SIEPR Discussion Paper No. 04-17

The Economic Impact of Wireless Number Portability

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May 2005

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May 10, 2005

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Abstract:

This paper examines the price response of wireless carriers to the introduction of number portability. My main empirical finding is that wireless prices decreased in response to number portability, but not uniformly across all plans. Average prices for the plans with the fewest minutes decreased by only $0.5/month, but average prices for plans with intermediate and large numbers of minutes decreased by $3.3/month and $8.0/month, respectively. Resulting welfare gains to wireless consumers are large. This paper studies several explanations for the heterogeneous impact of number portability. My analysis suggests that wireless carriers engaged in price discrimination against consumer groups with high switching costs. The results of this paper suggest that even in fairly competitive markets, switching costs can confer considerable market power upon firms and firms can engage in price discrimination based on heterogeneous switching costs.

[1] Department of Economics, Stanford University. Tim Bresnahan provided much inspiration and encouragement through this project. I thank Greg Rosston and Charles Mahla, who made the Econ One dataset available to me. I also thank Brian Viard and Katja Seim for their generosity in allowing me to use the TNS data. I am grateful to Paul Riskind for many useful comments.

1. Introduction

"A surprisingly small number of customers kept their phone numbers when changing wireless carriers in the first year number portability was available. While surveys last year suggested that as many as 20 million or more consumers would switch carriers (and keep numbers) as allowed by the new rules, only about 8 million did, according to federal statistics released earlier this week. Federal Communications Commission Chairman Michael Powell hailed the 8 million figure as evidence that the government-mandated action provided customers with greater choice and caused wireless carriers to improve service. But others question whether portability's modest benefits were worth the hundreds of millions that carriers spent to implement the rules."[2]

Wireless local number portability is a government mandate that allows wireless customers to have the option of keeping their current phone numbers when they change service providers within the same local geographical area. In the US, the Federal Communications Commission (FCC) required all wireless carriers to offer number portability in the top 100 Metropolitan Statistical Areas (MSAs) by November 24, 2003, and the policy has been expanded to the entire country beginning on May 24, 2004.

Before the policy went into effect, there was much speculation about the impact of the policy, with many telecommunications experts predicting a huge increase in churn rates (monthly customer turnover rates). For example, In-Stat/MDR, a research firm, predicted that number portability would result in an additional 22.2 million churning subscribers in the first full year after introduction.[3] The introduction of number portability, however, did not cause as high an increase in switching as industry analysts had predicted, and the apparent lack of a surge in consumer switching led some people to argue that number portability was not worth all the money and efforts invested into its implementation. However, a small increase in consumer switching after number portability does not necessarily mean that the policy was not effective, since consumers who do not switch can still benefit from reduced prices if number portability increases price competition among wireless carriers.

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[2] *The Duluth News Tribute*, December 05, 2004

[3] In-Stat/MDR report "WLNP: Understanding Number Portability & Its Impact on Wireless Churn," July 2002

More fundamentally, we want to know what the impact of number portability is, if any, on firm behavior, consumer behavior, and consumer welfare. This is a very interesting topic to study for a few reasons. First, with carriers reporting to have spent several hundred million dollars in preparation for number portability and expecting to spend similar amounts annually to offer it, it is crucial to know whether the benefits of the government mandate outweigh its costs, or whether the regulation led to waste of valuable resources. Second, the wireless industry is an important component of the US economy: the annual industry revenue is $102.1 billion for 2004,[4] and with current 180 million US wireless subscribers,[5] a major regulatory change in the wireless industry could affect more than 60% of the US population. Third, the inability to retain a phone number has been cited by consumer surveys as one of the top reasons for customers staying with their current carrier.[6] Finally, the topic is interesting to an economist since the policy is designed to increase market competition by removing a specific competition-barring component: consumer switching costs. By studying how prices responded to the introduction of number portability, we can see how the reduction in consumer switching costs empirically affects firms' pricing behavior and consumer welfare.

In this paper, I look at the change in the nonlinear pricing schedule of wireless carriers in response to the introduction of number portability. I interpret changes in the nonlinear pricing schedule as an indication that number portability affected market power of wireless carriers. Under this interpretation, changes in the level and curvature of the nonlinear pricing schedule will tell us whether number portability increased competition and whether the competitive impact was similar across plans of different usage levels.

Using Econ One's monthly data on cellular and PCS pricing plans, I compare the prices of wireless plans before and after the introduction of number portability. The comparison reveals that prices declined after the policy introduction, but the magnitude of the price decline was far from being uniform across consumers. The prices for the plans with fewest minutes decreased by 2.4%, while the prices for plans with

[4] Cellular Telecommunications and Internet Association's (CTIA) Semi-Annual Wireless Industry Survey (2004)
[5] From the CTIA website, April 3, 2005
[6] Ben Charny, "It's Your Number – Take It with You," Nov. 3, 2003, http://news.com.com/2100-1037-5100892.html

intermediate and large numbers of minutes decreased by 4.5% and 5.6%, respectively. In absolute terms, these correspond to $0.5, $3.3, and $8.0 reduction for monthly prices, respectively.

I find that the observed heterogeneous impact of the policy is consistent with the prediction of a model on price discrimination based on heterogeneous switching costs. High-volume users tend to have more contacts to inform of a phone number change and are more likely to be business users who do not want to change phone numbers for the fear of losing business contacts. As a result, high-volume users faced larger switching costs than low-volume users did before number portability, other things being equal. Exploiting this, wireless carriers charged higher prices than they would have charged if numbers were portable, and the premium was bigger for higher-volume users. The introduction of number portability eliminates the switching costs arising from the inability to keep phone numbers, so it would eliminate price discrimination based on such switching costs. According to this model, the prices for high-volume plans should fall more than the prices for low-volume plans in response to the introduction of number portability. This prediction holds true in the data.

According to this interpretation, my results suggest that number portability changed consumer welfare in interesting ways. The *direct* benefit of number portability, the benefit of keeping phone numbers when switching service providers, is larger for higher-volume users. The *indirect* benefit of number portability, the benefit from increased competition, is also larger for higher-volume users according to my results. Most carriers impose similar surcharges (which are not included in the price measure I use) on all customers to recover the costs of implementing number portability. Therefore, the results of this paper suggest that high-volume users disproportionately benefited from number portability and that low-volume users did not gain as much or even lost.

Using the distribution of plan sizes of wireless subscribers in the US, I calculate that the net welfare gains from increased competition for consumers in the top 100 US markets were $120.74 million per month, or $845.18 million by June 2004 for the 7

months the policy was in place in those markets.[7] Consumer welfare for the very low-end users decreased because of number portability, but the policy increased consumer welfare for most other wireless subscribers. Heavy users especially gained a lot. The figure is probably a lower bound for the true impact of the policy on consumer welfare since it does not include the benefit consumers enjoy by keeping their phone numbers when switching carriers, or the benefit from improvements in non-price dimensions. Since number portability is not the kind of policy that can be unilaterally implemented by a carrier, the benefits to consumers could not have realized even in the fairly competitive wireless market without the mandatory requirement by the government.

In the next section, I go through institutional details of the wireless industry, focusing on switching costs in the wireless market and the introduction of number portability. In Section 3, I discuss a theoretical framework on price discrimination based on heterogeneous switching costs. I describe the Econ One data in Section 4. In Section 5, I present the estimated impact of number portability on nonlinear pricing and on consumer welfare. Section 6 discusses alternative explanations for the finding. Section 7 concludes.

[7] The figure is net of a general time trend. It is also net of the surcharges carriers imposed on consumers *after* number portability. It is *not* net of the surcharges imposed on consumers *before* number portability began. In Section 5, I will discuss these in more details.

2. Switching Costs and Number Portability in the Wireless Market

In the mobile telephony market, consumers face various kinds of switching costs. When they change service providers, they have to incur the costs of closing their account with one carrier and opening a new account with another, which often requires a visit to a retail store. In addition, the inability of end-users to retain their phone numbers when changing service providers forces them to inform their family, friends, and business contacts of their new phone numbers. I will call this type of switching cost a network switching cost since it is the cost of informing one's social network of the phone number change. Because consumers in general cannot keep their current handsets, they have to pay for a new handset and learn how to use it. Finally, many wireless users face contractual switching costs, since most carriers require consumers to sign up for a long-term contract. If a wireless user wants to switch carriers before the contract is over, he has to pay an early termination fee of up to $200. Together, these switching costs amount to a considerable obstacle to switching by wireless users.

To reduce consumer switching costs and induce more competition in the wireless industry, the FCC mandated the introduction of number portability throughout the top 100 MSAs by November 24, 2003. The policy enabled consumers to retain their phone numbers when switching service providers. Therefore, number portability eliminated network switching costs, but not other kinds of switching costs.

The implementation of number portability was first discussed in the 1996 Telecommunications Act.[8] Although the 1996 Telecommunications Act required only local exchange carriers to provide number portability, the FCC extended number portability requirements to wireless carriers.[9] The initial compliance date of wireless number portability was June 1999, but it has been extended on multiple occasions due to the industry's fierce objections; initially it was extended six months and again to November 24, 2002 after the CTIA requested a temporary forbearance from enforcement. Then in July 2001, Verizon sought a permanent forbearance from the portability rules. In July 2002, Verizon's forbearance petition was denied, but the FCC agreed to extend the

[8] For the history of wireless number portability, I heavily borrowed from Kessing (2004).
[9] FCC (2004), Annual Report and Analysis of Competitive Market Conditions with Respect to Commercial Mobile Services (FCC CMRS Competition Report)

deadline to November 24, 2003. Verizon and the CTIA then filed an appeal to the D.C. Circuit in August 2002, which was denied by the court in June 2003. As a result, number portability began in the top 100 MSAs on November 24, 2003 and expanded to the entire country beginning on May 24, 2004.

It is important to examine if we can think of the introduction of number portability as a so-called natural experiment. The implementation date November 24, 2003 was set by the FCC in 2002, so wireless carriers during my sample period (January 2003 to June 2004) probably took the timing of the policy introduction as given, instead of trying to influence the implementation date by changing their prices. Hence, it seems plausible to assume that the timing of the policy introduction is exogenous with respect to carriers' pricing decisions.

It is possible that carriers started to change their prices before November 2003 in the anticipation of the approaching number portability. Carriers might have offered lower prices to their customers even before number portability began so that they could lock in the customers with long-term contracts before number portability goes into effect. If this were the case, my estimates would be a conservative estimate of the true impact of number portability on prices.

The reaction of wireless carriers to the proposed policy reveals some interesting facts about the expected impact of number portability. Less established carriers supported the policy, whereas dominant players in the market opposed it. "Number portability was initially supported by many participants in the wireless industry, especially newer wireless providers who were eager to compete with established providers."[10] Number portability would make it easier for carriers to poach customers from competitors. Newer entrants' customer bases were small, so they had more customers to gain than to lose. This also explains major carriers' persistent opposition to the policy.

[10] Kessing (2004)

3. Price Discrimination Based on Heterogeneous Switching Costs

Theoretical work on switching costs, pioneered by Klemperer (1987a, 1987b), established that switching costs can reduce competition. A few empirical papers on switching costs, such as Viard's paper on toll-free service market (2004) and Borenstein's paper on retail gasoline market (1991), showed that firms behave less competitively if consumers face switching costs.

In particular, Borenstein's paper empirically showed that gas stations price discriminate against customers who are less likely to switch to another station. If price discrimination based on heterogeneous switching costs is possible in the retail gasoline market that is "very close to perfect competition,"[11] we expect that such price discrimination might be possible in the wireless market as well.

In the wireless market, switching costs are likely to vary across consumers. A consumer's cost of switching depends on whether she is under a long-term contract, how much she values keeping her current phone number, etc. In particular, network switching costs may differ across consumers due to different valuations consumers put on keeping their current phone numbers. Intuitively, one would expect that those who heavily use their cell phones, for example, business people, tend to have a lot of contacts they would need to inform of a phone number change in the event of switching carriers, so would highly value keeping their phone numbers. Small users, on the other hand, probably have only a handful of contacts, such as family members or close friends, so changing a phone number might not be so much of a hassle for them. Therefore, it is possible that wireless carriers price discriminated against consumers with high network switching costs, namely high-volume users, prior to number portability.

The introduction of number portability on November 24, 2003 enabled customers to keep their phone numbers when changing carriers. If wireless carriers engaged in price discrimination against a group of consumers with high network switching costs before number portability, that practice would be no longer possible. Thus, the prediction of this price discrimination hypothesis is that the prices for high-volume plans should fall more than the prices for low-volume plans in response to the introduction of number portability.

[11] Borenstein (1991)

The idea that wireless carriers exercised price discrimination against consumers with high network switching costs before number portability is often found in news articles, even though they never use the phrase "price discrimination" and the idea is usually presented in the context of business vs non-business users, rather than high-volume vs low-volume users. For example, an article by *The Chicago Tribune* says "When cell phone customers can keep their numbers after changing carriers, expect a herd of users to switch providers. But the loudest roar is likely to come from business users with corporate accounts. The new rules allowing for number portability will lead to fat discounts and shifting control of cell phones used for business, industry insiders predict. … Corporate control was stymied because workers did not want new numbers with a new wireless service. They fear losing business contacts who have their old cell phone numbers."[12] A similar logic would extend to high-volume users vs low-volume users if, as I argued, high-volume users valued keeping their phone numbers more highly than low-volume users. The fact that a fair proportion of high-volume users are likely to use their cell phones at least partially for their business[13] helps this argument.

If I employ this theory of price discrimination based on switching costs to interpret my estimation results, I would attribute differential changes in prices across consumer groups to differential changes in the degree of market power in those groups. In Section 5, I will estimate a pricing equation that captures both the demand side and the supply side in one regression, and my interpretation will essentially assume that the change in prices we observe after number portability (net of some general time trend) is due to changes in markups, but not due to changes in demand or costs. In Section 6, I discuss alternative explanations, including a demand-side explanation and a cost-side explanation.

[12] Jon Van, "Portability Alters Power Balance," *The Chicago Tribune,* August 2003

[13] In many cases, business users choose their cell phone plans individually and get reimbursed from their employers for their usage. The same article mentions "It is common for executives and salespeople to buy their own cell phones and then to submit expense accounts covering the monthly charges." Moreover, self-employed business people might choose high volume plans to use their cell phones for business. Hence, high volume plans I observe in the data might be often used for business.

4. Data

The main data for my analysis are cellular and PCS pricing plan data collected by Econ One, a research firm. Econ One's wireless survey collects monthly data on cellular and PCS plan prices in the 26 largest cities in the U.S. The wireless survey examines single-user plans and does not include any pre-paid plans or multiple-line plans. Appendix A lists markets and providers included in the survey. My Econ One sample runs from January 2003 through June 2004, so I have information on prices before and after the introduction of number portability. All the markets in the sample implemented number portability in November 2003.

The dataset provides information on 107,335 plans, including providers, markets, monthly access fees, numbers of minutes included in the plans and their composition (anytime minutes,[14] peak minutes, and night & weekend minutes[15]), activation fees, lengths of contracts, per-minute charges, and other relevant information. The dataset contains almost all relevant information except information on handset prices.

Since the sole source of the data is carriers' internet web sites, one might doubt the reliability or relevance of the data, just as some have questioned the use of prices listed on manufacturers' web sites in the studies of price dispersion on internet. However, the information on wireless plans listed on carriers' web sites appears accurate: I personally compared the lists of plans offered by Palo Alto retailers and lists on the web. Even though the lists do not coincide perfectly, they are similar.

Each plan can be categorized as "local," "regional," "network," or "national," depending on coverage areas. No roaming charge applies to calls made or received within the specified coverage area. In the data, network plans are most common, making up

[14] For a customer whose plan does not include night & weekend minutes, anytime minutes are used whenever she calls, regardless of the time the call is made. For a customer whose plan includes night & weekend minutes, anytime minutes are essentially the same as peak minutes, except that anytime minutes can be used for night & weekend calls if she uses up her night & weekend minutes.

[15] The original data partially provide night minutes and weekend minutes separately, but I decided to pool these two types of minutes not to lose observations. There were some plans that offered weekday minutes as well (separately from peak minutes), but I do not include weekday minutes in the analysis since only 50 observations out of 107,335 have nonzero weekday minutes (and all of them have 200 weekday minutes). I exclude these 50 observations from the sample. In addition, I exclude from the sample an additional 2 plans whose sum of anytime minutes, peak minutes, and night & weekend minutes is zero, since these are not interesting cases to consider. The final sample size for my analysis is 107,013.

almost half of total plans, followed by national plans and local plans, while regional plans are not common.

Each plan specifies a contract length. Some plans do not require long-term contracts at all, while others require either one- or two-year contracts. The dataset treats two plans that are identical except for the contract length as two separate observations. Many carriers offer incentives for consumers to sign up for longer-term contracts.

The FCC does not prohibit carriers from charging a fee to recover the costs of implementing number portability as long as the fees do not exceed their porting costs.[16] To my knowledge, there is no carrier who charges one-time porting fees to terminating customers only. But most carriers have imposed monthly surcharges on all of their customers to recover the costs of number portability. Different carriers charge different amounts to their customers, but each carrier charges the same amount to all of its customers[17] regardless of their usage levels. The Econ One data do not provide information on those surcharges, and the surcharges are *not* included in the monthly access fee of the Econ One data.

It is difficult to obtain accurate information on how much carriers have charged to consumers to finance number portability. Typically, carriers lump the cost of number portability along with other charges like "number pooling," "Federal E911 program," and "Communications Assistance for Law Enforcement Act" into a single line item on subscribers' bills under a generic name like "federal recovery fee."[18] Exactly how much of the fee goes toward number portability is hard to say.[19] The Center for Public Integrity provides estimates of the federal recovery fees carriers have collected. I will use the estimates provided on its web site,[20] when I later discuss welfare gains to consumers from number portability.

Table 1 shows the summary statistics of the Econ One data for the pre- and post-number portability eras. A few things stand out in the table. The mean price of plans

[16] A FCC fact sheet on wireless local number portability, http://www.fcc.gov/cgb/consumerfacts/wirelessportability.html
[17] The only exception is AT&T Wireless. It charges only 1/3 of its customers such fees.
[18] Jindrich, M. (2004) "Group Wants Truth in Cell Phone Billing," Center for Public Integrity, http://www.publicintegrity.org/telecom/report.aspx?aid=250&sid=200
[19] The Center for Public Integrity article
[20] http://www.public-i.org/telecom/report.aspx?aid=67&sid=200 (October 2003), http://www.public-i.org/telecom/report.aspx?aid=250&sid=200 (April 2004)

offered after number portability is lower than the mean price of plans offered before number portability. Post-NP plans offer more minutes than pre-NP plans on average. In addition, more plans require two-year contracts (the longest contract in the data) since the introduction of number portability, which suggests that wireless carriers that are worried about more switching due to number portability might try to lock in consumers by requiring longer-term contracts.

Table 1, however, only reports the average changes and does not show whether and how the changes are different across different consumer groups. Moreover, Table 1 cannot tell us whether the changes are due to the policy itself or a general time trend (or both). In fact, wireless carriers have lowered prices and offered more minutes over time as technologies have advanced, costs have fallen, and demand has changed, even before the introduction of number portability.

To see if the changes are similar across consumers, Table 2 compares the average numbers of minutes and the average monthly access fees before and after number portability for different volume user segments. Within each month-provider-market combination, I rank plans based on the monthly access fee, and call the bottom 1/3 "low-volume plans," the middle 1/3 "medium-volume plans," and the top 1/3 "high-volume plans." The table shows that the changes vary widely across these categories. Even though the aggregate average price goes down by $1.79 after the introduction of number portability, the average price for low-volume plans goes up by $3.02 and the average prices for medium- and high-volume plans go down by $1.89 and $6.37, respectively. The changes in the number of included minutes are not uniform across the volume categories either, and these changes seem to offset the price change in low-volume plans and reinforce the price changes in medium- and high-volume plans.

To account for the fact that prices probably would have declined even without number portability because of the general time trend, I use data that could give us some hints about what the time trend looks like. The Bureau of Labor Statistics reports the Cellular Consumer Price Index every year, a price index for wireless services. The Cellular CPI is a measure of the average change over time in prices for a fixed basket of wireless services. The BLS states "For quote re-pricing, the respondents are asked to supply data for the selected plans on a regular basis, including plan changes or

promotional offerings, if any exist. The CPI attempts to price the same plans in each collection period."[21] The Cellular CPI may not be very representative of the overall movement in plan prices, since the CPI collects information on only one or a few plans carriers offer. From the BLS home page, it is also not clear which carriers in which markets are included in the index. However, the change in the Cellular CPI in years preceding the introduction of number portability could give us a rough idea about the pre-existing time trend.

When I analyze the Econ One data in the next section, I use the monthly access fee as a measure of price (hence my dependent variable) instead of charges for minutes used in excess of those included in the plan. For my analysis, the access fee, which is a price in an ex ante sense, is a more appropriate measure than the per-minute price of excess minutes. A customer chooses a wireless plan with an expected level of usage in mind and minimizes the cost of her expected usage. Since the charges for excess minutes are much higher than the average price of included minutes, we expect consumers to avoid plans with fewer included minutes than they regularly use. For example, a consumer who typically uses 400 minutes per month would not optimally buy a plan that includes 300 minutes and pay additional prices for minutes above 300. Charges for excess minutes are relevant only for those who make mistakes ex post, whereas monthly access fees are relevant for any wireless customer. Because we are interested in the impact of number portability on wireless customers in general, the monthly access fee is a more appropriate measure of price for our purpose.

[21] The BLS home page, http://www.bls.gov/cpi/cpifactc.htm

5. Price Responses to the Introduction of Number Portability

5.1. Main Specifications

I hypothesize that the monthly access fee for carrier *i*'s plan *p* in market *m* at time *t* is a function of the number of minutes included in the plan, characteristics of the plan such as the coverage area and the length of the contract, carrier-specific factors, market-specific factors, and number portability. These variables reflect demand, costs of the plan, and/or factors that could influence a carrier's market power. I estimate the following pricing equation of wireless carriers:

$$\begin{aligned}\ln(PRICE_{ipmt}) = {} & (\alpha_1 + \delta_1 * NP_t) + (\alpha_2 + \delta_2 * NP_t) * \ln(MINUTES_{ipmt}) \\ & + \gamma_1 * U\_ANYTIME_{ipmt} + \gamma_2 * U\_NIGHTWEEKEND_{ipmt} \\ & + \theta_1 * CONTRACT0_{ipmt} + \theta_2 * CONTRACT2_{ipmt} \\ & + \theta_3 * REGIONAL_{ipmt} + \theta_4 * NETWORK_{ipmt} + \theta_5 * NATIONAL_{ipmt} \\ & + \theta_6 * 7PM_{ipmt} + \theta_7 * ROLLOVER_{ipmt} + \theta_8 * PUSH2TALK_{ipmt} + \theta_9 * PCS_{ipmt} \\ & + \theta_{10} * FREENATIONLD_{ipmt} + \theta_{11} * FREEINNTWLD_{ipmt} \\ & + \sum \lambda_{1i} * CARRIER_i + \sum \lambda_{2m} * MARKET_m + \varepsilon_{ipmt} \qquad (1)\end{aligned}$$

The specification of the pricing equation reflects the observation that prices do not increase linearly with included minutes. Optimal screening models, such as in Mussa and Rosen (1978) and Maskin and Riley (1984), predict that for general assumptions about costs, buyers' valuation, and the distribution of buyer types, concave tariffs (volume discounts in our case) will be profit-maximizing for a monopolist. Volume discounts could also be due to fixed costs of customer service provision, billing, etc., which reduce the average costs of high-volume plans relative to those of low-volume plans. In real world wireless pricing, volume discounts are common. Hence, we expect α_2 to be less than one. I note that this specification is more general than using as a dependent variable ln(Price/Minutes). The latter case is equivalent to imposing $\alpha_2 = 1$ (ignoring δ_2 for now). The interaction between ln(MINUTES) and NP allows the curvature of the nonlinear

pricing schedule, i.e., the degree of volume discounts, to change with the introduction of number portability.

The dependent variable PRICE is the monthly access fee for carrier *i*'s plan *p* in market *m* at time *t*, adjusted for the activation fee and any promotional reduction in the monthly access fee. PRICE = (Monthly Access Fee*Length of Contract + Activation Fee – Promotional Access Fee Reduction*Length of Promotion) / Length of Contract.[22]

MINUTES is the number of minutes included in carrier *i*'s plan *p* in market *m* at time *t*. Each plan offers a bucket of minutes for a fixed monthly access fee. Plans may include "anytime minutes," "peak minutes," and "night & weekend minutes." When a firm sets a plan's price, it must implicitly value each type of minutes included in the plan. Hence, we need to estimate the relative weight given to each type of minutes. I define MINUTES = β_1*Anytime Minutes + β_2*Peak Minutes + β_3*Night & Weekend Minutes. The βs sum to one, and I estimate them using a nonlinear regression of (1). The βs reflect both consumers' relative willingness to pay for each type of minutes and the relative costs for each type. We would expect night & weekend minutes to have lower implicit prices than anytime minutes or peak minutes because consumers value more highly minutes they can use during 6AM-9PM (usual peak hours) on weekdays than those they can use only late at night or on weekends. We also expect higher weights for peak and anytime minutes because wireless carriers may include the marginal cost of capacity in the implicit prices of peak and anytime minutes, but not in the price of night & weekend minutes, since capacity only binds during peak hours.

NP is a dummy variable that is equal to one if numbers were portable at time *t* and zero otherwise. NP = 1 for December 2003 through June 2004 and NP = 0 before December 2003.[23]

U_ANYTIME is a dummy variable that is equal to one if the plan offers unlimited anytime minutes and zero otherwise. If a plan offers unlimited anytime minutes, I set Anytime Minutes = 0 in MINUTES and set U_ANYTIME = 1 for the plan. This is to

[22] Length of Contract and Length of Promotion are measured in months. I decided to include the activation fee in the price measure since some carriers use an activation fee waiver as an incentive for consumers to sign up for longer-term contracts. If a plan doesn't require any contract, I set Length of Contract = 12 when constructing PRICE.

[23] The data are collected at the beginning of each month, so November 2003 data were collected before number portability began.

avoid skewing the curvature of the pricing schedule by choosing an arbitrary number for Anytime Minutes when unlimited anytime minutes are offered. Similarly, if a plan offers unlimited night & weekend minutes, I set Night & Weekend Minutes = 0 in MINUTES and U_NIGHTWEEKEND = 1 for the plan. No plan in my sample offers unlimited peak minutes.

Carrier and market dummies are included to capture carrier-specific and market-specific influences on pricing. Also included in the pricing equation are variables for the characteristics of the plan that could affect the valuation of the plan by a consumer and/or the cost of the plan. The definition of these variables and the economic interpretation of the corresponding coefficients are provided in Appendix B.

Table 3 shows the estimation results of the pricing equation. Column A shows the regression results when I restrict δ_2 to be zero. Column B shows the regression results when I allow the curvature of the nonlinear pricing schedule to change with the introduction of number portability.

Since Column A does not include the interaction between NP and ln(MINUTES), the coefficient for the NP dummy in Column A represents the average impact of number portability on prices across all plans (as well as the general time trend). As expected, plan prices are lower after the policy introduction compared to before. The price of a plan offered after number portability is on average 4.7% lower than the price of a plan offered before number portability, when the two plans are identical except for the timing of the offering. Based on Column A of Table 3, Figure 1A shows the pricing schedules before and after number portability.

Column A of Table 3 assumes that number portability affected the prices of all plans by the same *proportion*. This means that in *absolute* dollar terms, the prices of high-volume plans fell by a large amount while the prices of low-volume plans fell only slightly. For example, a $30 plan became $28.59, a $70 plan became $66.71, and a $120 plan became $114.36 after the introduction of number portability according to the results of Column A of Table 3.

We might think that number portability could affect the prices of different volume plans by different proportions. In light of the discussion in Section 3, we would expect that the prices for high-volume plans would fall proportionally more than the prices for

low-volume plans in response to number portability if carriers exercised price discrimination against high-volume users prior to the introduction of the policy. Therefore, to allow number portability to affect different parts of the pricing schedule by different proportions, I no longer impose the restriction $\delta_2 = 0$ on the model.

Column B of Table 3 reports the corresponding estimation results. The NP dummy in the intercept has a positive and significant coefficient and the NP dummy in the curvature has a negative and significant coefficient, which means that the prices of high-volume plans fell proportionally more than the prices of low-volume plans. This pattern is clearly depicted in Figure 1B: the post-NP pricing curve lies below the pre-NP pricing curve, and the difference between the two is much larger at high-volume plans than at low-volume plans.

For concreteness, Table 4 provides the estimated percentage changes in prices for plans of various volume levels using the results of Column B of Table 3. For example, a low-volume plan whose price was $20 per month before number portability costs $19.5 after the introduction number portability, a price reduction of 2.4%. A medium-volume plan whose price was $73 per month before number portability costs $69 after number portability, a price reduction of 4.5%. A high-volume plan whose price was $143 per month before number portability costs $135 after number portability, a price reduction of 5.6%.

My empirical analysis establishes two things. First, plan prices after the introduction of number portability are lower than plan prices before the introduction of number portability. Second, the price decline is proportionally larger at the top than at the bottom. These results are consistent with the hypothesis laid out in Section 3. Under this hypothesis, we would interpret the observed price falls as evidence that reduced consumer switching costs due to number portability increased competition in the market. The proportionally larger price fall for high-volume plans would mean that number portability increased competition more for high-volume plans than for low-volume plans, and this would be interpreted as evidence that wireless carriers engaged in price discrimination against high-volume users who were less likely to switch.

Using the estimation results of Column B of Table 3, I perform a simple back-of-the-envelope calculation to compute a rough magnitude of the welfare gains to wireless

consumers due to the introduction of number portability. In doing so, I will interpret the observed price falls after number portability (net of the time trend, which I will discuss below) as a result of increased competition. I will discuss the plausibility of this assumption in Section 6.

The first step in computing welfare gains to wireless customers due to number portability is to determine how much of the observed decline in prices is attributable to the policy itself and how much is attributable to the general time trend. I use the Cellular CPI to infer the general time trend of wireless prices. Table 5 reports the Cellular CPI. The table shows that the price of wireless services declined drastically up to 2001, but since 2002 the price has stabilized, declining at a much slower rate of around 1% annually. The early periods of wireless services experienced rapid price declines due to technological breakthroughs, such as a transition from an analogue to a digital system, and competitive pressures, such as the entry of PCS providers into markets where previously at most two cellular carriers were allowed. As the market has matured over time, the drastic changes in technologies and prices have been replaced by gradual changes. I will assume that the gradual 1% annual decline in prices that occurred in 2002 and 2003 would have been the same in 2004 but for the introduction of number portability. I will also assume that the 1% annual decline is uniformly distributed over the year. Finally, I will assume that the general time trend in price changes is the same for all plans.[24]

The second step in the welfare analysis is to take into account the surcharges carriers imposed on customers to recover the implementation costs of number portability.[25] According to the Center for Public Integrity, 10 major carriers were collecting $94 million per month as a "federal recovery fee" as of April 2004.[26] There were about 158,721,981 wireless subscribers at the end of 2003, and 89% of them were served by those 10 major carriers.[27] Assuming that the other smaller carriers charge

[24] I will come back to this assumption in Section 5.2.
[25] Recall that the surcharges are not included in the monthly access fee of the Econ One data.
[26] The 10 major carriers are ALLTEL, AT&T Wireless, Cingular Wireless, Leap Wireless, Nextel, Sprint PCS, T-Mobile USA, US Cellular, Verizon Wireless, and Western Wireless.
[27] FCC CMRS Competition Report (2004)

similar amounts and that 80% of the fees are used for number portability,[28] each consumer pays $0.53 per month as a "price" to have the option of keeping his or her number when switching carriers.[29]

The summary of the welfare gains for consumers in various volume categories is provided in Table 6. The second column reports the observed price fall that occurred after the introduction of number portability, based on the estimation results of Column B of Table 3. The third column reports the amount of the price fall that is attributable to the general time trend.[30] The fourth column reports the amount of the surcharges carriers impose on a consumer to recover the costs of implementing number portability.[31] The last two columns report the net gains from number portability for each consumer in various volume categories, in dollar terms and as a percentage of the plan prices. Table 6 shows that consumer welfare for the very low-end users decreased because of number portability since they paid an equal share of number portability costs while the benefits to them from number portability were small. Customers who are not at the very bottom enjoyed net gains from number portability, and the size of the net gains increased with a customer's usage level.

To calculate aggregate consumer welfare gains, we need the distribution of wireless subscribers. From a consumer survey conducted by TNS, a research firm, I obtained a rough distribution of wireless subscribers by monthly access fees, and Figure 2 shows the heavily right-skewed distribution of monthly access fees.[32] Using the distribution of wireless subscribers and making an assumption that the impact of number portability in the top 100 MSAs is similar to the impact in the top 26 markets identified in the data, my calculation shows that the net benefits to wireless consumers in the top 100

[28] According to one estimate, the costs for number portability account for 61% of the total federal mandate costs (Lenard and Mast, 2003). Hence, 80% assumption is a conservative assumption.
[29] $94 million * 100/89 *0.8 / 158721981 = $0.5323. The $94 million/month figure is as of April 2004. In fact, the amount of the surcharges varies over time, but I'll assume that the 10 major carriers collected $94 million each month since December 2003 in my welfare analysis.
[30] There is a nine-month difference between the median pre-NP month (June 2003) and the median post-NP month (March 2004) in my data. Assuming that the 1% annual decline is uniformly distributed over the year, the price decline attributable to the general time trend for the sample period is 0.75%.
[31] Recall that each carrier imposes the same surcharges on all of its customers regardless of their plans.
[32] From the TNS survey, I obtained the distribution of wireless subscribers by monthly access fees in Q4 2001, and shifted the distribution to make the average monthly access fee of the survey data be the same as the average local monthly bill for the second half of 2003 reported by the CTIA ($49.91). In doing so, I assume that the shape of the distribution in the TNS survey is similar to that of the distribution for all wireless subscribers in 2003.

MSAs (where 70% of all wireless subscribers reside[33]) from increased competition due to the policy were $120.74 million per month, or $845.18 million by June 2004, for the 7 months the policy was in place.[34] The remaining 30% of wireless customers outside the 100 MSAs have been allowed to port their numbers since May 24, 2004, so the aggregate impact of number portability will be larger.

The figures are suggestive of how big the impact of number portability can be on consumer welfare. Even though the figures may not be precise, the sheer magnitude of them indicates that number portability had a huge impact on consumer welfare. Since number portability is a policy that requires coordination among carriers and cannot be unilaterally implemented by a competitive carrier, the gains to consumers probably would not have realized without the regulatory mandate by the FCC.

There are many factors I left out in the welfare analysis. First, since my data cover only up to 7 months after the policy introduction, the estimated results do not say anything about long-term impacts. If we believe that there will not be any additional impacts of the policy on prices in the long run, wireless consumers in the top 100 MSAs will continue to save $120.74 million per month (compared to the situation where no number portability is available). If, on the other hand, we believe that there are additional long-term impacts of the policy, for example, less locking power of existing carriers spurring more entry into the market, the benefits to consumers in the long run could be different from the numbers presented here. Moreover, the figures do not capture benefits in non-price dimensions, the possibility that number portability might have started having an impact many months before its introduction, the direct benefit of keeping phone numbers, consumers' adjusted responses, etc. These considerations suggest that the

[33] http://www.pcworld.com/news/article/0,aid,116146,00.asp

[34] To be precise, I need to consider a few more things: (1) Wireless carriers started charging number portability fees even before number portability was introduced. For example, Nextel started charging number portability fees in January 2002, 22 months before number portability was introduced (The Center for Public Integrity article). If we also consider all the costs charged before number portability, wireless consumers in the top 100 MSAs gained $352.28 million by June 2004 (based on the author's calculation using the numbers reported in the Center for Public Integrity article. Details are available from the author upon request). Then from July 2004 on, those consumers continue to obtain net gains of $120.74 million per month, if benefits and costs remain the same. (2) Monthly surcharges changed over time. Verizon and T-mobile did not charge any fees for number portability until March 2004. Also, Verizon and Sprint eliminated number portability charges in November 2004.

figures are likely to be a lower bound for the true impact of number portability on consumer welfare.

Most of the other coefficients in Table 3 are as expected. α_2 is less than 1, which is consistent with the volume discounts common in the wireless market. The magnitude of the βs, the relative weights for each type of minutes in pricing, implies that the number of anytime minutes and peak minutes included in plans largely determines their prices, whereas night & weekend minutes get almost no weight in determining prices. This is not very surprising given our earlier discussion about consumers' willingness to pay and costs for each type of minutes. This might also reflect wireless carriers' strategies of offering huge buckets of night & weekend minutes to catch consumers' attention while pricing does not depend on these types of minutes since they often go largely unused.

However, the negative coefficient for U_NIGHTWEEKEND is puzzling, since it means that plans with unlimited night & weekend minutes have lower prices than plans with no night & weekend minutes, other things being equal. In robustness checks later, I try alternative specifications to see if my main results are sensitive to how I treat unlimited night & weekend minutes. In those specifications, the coefficients for NP and NP*ln(MINUTES) remain fairly stable. Hence, I conclude that even though the coefficient for U_NIGHTWEEKEND is not reasonable, it has not biased my main results.

The coefficients for various plan characteristics generally take intuitive signs as well, with the exception of a few coefficients. For example, plans that offer free nationwide long distance calls or a push-to-talk function charge higher prices than those that do not.

The coefficients for the carrier dummies are also as expected (not reported), with small carriers charging lower prices than major national carriers. T-Mobile, known for its aggressive pricing, also has a negative coefficient. The coefficients for the carrier dummies likely reflect differences in network qualities, network sizes, market shares, target customers, and so on.

Overall, the pricing equation that I presented at the beginning of this sub-section seems to explain well all the important phenomena we would expect to find in the data. Most coefficients have economically sensible interpretations, and the high R-squared

(0.896) provides additional confidence that this model represents wireless carriers' pricing decisions fairly well.

5.2. Robustness Checks

In this sub-section, I discuss alternative specifications to make sure that the main results are robust to different functional form assumptions. I also check if the observed differential price changes existed even before the introduction of number portability.

Table 7 shows the estimation results of three different specifications. The first two specifications are examined to see if the curvature of the pricing schedule in my main model was skewed by plans that offer unlimited anytime minutes or unlimited night & weekend minutes. The third specification allows the effects on prices of variables other than minutes to change with the introduction of number portability. The results from these three alternative specifications are qualitatively the same as the results in Table 3. Quantitatively, the coefficients for NP and NP*ln(MINUTES) change, but the results in Table 3 yield rather a conservative measure of the impact of number portability compared to those of the alternative specifications.[35]

Figure 3 presents additional robustness checks. Instead of regressing log of price on log of minutes, I try three different functional forms: regress price on minutes and minutes squared, regress log of price on log of minutes and log of minutes squared, and regress log of price on minutes and minutes squared. Depending on specifications, pricing schedules look different, but it still holds that the prices of plans after number portability are lower than the prices of plans before number portability and that the price decline was proportionally larger for high-volume plans than for low-volume plans.[36]

I try one more specification to address the concern that equation (1) does not allow non-monotonic responses to number portability. For example, if the prices of the bottom 1/3 plans decrease by 3%, the prices of the middle 1/3 plans decrease by 7%, and the prices of the top 1/3 plans decrease by 5%, estimation results using equation (1)

[35] I also estimated my main model excluding December 2003 observations, in the worry that the end-of-year promotion might be driving all the results. The results of this new regression, not reported, are essentially the same as the results in Table 3.

[36] Plans with more than 2550 weighted minutes account for less than 2% of all observations, so I ignore that portion of the graphs.

would still find a negative and significant value for δ_2, wrongly suggesting that the prices for high-volume plans fell proportionally more than those for medium-volume plans. To see if my main finding is robust to this consideration, I run the following regression:

$$\begin{aligned}\ln(PRICE_{ipmt}) = {} & (\alpha_1 + \delta_1 * NP_t) + \alpha_2 * \ln(MINUTES_{ipmt}) \\ & + \rho_1 * VOL2_{ipmt} + \rho_2 * VOL3_{ipmt} + \rho_3 * VOL4_{ipmt} \\ & + \delta_2 * NP_t * VOL2_{ipmt} + \delta_3 * NP_t * VOL3_{ipmt} + \delta_4 * NP_t * VOL4_{ipmt} \\ & + \gamma_1 * U\_ANYTIME_{ipmt} + \gamma_2 * U\_NIGHTWEEKEND_{ipmt} \\ & + \theta_1 * CONTRACT0_{ipmt} + \theta_2 * CONTRACT2_{ipmt} \\ & + \theta_3 * REGIONAL_{ipmt} + \theta_4 * NETWORK_{ipmt} + \theta_5 * NATIONAL_{ipmt} \\ & + \theta_6 * 7PM_{ipmt} + \theta_7 * ROLLOVER_{ipmt} + \theta_8 * PUSH2TALK_{ipmt} + \theta_9 * PCS_{ipmt} \\ & + \theta_{10} * FREENATIONLD_{ipmt} + \theta_{11} * FREEINNTWLD_{ipmt} \\ & + \sum \lambda_{1i} * CARRIER_i + \sum \lambda_{2m} * MARKET_m + \varepsilon_{ipmt} \qquad (2)\end{aligned}$$

VOL1 is a dummy variable that is equal to 1 if the size of the plan's bucket of minutes falls into the bottom 1/4 volume category and zero otherwise. VOL2, VOL3, and VOL4 are similarly defined, with VOL4 being a dummy for the top 1/4 volume category. To construct these volume dummies, I use the estimated βs from Column B of Table 3 to compute a volume for each plan,[37] and divide plans into low (VOL1), medium/low (VOL2), medium/high (VOL3), and high (VOL4) volume categories (of equal size) within each carrier-market-month combination. Other variables are the same as before. The inclusion of NP*VOL2, NP*VOL3, and NP*VOL4 allows a non-monotonic impact of number portability on plan prices. The main estimation results of equation (2) are reported in Panel 1 of Table 8. The results suggest that the impact of number portability is in fact roughly monotonic: the prices for low-volume plans did not change after number portability, the prices for medium/low-volume plans decreased by 1.9%, the prices for medium/high-volume plans decreased by 4.4%, and the prices for high-volume plans decreased by 7.2%.

[37] I set vol = β_1_hat*Anytime Minutes + β_2_hat*Peak Minutes + β_3_hat*Night & Weekend Minutes, where β_hat is the estimated value of β.

Finally, I check if the observed differential price changes existed even before the introduction of number portability. If there was a pre-existing trend such that the prices of high-volume plans decreased more rapidly than the prices of low-volume plans, we cannot say that the pattern in price changes we observe after number portability is due to the policy itself. To check this possibility, I run a regression similar to (2) using only the pre- number portability data. Since it is likely that number portability started to have an impact on carriers' pricing even before its implementation, I use observations before July 2003 only.[38] The only modification to equation (2) is that instead of the NP dummy, I use a new dummy variable LP that is equal to one for late periods (April 2003 – June 2003) and zero for early periods (January 2003 – March 2003).

The main coefficient estimates are reported in Panel 2 of Table 8. Clearly, the pre-existing time trend is not the same as the pattern observed after number portability. The prices of low-volume plans increased by 1.7%, the prices of medium/low-volume plans experienced a 1% decline, the prices of medium/high-volume plans increased by 3%, and high-volume plans experienced a similar price change as low-volume plans. Hence, my main results are not simply a reflection of the pre-existing time trend. On the other hand, this robustness check shows that the pre-existing time trend was not common to all groups, while my calculation of welfare gains assumed a common time trend for all plans. Taking this into account will probably change the quantitative results of my calculation, but the qualitative conclusion will not be much affected.

[38] Number portability received huge publicity around June 2003, when the D.C. Circuit denied the petition by Verizon and the CTIA. "The decision of the Court of Appeals (in June 2003) received a great deal of publicity and appeared to be the end of the road for CTIA and Verizon's attempts to avoid implementation of the portability rules." (Kessing 2004)

6. Alternative Explanations

The empirical evidence presented in the previous section is consistent with price discrimination against consumers with high switching costs. In this section, I consider alternative explanations for the empirical finding.

First I note that any evolution in demand or costs that occurs smoothly over time is not likely to explain my finding. For example, one might argue that a change in the cost structure, e.g., costs falling faster for high-volume plans than for low-volume plans, led to the observed price changes after number portability. But if it has been a general trend that costs fall more rapidly for high-volume plans, we should have observed a similar pattern of price changes before number portability. Panel 2 of Table 8 establishes that the pre-existing time trend in demand or costs cannot explain what we observe after number portability.[39] Therefore, I restrict my attention to explanations that argue that certain shocks to demand, costs, or market power occurred due to number portability.

The first alternative explanation I consider is a demand-side explanation: the relative demand for high- and low-volume plans changed due to number portability. One straightforward argument along this line would be that number portability increased demand for low-volume plans more than demand for high-volume plans. Such a change in demand, if combined with general price falls (probably due to cost falls), could explain the proportionally larger price fall for high-volume plans that we observed after number portability. It is not clear, though, whether number portability impacted the relative demand of high-volume plans and low-volume plans. The only impact of number portability on demand I can think of (other than through prices) is through increasing a potential consumer's expected utility of buying wireless services by making switching in the future easier or through increased advertisements. However, it is hard to believe that these channels affected potential low-volume users more heavily than potential high-volume users. It is even harder to believe that the differential increase in demand due to number portability could explain the huge difference in price changes between high-volume plans and low-volume plans.

[39] I assume that the time trend doesn't change over time in the sample. This assumption seems plausible given the short time span of my sample.

The second alternative explanation I consider is a cost-side explanation: the costs of providing number portability for low-volume plans are larger than the costs of providing number portability for high-volume plans as a percentage of a plan price. Such a difference, if combined with general price falls, could explain the proportionally larger price fall for high-volume plans. There are fixed costs and marginal costs of providing number portability. The costs of developing or purchasing technologies and databases to make number portability available are examples of the fixed costs. The costs of database queries and interconnections to route phone calls to a ported number are examples of the marginal costs. A difference in the costs of providing number portability among different volume plans would translate into a difference in price responses to number portability among those plans, *only if* wireless carriers allocated number portability costs on the basis of plan sizes. As mentioned before, however, in practice carriers impose the same surcharges on all customers, regardless of their plan sizes, to recover the costs of implementing number portability. Even if carriers partially incorporated the cost difference into nonlinear pricing, the corresponding price discrepancy probably wouldn't be large enough to explain the huge difference in the price responses to number portability between high- and low-volume plans.

The final alternative explanation I consider comes from a theoretical work of Rochet and Stole (2002). Rochet and Stole showed that when brand preference and willingness to pay for incremental quantity are *uncorrelated*, increased competition leads to a proportionally more price decline at the top of the product range (in our case, high-volume plans) than at the bottom of the product range. The basic idea behind this prediction is that since high-volume users keep more surplus from a purchase than bottom users, high-volume users can afford to incur some costs of buying a product from a less preferred firm (travel costs in a Hotelling model), so they are more eager to respond to price cuts than low-volume users are.[40] Therefore, increased competition will lower prices more for high-volume users than for low-volume users. Stole (1995), on the other hand, showed that when brand loyalty is *positively correlated* with willingness to pay for incremental quantity, small users will gain the most from increased competition. This is because small users are most willing to consider buying a product from a less

[40] Busse and Rysman (2002)

preferred firm when a price cut is offered. My finding is consistent with the prediction of Rochet and Stole, and according to this explanation, my finding is due to a bigger impact of increased competition on large users in the presence of second degree price discrimination.

It's difficult to tell whether the observed price change after the introduction of number portability is due to the differential impact of increased competition on various users in the presence of second degree price discrimination (Rochet and Stole story) or due to the disappearance of price discrimination based on heterogeneous network switching costs (price discrimination story). For the purpose of assessing the welfare consequences of the policy, it does not matter by which of the two mechanisms number portability generated the observed pattern of price changes. Under either interpretation, the price reduction is a consequence of increased competition generated by the policy.

However, knowing the exact source of the outcome can be critical to some policy considerations. For example, suppose that the US government is considering a mandate that will make handsets compatible across carriers. In addition, suppose that the switching costs arising from the incompatibility of handsets are the same for all users, regardless of their usage levels. Then the distributional implications of the proposed policy can be quite different under the two scenarios. Under the Rochet and Stole scenario, high-volume users will gain the most from the proposed policy. On the other hand, under the scenario of price discrimination based on switching costs, the proposed policy will affect all users similarly.

To see if the Rochet and Stole story might be a valid explanation for my finding, I check the correlation between brand preference and willingness to pay for incremental quantity in the data. If the two factors are uncorrelated or weakly correlated, the Rochet and Stole story can be a valid explanation for my finding. If I find that they are strongly and positively correlated in the data, the power of the Rochet and Stole story as an explanation for the finding will be small.

I do not have a measure of brand loyalty or consumer's valuation for quantity, but I can use the following two facts. (1) In equilibrium, consumers with high valuation for quantity will choose high-volume plans. (2) If brand preference is strongest among users who choose a certain level of volume, price dispersion across carriers will be biggest

among those users, other things being equal. If brand loyalty is not strong, a high level of price dispersion across carriers cannot be sustained since carriers would compete away such dispersion.

To measure price dispersion across carriers for different volume user segments, I divide plans into three equally-sized categories depending on monthly access fees: plans that cost less than $57 per month, plans that cost between $57 and $102 per month, and plans that cost more than $102 per month. I run 6 separate regressions of equation (1) (excluding the NP dummies in the intercept and in the curvature), for each of the three categories before and after number portability. Then I compute standard deviations of the estimated carrier effects.[41] The idea is that the estimated coefficients on carrier dummies capture a carrier premium or discount which cannot be explained by the observed characteristics of plans. If the standard deviation of the estimated carrier effects is big, it means that a high level of price dispersion can be sustained in the market, probably because of differences in network qualities, customer services, or reputation, consumer search costs, switching costs, etc. If we find that the level of price dispersion in the high-volume user segment is greater than the level of price dispersion in the low-volume user segment, it suggests that high-volume users have stronger brand loyalty[42] than low-volume users. I note that discrepancies in network qualities or customer services across carriers alone cannot explain the difference between the high- and low-volume user segment in the level of price dispersion, since both high- and low-volume users use the same network and customer services within a carrier.

I report the standard deviations of the estimated carrier effects in Table 9. Table 9 also reports standard deviations of the estimated carrier effects when I divide groups in different ways as a robustness check. The second panel uses different cutoffs. The third panel uses the volume measure (constructed using the estimated βs as explained before)

[41] This is similar to what Milyo and Waldfogel did in their 1999 paper. Things are more complicated in my case since carriers do not offer homogeneous products (In their case, same alcoholic beverages were sold in different stores). Explanatory variables included in equation (1) will try to make products as comparable as possible across carriers.

[42] Brand loyalty here is broadly defined as anything that makes a consumer willing to pay a higher price to buy from one carrier than from another when the two firms offer the same product. Hence, a difference in the degree of brand loyalty between high volume users and low volume users might be due to various things like differences in sensitivities to price or quality, switching costs, search costs, risk aversion, innate brand loyalty, etc.

to divide plans into three groups. The last panel uses the same volume measure, but divides plans into four groups instead of three.

A few patterns emerge from the table. (1) Price dispersion decreased in the aftermath of number portability for all the segments. (2) The decrease in price dispersion after number portability tends to be bigger for the high-volume user segment than for the low-volume user segment. (3) The level of price dispersion is higher for the high-volume user segment than for the low-volume user segment both before and after number portability.[43]

Hence, the table suggests that high-volume users probably have stronger brand loyalty than low-volume users, and this positive correlation between brand loyalty and valuation for quantity indicates that the model in Rochet and Stole's 2002 paper may not be appropriate for our case.

One potential problem with this interpretation of Table 9 is that the higher level of price dispersion in the high-volume user segment could be due to greater product differentiation among carriers for high-volume plans. Carriers might differentiate themselves by offering distinctive features, and this differentiation could be more intense for high-volume users because of high-volume users' demand for extra features other than basic voice services.

As far as voice services are concerned, there does not seem to be any feature not included in the regression that generates more differentiation at the top range of plans than at the bottom range. After all, I included in the regression most voice-related features that carriers listed on their websites (which presumably indicates that those are what consumers care about). But, there might be some features that are related to data services (messaging, internet surfing, downloading of music and videos, etc.) that create more differentiation among carriers for high-volume plans than for low-volume plans.

However, two facts work against this possibility in my data. First, most plans in my data do not have pre-included data services. A few exceptions are plans that include a fixed number of text messages as a standard feature, but even in those cases the price of

[43] Since my dependent variable in the regression is log of price, the coefficients for carrier dummies are carrier premium/discounts in percentage terms. Hence, my measure of price dispersion, the standard deviation of the estimated carrier coefficients, captures relative dispersion. Since this measure of price dispersion increases with price (volume), it follows that absolute price dispersion also increases with price (volume).

such data services is added on top of monthly access fees. Since the monthly access fee is what I use as a price measure in my regression, the price dispersion I observe in the data is not caused by such data services. Second, in most cases wireless carriers offer data services to any customer who wants them, not just high-volume users. A customer, being a low-volume user or high-volume user, can add data services to his calling plan with an extra charge. Hence, I do not think product differentiation is likely to be the source of the different levels of price dispersion in the high and low-volume user segment.

7. Conclusion

This paper has examined the price response of wireless carriers to the introduction of number portability. My main empirical finding is that wireless prices decreased in response to number portability, but not uniformly across all plans. The prices for low-volume plans decreased by 2.4%, and the prices for medium- and high-volume plans decreased by 4.5% and 5.6%, respectively.

I presented a price discrimination hypothesis whose predictions are consistent with the empirical finding. Under the hypothesis, I interpreted the observed price falls as evidence that reduced consumer switching costs due to number portability increased competition in the market. The proportionally larger price fall for high-volume plans was interpreted as evidence that wireless carriers price discriminated against high-volume users who were less likely to switch. I explored alternative explanations for my empirical finding, and concluded that price discrimination based on switching costs is the most likely explanation for my finding.

My results suggest that number portability changed consumer welfare in interesting ways. High-volume users disproportionately benefited from number portability, while the benefits to low-volume users were modest at most. In the aggregate, the net benefits from increased competition due to number portability to over 111 million wireless consumers in the top 100 MSAs were roughly $120.74 million per month.

The results suggest that even in fairly competitive markets, switching costs can confer considerable market power upon firms, and firms can engage in price discrimination based on heterogeneous switching costs.

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<Table 1>

Summary Statistics of the Sample

		Mean	
		Before Number Portability Jan. 2003 – Nov. 2003	After Number Portability Dec. 2003 – June 2004
Activation Fee		$27.92	$26.13
Monthly Access Fee		$98.54	$96.69
Unlimited Anytime Minutes		0.28%	0.43%
Unlimited Peak Minutes		0%	0%
Unlimited Night & Weekend Minutes		52.68%	64.19%
Anytime Minutes[44]		1156.5 minutes	1086.89 minutes
Peak Minutes		177.38 minutes	341.54 minutes
Night & Weekend Minutes[45]		1138.53 minutes	1516.48 minutes
Coverage	National Plan	25.75%	32.78%
	Network Plan	45.28%	45.51%
	Regional Plan	3.63%	2.13%
	Local Plan	25.35%	19.58%
Contract Length	No Contract	0.06%	0.04%
	1 Year Contract	45.67%	41.34%
	2 Year Contract	54.26%	58.62%
Cancellation Fee[46]		$172.84	$168.84
Availability of Promotion[47]		12.40%	13.31%
Length of Promotion[48]		11.41 months	4.45 months
Per-Minute Charge[49]	Peak	$0.35	$0.33
	Night & Weekend	$0.35	$0.33
Early Nights (7PM)		6.04%	17.08%
Rollover		11.79%	11.04%
Push2Talk		1.67%	6.43%
PCS		47.31%	50.53%

[44] Excluding plans which offer unlimited anytime minutes
[45] Excluding plans which offer unlimited night & weekend minutes
[46] A cancellation fee applies if a customer cancels his service with a carrier before the contract expires.
[47] I say a promotion is available if the plan offers additional minutes and/or an access fee reduction.
[48] Conditional on the availability of a promotion
[49] Additional airtime charges for minutes used in excess of included minutes

Free Nationwide Long Distance	37.13%	30.69%
Free In-Network Long Distance	47.02%	52.41%
Number of Observations	63,979	43,034

For the definition of the variables, look at Appendix B

<Table 2>

Heterogeneous Impacts?

	Mean					
	Before Number Portability Jan. 2003 – Nov. 2003			After Number Portability Dec. 2003 – June 2004		
	Low	Medium	High	Low	Medium	High
Monthly Access Fee	$39.82	$79.36	$174.58	$42.84	$77.47	$168.21
Unlimited Anytime Minutes	0.07%	0.31%	0.44%	0.08%	0.62%	0.59%
Unlimited Night & Weekend Minutes	50.12%	54.75%	53.15%	62.32%	66.88%	63.38%
Anytime Minutes[50]	330.93	847.48	2267.37	373.70	784.64	2084.4
Peak Minutes	75.69	166.40	287.48	115.03	276.61	626.86
Night & Weekend Minutes[51]	1069.43	1184.93	1166.93	1035.00	1867.12	1691.75
Number of Observations	21211	21075	21693	14256	14224	14554

[50] Excluding plans which offer unlimited anytime minutes
[51] Excluding plans which offer unlimited night & weekend minutes

<Table 3>

Estimation of Wireless Carriers' Pricing Equation

	A: No Differential Impacts	B: Differential Impacts
Intercept (α_1)	0.655 (0.008) ***	0.632 (0.009) ***
NP in Intercept (δ_1)	-0.047 (0.001) ***	0.016 (0.008) **
Curvature (α_2)	0.603 (0.0007) ***	0.606 (0.0009) ***
NP in Curvature (δ_2)		-0.010 (0.001) ***
Anytime Minutes (β_1)	0.483 (0.001) ***	0.483 (0.001) ***
Peak Minutes (β_2)	0.522 (0.001) ***	0.523 (0.001) ***
U_ANYTIME	3.886 (0.017) ***	3.880 (0.017) ***
U_NIGHTWEEKEND	-0.230 (0.002) ***	-0.230 (0.023) ***
CONTRACT0	-0.033 (0.031)	-0.028 (0.031)
CONTRACT2	-0.028 (0.001) ***	-0.028 (0.001) ***
REGIONAL	-0.155 (0.004) ***	-0.155 (0.004) ***
NETWORK	0.078 (0.003) ***	0.079 (0.003) ***
NATIONAL	0.183 (0.003) ***	0.184 (0.003) ***
7PM	0.083 (0.002) ***	0.083 (0.002) ***
ROLLOVER	-0.111 (0.004) ***	-0.111 (0.004) ***
PUSH2TALK	0.219 (0.004) ***	0.220 (0.004) ***
PCS	-0.043 (0.003) ***	-0.043 (0.0023) ***
FREENATIONLD	0.112 (0.004) ***	0.110 (0.004) ***
FREEINNTWLD	0.081 (0.003) ***	0.080 (0.003) ***
No. Obs	107013	107013
R-squared	0.8955	0.8956

*** Significant at the 1% ** Significant at the 5% * Significant at the 10%
Inside the parentheses are standard errors.

<Table 4>

Price Changes based on Column B of Table 3

Weighted Minutes	Pre-NP Price	Post-NP Price	Price Change (%)
49.29	$20	$19.52	-2.40%
126.12	$35.37	$34.19	-3.33%
223.48	$50.03	$48.08	-3.90%
413.59	$72.68	$69.40	-4.50%
708.65	$100.74	$95.68	-5.03%
1268.84	$143.43	$135.41	-5.59%
1932.49	$185.12	$174.01	-6.00%

Based on Column B of Table 3
Weighted Minutes = B1*Anytime Minutes + B2*Peak Minutes + (1-B1-B2)*Night & Weekend Minutes, where the Bs are the estimated βs from Column B of Table 3

<Table 5>

Changes in the CPI

	CPI		Cellular CPI		All Telephone CPI	
	Index value	Annual Change	Index value	Annual Change	Index value	Annual Change
1997	100		100		100	
1998	101.6	1.6%	95.1	-4.9%	100.7	0.7%
1999	103.8	2.2%	84.9	-10.7%	100.1	-0.6%
2000	107.3	3.4%	76	-10.5%	98.5	-1.6%
2001	110.3	2.8%	68.1	-10.4%	99.3	0.8%
2002	112.1	1.6%	67.4	-1.0%	99.7	0.4%
2003	114.6	2.3%	66.8	-0.9%	98.3	-1.4%

Source: FCC CMRS Competition Report (2004)

<Table 6>

Welfare Gains from Number Portability

	Price Fall after NP (1)	Time Trend (2)	Surcharges (3)	Net Gains from NP (1) – (2) – (3)	Net Gains from NP %
Consumer 1: $20/month plan	$0.48/month	$0.15/month	$0.53/month	-$0.20/month	-1.00%
Consumer 2: $35/month plan	$1.16/month	$0.26/month	$0.53/month	$0.37/month	1.06%
Consumer 3: $50/month plan	$1.95/month	$0.38/month	$0.53/month	$1.04/month	2.08%
Consumer 4: $75/month plan	$3.42/month	$0.56/month	$0.53/month	$2.32/month	3.09%
Consumer 5: $100/month plan	$5.02/month	$0.75/month	$0.53/month	$3.73/month	3.73%
Consumer 6: $125/month plan	$6.72/month	$0.94/month	$0.53/month	$5.25/month	4.20%
Consumer 7: $150/month plan	$8.50/month	$1.13/month	$0.53/month	$6.84/month	4.56%
Consumer 8: $200/month plan	$12.24/month	$1.50/month	$0.53/month	$10.21/month	5.11%

<Table 7>
Robustness Checks: Part I

	Robustness Check 1		Robustness Check 2		Robustness Check 3	
	A	B	A	B	A	B
Intercept (α_1)	0.653 (0.008) ***	0.640 (0.009) ***	0.803 (0.009) ***	0.790 (0.009) ***	0.677 (0.009) ***	0.666 (0.009) ***
NP in Intercept (δ_1)	-0.048 (0.001) ***	-0.011 (0.008)	-0.056 (0.001) ***	-0.018 (0.008) **	-0.079 (0.011) ***	-0.049 (0.012) ***
Curvature (α_2)	0.603 (0.0007) ***	0.605 (0.0009) ***	0.551 (0.0008) ***	0.554 (0.0009) ***	0.604 (0.0007) ***	0.607 (0.0009) ***
NP in Curvature (δ_2)		-0.006 (0.001) ***		-0.006 (0.001) ***		-0.007 (0.001) ***
Anytime Minutes (β_1)	0.483 (0.001) ***	0.483 (0.001) ***	0.504 (0.001) ***	0.504 (0.001) ***	0.477 (0.001) ***	0.477 (0.001) ***
Peak Minutes (β_2)	0.522 (0.001) ***	0.522 (0.001) ***	0.503 (0.001) ***	0.503 (0.001) ***	0.529 (0.001) ***	0.529 (0.001) ***
No. Obs	106634	106634	107013	107013	107013	107013
R-squared	0.8961	0.8961	0.8870	0.8870	0.8978	0.8978

Robustness Check 1: Drop plans that offer unlimited anytime minutes (361 obs); then drop SureWest plans (18 obs)[52]
Robustness Check 2: Set anytime minutes = 8000 if the plan offers unlimited anytime minutes. Set night & weekend minutes = 7000 if the plan offers unlimited night & weekend minutes. Then exclude the dummies for unlimited minutes.[53]
Robustness Check 3: Add interactions between NP and other covariates (carrier dummies, coverage dummies, contract lengths, PUSH2TALK, ROLLOVER, 7PM, PCS, FREENATIONLD, and FREEINNTWLD)
*** Significant at the 1% ** Significant at the 5% * Significant at the 10%
Inside the parentheses are standard errors.

[52] Since most of SureWest plans offer unlimited anytime minutes, there are only 18 SureWest plans left once I drop plans with unlimited anytime minutes. I exclude the remaining 18 SureWest plans as well since it is hard to precisely estimate the coefficient for the SureWest dummy with 18 observations.
[53] From customers' and firms' perspectives, unlimited minutes might not be different from, say, 8000 minutes, since people don't make full use of unlimited minutes. A person has to talk for four and a half hours per day to use up 8000 minutes. Choices of different numbers (for example, anytime minutes = 10000 if unlimited anytime minutes, night & weekend minutes = 6000 if unlimited night & weekend minutes) don't affect the results.

<Table 8>

Robustness Checks: Part III

	1		2
	Estimated Coefficient		Estimated Coefficient
Intercept (α_1)	1.333 (0.009) ***	Intercept (α_1)	1.509 (0.018) ***
NP in Intercept (δ_1)	-0.004 (0.002)	LP in Intercept (δ_1)	0.017 (0.004) ***
ln(MINUTES)	0.435 (0.001) ***	ln(MINUTES)	0.403 (0.002) ***
Anytime Minutes (β_1)	0.471 (0.002) ***	Anytime Minutes (β_1)	0.441 (0.003) ***
Peak Minutes (β_2)	0.531 (0.002) ***	Peak Minutes (β_2)	0.555 (0.003) ***
VOL2	0.053 (0.002) ***	VOL2	0.097 (0.005) ***
VOL3	0.242 (0.003) ***	VOL3	0.296 (0.006) ***
VOL4	0.498 (0.004) ***	VOL4	0.594 (0.007) ***
NP*VOL2	-0.015 (0.003) ***	LP*VOL2	-0.027 (0.006) ***
NP*VOL3	-0.040 (0.003) ***	LP*VOL3	0.013 (0.006) **
NP*VOL4	-0.068 (0.003) ***	LP*VOL4	0.001 (0.006)
No. Obs	107013	No. Obs	36605
R-squared	0.9198	R-squared	0.9197

*** Significant at the 1% ** Significant at the 5% * Significant at the 10%
Inside the parentheses are standard errors.
The reported standard errors are not correct since I used the estimated βs from Column B of Table 3 to construct the volume dummies. However, since the estimated βs I used to construct the volume dummies were quite precisely estimated, I expect the correct standard errors, accounting for the estimation errors, not to be very different from the reported ones.

<Table 9>

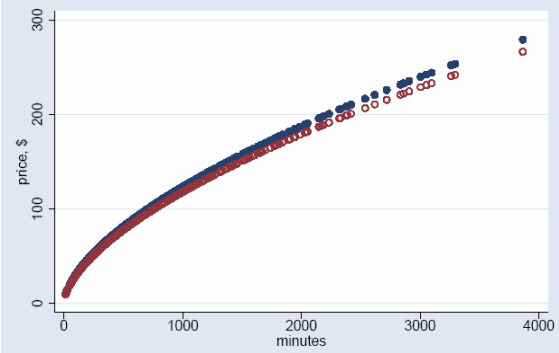
Price Dispersion: Standard Deviation of Carrier Effects

		Before NP	After NP
1	Plans of less than $57	0.062	0.056
	Plans of between $57 and $102	0.098	0.062
	Plans of more than $102	0.241	0.214
2	Plans of less than $40	0.049	0.050
	Plans of between $40 and $80	0.102	0.064
	Plans of more than $80	0.238	0.163
3	Low-Volume Plans	0.104	0.071
	Medium-Volume Plans	0.157	0.082
	High-Volume Plans	0.303	0.198
4	Low-Volume Plans	0.104	0.067
	Medium/Low-Volume Plans	0.174	0.090
	Medium/High-Volume Plans	0.204	0.095
	High-Volume Plans	0.329	0.218

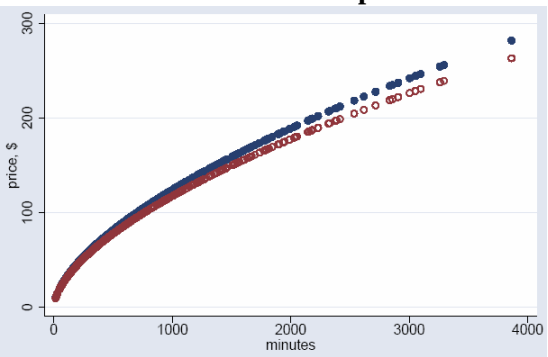
Plans offered by Metro PCS and SureWest are not included in the regression since they mainly offer plans of less than $57/month. Standard deviations will not be comparable across different volume categories if we include those carriers in the regression.

<Figure 1>

A
No Differential Impacts

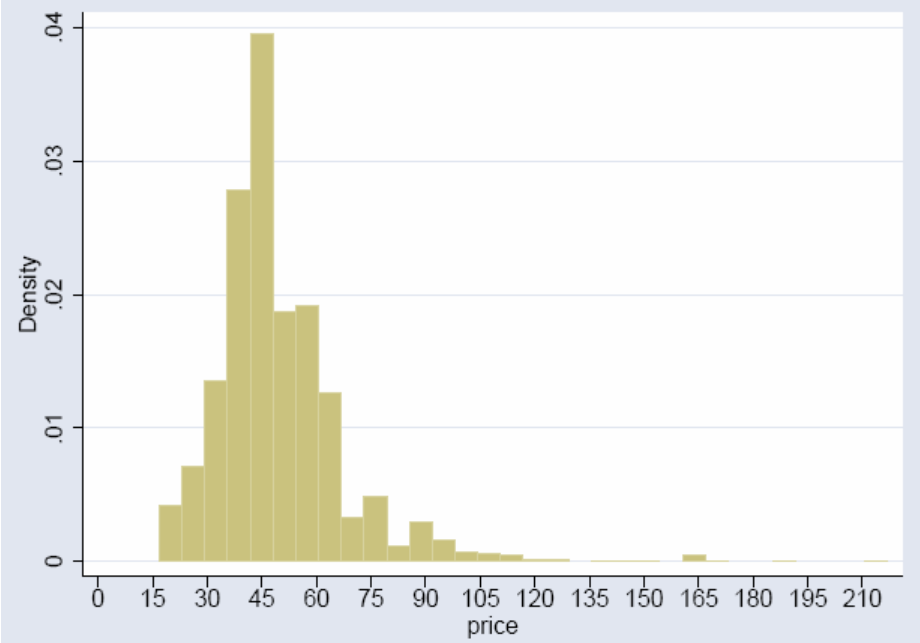


B
Differential Impacts



Based on Column A and B of Table 3 respectively
Minutes are the weighted average of anytime, peak, and night & weekend minutes, where the weights are the estimated βs
The pricing schedule before number portability is denoted with filled circles
The pricing schedule after number portability is denoted with hollow circles

<Figure 2>
Distribution of Wireless Subscribers by Monthly Access Fees

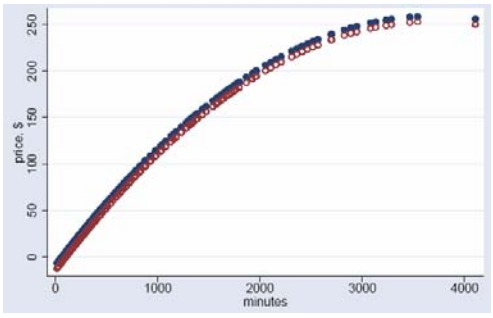


Source: TNS

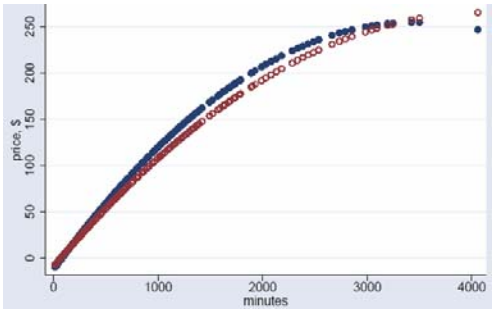
<Figure 3>

Robustness Checks: Part II

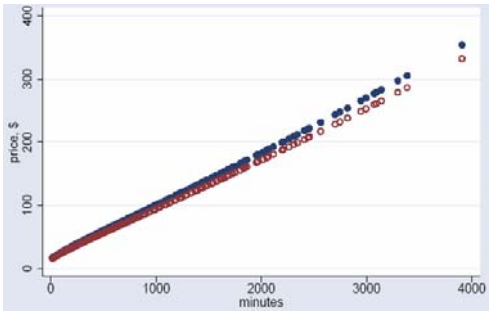
Robustness Check 4A



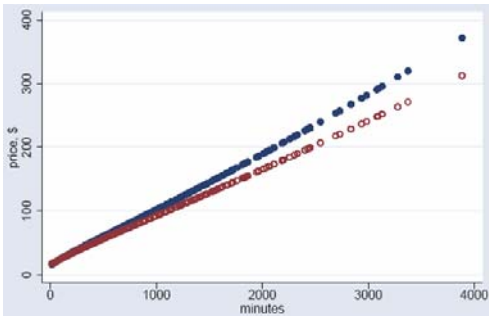
Robustness Check 4B



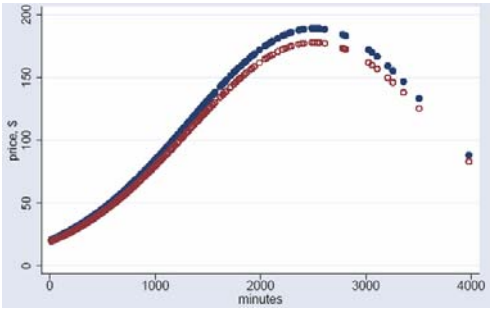
Robustness Check 5A



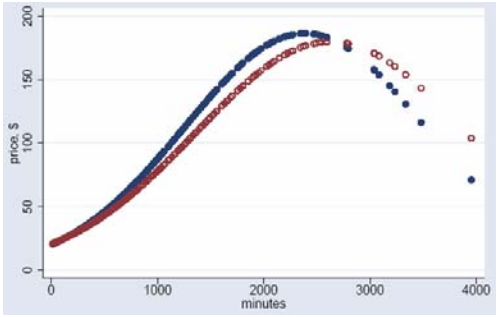
Robustness Check 5B



Robustness Check 6A



Robustness Check 6B



Robustness Check 4: Regress Price on MINUTES and $MINUTES^2$
Robustness Check 5: Regress ln(Price) on ln(MINUTES) and $(\ln(MINUTES))^2$
Robustness Check 6: Regress ln(Price) on MINUTES and $MINUTES^2$
In each figure, column A includes NP in the intercept only; column B includes NP in the curvature as well as in the intercept.

<Appendix A>

Markets and Providers included in the Econ One Data

Market	Providers
Atlanta	AT&T Wireless, Cingular Wireless, Metro PCS, Sprint PCS, T-Mobile, Verizon Wireless
Boston	AT&T Wireless, Cingular Wireless, Sprint PCS, T-Mobile, Verizon Wireless
Chicago	AT&T Wireless, Cingular Wireless, Sprint PCS, T-Mobile, US Cellular, Verizon Wireless
Cincinnati	Cincinnati Bell Wireless, Cingular Wireless, Sprint PCS, T-Mobile, Verizon Wireless
Cleveland	Alltel, AT&T Wireless, Cingular Wireless, Sprint PCS, T-Mobile, Verizon Wireless
Dallas	AT&T Wireless, Cingular Wireless, Sprint PCS, T-Mobile, Verizon Wireless
Denver	AT&T Wireless, Qwest, Sprint PCS, T-Mobile, Verizon Wireless
Detroit	AT&T Wireless, Cingular Wireless, Sprint PCS, T-Mobile, Verizon Wireless
Hawaii	AT&T Wireless, , Sprint PCS, T-Mobile, Verizon Wireless
Houston	AT&T Wireless, Cingular Wireless, Sprint PCS, T-Mobile, Verizon Wireless
Kansas City	AT&T Wireless, Cingular Wireless, Sprint PCS, T-Mobile, Verizon Wireless
Los Angeles	AT&T Wireless, Cingular Wireless, Sprint PCS, T-Mobile, Verizon Wireless
Miami	AT&T Wireless, Cingular Wireless, MetroPCS, Sprint PCS, T-Mobile, Verizon Wireless
Minneapolis	AT&T Wireless, Qwest, Sprint PCS, T-Mobile, Verizon Wireless
New York	AT&T Wireless, Cingular Wireless, Sprint PCS, T-Mobile, Verizon Wireless
Philadelphia	AT&T Wireless, Cingular Wireless, Sprint PCS, T-Mobile, Verizon Wireless

Phoenix	Alltel, AT&T Wireless, Qwest, Sprint PCS, T-Mobile, Verizon Wireless
Pittsburgh	AT&T Wireless, Sprint PCS, T-Mobile, Verizon Wireless
Portland	AT&T Wireless, Qwest, Sprint PCS, T-Mobile, Verizon Wireless
Sacramento	AT&T Wireless, Cingular Wireless, Metro PCS, Sprint PCS, SureWest Wireless, T-Mobile, Verizon Wireless
San Diego	AT&T Wireless, Cingular Wireless, Sprint PCS, T-Mobile, Verizon Wireless
San Francisco	AT&T Wireless, Cingular Wireless, Metro PCS, Sprint PCS, T-Mobile, Verizon Wireless
Seattle	AT&T Wireless, Cingular Wireless, Qwest, Sprint PCS, T-Mobile, Verizon Wireless
St. Louis	AT&T Wireless, Cingular Wireless, Sprint PCS, T-Mobile, Verizon Wireless
Tampa	Alltel, AT&T Wireless, Cingular Wireless, Sprint PCS, T-Mobile, Verizon Wireless
Washington D.C.	AT&T Wireless, Cingular Wireless, Sprint PCS, T-Mobile, Verizon Wireless

The wireless survey does not include Nextel Communication, Inc., because Nextel primarily offers multiple-user plans.

<Appendix B>

Definition of the Variables and Economic Interpretation of the Parameters

$PRICE_{ipmt}$: Monthly access fee for carrier *i*'s plan *p* in market *m* at time *t*, adjusted for the activation fee and any promotional reduction in the monthly access fee. PRICE = (Monthly Access Fee*Length of Contract + Activation Fee – Promotional Access Fee Reduction*Length of Promotion) / Length of Contract.[54]

$MINUTES_{ipmt}$: The number of minutes included in carrier *i*'s plan *p* in market *m* at time *t*. Each plan offers a bucket of minutes for a fixed monthly access fee. Plans may include "anytime minutes," "peak minutes," and "night & weekend minutes." When a firm sets a plan's price, it must implicitly value each type of minutes included in the plan. Hence we need to estimate the relative weight given to each type of minutes. I define MINUTES = β_1*Anytime Minutes + β_2*Peak Minutes + β_3*Night & Weekend Minutes. The βs sum to one, and I estimate them using a nonlinear regression of (1). The βs reflect both consumers' relative willingness to pay for each type of minutes and the relative costs for each type. We would expect night & weekend minutes to have lower implicit prices than anytime minutes or peak minutes because consumers value more highly minutes they can use during 6AM-9PM (usual peak hours) on weekdays than those they can use only late at night or on weekends. We also expect higher weights for peak and anytime minutes because wireless carriers may include the marginal cost of capacity in the implicit prices of peak and anytime minutes, but not in the price of night & weekend minutes, since capacity only binds during peak hours.

NP_t: NP is a dummy variable that is equal to one if numbers were portable at time *t* and zero otherwise. NP = 1 for December 2003 through June 2004 and NP = 0 before December 2003.[55]

$U\_ANYTIME_{ipmt}$: U_ANYTIME is a dummy variable that is equal to one if the plan offers unlimited anytime minutes and zero otherwise. If a plan offers unlimited anytime minutes, I set Anytime Minutes = 0 in MINUTES and set U_ANYTIME = 1 for the plan. This is to avoid skewing the curvature of the pricing schedule by choosing an arbitrary number for Anytime Minutes when unlimited anytime minutes are offered. Similarly, if a plan offers unlimited night & weekend minutes, I set Night & Weekend Minutes = 0 in MINUTES and U_NIGHTWEEKEND = 1 for the plan. No plan in my sample offers unlimited peak minutes.

[54] Length of Contract and Length of Promotion are measured in months. I decided to include the activation fee in the price measure since some carriers use an activation fee waiver as an incentive for consumers to sign up for longer-term contracts. If a plan doesn't require any contract, I set Length of Contract = 12 when constructing PRICE.

[55] The data are collected at the beginning of each month, so November 2003 data were collected before number portability began.

$CONTRACT0_{ipmt}$: CONTRACT0 is a dummy variable that is equal to one if no long-term contract is required and zero otherwise. Similarly CONTRACT2 is a dummy variable that is equal to one if the plan requires two year contracts and zero otherwise. Different plans require different contract lengths, and in the data, carriers generally either impose the same contract duration for all plans they offer or offer a choice between one year and two year contracts. They sometimes provide incentives for consumers who sign up for two year contracts. The coefficient for CONTRACT2 is expected to be negative, reflecting activation fee waivers or reductions in access fees for customers who choose two year contracts over one year ones.

$REGIONAL_{ipmt}$: REGIONAL is a dummy variable that is equal to one if the plan is a regional plan and zero otherwise. Since national plans cover larger areas than regional plans and regional plans cover larger areas than local plans, prices for national plans tend to be higher than those for regional plans, which are in turn higher than local plan prices, given the same bucket of minutes. Therefore we expect positive coefficients for REGIONAL and NATIONAL. Consumers could either prefer network plans to local plans or the reverse, depending upon the size of the network. However, most of the carriers in the data are national carriers, and their network sizes are bigger than usual local coverage areas. Hence we expect the coefficient for NETWORK to be positive.

$7PM_{ipmt}$: 7PM is a dummy variable that is equal to one if the plan's off-peak hours start at 7PM and zero otherwise. Not only does the number of included minutes matter, but also the definition of peak hours does. For example, the same number of night & weekend minutes will be more valuable if off-peak hours start at 7PM than if they start at 9PM. The variable 7PM is included to account for price differences due to this feature.[56] We expect a positive coefficient for 7PM given that the majority of the plans in the data offer unlimited night & weekend minutes.[57]

$ROLLOVER_{ipmt}$: Rollover is a dummy variable that is equal to one if the plan allows rollover and zero otherwise. With rollover, when a wireless customer doesn't use all the minutes included in the plan, he can rollover the unused minutes to the next month. Rollover helps to avoid overage charges and hence we expect a positive coefficient for ROLLOVER. In the data, only Cingular offers rollover minutes.

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[56] About 15% of the data don't report starting time for off-peak hours. In these cases I assumed that 7PM = 0, since about 88% of non-missing observations have 7PM=0. The results for most of the coefficients remain stable if I instead assume the missing points have 7PM = 1. Most plans' off-peak hours start at either 7PM or 9PM. A very small fraction of plans have off-peak hours starting at 8PM.

[57] By the same logic, off-peak hour ending time and weekend hour begin/end day and time can also affect pricing of the plan. I decided to ignore these aspects because off-peak hour starting time of 7PM vs 9PM is very conspicuous while off-peak hour ending time or weekend hour begin/end day and time are not as conspicuous. For some time, it was a trend to introduce plans whose off-peak hours start at 7PM and carriers heavily advertised this feature. No such attention has been given to off-peak hour ending time or weekend hour begin/end day and time. Also, whether your off-peak hours end at 6AM or 7AM seems to matter a little, since most people would be in bed at the time anyway.

$PUSH2TALK_{ipmt}$: PUSH2TALK is a dummy variable that is equal to one if the plan offers walkie-talkie services and zero otherwise. Walkie-talkie feature allows a wireless user to talk instantly to another user just by pressing a dedicated walkie-talkie button. This feature is commonly used by police officers, taxi drivers, and construction workers. In the data, only Verizon offers this service.[58] For example, it could affect usage outside the carrier's coverage area.[59]

PCS_{ipmt}: PCS is a dummy variable that is equal to one if the service operates on PCS frequency (1.9 GHz) and zero if the service operates on cellular frequency (800 MHz). PCS and cellular services are believed to have almost identical qualities from users' point of view, but there might be some differences in costs or consumer's valuations for these two types.

$FREENATIONLD_{ipmt}$: FREENATIONLD is a dummy variable that is equal to one if the plan includes free nationwide long distance calls and zero otherwise.

$FREEINNTWLD_{ipmt}$: FREEINNTWLD is a dummy variable that is equal to one if the plan includes free in-network long distance calls (but not free nationwide long distance calls) and zero otherwise.

$CARRIER_i$: This is a carrier dummy that is equal to one if the plan belongs to carrier *i* and zero otherwise. This dummy variable captures carrier-specific influences on pricing. For example, we expect that small carriers like SureWest, Metro PCS, and carriers like T-Mobile who compete primarily on price would probably charge lower prices for the same bucket of minutes than national carriers like Verizon or AT&T, because the latter are likely to offer better coverage and more extensive networks.

$MARKET_m$: This is a market dummy that is equal to one if the plan belongs to market *m* and zero otherwise. This variable can capture market-specific characteristics that might affect prices, such as the level of demand or labor costs.

[58] Nextel, who has been the only wireless company to offer push-to-talk service until mid-2003, is not in the dataset.

[59] Cell Phone Buyer's Guide (2002)