rondeli, M. (2011). *Wireless substitution cuts into wireline phone forecast. Multichannel Market Trends.* SNL Financial.

Rodini, M. (2009). *A discrete/continuous model of mobile telephone demand using household data. Unpublished Dissertation.* Berkeley: University of California.

Rodini, M., Ward, M., & Woroch, G. (2003). Going mobile: Substitutability between fixed and mobile access. *Telecommunications Policy, 27,* 457–476.

Stock, J., & Yogo, M. (2005). Testing for weak instruments in linear IV regression. In D. Andrews, & J. Stock (Eds.), *Identification and inference for econometric models: Essays in honor of Thomas Rothenberg.* Cambridge: Cambridge University Press pp. 80–108.

Vogelsang, I. (2010). The relationship between mobile and fixed-line communications: a survey. *Information Economics and Policy, 22,* 4–17.

Ward, M., & Woroch, G. (2004). *Usage substitution between mobile telephone and fixed line in the U.S. Center for Research on Telecommunications Policy.* University of California-Berkeley Retrieved from.

Ward, M., & Woroch, G. (2010). The effect of prices on fixed and mobile telephone penetration: using price subsidies as natural experiments. *Information Economics and Policy, 22,* 18–32.

Yoon, C., & Song, Y. (2003). Telecom development in Korea: substitution and integration of fixed-mobile services and regulatory implications. *Communications and Strategies, 52,* 257–270.