

“Usage Substitution between Mobile Telephone and Fixed line in the U.S.”

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**ABSTRACT:** We empirically estimate the substitutability of fixed and mobile services for telecommunications access using a large, U.S. household survey conducted over the period 1999-2001. We find significant positive cross-price elasticities between mobile and wireline usage. Because mobile usage prices fell dramatically over this period, we estimate that wireline usage may have been about 50% higher had mobile prices not fallen.

**KEYWORDS:** Telecommunications, Mobile, Usage, Demand, Substitution

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## I. INTRODUCTION

This paper documents the changing patterns of usage of mobile telephones in the US from 1999 through 2001. While the rapid pace of consumer adoption of mobile telephones is often noted when discussing the integration of this technology into everyday life, mere counts of subscribers tend to understate the degree to which wireless communications has been incorporated into consumers' lifestyles. Due to improvements in battery life, coverage, handset size and functionality, consumers are increasingly relying on mobile phones to stay in contact with their family, friends, and co-workers.

We document these trends using data from household surveys and consumer bills from TNS Telecoms. This data set is constructed from a U.S. consumer panel that contains detailed information on households' communications purchase behavior over ten quarters. The data set includes information about a household's subscription and usage of mobile telephone service. Moreover, it includes information about features of wireless service that these consumers have available as well as survey responses regarding the effect that mobile telephone service has had on other telecommunications choices.

Analyses of survey responses and usage trends indicate many consumer behavioral changes that are consistent with mobile phone being more integrated into everyday common use. While 40% of households had mobile service initially, about 55% did at the end of 2001. The fraction of households with multiple mobile phones increased from about a third to a half of the sample population. In addition, the average minutes of use per household more than doubled over this period. While subscription appears to be affected greatly by income, usage is more closely tied to age of subscriber. Expanded vertical services or features, such as caller ID, voicemail, and speed dialing, are increasingly bundled with service. The fraction of calls that were mobile-to-mobile calling may have doubled. Consumers are increasingly accepting incoming calls rather than using their mobile phones primarily for outgoing calls. A smaller fraction of calls are considered roaming calls. Average charges per call have fallen by about half

due to migration to calling plans with larger amounts of bundled “free” minutes.

Our findings may relate to wireless technology replacing fixed line services. Consumers indicate that mobile usage has replaced wireline calling to a large degree. This is especially true for long distance calling. Unlike many developing countries, US consumers tend not to disconnect their wireline service when they subscribe to mobile service. However, we find that they have migrated minutes from their wireline service to their mobile service due to growing price differences.

Recent trends in wireless technology suggest that mobile phones will continue to make inroads into everyday life. Mobile phones continue to add functionality in the form of hands-free, text message, WAP enabled, and onboard cameras. Phones are getting still smaller with longer-lived batteries. Coverage continues to improve and bandwidth continues to increase. As networks of friends with mobile phones increase in size, the incentive to join the network becomes stronger. As consumers can do more with the phones, they tend to become more indispensable.

Our results may have important implications for the scope for mobile and wireline competition. Callers appear to be placing more calls on their mobile phones rather than their wireline phones. Mobile-to-mobile calling still represents a small fraction of all mobile minutes but this fraction doubled over our sample. This suggests that local telephone companies’ access revenue for termination may also be vulnerable. Local telephone companies may not be losing subscribers to mobile phone carriers, but they may be losing access minutes that long distance calling generates. Using the same dataset, Rodini, Ward and Woroch (2003) found only modest subscription substitution between wireline and mobile. These newer results suggest more extensive platform competition.

## **II. BACKGROUND ON FIXED-MOBILE SUBSTITUTION**

Historically, mobile telephone service did not pose an attractive alternative to fixed service. Given its high relative price, cellular service was truly a luxury, not a substitute for fixed

line. Cellular technology also lagged significantly in nonprice terms: transmission quality and geographic coverage were poor by fixed-line standards; early cell phones were cumbersome and not at all portable. These differences resulted in cellular's limited penetration rates when first introduced in the 1980s. Since those early days, mobile service adoption has grown at astonishing rates as the quality of the service and the performance of mobile providers steadily improved.

The spread of mobile services comes at a time when telecommunications authorities and the public are concerned over the lack of speed in the development of competition in local services. Unbundling and resale of network services to facilitate entry has not produced the competition originally envisioned by legislation such as the 1996 Telecommunications Act in the U.S. Nor have competitive carriers overbuilt incumbent networks to any great extent. While large business customers in dense city centers may be able to choose between providers, most smaller businesses and residents have few facilities-based options available. The slower-than-anticipated pace at which fixed-line incumbents have relinquished market share to competitors leaves mobile services as their most immediate and potent competition.

The promise of fixed-mobile competition turns, in part, on whether, under prevailing market demand and cost conditions, mobile alternatives prevent fixed-line carriers from exercising market power. As costs of mobile telephony continue to drop, allowing prices to fall and quality to rise, mobile becomes an increasingly attractive alternative to fixed-line service. Technically, mobile is a substitute because users can place and receive voice calls just as they do with fixed service. The relevant questions are whether consumers shift minutes from their fixed line(s) to their mobile phones.

So far, the incidence of users who forgo fixed service entirely and depend completely on mobile, are few in number. The profile of the typical wireless-only user is young and single. In its last two annual reports on the wireless industry, the FCC concluded from its review of third-party research that about 3% of U.S. users rely on mobile as their only phone service, while about 12% reported that they purchased mobile service rather than adding a supplementary fixed

line<sup>2</sup>. Two recent surveys of British residential consumers, conducted a year apart, both found that 5-6% of individuals claim mobile as their only source of telephone service in their home.<sup>3</sup>

An alternative view is that fixed and mobile services are complementary. Mobile service enables calls that were otherwise impossible, as when a user is traveling in a car or walking on the street. These and other mobile calls typically originate or terminate on a fixed line, so that mobile usage could stimulate fixed-line usage<sup>4</sup>. Also, even new calling that never leaves the mobile network could nevertheless trigger return calls from fixed lines that otherwise might not occur.<sup>5</sup>

The academic literature containing econometric analysis of the demand for mobile communications is primarily limited to analyses of subscription rates. Most of the contributions rely on data aggregated to the metropolitan or country level. Hausman (1999, 2000) estimates the elasticity of aggregate subscription to cellular service in the 30 largest U.S. markets over the period 1988-1993. Ahn and Lee (1999) estimate demand for mobile access in Korea using more recent wireless subscription data for 64 countries. Only recently has research appeared that examines fixed-mobile substitution. Sung, Kim and Lee (2000) find that the number of Korean mobile subscribers is positively correlated with the number of fixed-line disconnects, but negatively related to the number of new fixed-line connections, suggesting net substitution between the two services. This pattern occurs even while the stock of fixed lines is positively correlated with the number of mobile subscribers, offering evidence that the two services are

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<sup>2</sup> FCC (2001, 2002c)

<sup>3</sup> Oftel (2001, 2002).

<sup>4</sup> A household may make calls between its home fixed line and mobile phones carried by members while away from home.

<sup>5</sup> See Taylor (2002).

complements.<sup>6</sup> Recently, Rodini, Ward and Woroch (2003) found only modest substitution between mobile subscription and the demand for second-lines.

### **III. DATA DESCRIPTION**

The main source of data in our analysis are the Bill Harvesting data from TNS Telecoms ReQuest Market Monitor<sup>®</sup> along with its survey responses<sup>7</sup>. This quarterly sample of U.S. household consumption of various telecommunications services is derived from a large national panel. Participating households are asked to submit one set each of their original bills for local, long distance, cable TV, cellular and Internet services. Besides summary information, the data set extracts detailed call information from each “harvested” phone bill. While these data were first collected in 1995, this paper uses data from the ten-quarter period July 1999 - December 2001 during which a uniform sampling method and survey instrument were employed. While constructed from a subset of a panel, the Bill Harvesting data do not themselves constitute a panel<sup>8</sup>. Finally, household demographic information was also collected as well as responses from survey questions. Table 1 provides overall summary statistics for the ReQuest data.

The ReQuest survey indicates a number interesting trends in consumer perceptions of mobile calling. These tend to indicate that higher priced wireline services are being replaced with mobile calling. Figure 1 indicates that consumers believe that they are increasingly replacing wireline calls with mobile calling, although the trend is slight. Figure 2 indicates that consumer believe that primarily local calls are being replaced, although the fraction of calls replaced that are local toll or long distance appears to be growing slightly. This pattern of growing call replacement and a stronger effect can also be seen in Figures 3 and 4 depicting perceptions of mobile’s effect on wireline usage.

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<sup>6</sup> Ahn and Lee (1999) also find evidence of complementarity also using aggregate data.

<sup>7</sup> See <[www.tnstelecoms.com](http://www.tnstelecoms.com)>.

<sup>8</sup> About a quarter of all survey respondents actually submitted their phone bills, and of these households, about 10% were re-sampled during the 2000-2001 period.

Consumers also seem to be more fully incorporating mobile phones into their lifestyles. Figure 5 indicates that the growth in households with multiple mobile phones outstripped those with just one mobile phone. Households are likely to initially adopt one mobile phone and, as they discover its usefulness, migrate to multiple phones for multiple household members. The ability to easily contact multiple household members is likely to stimulate calling.

Likewise, Figure 6 indicates trends in calling mobile patterns consistent with a deeper incorporation into consumers' lifestyles. First, the fraction of calls that are incoming grew over this period. Initially, mobile customers were hesitant to give out their mobile number for fear of charges for incoming calls. These fears seem to be alleviating. Second, the fraction of mobile-to-mobile calls is rising<sup>9</sup>. This suggests that consumers are increasingly in the habit of calling friends and family when they are away from their phones, perhaps to coordinate spontaneous activities. Finally, the fraction of calls incurring roaming charges is falling. This suggests that consumers are increasingly migrating to plans that do not incur extra charges for out of area calling.

Perhaps the most striking trend in mobile calling is found in Figure 7. Average calling volumes per mobile phone more than doubled over these 10 quarters. This was primarily due to increases in "free" minutes used by consumers that nearly quadrupled as non-free "additional" minutes actually fell by half. Total charges for "non-free" calls fell with the number of calls while average monthly access charges tracks the number of "free" minutes, albeit at a lower rate of increase. It appears that consumers are increasingly subscribing to more expensive plans with more "free" minutes and they are using these minutes.

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<sup>9</sup>The data likely understate the number of mobile-to-mobile calls because not all carriers indicate if the connected party is mobile or not.

### III. MODELING CONSUMER PLATFORM CHOICE FOR USAGE

To model this problem, we take the household as the decision maker.<sup>10</sup> We start with the assumption that a consumer already has access to multiple platforms for communicating with associates. These could include email, text messaging, posting a letter, and perhaps others, in addition to fixed line phone service and mobile phone service. Each have different bundles of attributes such as voice versus written, mobility, instantaneousness, simultaneity, record of contact.. Because they share many of these attributes, we expect fixed and mobile service are likely the most substitutable with each other. Still, each have their strengths and weaknesses entailing some tradeoffs - the two major ones currently being mobility versus clarity - so that they would not be perfectly substitutable for all occasions.

#### A. LA/AIDS Demand Estimator

We model the demand for a call using the Linear Approximate/Almost Ideal Demand System (LA/AIDS). The AIDS model allows the estimation of a demand system consistent with utility theory while imposing few *a priori* restrictions on the data (Deaton & Muelbauer, 1980). Operationally, the specification regresses a good's budget share against the natural logarithm of prices of related goods and a real consumption parameter.

$$s_k = \alpha_k + \sum_j \gamma_{kj} \ln P_j + \beta_k \ln(I / P) + \varepsilon_k \quad (1)$$

As a utility based system, demand is interpreted as utility constant, or Hicksian. The real consumption parameter is meant to capture changes in utility from observation to observation. It is customary to approximate this with either real income or actual consumption. In our case, we will use total telephone minutes across all segments and platforms.

As price falls, consumers will value more potential calls above the price, inducing them

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<sup>10</sup> While mobile telephony is a single-user technology, whether to subscribe to a mobile service is likely to be part of a household's overall budgeting problem. Note also that answers given by survey respondents may not represent accurately the preferences of the entire household or the household's designated decision maker—a weakness of the survey procedure used to collect information in our data set.



to complete more calls or talk for longer. The value a consumer places on a call will usually depend on many non-price factors such as income, extent of the network of family and friends, living arrangements, etc. The price of the call will likely depend on the type of the call. For example, in the US, the marginal price of a local call is usually zero while the price of toll calls depends greatly on the regulatory agency overseeing the type of call. As a consequence, estimates of demand elasticities for local toll, intrastate interLATA, and interstate interLATA often differ.

It is likely that non-price quality improvements, rather than price reductions, played a major role in the increase in mobile usage. Non-price characteristics of mobile services can vary considerably, and they should be taken into account. Coverage area has always been a critical aspect of mobile service—in the early days when the networks were first built, as well as today in terms of digitalization and 3G capabilities. Moreover, local areas exist where calling volume demanded currently is beyond the capacity of the infrastructure or where transmission is obstructed. These “hot spots” and “dead zones” are largely determined by the number and placement of base stations. In addition, with new digital transmission and signaling technologies, the feature set of mobile phones has expanded considerably, the size and weight of the handset has fallen, and the battery life has been extended.

We attempt to account for these improvements in “quality” over time with a single time trend variable. This is at best a rudimentary measure of improvements over time that will capture any the effects of all trending variables on usage. As such it may over-state the effects of quality improvements. At the same time, it may capture much of the time variation due to generally falling prices. In this case, the inclusion of a trend may tend to bias the effects of price changes toward zero. Since it is difficult to interpret the coefficient estimates directly, we follow Green and Alston (1990) to calculate elasticities at the sample mean.

## *B. Prices*

We wish to relate the choice of fixed versus mobile service for a particular call to the

prices implicit in using these services. The charge for a call will be informative of the price for the choice of services actually used, but not for the unchosen alternative. Moreover, as will be shown below, the actual usage charges for the call can deviate sharply from economists' notions of the appropriate price. For these reasons, we consider what a consumer expect the marginal charges a caller would incur from his decision to place a call via service from fixed or mobile providers.

Prices for fixed toll services are relatively straight forward. Most toll calls are charged a constant marginal price per minute. Prices can vary by distance, time-of-day and a consumers aggregate calling volume. We aggregate all calls across all these dimensions to construct an average price per minute for each region and time period. To the extent that calling patterns differ across regions, we implicitly assume that any price differences they generate are representative of the expected price for another call.

Expected prices for mobile calls are more difficult to construct due to the two-part tariff nature of mobile phone bills. Most mobile customers choose among calling plans that bundle varying numbers of "free" minutes. A portion of the monthly charge does not reflect usage at all and can be considered the option value of placing or receiving calls. Plans with more "free" minutes entail higher monthly charges. To the extent that consumers forecast their expected calling volume and choose calling plans accordingly, the difference in monthly calling plan charges divided by changes in "free" minutes used is a component of the usage price. This implicit price of a "free" minute tends to fall as more or bundled into one's calling plan. Calls beyond one's allotment of "free" minutes are charged a relatively high marginal price, usually five to ten times the implicit price of more "free" minutes. Finally, a fraction of calls will incur additional charges because they entail "roaming," an out-of-territory connection, or are off-network.

Some issues in inferring mobile pricing can be uncovered from Figures 7 and 8. Mobile calling volumes per consumer have risen dramatically, especially for "free" minutes. Charges for "non-free" or "additional" minutes have remained nearly constant while monthly base charges

have risen, albeit at a slower pace than usage. “Free” minute usage rose fast enough that the probability that any particular call will exceed the “free” minutes fell from about 40% to near 10%. Consequently, even though the price of “additional” minutes has remained relatively unchanged, the expected marginal price of an “additional” minute, conditional on choosing a calling plan, has fallen dramatically. Total calling, both “free” and “additional” has grown faster than monthly charges, causing average charges per minute to fall from almost \$0.30 per minute to about \$0.17, nearly a halving. The conditional expected price understates usage prices because it ignores the choice of calling plans with more “free” minutes. The average price overstates usage prices because it incorporates recurring monthly charges not associated with usage. In the analysis below, we have identified the average charge per minute with usage price.

We use an instrumental variables approach to estimate predicted prices for inclusion in our demand estimation. Our instruments are dummy variables for time period and region which we choose as the quarter and LATA. Prices for fixed and mobile usage have generally fallen over time due to both factor cost reductions and better capacity utilization. Generally, prices differ across regions due to differences in costs of provision. For example, a given quality of cellular service can be more difficult to provide when there are many obstructions, such as hills or tall buildings, or when call density is more localized in a downtown area. More specifically, regulatory differences across states and possibly LATAs may lead to differences in toll prices. In addition to helping to identify demand effects from supply effects, instrumental variables may also help to purge price variables of measurement error. It is likely that the changes in costs have uniformly fallen for all regions and that a regional cost difference persisted over time. While the actual data reflect these trends, they also exhibit greater variation about the trend than would be predicted by the effects described above. Finally, the use of instrumental variables to predict prices allows us to predict prices in LATA and quarters in which few or even no calls were placed using a particular service by interpolating from the LATA fixed effect and the time trend. This interpolation keeps us from having to omit a large number of observations in the second stage.

## V. ESTIMATION

Calling volumes per household were aggregated to the LATA and quarter, the same level of aggregation as for prices. Usage was desegregated into IntraLATA, InterLATA interstate, and Interstate calling. As Table 1 indicates, the aggregation was not directly comparable for IntraLATA calls since the data included only toll calls placed on the wireline network but all calls placed on the mobile network. For some observations, there were very few InterLATA Intrastate calls. For some regions, there is only one LATA per state precluding the possibility of Intrastate InterLATA calling. Additionally, since InterLATA Intrastate is not as common, our aggregation will sometimes include only a few households or even calls. The interstate sample is free from these sorts of aggregation issues.

Regression results for equation (1) where the wireline share is the dependent variable are reported in Tables 2 and 3.<sup>11</sup> The specification in table 2 allows for a time trend to affect demand directly while that in table 3 does not. LATA and quarter dummies are used as instruments in the first stage. Instrumental variables are intended to both control for possible supply and demand endogeneity and to mitigate errors in variables issues.

Almost all price effects are statistically significant. To better interpret these results, we calculate elasticities based on coefficient values and the sample means of budget shares following Green and Alston (1990) in Table 3. As expected, the effect of mobile price is larger when the time trend is omitted. Estimated own-price elasticities are larger than demand elasticities those typically found in the literature for the type of call. This might be explained in that we are holding the price of the substitute platform choice constant. The correct comparison would be to allow the mobile price to change as the wireline price changes. An approximation to this is to measure the percent change due to a one percent simultaneous increase in both wireline and mobile usage prices:

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<sup>11</sup> Since, by construction, the results where mobile share is the dependent variable are exactly the negative of these, these regression results are unreported.

$$\tilde{\eta}_w = s_m \eta_{wm} + s_w \eta_{ww}. \quad (2)$$

In this case, the estimates from Table 3 yield wireline elasticities of about -0.3, -0.7 and -0.7 for IntraLATA, InterLATA Intrastate and Interstate respectively.<sup>12</sup> These values are much closer to the estimates found elsewhere.

Substitutability is gauged from the sign of the cross-price effects. Estimated cross-price elasticities are generally positive and the underlying coefficients are usually significant. In particular the range for the effect of mobile prices on wireline usage across all estimates is from 0.13 to 0.33. Because of data issues alluded to above, we may have most confidence in the Interstate estimates of 0.22 and 0.33. Recall that average mobile usage prices nearly halved over the sample. These estimates imply that, had they remained unchanged, or twice their current level, Interstate wireline calling volume would have been 22-33% higher than end of sample levels. If the production of mobile calls is described by high fixed costs and low variable costs, it is possible that dramatic reductions in mobile usage prices will continue into the future as demand increases and prices follow average costs. If so, we could witness additional large migrations of minutes across platforms.

## VII. CONCLUSIONS

Substitutability between wireline and mobile telephone service impacts public policy toward competition in both of these markets. In the U.S., the principal concern over competition in these markets derives from the market power held by providers of wireline local telephone service. Our estimates indicate that mobile service is a moderate substitute for wireline usage. Evolving usage patterns suggest that mobile and wireline service will become greater substitutes over time. It would be premature, however, to infer from these estimates that mobile service currently constrains local telephone service market power to any economically significant

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<sup>12</sup> The corresponding changes in mobile usage from a one percent increase in both prices would be -0.4, -0.3 to -0.7 and -0.3 to -0.5.

degree.

Substitutability may increase over time due to continued price declines and feature improvements of mobile services outpacing those of wireline service. At some point in the near future, it is possible that mobile telephone service will be able to significantly constrain wireline providers' exercise of market power. When this does occur, it will be appropriate to modify many of the current regulatory stances toward telecommunications provision. In the meantime, while mobile has displaced wireline service for a select subset of the population, the two services appear to have achieved a coexistence in the marketplace as well as in household budgeting, each providing consumers with particular advantages.

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Table 1  
Total Calls by Type

	IntraLATA	InterLATA Intrastate	InterLATA Interstate
Number of Calls			
Wireline	148,124	70,410	139,891
Mobile	470,359	34,543	98,371
Percent of Calls			
Wireline	23.9%	67.1%	58.7%
Mobile	76.1%	32.9%	41.3%
Percent of Expenditures			
Wireline	42.4%	80.0%	67.4%
Mobile	57.6%	20.0%	32.6%

Note: IntraLATA wireline calls only include calls for which toll charges would apply while IntraLATA Mobile calls include all calls placed.

Table 2  
LA/AIDS Estimates with Trend  
Dependent Variable: Wireline Share of Minutes

	IntraLATA		InterLATA		Intrastate		Interstate	
	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err
Ln Wireline Price	-0.090**	(0.014)	0.020	(0.011)	-0.064**	(0.012)		
Ln Mobile Price	0.138**	(0.015)	0.124**	(0.013)	0.142**	(0.013)		
Total Duration	0.048**	(0.006)	0.034**	(0.008)	0.011	(0.006)		
Quarterly Trend	-0.006*	(0.003)	-0.010**	(0.003)	-0.027**	(0.002)		
Intercept	-0.009	(0.046)	0.814**	(0.056)	0.648**	(0.055)		
Observations	1450		1349		1512			
Adjusted R <sup>2</sup>	0.15		0.14		0.19			

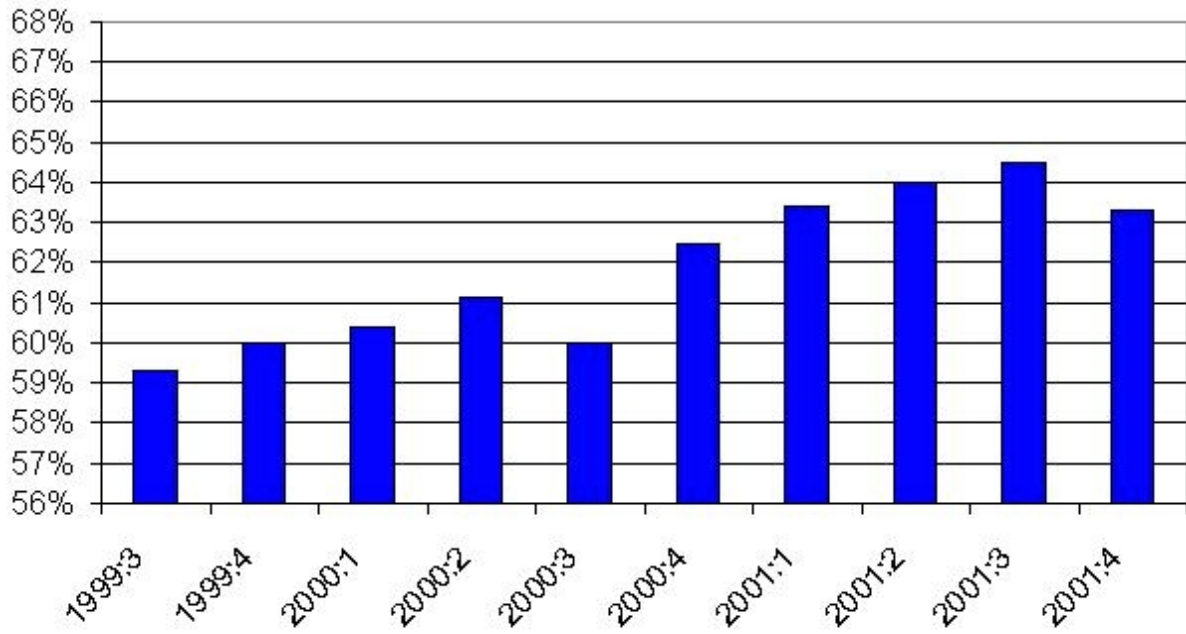
Table 3  
LA/AIDS Estimates without Trend  
Dependent Variable: Wireline Share of Minutes

	IntraLATA		InterLATA		Intrastate		Interstate	
	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err
Ln Wireline Price	-0.083**	(0.014)	0.027*	(0.011)	-0.028*	(0.013)		
Ln Mobile Price	0.160**	(0.012)	0.153**	(0.011)	0.229**	(0.012)		
Total Duration	0.050**	(0.006)	0.037**	(0.008)	0.010	(0.006)		
Intercept	-0.013	(0.046)	0.786**	(0.057)	0.702**	(0.062)		
Observations	1450		1349		1512			
Adjusted R <sup>2</sup>	0.14		0.09		0.22			

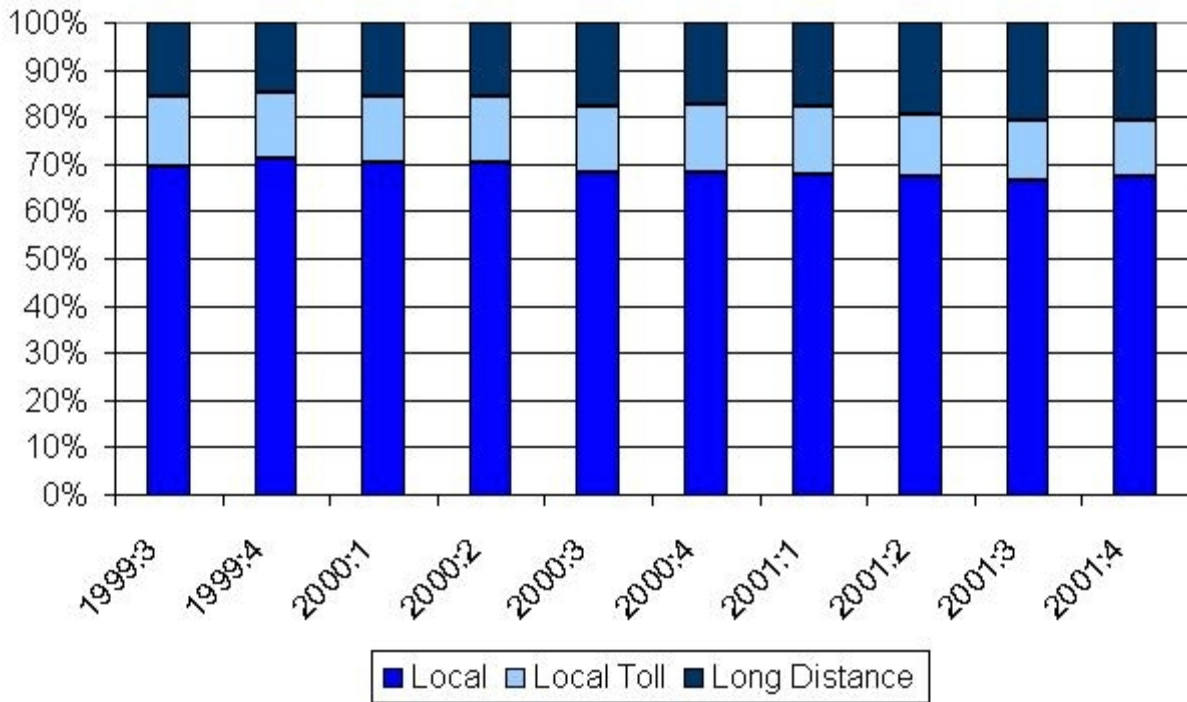
Table 4  
Elasticity Estimates from LA/AIDS Estimation

	IntraLATA		IntraLATA InterState		InterState	
	Mobile Usage	Wireline Usage	Mobile Usage	Wireline Usage	Mobile Usage	Wireline Usage
With Trend						
Mobile Price	-1.19	0.26	-1.52	0.13	-1.42	0.20
Wireline Price	0.19	-1.26	-0.03	-0.99	0.21	-1.10
Without Trend						
Mobile Price	-1.23	0.31	-1.73	0.18	-1.69	0.33
Wireline Price	0.18	-1.25	0.01	-1.00	0.11	-1.05

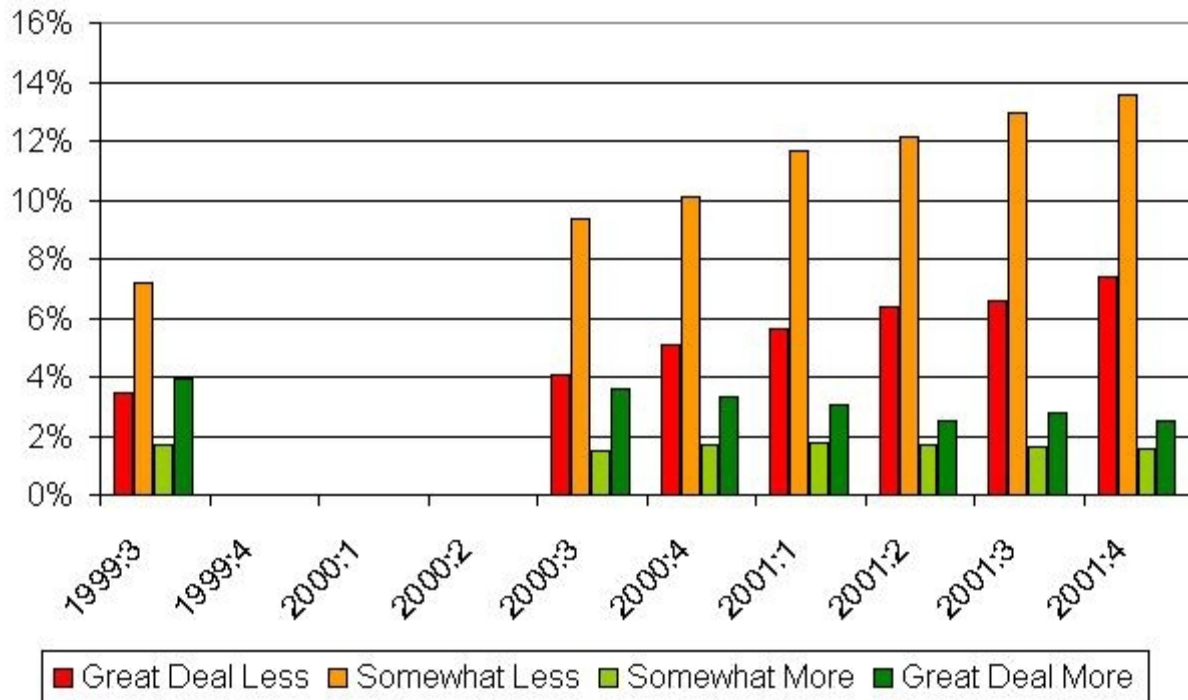
### Most Recent Wireless Call Replace a Call On Existing Phone?



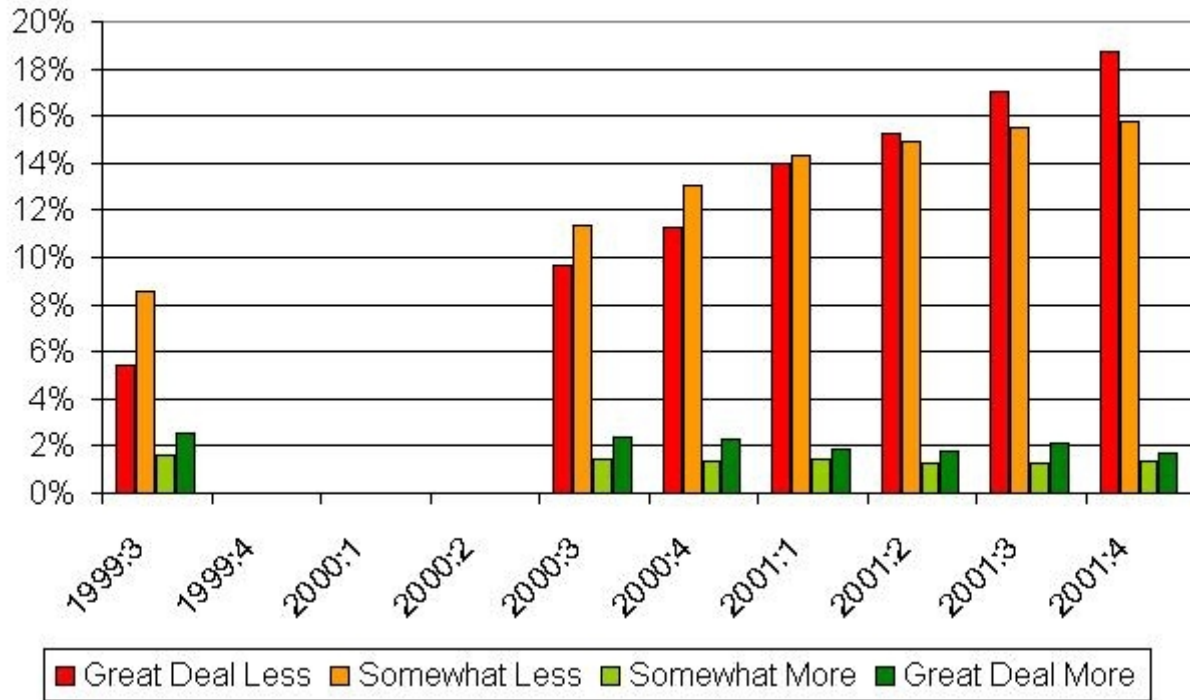
### Type of call Most Recently Replaced by Wireless



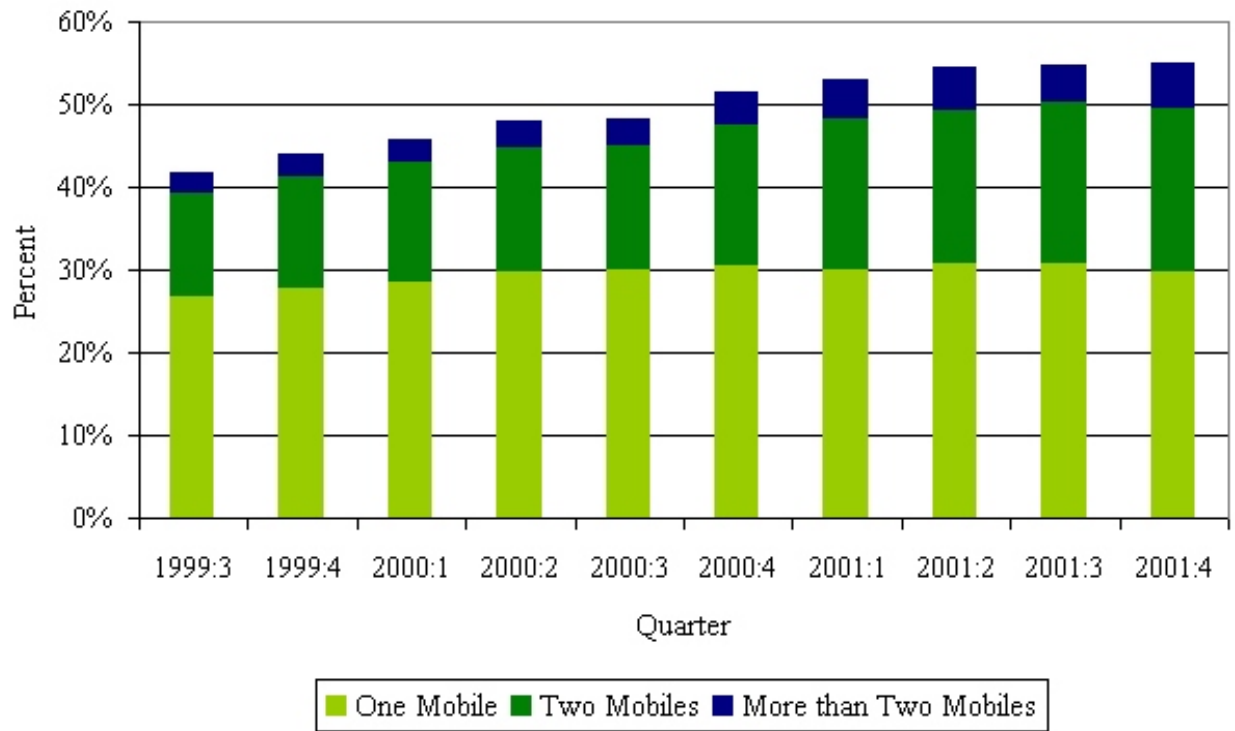
## The Effect of Wireless on Home Phone Usage



## The Effect of Wireless on Long Distance Usage



Mobile Phones Per Household



Changes in Types of Calls

