Do switching costs make markets more or less competitive?: the case of 800-number portability

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Do switching costs reduce or intensify price competition if firms charge the same price to old and new consumers? I study 800-number portability to determine how switching costs affect price competition under a single price regime. AT&T and MCI reduced their toll-free services prices in response to portability, implying that reduced switching costs increased competition. Despite rapid market growth, gains from higher prices to "locked-in" consumers exceeded the incentives to capture new consumers. Prices on larger contracts dropped more, consistent with greater lock-in for larger users. Price changes between portability's announcement and implementation are consistent with rational expectations.

1. Introduction

Firms offering products with significant switching costs generally prefer to charge a higher price to existing customers who are "locked-in" and a lower price to unattached consumers who offer higher future profitability. However, transactions costs, regulatory constraints or customer arbitrage may prevent price discrimination. The previous empirical switching costs literature primarily examines differential pricing. I study a unique situation in which switching costs changed to determine the effect in a single-price regime.

I summarize previous theoretical models in which firms charge a single price. These models compare markets with and without switching costs. A decrease in switching costs has an ambiguous effect on equilibrium prices. The effect depends on the relative number of old and new consumers and the importance of "lock-in" relative to the incentives for attracting new customers. I test the effect of switching costs on competition in the high-growth, toll-free services market. Since rapidly growing

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markets have a greater proportion of new consumers, decreased switching costs are more likely to lead to less competition. I nevertheless find that lower switching costs led to lower prices for toll-free services.

Initial users of 800-, or toll-free, service could not switch providers without changing their telephone number. The introduction of portability on May 1, 1993 reduced switching costs, and regulatory restrictions required firms to charge the same price to new and existing customers. Price declines resulting from portability are evidence that switching costs make markets less competitive.

Portability lowered prices for the two types of toll-free services I examine. I first examine contracts for AT&T virtual private network (VPN) services, a bundle of long-distance services offered to large users. I estimate a price regression in which I can control for actual marginal cost. I find that VPN contracts constrained by non-portability had significantly higher prices than unconstrained contracts. I use contracts that contained no toll-free services (other services were always portable) as a control group. Prices on these contracts were not significantly affected by portability. I also find that post-portability, prices on contracts with more toll-free service declined more than those with less toll-free service.

I next examine prices for stand-alone (unbundled) services offered by both MCI and AT&T. I again estimate a price regression, controlling for actual marginal cost. I find that prices for toll-free services dropped after portability in a manner consistent with higher prices due to switching costs. Moreover, portability had no significant effect on prices for toll services, which were always portable.

Together these two services represent virtually all toll-free services purchased by businesses in my sample period. The magnitude of the effect on the average VPN and stand-alone toll-free users is approximately the same once I adjust for the fact that toll-free services comprise only a portion of VPN contracts. I estimate that portability lowered toll-free prices by approximately fourteen percent for the average customer. I offer evidence that these effects are not due to confounding events, including AT&T's loss of monopoly power over vanity numbers and regulatory changes.

The nature of the contracts in my data set and the timing of the portability decision allow me to test other aspects of switching costs effects. After portability AT&T lowered prices more on its larger VPN contracts, consistent with large users being more locked-in. Using overall contract revenue and a noisy measure of marginal cost for the overall contract, I find that AT&T lowered fixed fees on VPN contracts in addition to voice prices, so that overall margins fell by 22% after portability for the average contract. In addition, contracts issued between the portability decision and implementation reflected some but not all of the price reduction experienced after portability, consistent with rational expectations.

Because it is difficult to measure switching costs, there are few tests of single-price switching costs models.[1] Sharpe (1997) tests the Klemperer (1987) result that prices are more competitive the greater consumer turnover. Sharpe finds that the degree of migration in a local market has a positive

effect on bank deposit interest rates. He does not address the overall effect of switching costs on prices, the question of this paper. Kim, Kliger, and Vale (2003) employ an Euler equation approach to estimate switching costs and probabilities from a panel data set of Norwegian banks. They can infer switching costs from prices and aggregate share movements. I instead use a change in switching costs to measure the effect on prices. Knittel (1997) finds that the higher fees charged for switching long-distance providers are associated with greater margins for the long-distance providers. However, his empirical setting does not offer a control group. The variation in switching costs is temporal, and other factors may also have changed. Here toll services are used as a control.

In the next section I provide background on the toll-free services industry. Section 3 summarizes theoretical results relevant to my empirical tests. In Section 4, I describe VPNs and the data. Section 5 describes the econometric tests and empirical results. I conclude in Section 6.

2. Toll-free services and portability

After the divestiture of AT&T in 1984, other inter-exchange carriers (IXCs) were allowed to provide 800- or toll-free service.[2] However, the District Court charged with overseeing AT&T's breakup ruled that AT&T retained patent rights over the database technology that enabled local exchange carriers (LECs) to switch toll-free calls to different IXCs.[3] In 1986, the Federal Communications Commission (FCC) decided, as an interim measure, that toll-free calls would be routed based on the next three digits after 800 (800-NXX-YYYY), referred to as NXX screening. The FCC assigned each IXC one or more NXX prefixes for use in 800-service, and the LECs routed all calls beginning with "800-NXX" to the IXC assigned that NXX code. Although NXX screening allowed entry, the method imposed substantial switching costs on toll-free users. Because of the dependence on NXX, a user who wanted to switch carriers for its toll-free service had to switch numbers. Because firms usually publish 800-numbers widely, imprinting them on stationery, advertisements and business cards, the cost of changing numbers is significant.[4]

The FCC required the LECs to install a new switching system on May 1, 1993, which allowed them to assign and route any 800-call to any IXC.[5] Users could now switch providers without changing their phone number. There were still switching costs after portability, from renegotiating a contract, running a redundant parallel system during the transition, and relationship-specific costs. Nonetheless, switching costs were much lower than under non-portability. Most popular articles published prior to portability speculated that there would be lower prices for toll-free services.[6] This view prevailed in academic articles published since portability. Ward (1993) and MacAvoy (1995) cite portability as a

reason to expect more competition for 800-services. However, there has been no rigorous analysis of the effect of portability on prices.

Since comprehensive data on switching by toll-free customers is not available, I gathered evidence of whether non-portability precluded switching altogether. I identified all firms with sales over five million dollars in successive editions of *The Directory of Mail Order Catalogs* and traced the ownership of their 800-numbers over time based on NXX codes. I focused on only the largest mail-order firms since they were most affected by non-portability. Table 1 shows that many customers of the later entrants (MCI and Sprint) switched from AT&T, although the sample size is small. The fact that no users switched to AT&T is reasonable given the small sample size and because fewer customers would switch to a long-established incumbent. I cannot perform this analysis post-portability because NXX codes no longer map to specific carriers, and no comprehensive toll-free directories are available. I have to rely on (potentially biased) reports of switching made by the IXCs themselves.[7]

Switching costs can lower prices in a dynamic setting only if the number of new customers is sufficiently large relative to the number of old customers. My data indicate that toll-free minutes grew almost nine-fold from 1985 to 1999. I do not know whether new customers generated this growth, but the growth rate is sufficiently high that less competition may have resulted from a drop in switching costs.

3. Theoretical background

Previous theoretical work suggests that the *presence* of switching costs has an ambiguous effect on prices when firms charge a single price.[8] These models imply that a change in switching costs can either lower or raise prices depending on industry features.[9] In assessing a change in switching costs, it is important to include the effects from consumers actually switching. If all consumers are locked-in over the range of switching costs, then a change in switching costs will have no price effect. In my setting, customers do switch, as shown in Table 1. In this section I survey the theoretical predictions for the effect of portability on toll-free pricing, discussing them from the perspective of AT&T. The predictions for MCI are analogous.

Klemperer's (1987) model corresponds reasonably well to my empirical context, but he considers competition over only two time periods and therefore does not fully capture the dynamic effects of switching costs. In the model, two differentiated firms compete for heterogeneous consumers subject to switching costs if they change providers in the second period. Toll-free services can be viewed as a duopoly since AT&T and MCI provided most toll-free services during my sample period, and their 800-services were horizontally differentiated. AT&T and MCI's physical infrastructures were nearly identical because they both used the LECs' switching network for local access and their long-distance backbones

were similar; however, their billing and support services differed. In each period of Klemperer's model, each firm chooses a single price (consistent with regulatory constraints in the toll-free services industry) to maximize its discounted profits and it cannot commit to future prices. Consumers make purchase decisions to maximize expected lifetime utility.

Klemperer's model assumes there are changes in "fit" between the consumers' needs and the firms' offerings, modeled as a probability that consumers' differentiation costs change between the two time periods. Similarly, a consumer's evaluation of IXC services may change. Ex ante, consumers expect a certain level of service, but trying the product may change their expectations. A consumer dissatisfied with service at MCI may find AT&T more attractive ex-post. Equivalently, a consumer's business needs may change in unanticipated ways.

Klemperer finds that switching costs lead firms to charge lower prices in the first period and higher prices in the second period. However, these unambiguous predictions may be due to the two-period setup. In the first period, the firms face demand only from unattached consumers (as in a new market). In the presence of switching costs, firms have an incentive to price lower to "capture" consumers for their future profits. The second period contains both new and old consumers, but an "end-of-the-world" effect distorts pricing. Because new consumers in the second period are not valuable as repeat consumers, the firm has less incentive to capture them. The incentive to take advantage of locked-in consumers dominates, and the firms charge high prices.

In a fully dynamic model, both effects will be present in every period.[10] Since it cannot price discriminate, AT&T must balance charging lower prices to capture new consumers, who offer higher future profits, and pricing higher to take advantage of its locked-in consumers who have less elastic demand, both those whose preferences for the two firms changed and those whose did not. If consumers are not fully locked-in, lower switching costs gives an incentive to price higher, because new consumers are less valuable in the future, and lower, to current customers who are less locked-in. The overall effect is ambiguous.

Klemperer (1995) identifies two additional differences in markets with switching costs. New consumers and those whose tastes changed face an "anticipatory effect" and a "strategic effect," because consumers are forward-looking. These dampen the incentive for AT&T to price lower to capture them. Consumers realize that if AT&T builds a greater market share in the current period, it will charge more in the future. Therefore, they are less attracted by a price cut and have less elastic demand. Also, consumers realize that if AT&T builds a greater current market share by pricing low, MCI will charge lower prices in the future because it will have a smaller market share. This also makes demand for AT&T's services less elastic. With lower switching costs, demand is more elastic and AT&T has an incentive to price lower.

Finally, there is a fifth effect that previous models do not explicitly identify. With higher switching costs, demand for AT&T's services from MCI's customers whose tastes changed is lower because these consumers are more locked-in to MCI. This is the flip side of lock-in – your rival's customers are more captive and have less elastic demand. With lower switching costs, AT&T can discount less to attract these consumers.

The overall effect of a decrease in switching costs, such as that brought about by portability, is ambiguous. It depends on the proportion of new and old consumers, the intensity of the underlying desire to switch, firm and consumer discount factors and the relative markets shares of the two firms. With lower switching costs, capturing new consumers is less valuable and the rival's customers are less locked-in to the rival. Both imply higher prices. But the firm's customers are less locked-in, implying lower prices. Both the anticipatory and strategic effects are dampened with lower switching costs, because consumers expect lower future prices from a firm's large current market share, implying lower current prices.

4. Toll-Free Services Data

I estimate the effect of portability on prices for toll-free services filed in FCC tariffs.[11] The timing of the portability decision and implementation were unrelated to firms' pricing decisions. Portability required implementation of a new switching technology, Signaling System 7 (SS7), which had more far-reaching effects. The timing of SS7 implementation was driven by investment decisions of the LECs, who were independent of the IXCs. LECs and IXCs had been separate firms since the breakup of AT&T in 1984. AT&T could have attempted to influence the portability decision (via SS7 implementation decisions) by lowering toll-free prices before May 1993, indicating to the FCC that the potential gain from portability was minimal. My estimates would then be understating the true effect of portability.

I focus on the interstate market for toll-free service because of its importance. The interstate market is a national market and includes all calls originating and terminating in different states.[12] The FCC regulates the market for interstate 800-services. The "filed-rate" doctrine requires all rate-related information to be filed in an FCC tariff. In order to understand how I constructed the data sets and why I chose VPN service as the primary data source, it is necessary to understand the tariff process.

IXCs file two types of tariffs. Baseline tariffs contain rates for stand-alone services (no bundling). These tariffs contain volume discounts, but do not require the user to pre-commit to an expenditure level or length of service. The prevailing rates are in effect until the carrier files a change. The second type, contract-based tariffs, provides discounts off baseline rates for users who pre-commit to expenditure levels, bundles of services and contract duration.[13] AT&T offered two types of contract-based tariffs:

Tariff 12 options for VPN services and Contract Tariffs for bundles of stand-alone services. AT&T issued the first Tariff 12 option in March 1987 and the first Contract Tariff in February 1992.

The Communications Act of 1934 prohibits "unfair" price discrimination, which the FCC and courts have interpreted as the IXCs charging the same price to "similarly-situated" customers. Although the definition of "reasonable" differences between customers has been debated, the FCC has generally allowed IXCs to tailor prices only by time of day, type of service, volume purchased, contract length and mix of services. For the class of switching costs models that I wish to test, it is only necessary that carriers not charge different prices to old and new customers, which the FCC does not allow. I confirm the FCC's success in implementing the policy in my results.

I estimate portability's effect on prices of two toll-free service offerings: those bundled in Tariff 12 contracts for VPN service and stand-alone, or unbundled, services. These two offerings represented virtually all toll-free services sold to businesses during my sample period. Contract Tariffs, which allowed AT&T to tailor contracts to specific customers, were not allowed until 1992 and were used sparingly for toll-free services through the end of my VPN data set in October 1994. Although AT&T issued 1688 Contract Tariffs before October 1994, only 54 of them contained toll-free services (AT&T could use Contract Tariffs for many types of services). Subsequently, Contract Tariffs took much of the Tariff 12 volume because of their greater flexibility; AT&T issued over twelve thousand between 1994 and 2001. The contracts issued before October 1994 represented a small fraction of the ultimate Contract Tariff volume.

Virtual private network services data

The primary data are for AT&T VPN service contained in Tariff 12 options (distinct contracts) filed between February 1990 and October 1994. This period provides three years of data prior to portability and over one year after. The largest users of toll-free service, and therefore those most affected by portability, employed VPNs. VPN contracts are convenient for two reasons. First, AT&T wrote a significant number of VPN contracts before and after portability. Second, some VPN contracts included toll-free services while others did not. I use the latter as a control group since other services were always portable. AT&T, MCI and Sprint provided ninety-one percent of 800-services revenues at the portability date. Unfortunately, MCI did not begin filing contract-based tariffs for VPN service until 1992 and Sprint until 1995. I therefore focus on AT&T.

A VPN is a virtual network for large businesses. The user specifies a set of telephone numbers and commits to expenditure levels in exchange for discounts on calls made to and from these numbers. VPNs include up to five types of voice services, data services and, sometimes, international voice and

data services. Three of the voice services are toll and two are toll-free. The categories are determined by whether the call utilizes dedicated ("on-net") or switched ("off-net") services. Switched calls utilize the LECs' switching network, while dedicated calls do not. IXCs pay LECs a regulated per-minute access fee for switched service. For dedicated calls, IXCs lease lines from the LECs by a regulated monthly fee with a zero marginal usage cost. There are three types of toll calls depending on whether both, one or neither end of the call is on-net. Toll-free calls are of two types depending on whether the call terminates on-net or off-net.[14] Data service is provided over dedicated lines.

An observation, i, is an original or revised contract with effective date t. AT&T often revises an existing contract instead of issuing a new one. In my main regressions, I explain the average voice price of contracts. Since voice services are bundled in contracts they are potentially subject to cross-subsidization with non-voice services, and since these contracts also include fixed fees that AT&T might use to price discriminate, I also estimate a regression using the total contract price. I focus primarily on the average voice price, because estimating contract prices requires assumptions about the services mix as I explain below.

AT&T filed 233 active contracts during my sample period. Twelve were subject to different regulations, one did not contain any domestic services and another was for a different type of VPN service, leaving 219 observations. Of these 219, 93 are original filings and 126 are revisions. Figure 1 shows the distribution of issuance dates for these contracts and distinguishes between revised and original contracts. The early part of the data set contains no original contracts because I had access to tariffs beginning in February 1992, by which time these older contracts had already been revised. The spike in revised contracts in the latter half of 1993 is due to the FCC's "fresh look" decision, issued on September 30, 1991, which allowed customers to cancel any Tariff 12 option active at the portability date. AT&T renegotiated many contracts preemptively. The spike in original contracts in the third quarter of 1993 through the first quarter of 1994 is presumably due to increased demand from lower post-portability prices.

Multiple users often sign up for a single Tariff 12 contract. I do not observe the user(s) who subscribe to a particular contract. However, comparing usage patterns of Tariff 12 contracts to those of Contract Tariffs provides evidence that multiple users do subscribe. In contrast to the 231 Tariff 12 contracts issued or revised in the seven years of my sample period, AT&T issued over twelve thousand Contract Tariffs in the seven-year period between 1994 and 2001. Prior to 1994, Contract Tariff users would have had to subscribe to a Tariff 12 contract or pay the significantly higher stand-alone services rates.[15]

Contracts vary in size, duration and services mix. $revenue_i$ is AT&T's monthly revenue in thousands of millions from the contract based on the minimum revenue commitment. Contract duration $(duration_i)$ is the minimum time commitment allowed. The average contract length was 3.7 years and ranged from three to nine years. Each contract specifies up to six different prices: up to five per-minute prices for each type of voice service $\left(p^t_{Aij}\ j=1,2,..,5\right)$ and a fixed monthly fee (F_i). Voice service prices are usage-dependent while data service charges are volume-independent. Each contract provides imperfect information about the proportion $\left(w^t_{ij},\ j=1,2,..,5\right)$ of the voice services consumed, as explained in the Appendix. I calculate the average voice price as $\overline{P^t_{Ai}}=\sum_{j=1}^{5} w^t_{ij}\,p^t_{Aij}$. The Appendix contains more detail and Table 2 provides summary statistics.

Because VPNs utilize the LECs' networks and the FCC regulates access rates, I observe the marginal cost of voice calls and therefore the contribution of each contract's voice usage to AT&T's fixed network costs. Voice usage marginal costs are per-minute $\left(c^t_j\ j=1,2,...,5\right)$ and the average voice marginal cost for the contract is $\overline{c^t_i}=\sum_{j=1}^{5} w^t_{ij}c^t_j$.

Off-net prices and marginal costs are greater than those for on-net. Toll-free service prices exceed toll service prices; while marginal costs for toll-free service differ only slightly from those for toll service due to a small database query charge and operating costs difference (see the Appendix). As a result, margins are greater for toll-free than for toll services.

Two other variables may affect IXCs' costs of providing VPN voice service. Voice network dispersion $(vdisp_i)$, which measures the geographic dispersion of the voice network, may affect the carrier's monthly billing and support costs. A dummy variable, $isched_i$, indicates whether the contract includes international voice services, whose margins may differ from those for domestic services. Only eleven percent of contracts included international service. Although contracts specify compensation for network outages and charges for altering network size, these vary little across contracts. Customer-specific implementation details are contained in a separate, non-public document. However, as noted earlier, this document cannot contain any rate-related items.

The dummy variable, $dport^t$, equals 1 if portability was implemented at time t and 0 otherwise. The dummy variable, $ddecid^t$, equals 1 if portability had been decided but not yet implemented when

the contract was issued.[16] Forty-seven percent of the contracts were written after portability and 28% were written after portability was decided but before it was implemented. I measure AT&T's toll-free market share at the time the contract was issued, σ_A^t. This declined from a high of 80 percent in the first quarter of 1990 to a low of 67 percent in the fourth quarter of 1994.

Finally, three other variables control for non-voice services costs in my total contract revenue regression. To allow for different markups on voice usage and infrastructure, I computed their costs. Total monthly voice costs $(voicost_i)$ is the average voice marginal cost times the quantity of voice minutes consumed per month. The Appendix describes how the latter is inferred. Total monthly infrastructure costs $(infracost_i)$ is the fixed cost of data and voice lines per month $(c_{d,i}^t + c_{v,i}^t)$.

Stand-alone toll-free services data

I employ a secondary data source for stand-alone toll and toll-free services over dedicated lines. I use toll services as a control group since they were always portable and had virtually identical marginal cost. I find the best available rate (including all discounts) for large users (those spending approximately $3 million annually) from the fourth quarter of 1988 through the first quarter of 1999. The best rate for AT&T is taken from baseline tariffs through the third quarter of 1992 and for MCI through the third quarter of 1993. These tariffs specify a unique price for a given volume at each point in time. After this, better rates are available in contract-based tariffs. I use the median rate from AT&T and MCI Contract Tariffs of three-year duration. Unfortunately, similar data are unavailable for Sprint because it did not begin filing its contract tariffs until June 1995. The marginal costs for stand-alone services are the same as those for on-to-off services in VPN contracts. Table 3 provides summary statistics for these data.

Figure 2 plots the margins and market shares for AT&T's and MCI's stand-alone services over my sample period. Toll-free prices are higher than toll prices prior to portability; a gap that closes once portability is implemented. I estimate this effect more precisely in the next section.

5. Estimation and Results

In this section I offer two types of empirical evidence on portability's effects. First, I estimate the average voice price regression for AT&T VPN contracts. Second, I estimate the price regression for stand-alone services. The results from both data sets are consistent with the hypothesis that portability reduced switching costs and made the toll-free services market more competitive.

Estimation – VPN rates

I estimate an average voice price regression controlling for factors that might affect price, including marginal cost. Although I cannot assess counterfactuals, the regression estimates the direction and significance of portability's effect. I compute robust standard errors, allowing for heteroskedasticity and autocorrelation.[17] The baseline regression is:

$$p_{Ai}^{t} = \alpha + \beta_1 \overline{c_i^t} + \beta_2 \sigma_A^t + \beta_3 dport^t + \beta_4 \log\left(revenue_i\right) + \beta_5 duration_i + \beta_6 vdisp_i + \beta_7 isched_i + \varepsilon_i \,. \quad (1)$$

I include AT&T's market share to control for demand persistence, perhaps due to switching costs. I expect this coefficient to be positive if significant. To control for differences across contracts I include the contract's duration, size, voice network dispersion and inclusion of international service. I expect the coefficient on duration to be negative, since prices are declining during my sample period,[18] and the coefficient on size to be negative, due to volume discounts. I expect voice dispersion to have a positive effect since it proxies for billing and network management costs. I have no prior expectation on the effect of international service on domestic voice prices.

My specification assumes that pricing results from a profit-maximization decision by the firm rather than an average incremental cost condition derived from free-entry. There are at least two reasons to think that this is the case. First, providing telecommunications services to business customers is a high fixed and sunk cost business limiting competition to a few firms. Incumbent firms then play a price-setting game for their services. Second, even if entry were feasible because firms' services are differentiated, only the marginal entrant would earn zero long-run profits. More efficient or higher quality firms, like AT&T or MCI, would be infra-marginal.

The effect of portability on prices is identified in two ways. First, not all contracts included toll-free usage, and therefore some were unaffected by non-portability. Second, not all contracts originated before SS7 (and therefore portability) was decided, or after SS7 (and therefore portability) was implemented. Under contracts originating prior to the portability decision, AT&T subscribers whose contracts were expiring were subject to switching costs from non-portability if they did not renew with AT&T. New and existing users choosing this same contract expected to be locked-in to AT&T upon the contract's expiration. After implementation, pre-existing AT&T subscribers whose contracts were expiring were not subject to switching costs from non-portability; both old and new users knew they would not be locked-in due to non-portability when their contract expired.[19] If users incorrectly expected portability to be implemented before the decision on August 2, 1991, then I would be misinterpreting my

results. Although the FCC discussed portability since the implementation of NXX screening in 1986, based on press accounts it was not widely considered a reality until the August 1991 decision.[20] Although carriers may have assigned a positive probability to SS7 implementation prior to the August 1991 decision, even major customers were not likely to be following the FCC's SS7 discussions prior to the decision given the minor impact on their overall business plans.

I estimate the effect of a common explanatory variable, portability, on individual contract margins. My standard errors will be understated if there are unobserved random factors that affect margins on VPN contracts with toll-free services differently (Donald and Lang (2001)). Portability did not have a significant effect on toll-free margins vis-à-vis toll margins if the difference in variance of these unobserved shocks across the two groups is large enough relative to my point estimates. As Wooldridge (2003), argues the question is whether the observed difference in mean margins is due entirely to the policy change. In Section 4, I discuss several alternatives, including regulatory and quality changes, which might affect the two contract types differentially, and offer evidence contradicting these.

Column 1 of Table 4 reports estimates of the average voice prices in the VPN contracts (Base Model). Overall, portability is associated with 4.4 percent lower average prices. The other coefficients generally have the expected signs. Price is increasing in marginal cost and decreasing in contract size. Contracts with more disperse voice networks have higher prices, but neither duration nor presence of international service significantly affects prices. AT&T's market share does not have a significant effect; likely because it varies relatively little over time (see Figure 2). This lack of variation is consistent with gradual changes in shares due to lock-in.[21]

If AT&T could price discriminate between old and new users, I would be misinterpreting the results. Although the FCC requires AT&T to make Tariff 12 contracts available to similarly-situated customers, AT&T could still price discriminate if it tailored individual contracts so that only new or existing users could qualify. The filed-rate doctrine limits AT&T's ability to do this. Since AT&T must file all rate-related items with the FCC, they are publicly available and used to inform subsequent negotiations. Because a contradicting tariff takes legal precedence over a private contract, "under-the-table" agreements are difficult to enforce. Moreover, resellers of AT&T's 800-services can arbitrage away any price differences across tariffs.

The most efficient means for AT&T to implement price discrimination would be to target new customers with new contracts and incumbent users with revised contracts. While in theory AT&T could target a new customer by revising all aspects of an existing contract and making it effectively new, this would require them to move existing customers onto other new contracts. I do not observe such revamping of Tariff 12 Contracts. Therefore, if AT&T were able to tailor Tariff 12 contracts to

discriminate between old and new users, prices in new contracts would differ from those in revised contracts. To test for this, I estimated the Base Model with a sub-sample consisting of only revised contracts. The unreported results are not significantly different from those in the Base Model. All of the significant coefficients are of the same sign (although marginal cost and voice network dispersion are no longer significant) and the portability coefficient is virtually the same (-0.00491) and highly significant. A Chow test yields a test statistic of 0.63, which is not significant (significance level of 99 percent). I cannot reject the hypothesis that the parameters are the same for the revised and new contract sub-samples.

I re-estimate the Base Model to allow for a control group to distinguish the effect of portability implementation from announcement. I include a dummy for the contracts without toll-free service and interact it with the portability dummy to estimate the effects on the control group. There was a lag between the time that the FCC decided to implement SS7 (August 2, 1991) and its implementation (May 1, 1993). During the intervening period, AT&T would have less incentive to price lower to capture new customers because fresh look freed them from lock-in as of the portability date but it would have the same incentive to take advantage of locked-in customers. Based on these two effects we would expect an increase in prices once portability is announced. However, both the anticipatory and strategic effects are diminished once portability is announced because future implementation implies a weaker relationship between current market share and future prices. These forward-looking effects alone imply lower prices. Overall, we would expect either an increase or a less severe drop in prices than was experienced post-portability during this intervening period. I distinguish contracts issued between the SS7 decision and implementation by a dummy variable.

The results In Column 2 of Table 4 confirm that portability lowered prices only on contracts with toll-free service and that part of this effect occurred prior to portability's implementation (but after the decision). Prior to portability, contracts with toll-free service sold at a premium relative to those without. The premium more than vanishes after portability so that the two prices are not statistically different (portability reduces prices of contracts with toll-free service by 7.8% with a standard error of 2.3% and contracts without toll-free service were lower prior to portability by 4.9% with a standard error of 2.4%). Moreover, portability had no significant effect on contracts without toll-free service. Of the 7.8% drop in prices with portability, 3.4% occurred after the portability decision and another 4.4% after portability implementation. This is consistent with rational expectations; if customers were myopic prices would increase between the portability decision and implementation.

In unreported regressions I included a time trend and interact it with the portability dummy to ensure that the effects from portability are not confounded with systematic changes over time.[22] Prices for contracts with toll-free service were 4.9% higher pre-portability than those on contracts without, but

dropped by 4.4% after portability while contracts without toll-free service were not significantly affected. There was no significant trend in prices on contracts prior to portability but prices trended upward on average for all contracts post-portability.

To evaluate whether AT&T adjusted prices more for longer or larger contracts in response to portability, I interact contract duration and size with the portability dummy. The results in Column 3 of Table 4 show that margins on larger contracts fell significantly more after portability than margins on smaller contracts. Each doubling of contract revenue decreased the contract margin by 2.4% so that the largest contract in the data set declined by 12% more than the smallest contract at the means of all other variables. Prices on longer contracts were not affected significantly differently than those on shorter contracts. Figure 3 compares the distribution of durations pre- and post-portability to examine whether AT&T altered the distribution of contract durations in response to portability. The distributions are very similar, and a Chi-Square test for equality of distributions yields a test statistic of 5.03 and a significance level of 89 percent so I cannot reject the null hypothesis of the same distributions.

To test whether AT&T lowered margins more on contracts with a greater proportion of toll-free services after portability, I include a linear function of the fraction of toll-free services in contracts before and after portability. Less emphasis should be placed on these results than on those above because of the additional assumptions needed to approximate the fraction of toll-free services (see the Appendix). The results in Column 4 of Table 4 indicate that pre-portability margins increased in the fraction of toll-free services by 0.22% for each one percent increase in the fraction. Post-portability margins on contracts without toll-free service were not significantly affected, whereas margins on contracts with toll-free service decreased by 0.13% for each one percent increase in the fraction of toll-free services. Thus, margins on a contract with only one percent toll-free service declined by only 0.35% with portability, while the contract with the highest fraction of toll-free service in the data set (71%) declined 25% after portability.

To test whether AT&T may have adjusted the fixed fee or altered the degree of cross-subsidization in the VPN contracts, I estimate the effect of portability on total contract revenue. Less emphasis should be placed on these results because of the additional assumptions needed to approximate the non-voice and fixed voice costs of a contract (see the Appendix). Column 5 of Table 4 shows estimates using total contract revenue. Portability had a significant negative effect on margins (6.9%), greater than the effect on voice margins alone, implying that AT&T lowered not only the average voice price but also the fixed fee on contracts in response to portability.

Estimation –stand-alone rates

For stand-alone services data the effect of portability is identified by whether the price pertains to pre- or post-portability.[23] The regression I estimate is:

$$p^t_{jk} = \alpha_{jk} + \beta_{1,jk} c^t_k + \beta_{2,jk} \sigma^t_j + \beta_{3,jk} dport^t + \varepsilon_{jk} \quad j = ATT, MCI \; k = Toll, Toll - Free . \tag{2}$$

Table 5 displays the results. Portability has a significant negative effect on toll-free services prices for both firms but no significant effect on toll prices, consistent with portability increasing competition.[24] The negative effect of portability on MCI's prices is evidence that the effect on AT&T's prices did not result from its loss of monopoly on the most popular NXX vanity numbers. Since AT&T had offered toll-free service longer and had a much larger market share, it may have had more popular NXX codes (e.g. those corresponding to "THE" or "USA.") That only five percent of the toll-free numbers in the sample described in Table 1 contained vanity numbers in the NXX code is additional evidence that this was not portability's primary effect. Portability's effect is greater here than for VPN services. This is reasonable given that toll-free services comprised only 31 percent, on average, of the VPN contracts. This implies that the price of a hypothetical VPN contract with only toll-free service would decrease by approximately 14 percent due to portability – the same magnitude as for stand-alone toll-free service prices.[25]

The FCC subjected AT&T to price regulation on stand-alone toll-free services until portability, but there is significant evidence that these regulations did not constrain AT&T's pricing.[26, 27] The design of the regulation gave AT&T more freedom than it appeared. From March 1989 to May 1993 the FCC imposed price-cap regulation on AT&T's stand-alone toll-free services. The regulation was applied by baskets, and toll-free services were in Basket 2. AT&T could change prices within each basket by five percent in either direction of a price cap index set annually by the FCC. The FCC subdivided Basket 2 into four categories and AT&T could change rates for services in a category by more than five percent as long as the weighted average across all four categories stayed within the allowed range.[28] The FCC initially set the price cap index at AT&T's existing rates and then adjusted it annually for inflation and reduced it by a 2.5 percent "productivity offset" and a 0.5 percent "consumer productivity dividend." AT&T could also submit tariffs that deviated from the price bands subject to FCC approval. Hall (1993) offers evidence that AT&T's weighted price was well below the price cap index for Basket 2 services during price cap regulation. Lastly, if price regulation had constrained AT&T's pricing, AT&T should have increased its price after portability.

6. Conclusion

In this paper I test the effect of switching costs in a market in which firms could not price discriminate between new and existing users. I find that firms in the market reduced their prices in response to a decline in switching costs. I use the advent of number portability for toll-free services to measure its effect on prices and employ a difference-in-differences approach with toll services, which were always portable and had virtually identical marginal cost, as a control. In the empirical switching costs literature a persistent problem has been the difficulty of isolating switching costs that are embedded in complicated pricing schemes. In this paper, I offer a unique setting with a clear control group in which to isolate them.

Although the primary contribution of this paper is to the switching costs literature, it also contributes to the telecommunications literature. A perennial problem in studies of the telecommunications industry has been the difficulty of measuring discounts for services, especially business services. Previous authors have either approximated these discounts or avoided studying business services.[29] I construct a unique data set that fully captures discounts for large users. The results also have implications for decisions on portability in other telecommunications markets. From a policy perspective, the technology for implementing portability was available in 1987 but the court overseeing AT&T's breakup ruled that the technology belonged to AT&T, delaying portability and these lower prices by six years.

Appendix

This appendix describes the sources of data and methods used to measure the variables in the VPN services dataset.

$w_{ij}^t,\ j=1,2,..,5$ (Mix of voice usage): Contracts specify four port types corresponding to telephone numbers. Measured ports and rate option 1 measured remote ports were toll numbers carried over a dedicated line. Rate option 2 measured remote ports were toll-free numbers carried over a dedicated line. Outside ports were toll numbers carried over switched lines. Publicly unavailable documents specify port access telephone numbers that defined the total number of toll-free numbers carried over switched or dedicated lines. The following matrix defines the five types of voice services and the corresponding number of ports that contract i contains (the mix of voice usage can differ over time (t) for revised contracts):

		Calls To		
		Number of measured (m_i) or rate option 1 measured remote $(r1_i)$ ports	Number of rate option 2 measured remote ports $(r2_i)$	Number of outside ports (o_i)
Calls From	Number of measured (m_i) or rate option 1 measured remote $(r1_i)$ ports	On-to-on toll calls $(j=1)$		Off-to-on toll calls $(j=2)$
	Number of outside ports (o_i)	Off-to-on toll calls $(j=2)$		Off-to-off toll calls $(j=3)$
	Number of port access telephone numbers (p_i)	Off-to-on toll-free calls $(j=4)$	Off-to-off toll-free calls $(j=5)$	

Based on this, the weights assigned to voice service j in contract i at time t, w_{ij}^t, are given by the equations:

$$2\left(w_{i1}^t+w_{i1}^t\right)+w_{i4}^t=m_i+r1_i,\ w_{i5}^t=r2_i,\ 2\left(w_{i2}^t+w_{i3}^t\right)=o_i,\text{ and }w_{i4}^t+w_{i5}^t=p_i. \tag{A1}$$

Because the contract provides $m_i, r1_i$ and $r2_i$ but not o_i and p_i (since they do not affect AT&T's fixed costs), we have four equations and seven unknowns. Using the assumptions in MacAvoy (1995, p.107), I assume $w_{i2}^t=3.25w_{i1}^t$ and $w_{i3}^t=0.75w_{i1}^t$. Finally, I impose: $w_{i4}^t=\max\left\{3.25/0.75\,w_{i5}^t, w_{i2}^t\right\}$. I solve these seven equations and impose $\sum_{j=1}^{5}w_{ij}^t=1$ to express the weights as fractions.

$p_{Aij}^t\ j=1,2,...5$ (per-minute voice prices): Contracts tailor per-minute voice rates to time of day and distance. I use the per-minute rate for a daytime call of four hundred miles, the most common call placed. Contracts often contain monthly volume discounts for voice service. In applying these discounts I assumed the user consumed $revenue_i$ according to $w_{ij}^t,\ j=1,2,..,5$.

$c_j^t\ j=1,2,...,5$ (voice usage marginal cost): Includes access fees, operational costs and, for toll-free calls, database lookup fees. IXCs pay LECs per-minute access fees, regulated and published in FCC tariffs, to complete the switched portion of calls. Since access fees vary slightly across LECS and the telecommunications operations of VPN users span multiple LECs, I use an average across all LECs from

FCC (1999). I base operational costs on court testimony by AT&T in their June 1990 application to provide intrastate toll-free service in California.[30] Operational costs are constant over all output levels until demand exceeds capacity. There is significant evidence that the three firms had excess capacity during my sample period. Huber, Kellogg, and Thorn (1992, p.321) cites several studies. Toll-free numbers were also readily available. The industry did not exhaust 800-prefix numbers until 1996, and 60% of the numbers were still available in April 1993 (FCC, 1999). After portability, the LECs charged the IXCs a per-query fee for each 800-number lookup. Since this fee varied across LECs and VPN users generally span multiple LECs, I average across the nine major LECs, assuming a 3.6 minute call.[31]

$revenue_i$ (monthly contract revenue): 120% of the minimum volume commitment per month. Users avoid choosing a minimum above their monthly usage because penalties require paying the shortfall, or choosing a minimum too far below their monthly usage since they could have negotiated further volume discounts. Consultants advise users to choose a revenue commitment at approximately 120% of expected usage.

$duration_i$ (contract duration): Minimum time commitment allowed under the contract. Contract penalties required users to pay the minimum revenue commitment in each year regardless of usage. Since prices were falling during this period, the minimum time commitment was most favorable to users.

q_i (monthly voice minutes consumption): Monthly contract revenue less the fixed monthly fee divided by the average voice price: $q_i = \left(revenue_i - F_i\right) \Big/ \overline{P_{Ai}^t}$.

σ_A^t (AT&T's toll-free services market share): Levinson, Modesitt, and Robson (1990) estimate annual toll-free revenues by firm from 1985 to 1990 and Strategic Telemedia (1997) from 1992 to 1997. To concatenate these two, I stack them in a regression on an AT&T dummy, an MCI dummy, a source (Levinson versus Strategic Telemedia) dummy and total long-distance revenues estimated by the FCC (1998). I use predicted values of annual toll-free revenues assuming Strategic Telemedia as the source. To obtain quarterly revenues, I assume the same seasonality as total long-distance revenues reported in FCC (1998). I assume that the time trend in usage is the same for different sized users.[32]

$vdisp_i$ (Voice network dispersion): Number of remote dedicated voice lines as a fraction of total number of dedicated voice lines. IXCs lease dedicated voice lines from LECs paying per-month fees regulated and published in FCC tariffs. Dedicated voice lines are either access (high-volume lines terminating at an AT&T switching office) or remote (low-volume lines terminating at the subscriber's premises). The number of access lines equals the number of measured ports $\left(m_i\right)$. The number of remote lines equals the number of rate option 1 and 2 remote ports $\left(r1_1 + r2_i\right)$.

$c_{v,i}^t$ (dedicated voice lines monthly cost): IXCs lease dedicated voice lines from the LECs paying per-month fees regulated and published in FCC tariffs. Dedicated voice lines are either access (low-volume lines terminating at an AT&T switching office) or remote (high-volume lines terminating at the subscriber's premises). The number of access lines is equal to the number of measured ports $\left(m_i\right)$. The cost per access line is taken from Table 1.1 of FCC (1999) and is an average across all LECs. The number of remote lines is equal to the number of rate option 1 and 2 remote ports $\left(r1_1 + r2_i\right)$. Remote lines are single data lines (64 kbps or slower). I take their costs from a quarterly price index compiled by CCMI from LEC tariff filings for 1989 through 1991. Prices for subsequent periods are extrapolations based on changes in access line costs.

$c_{d,i}^t$ (dedicated data lines monthly cost): IXCs lease dedicated data lines from LECs paying per-month fees regulated and published in FCC tariffs. LECs provision data lines in three speeds. Single data lines operate at 64 kbps or slower. Medium speed lines (128 kbps to 1.5 mbps) and high-speed lines (45 mbps) are bundles of single voice lines (24 and 672 lines respectively) for which the LECs provide discounts. I base costs of single- and medium-speed lines on quarterly price indices compiled by CCMI

from LEC tariff filings for 1989 through 1991 and extended thereafter based on changes in voice access line costs. I base high-speed line costs on 28 times the cost of a T-1 line adjusted by discounts given in Huber (1987) on page 3.31.

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[1] Other studies look at cases in which firms can price discriminate between old and new consumers. Borenstein (1991) examines gasoline stations, Calem and Mester (1995) the credit card industry, and Elzinga and Mills (1998) wholesale cigarettes.

[2] The service is often called 800-service because all toll-free numbers originally began with the numbers "800."

[3] The difficulty in switching toll-free calls was that the recipient of the calls pays so that the LEC could not simply route the call to the initiator's chosen long-distance provider.

[4] See "Carriers Plot Strategies at Dawn of War Over 800 Users" (*Network World*, November 9, 1992), "Firm Predicts Savings With Tariff 12 Net" (*Network World*, February 12, 1990), "Net Users Remaining Loyal After AT&T's Recent Outage" (*Network World*, January 29, 1990).

[5] As I explain below, portability was not the primary intent of the new switching technology.

[6] See "Portability Sparks Price Wars" (*Catalog Age*, May 1993), "Airlines + Price Wars = Big 800 Traffic" (*800-900 Review*, Strategic Telemedia, May 1, 1992), "Portability Adds Fuel to 800 Fire" (Karen Burka, *Catalog Age*, October, 1992).

[7] AT&T claimed that 10,000 users ($140 million) switched to its service, while MCI claimed 6,550 users ($170 million), and Sprint "several thousand" customers. ("Winds of Change Sweeping Over Cooped-Up 800 World," *Network World*, May 3, 1993).

[8] Klemperer (1995) reviews switching costs models in which firms charge a single price. There are also switching costs models that consider third-degree price discrimination (Chen (1997), Nilssen (1992) and Taylor (1999)) and endogenous switching costs (Caminal and Matutes (1990)).

[9] A model with overlapping generations of finite-lived consumers is presented in Viard (2003).

[10] Beggs and Klemperer (1992) relaxes the finite horizon assumption of Klemperer (1987) but assumes full lock-in. Switching costs are high enough that consumers never switch and the level of switching costs does not affect prices. Since toll-free customers switched both before and after portability, this does not apply.

[11] Since the FCC does not index tariffs in any meaningful way, I obtain them from CCMI, a division of UCG, which provides pricing information and analysis to telecommunications users.

[12] The court overseeing AT&T's divestiture defined three types of markets for 800-services: intra-LATA, intrastate (inter-LATA) and interstate (regardless of whether within the same LATA).

[13] A contract-based tariff is available to any "similarly-situated" customer for ninety days after its effective date. The FCC required IXCs to file both types of tariffs fourteen days before their effective date throughout my sample period (except for corrections to a tariff which had to be filed three days before).

[14] Calls to a user's toll-free number originate off-net by definition.

[15] As noted earlier, AT&T did issue 54 Contract Tariffs with toll-free service in my sample period.

[16] The decision to implement portability was made on August 2, 1991. Portability was discussed as a possibility before this, but the timing was uncertain.

[17] My dependent variable is left truncated at marginal cost and I re-estimated all results using a Tobit model. These results are all virtually identical, because there are no predicted prices below actual marginal cost.

[18] Since firms choose duration and price simultaneously, duration may be endogenous. In an unreported regression I estimated the effects of portability on a subset of contracts of identical duration (three years). The effects were similar to those in the full sample although noisier due to the small sample.

[19] There were contracts written between the portability decision (August 2, 1991) and its implementation (May 1, 1993). For these, pre-existing users remained locked-in but they and new customers would anticipate the lower switching costs at contract expiration. I describe and estimate the effects of this forward-looking behavior below.

[20] Before the August 2, 1991 story announcing the SS7 decision, the *Wall Street Journal* had published no articles related to 800-number portability since 1985 when it reported that the court overseeing AT&T's breakup would not allow other IXCs to use AT&T's original technology, which would have allowed portability.

[21] I also estimated a percentage markup regression and find that portability has a highly significant although larger effect on margins (10%). I prefer the price specification because the marginal cost coefficient can differ from one if AT&T alters the fixed fee or cross-subsidizes services in a contract.
[22] To preserve degrees of freedom I eliminate insignificant variables from the regression.
[23] Unlike Tariff 12 contracts for VPN service, fixed monthly fees for stand-alone services are miniscule (e.g. $50 per month for AT&T services) and do not vary over my sample period so that usage fees capture the price change due to portability.
[24] The other variables are generally of the expected sign. Marginal cost and AT&T's market share are positively related to prices. MCI's market share is negatively related to its price (but only significant for toll-free services). This is due to the run-up in prices prior to portability (see Figure 2).
[25] The stand-alone prices in my dataset pertain to a $3 million annual user, approximately the same amount that the average VPN user in my dataset spends on toll-free services ($16.4 million annually with 31% on toll-free service).
[26] I talked to a consultant who had worked for AT&T as a salesperson prior to portability. He claimed that AT&T was not constrained by price caps in filing their tariffs and that the FCC rarely challenged tariffs.
[27] The Tariff 12 contracts used in the VPN analysis were not subject to price regulations. They were subject only to tariff review, and the guidelines for this review did not change during the period of my study.
[28] Basket 2 included the following service categories: 1) Readyline 800 (inbound WATS switched), 2) AT&T 800 (classic inbound WATS), 3) Megacom 800 (inbound WATS dedicated) and 4) other 800.
[29] For example, Knittel (1997) avoids studying business customers due to the difficulty of measuring discounts (page 529). "Competition for 800 Service," (Kaserman and Mayo, 1991) contains no actual price data besides a statement that, "For interstate 800 service AT&T has reduced prices by approximately twenty percent since 1986" (page 405).
[30] An AT&T executive estimated operational costs for switched toll service to be 1.01 cents, switched toll-free service to be 1.08 cents, dedicated toll service to be 1.30 cents and dedicated toll-free service to be 1.29 cents per minute. Application of AT&T Communications of California, Inc. (U 5002 C), June 18, 1990 as reported in MacAvoy (1996).
[31] This data is taken from "Rates May Deter Use of 800 Portability," *Network World*, May 10, 1993, pp. 23, 24 and 34. 3.6 minutes is the average call length according to Strategic Telemedia (1996), p. 64.
[32] The *Telecommunications Market Sourcebook* (Frost & Sullivan, 1995) provides evidence that the mix in revenues did not change much between dedicated service, used primarily by large users, and switched service, used primarily by small users, between 1992 and 1998 (page 15-8).

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Table 1 Estimates of Customer Switching Between Toll-Free Providers in 1989, 1991 and 1993

	AT&T	MCI	Sprint	Other	Total
1989 Total	153	3	1	4	161
(% of market)	(95%)	(2%)	(1%)	(2%)	(100%)
Switched From	4				4
(% of 1991 Total)	(2%)				(2%)
Switched To		1	1	2	4
(% of 1991 Total)		(13%)	(33%)	(29%)	(2%)
1991 Total	170	8	3	7	188
(% of market)	(90%)	(4%)	(2%)	(4%)	(100%)
Switched From	6				6
(% of 1993 Total)	(3%)				(3%)
Switched To		3	1	2	6
(% of 1993 Total)		(25%)	(9%)	(15%)	(3%)
1993 Total	194	12	11	13	230
(% of market)	(85%)	(5%)	(5%)	(6%)	(100%)

Source: Sample contains all customers with sales of $5 million or more in the *Directory of Mail Order Catalogs* 4th (1989), 5th (1991) and 7th (1993) editions. Switching is detected based on the customer's NXX code in their toll-free number.

Table 2 AT&T VPN Contracts Sample Descriptive Statistics, n = 219

Variable	Mean	Standard Deviation	Minimum	Maximum
Contract Revenue ($ million/month)	1.37	1.76	.108	16.2
Log Contract Revenue	-.121	.857	-2.22	2.79
Duration (years)	3.71	1.01	3	9
Average Voice Price ($/minute)	.107	.0109	.0828	.159
Average Voice Marginal Cost ($/minute)	.0485	.00360	.0130	.0565
Portability Implementation Dummy	.470	.500	0	1
Portability Decision Dummy	.279	.449	0	1
Market Share	.705	.0302	.667	.800
Voice Network Dispersion	.128	.208	0	1
International Schedule	.114	.319	0	1
No Toll-Free Service	.105	.307	0	1
Fraction Toll-Free Service	.312	.151	0	.705
Voice Cost ($1000/month)	.400	.542	.0191	5.33
Infrastructure Cost ($1000/month)	.554	.895	.0190	5.39

Sample includes all AT&T VPN contracts issued between February 1990 and October 1994 except those excluded as described in the text.

Table 3 Stand-Alone Services Quarterly Prices Descriptive Statistics, n = 45

Variable	Mean	Standard Deviation	Minimum	Maximum
AT&T Toll Price	.101	.0198	.0631	.128
AT&T Toll-Free Price	.107	.0262	.0592	.135
MCI Toll Price	.0880	.0174	.0528	.113
MCI Toll-Free Price	.0994	.0261	.0538	.132
Toll Marginal Cost	.0494	.00531	.0384	.0597
Toll-Free Marginal Cost	.0500	.00488	.0396	.0597
AT&T Market Share	.708	.102	.589	.959
MCI Market Share	.190	.0661	.0323	.263
Portability Dummy	.533	.505	0	1

Sample includes quarterly prices for AT&T and MCI stand-alone services between the fourth quarter of 1988 and the first quarter of 1999.

Table 4 Estimated Price Regressions for Average Voice Price (Columns 1 through 4) and Contract Revenue (Column 5) in Sample of AT&T VPN Contracts (n = 219)

Independent Variable	1 Base Model	2 Control Group/ Portability Decision	3 Size/ Duration Effects	4 Fraction Toll-Free Service	5 Contract Revenue
Intercept	.114***	.154***	.108***	.116***	.572
	(.0241)	(0.0255)	(0.0247)	(0.0205)	(.547)
Marginal Cost	.738*	.520	.767*	.319	
	(.425)	(0.402)	(0.408)	(.356)	
Previous Market Share	-.0757	-.124**	-.0716	-.0557	-.926
	(.0641)	(0.0525)	(0.0653)	(.0505)	(.975)
Portability Implementation Dummy	-.00469***	-.00840***	-.00205		-.0946***
	(.00177)	(0.00241)	(0.00460)		(.0313)
Log Contract Revenue	-.00420***	-.00410***	-.00289***	-.00390***	
	(.000580)	(0.000680)	(.000786)	(.000704)	
Duration	-.000142	-.000184	.000392	-.000123	.0137
	(.000515)	(0.000534)	(.000737)	(.000564)	(.0181)
Voice Network Dispersion	.00464*	.00487*	.00494*	.00615**	-.193*
	(.00258)	(0.00283)	(.00257)	(.00275)	(.103)
International Schedule	-.00182	-.00174	-.00149	-.00238*	-.0334
	(.00139)	(0.00149)	(.00159)	(.00137)	(.0544)
Portability Decision Dummy		-.00364*			
		(0.00193)			
No Toll-Free Service		-.00521**			
		(0.00257)			
No Toll-Free Service – Under Portability		.00517		.000878	
		(0.00508)		(.00523)	
Log Contract Revenue – Under Portability			-.00257**		
			(.00123)		
Duration – Under Portability			-.000783		
			(.00102)		
Fraction Toll-Free Service				.0236***	
				(.00590)	
Fraction Toll-Free Service – Under Portability				-.0140***	
				(.00468)	
Infrastructure Cost					.925***
					(.0400)
Voice Cost					2.02***
					(.0434)
Adjusted R^2	.276	.292	.283	.307	.988

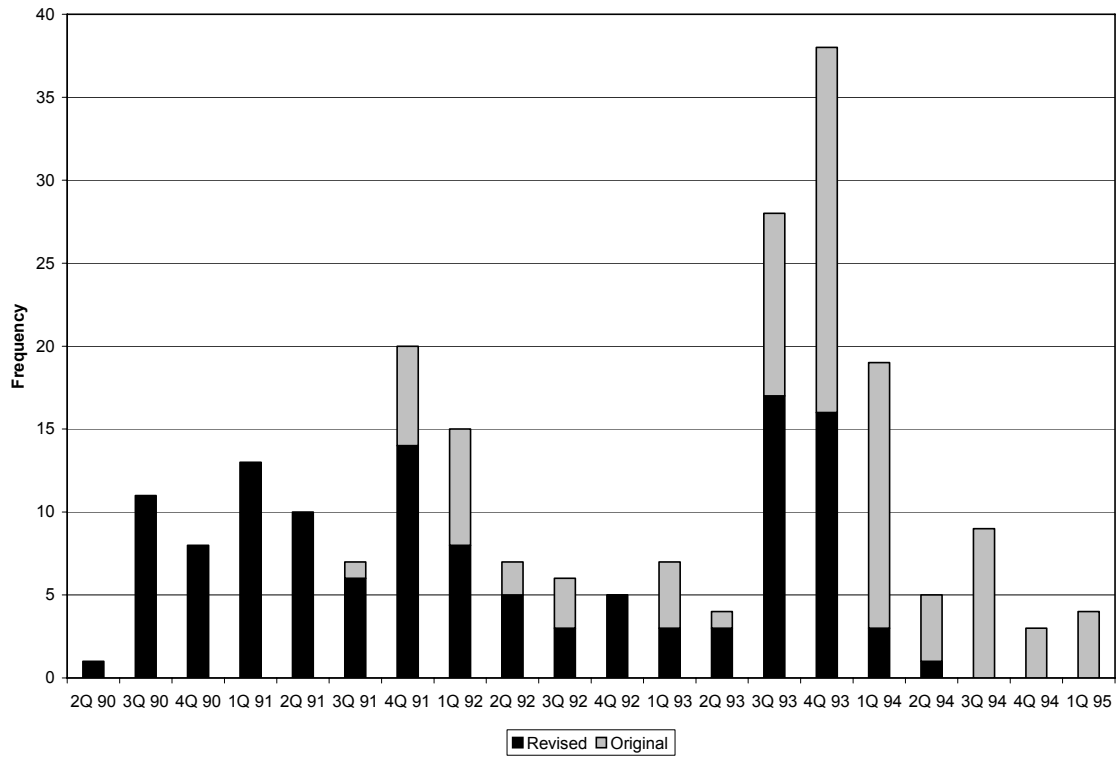
Newey-West (1987) standard errors in parentheses. Errors allow for heteroskedasticity and autocorrelation up to a lag of 5 (bandwidth parameter according to Andrews (1991). * Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level. Column 1 is the baseline model. Column 2 distinguishes contracts without toll-free service as a control group and distinguishes contracts issued between portability decision and implementation. Column 3 allows effects of contract size and duration to differ pre- and post-portability. Column 4 estimates the effect of fraction of toll-free service pre- and post-portability. Column 5 replicates the base model using total contract revenue.

Table 5 Estimated Price Regressions for Quarterly Price of AT&T and MCI Stand-Alone Services from Fourth Quarter 1988 through First Quarter 1999

Independent Variable	AT&T Toll	AT&T Toll-Free	MCI Toll	MCI Toll-Free
Intercept	-.0314	-.0508	.0235	.0389
	(.0248)	(.0338)	(.0262)	(.0279)
Toll Marginal Cost	1.85***		1.72***	
	(.405)		(.444)	
Toll-Free Marginal Cost		2.76***		1.91***
		(.537)		(.553)
Market Share	.0625***	.0405**	-.0944	-.145***
	(.0153)	(.0184)	(.0570)	(.0349)
Portability Dummy	-.00549	-.0160**	-.00233	-.0143**
	(.00481)	(.00661)	(.00579)	(.00712)
Observations	45	45	42	45
Adjusted R^2	.744	.751	.707	.796

Newey-West (1987) standard errors are in parentheses. The errors allow for heteroskedasticity and for autocorrelation with a lag of 1.
* Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

Figure 1 Distribution of Origination and Revision Dates for VPN Contracts in Sample



Number of AT&T VPN contracts originated and revised in each quarter during the sample period. Sample includes all the AT&T VPN contracts issued between February 1990 and October 1994 except for those excluded as described in the text.

Figure 2 Stand-Alone Toll-Free and Toll Services Margins 4th Quarter 1988 Through 1st Quarter 1999

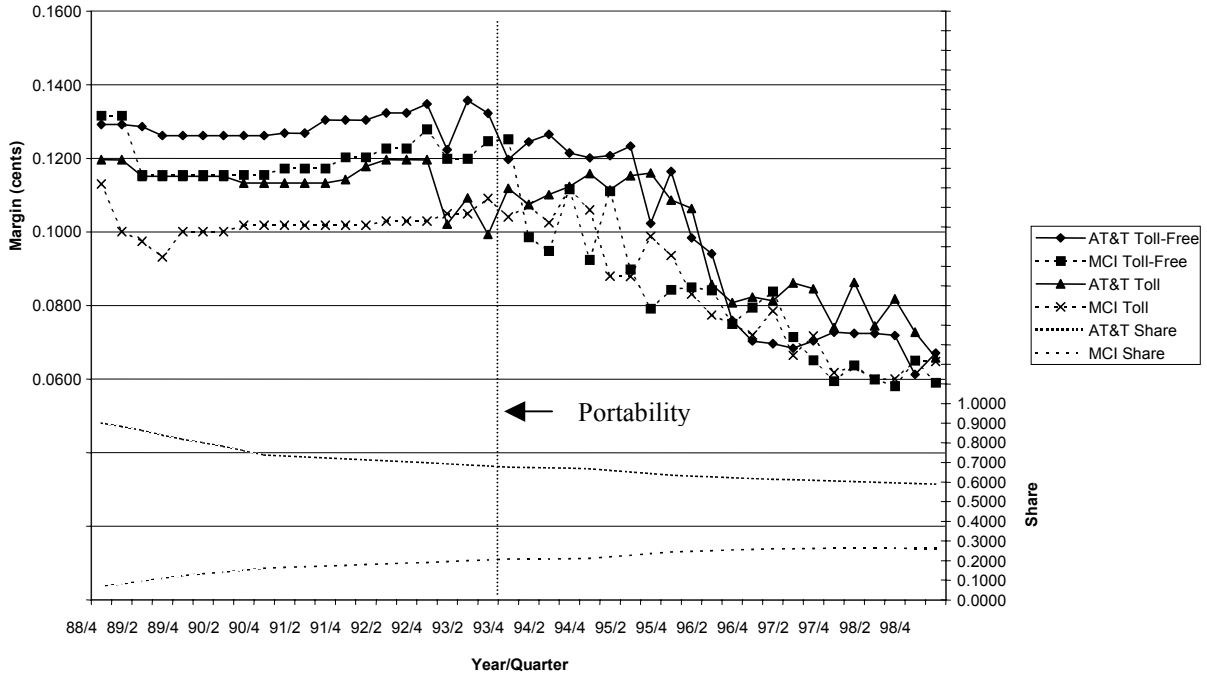
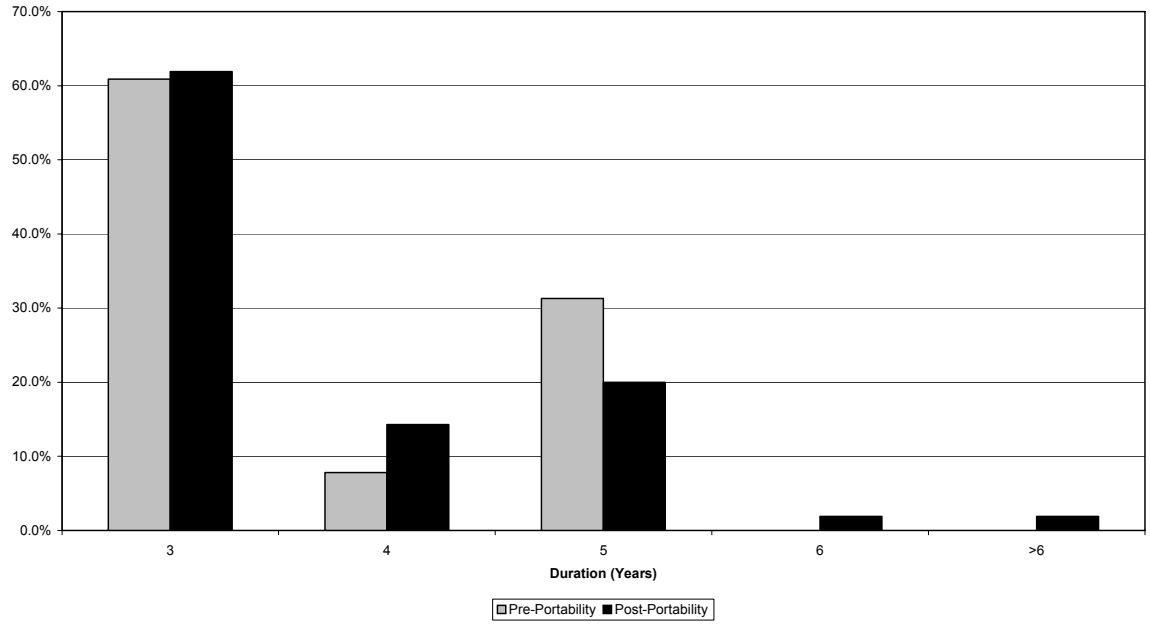


Figure 3 Distribution of Durations for Sample of AT&T VPN Contracts



Percentage of contracts in the sample of 219 AT&T VPN contracts that expire in the given number of years. The light shaded bars are for contracts issued before portability and the dark bars for contracts issued after portability.