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Wireless Carriers' Exclusive Handset Arrangements: An Empirical Look at the iPhone

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Abstract

Since the Apple iPhone's first launch in 2007 with an exclusive arrangement with AT&T, it has garnered overwhelmingly positive responses from consumers and from the media. With its success, exclusive contracts between handset makers and wireless carriers have come under increasing scrutiny by regulators and lawmakers. Such practices have been criticized by regulators, by the media, and by "locked-out" consumers, due to the fact that a consumer has to subscribe to a particular service provider if he or she strongly prefers one handset to others. In this paper, we empirically examine the impact of handset exclusivity arrangements on consumer welfare. First we study consumers' purchase decisions in mobile services that include the choice of a handset and of a service provider. We do so by combining survey data on consumers' purchase decisions with supplemented data on prices and features of common handsets. Next, assuming a Stackelberg leader-follower relationship between the handset manufacturers and the service providers, and using our demand estimates, we recover the marginal costs for the players in the market. We then simulate what would have happened in the counterfactual scenario when the iPhone is available from all carriers. Our results suggest that, if we take into account price adjustments from handset manufacturers and service providers in response to the change in market structure, consumer welfare will increase by $326 million without the exclusive arrangement. We view our analysis as a starting point to a more complete characterization of consumer behavior and the complex relationships among players in this industry.

Keywords: Exclusive Arrangement, Distribution Channels, Wireless Service
JEL codes: L13, L25, L42, L96

1. Introduction

The Apple iPhone was launched in 2007 under an exclusive distribution agreement with AT&T. Apple and AT&T activated two million units of the device in six months after its launch (Kharif and Burrows 2008). Due to the overwhelming success of the iPhone, exclusive contracts between handset makers and wireless carriers have drawn increasing scrutiny from lawmakers and regulators. For example, the Senate Commerce Committee held a hearing in 2009 on the subject of competition in the wireless industry, and urged the FCC to investigate whether such exclusive contracts are harming consumers by precluding consumers' handset access.[3] Further, the legal literature has seen a big debate on whether *Carterfone* type regulations that were enacted by the FCC in 1968 should also be brought to bear on the wireless market (see e.g. Ford et al. 2008, Hoeker 2008, Hahn and Singer 2009). These regulations forced "the separation of the sales of wireline telephone service from equipment and provided consumers the freedom to attach non-harmful third-party devices to the telephone network" (Hoeker 2008).[4]

Exclusive agreements typically allow a wireless carrier to serve as the sole distributor of a particular handset for a given period of time. Because most consumers in the U.S. purchase handsets in a bundle with a two-year service contract from a wireless carrier, the availability of handsets can significantly influence consumers' choice of wireless carriers.[5] Thus wireless carriers can use an exclusive handset as a competitive differentiator to attract more consumers (Subramanian et al. 2008). For example, in the first quarter of 2009, 23% of the new AT&T subscribers signed up for "a phone not offered by my carrier" (i.e., for the iPhone), and the company has reported that 40% of its iPhone customers switched from other services.[6]

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[3] "FCC to Review Exclusive Deals that Lock up Hot Cellphones," by Amy Schatz, *Wall Street Journal*, June 19, 2009, page B3.

[4] This regulation is viewed by many as a watershed event that eventually led to the breakup of AT&T.

[5] According to Global Wireless Matrix 2007Q4, a study conducted by Merrill Lynch, the wireless penetration rate in the U.S was 84.4%, including 16.1% prepaid customers and the rest on long term contracts. In our data 70% of consumers chose a two-year service contract.

[6] "Is Handset Exclusivity Really the Wireless Issue of the Day?" by Roger Entner, *Nielsen Wire,* August 27, 2009.

Large wireless carriers such as Verizon and AT&T, who are more likely to benefit from these exclusive deals, have opposed any efforts to stop the practice. They argue that the deals encourage innovation and competition among handset manufacturers. However, smaller carriers such as U.S. Cellular[7] and consumer groups such as Rural Cellular Association[8] have complained about such deals, arguing that an exclusive arrangement hurts competition and prevents residents of rural areas from getting access to the latest technologies.

Scholars and researchers have offered a diverse range of views on the regulation of exclusive arrangements. For instance, Baker (2007) criticized exclusive arrangements since they limit options for consumers and diminish the ability of smaller carriers to compete. Exclusive deals deprive some consumers of either their desired handsets, or their desired carriers, or both. On the other hand, Hahn and Singer (2009) suggested that the practice encourages carriers to share the risk of launching a new handset; aligns the incentives of carriers with handset makers to provide high-quality services; and drives innovations by handset makers as they are able to share the costs of innovating with the service providers. Therefore exclusive arrangements can promote consumer welfare, and should be applauded by the government.

Despite the importance of understanding the welfare consequences of such exclusive deals, empirical evidence on these types of arrangements has been lacking. Specifically, while legal scholars have weighed in on both sides of the "*Carterfone* for wireless" debate, their arguments have been based largely on either what happened as a consequence of *Carterfone* or how the characteristics of the wireless market are different from those of the wired telephone market in the 1960s. Further, some authors (see Ford et al. 2008, Hermalin and Katz 2010) have written out analytical models of the consequences of exclusive arrangements. For example, Ford et al. (2008) show that handset prices would rise and service prices would remain unchanged if *Carterfone* type regulations are instituted for the wireless market. This seems to indicate that consumers will be worse off due to regulatory intervention.

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[7] See the written statement of Mr. John E. Rooney, President and CEO, U.S. Cellular Corporation, before the U.S. Senate Committee on Commerce, Science and Transportation, June 17, 2009.
[8] See Rural Cellular Association's "Petition for Rulemaking Regarding Exclusivity Arrangements between Commercial Wireless Carriers and Handset Manufacturers" before the Federal Communications Commission.

Our objective in this paper is to empirically measure the impact of handset exclusivity arrangements on consumer welfare. Achieving this objective however, is a challenging task for a variety of reasons. In order to measure the welfare impact we need an appropriately specified consumer demand model that reflects the complexities of the cellphone handset-service marketplace. Further, we need to appropriately characterize how prices could change under the counterfactual of no-exclusivity. For this we need to specify the objectives of the various players in the market and the nature of interactions among them. Specifying the consumer demand model is complicated by the following: (a) the durable nature of the handset; (b) the large number of handset options available to subscribers; (c) the largely contractual nature of the relationship between the service provider and the customer; (d) variation across geographic markets of the service quality of various service providers. Further, in order to appropriately capture the potentially rich substitution patterns among handset and service providers, it would be preferable to have subscriber-level handset purchase and subscription data.

Turning now to the supply side of the analysis, we note that the nature of the relationships, contracts and agreements among the handset manufacturers and the service providers are largely unobserved and the nature of transfer payments to the handset providers is unknown to us. Consequently, on both demand and supply sides we will need to make several simplifying assumptions that we describe next. Thus our study needs to be construed, at best, as a first step in understanding an otherwise complex problem. At the same time, we need a first step given the paucity of empirical research in this area.

For demand estimation, we use Forrester Research's Consumer Technographics survey data from 2007 and 2008. The survey data contain consumers' demographic information, as well as their wireless service providers and their handset characteristics. Since our data include consumers who did not have wireless service in 2007 but did so in 2008, we are able to account for possible category expansion. For those who had wireless service in 2007, we model the purchase decisions of potential consumers only, i.e., those that are at the end of their contract period and are therefore "in the market" for wireless services in 2008. We construct consumers' choice sets by collecting the prices and features of the common handsets from Consumer Reports. Further, we collect data on the service quality of the different service providers in the different geographic markets.

Together, these aspects of our data deal with the ability to identify substitution patterns, variations in service availability across markets and accounting for the contractual nature of the customer – service provider relationship.

A challenge associated with our empirical task is how to handle the large number of choice alternatives. Because we define each choice alternative as a bundle of a handset and a service contract from a wireless carrier, the number of possible alternatives is even larger. To make the choice set manageable, we collect information on the common handset models from Consumer Reports, and aggregate over all other models. Note that if two handset models share very similar attributes, we treat them as the same alternative. In the end consumers' choice sets are constructed to include 88 different alternatives.

Using the above panel dataset assembled for the purpose, we first estimate a random coefficient logit model of consumer demand for wireless services that accounts for consumers' choices of both carriers and handsets. This demand function ignores the various dynamic aspects associated with the durable nature of the handset and service provision, i.e., we do not account for consumers' forward-looking expectations regarding, e.g., the availability and prices of handsets from providers, service quality (via the installation of more cellphone towers), etc. Our justification for this simplification is that consumers treat the plan-handset decision as a "repeat" purchase made every 2 years. In 2009, 150 million handsets were sold to 270 million subscribers – an approximately 1:2 ratio. While there could be several reasons for this (e.g., a subset of customers own multiple handsets), it is also consistent with the 2-year purchase cycle. Clearly, this does not preclude consumers' forward-looking expectations regarding aspects of the plan-handset bundle, but it does make this category appear different from standard durable goods products such as automobiles and could potentially make it amenable to be approximated by myopic behavior.[9] We learn about the demand function for wireless services from the observed sales and price information for different handsets and service providers. We are particularly interested in consumers' intrinsic preferences for different handsets and service providers. Given the demand function, we can infer the substitution patterns between handsets and across service providers.

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[9] Even in those markets, researchers have often assumed myopic consumers (e.g., Berry, Levinsohn and Pakes 1995, Petrin 2002, Sudhir 2001, etc.).

Next, we model the handset pricing decisions of handset makers and wireless carriers as a Stackelberg leader-follower game, in which the handset manufacturers set wholesale prices first and the service providers then set prices for the handsets to the subscribers. A handset maker can charge different wholesale prices for the same handset model to different service providers. We then calculate the margins for handset manufacturers and for the wireless carriers on each handset. Here again, we ignore possible dynamic considerations on the supply side, the presence of long-term contracts between handset manufacturers and service providers, etc.

Based on estimates for consumers' demand and firms' margins, we conduct counterfactual experiments to examine the welfare consequences of the exclusive contract between Apple and AT&T vis-à-vis the iPhone. In particular we simulate what would have happened if the exclusive arrangement did not exist and hence the iPhone was available from all carriers. As a baseline for comparison, we first assume no competitive responses from other service providers and cell phone makers. Holding all prices constant, we find an annual welfare gain of $210 million in the U.S. market. Next, since we would expect firms to set different wholesale and retail prices for handsets in the counterfactual market environment, we need to take into account the competitive responses in the market. After incorporating possible price adjustments according to our supply-side model, the annual welfare gain becomes $326 million in the U.S. market.

An important question regarding our analysis is: how sensitive are our results to the assumptions we make on the demand and supply sides in terms of the dynamics and the nature of interactions between the various firms in the market. To accurately assess this we will need to, of course, explicitly relax these assumptions.[10] An alternative would be to examine the degree to which key quantities of interest are likely to be incorrectly estimated by e.g., ignoring demand-side dynamics. For example, key factors that drive our counterfactual analysis are the estimates of preferences and price elasticities. We find that our price elasticity estimates for the iPhone are comparable to the estimates obtained by other economists who have detailed information on iPhone's profit margins. This gives us some assurance as to the validity of our estimates.

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[10] We are in the process of trying to relax some of the assumptions vis-à-vis the demand model. As noted previously, this is a challenging task for several reasons.

The remainder of this paper is organized as follows. In Section 2 we discuss the role of exclusive arrangement in the U.S. wireless market. Literature and data are described in section 3 and 4 respectively. We specify the demand model in Section 5. After a discussion of the estimation results in Section 6, we present the counterfactual analysis and the welfare consequences of the exclusive arrangement on iPhone in Section 7. We conclude in Section 8.

2. The U.S. Wireless Market

Revenues in the U.S. wireless industry reached $145 billion in 2008 after annual increases of over 10 percent since 2003. The number of users was estimated to have exceeded 270 million cellular phone subscribers in the U.S. by the beginning of 2009[11] and was the fastest growing sector among telecommunication services. The strong growth was attributed to improvements in the quality of wireless service and increases in the range of available features such as video content, e-mail and text messaging capabilities, and wireless Internet. Players in the wireless industry include device manufacturers (e.g. Nokia, Blackberry, Apple), wireless carriers (e.g. AT&T, Verizon), broadband infrastructure companies (e.g. ClearWire, Qualcomm, Siemens, Ericsson), and application developers.

Wireless Service Providers

The wireless service market in the U.S. appears to be highly concentrated. In 2008, the four leading wireless service providers – AT&T, Verizon Wireless, Sprint Nextel and T-Mobile USA (owned by German-based Deutsche Telekom) – accounted for approximately 80 percent of the U.S. market (with the concentration ratio steadily increasing from 61% in 2003). Other wireless service providers include Alltel (now part of Verizon), U.S. Cellular and several more rural players. Notwithstanding these numbers, Merrill Lynch reports that in 2009, the concentration in the U.S. was the second lowest among the 26 countries under examination (Global Wireless Matrix 2Q09). And according to the 13th Commercial Mobile Radio Services Competition Report (FCC 2009), over 95% of the U.S. population lives in census blocks where there are 3 or more

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[11] "Wireless, Cellular & RFID Industry Trends" by Plunkett Research, LTD.

wireless service providers. Given this scenario, service providers compete on several dimensions – coverage (including factors such as dropped calls), plan attributes (price, rollover minutes, free calling to other subscribers of the same provider), customer service quality, and quality of handsets. Service providers are aggressively working to attract new customers and to maintain current ones by improving coverage and service quality, fine tuning plan attributes to provide innovative services, and offering the latest handsets to their customers.

Wireless Phones

Demand for wireless phones in the U.S. increased 12 percent annually during 2003-2008 and reached 150 million units in 2008. It benefited from an increasing number of wireless service subscribers and decreasing wireless phone prices. In addition, continuous introductions of wireless phones with better design and more features had a strong influence on demand (FCC 2009).

Wireless phones were initially limited to one primary function – voice communication. Over time, manufacturers have added more and more features such as cameras, MP3 players and GPS systems. The introduction of "smartphones" was a major innovation in the wireless industry (Ford et al. 2008, Hahn and Singer 2009). Smartphones are cell phones that have many features of a desktop computer and are connected to the Internet. In addition to allowing people to make and receive calls and to check e-mails, smartphones run complete operating system software thereby providing a platform for application developers to write software for these platforms.

Although smartphones have been around for more than a decade[12], substantial growth only started in recent years. While early entrants included Nokia, Palm, BlackBerry, etc., that were popular with corporate customers, the launch of the iPhone was the most notable event in the consumer segment. Introduced in 2007, the iPhone accounted for a 10.8% share of the worldwide smartphone market by Q1 2009 with a total of 21 million units sold till January of that year. Because AT&T was the sole distributor of iPhone under an exclusive deal, such exclusivity agreements have become a contentious issue (IDG news, 2009).

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[12] An early example of a smartphone was the IBM Simon introduced in 1993. It was hailed as "the first time a company had placed a computer in a cellular phone" (*Mobile Phone News*, November 8, 1993).

Handset Exclusivity

The four principal wireless carriers have been, over the years, able to tie up the most advanced, attractive handsets through exclusive arrangements. The negotiated handset exclusivity period is often several years or for the entire lifetime of the device. Handset technologies and features advance rapidly. According to Rooney (2009), the average lifecycle of handsets is twelve months after initial launch. As a result, even an exclusive period of six months can impact the sales of that handset through other carriers greatly. While exclusivity was not always the norm, many of the recent iconic handsets were introduced under exclusive contracts. For example, The Sidekick was a T-Mobile exclusive in 2002; Motorola's Razr V3 was exclusively offered by AT&T in 2004; the Blackberry Pearl was introduced in 2006 through T-Mobile only; Verizon was the exclusive distributor of the BlackBerry Storm; AT&T was the exclusive distributor for the Blackberry Curve; and Sprint was the exclusive distributor of the Palm Pre. What is notable in this list is that the same handset provider (e.g. Blackberry) offers exclusive handsets to different service providers.

Although exclusive deals have been criticized by smaller rivals and consumer groups, the major carriers claim that such exclusive deals enable them to take risks on expensive new smartphones and bring them to market at discounted prices, hence leading to more choices and lower prices for consumers.[13] So AT&T paid Apple $300 per 8GB iPhone 3G; Verizon paid Blackberry about $200 per Storm; and Sprint paid Palm approximately $340 per unit of the Palm Pre. Exclusive deals restrict handset manufacturers such as Palm, RIM and Apple from distributing their devices widely (i.e., by being exclusive to AT&T, Apple only has access to about 30% of the U.S. market), but analysts point out that those companies benefit by getting a significant share of carriers' marketing and sales resources.[14] For example, AT&T's annual reports state that for the fiscal year 2007, increased sales and marketing costs of $572 million, were attributable to the iPhone.

3. Literature

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[13] "Cellphone Politics," *Wall Street Journal*, July 7, 2009, page A14.
[14] "Telecoms Face Antitrust Threat," by Amol Sharma, *Wall Street Journal*, July 7, 2009, page A1.

The Wireless Industry

Despite the wireless industry having changed dramatically since the 1990s, the nature of the cellular phone market has not yet been explored in much detail. One research stream examines the penetration of mobile services (e.g. Hausman 1999). Some other studies analyze the market structure and competition between wireless service providers. For example, Iimi (2005) analyzes the demand for wireless services using data on the Japanese market in late 1990s, and finds that the service providers are highly differentiated. Bajari et al. (2008) studies the importance of national coverage to consumers' choices of service providers. Another stream of research investigates how users choose service plans under different pricing regimes (Lambrecht et al. 2007).

Past studies have focused on consumers' choice of service providers, without taking into account their handset choices. To our knowledge, there are two exceptions. Jain et al. (1999) develops an analytical model to examine consumer subscription decisions based on prices of both cellular phones and service plans. In their framework the handset is assumed to be a homogenous product across service providers. By contrast we model consumers' purchase decisions in combinations of differentiated handsets and service providers. The second exception is the study by Aribarg and Foutz (2009). They use a conjoint choice experiment to investigate consumers' decision process when they purchase a product bundle of a handset and a service plan. In our paper, we use real purchase data to identify consumers' preferences for handsets and carriers without imposing any structure on their decision processes.

Vertical Restraints

An exclusive contract requires a handset model to be sold by certain service providers. Such restrictions are referred to as vertical constraints by industrial organization economists. There is a large literature on the economic impact of such constraints (see e.g. Lafontaine and Slade 2005). Theoretical work has investigated the justification for and the consequences of exclusive contracts. In some cases such constraints can reduce economic welfare, whereas in other cases they may increase economic welfare. In particular, Subramanian et al. (2008) examines when and why a cellular service provider and a handset manufacturer may decide to enter an exclusive

contract. Their model suggests that the exclusive contract raises the rival service provider's handset costs by reducing the competition faced by a rival handset manufacturer. A service provider's benefit from an exclusive contract increases with the degree of service differentiation.

A number of empirical papers on channel structure also relate to this study (e.g. Besanko et al. 2003, Chen et al. 2007, Chu et al. 2007, Villas-Boas 2007). In particular Asker (2005) evaluates the effect of exclusive arrangement on competition in the Chicago beer market. Brenkers and Verboven (2006) study the competitive effects of liberalizing the selective and exclusive distribution system in the European automobile market. For our counterfactual analysis, our pricing model follows this stream of research and especially Asker (2005), Chen et al. (2007) and Villas-Boas (2007).

4. Data Description

In this paper we study consumers' purchase decisions in mobile handsets and service providers. We use Forrester Research's Consumer Technographics survey data collected in early 2008 and 2009. The data reflect purchase information in 2007 and 2008 respectively. The survey goes out to about 60,000 consumers in the U.S. and Canada each year with some overlap in respondents across years. There are 10,546 consumers in the U.S. who participated in both 2008 and 2009. Among them we identify 7526 consumers who made a purchase decision in 2008, while others continued with the second year of their two-year contract. We have detailed information on household demographics, their attitudes towards technology, their mobile service providers, and characteristics of their handsets.[15]

Tables 1 and 2 summarize consumers' subscription decisions in 2007 and 2008. In Table 1, we compare the market share of leading handset manufacturers. It shows that the market share for smartphone brands such as Apple and BlackBerry increased in 2008. However, regular wireless phones still dominated the market. Table 2 describes consumers' switching patterns across service providers. The two leading carriers, AT&T

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[15] Other studies have looked at the representativeness of such a panel derived from repeated cross-sections of overlapping data (e.g., Liu et al. 2010).

and Verizon, accounted for almost 50% of the market in 2008. The table also shows s strong state dependence in choice of service providers. For example, 1378 out of 1669 AT&T users in 2007 chose to stay with AT&T in 2008. Note that these customers were at the end of their two-year contracts and could, in principle, have switched providers. Similar patterns can also be found for other service providers. Verizon has the lowest churn rate (15%), and is followed by AT&T at 17%. Both Sprint and T-Mobile have higher churn rate at about 30%. The data are consistent with the monthly churn rates reported by Merrill Lynch – 1.3%, 1.6%, 2.3% and 2.7% for Verizon, AT&T, Sprint and T-Mobile respectively (Global Wireless Matrix 2Q09).

Given consumers' brand switching behavior; we look for indications of any "iPhone effect" on consumer purchasing decisions including the choices of handsets and carriers. In Table 2, we observe that both AT&T and Verizon had more service subscribers in 2008 than in 2007, whereas AT&T attracted more new subscribers than Verizon. We further look into the handset choices by AT&T subscribers. Table 3 indicates that compared to existing AT&T subscribers, those who switched from Verizon were more likely to purchase the iPhone. This seems to suggest that some Verizon customers switched to AT&T for the iPhone. If a consumer preferred Verizon but had to switch because iPhone was only available through AT&T, this would constitute a welfare loss caused by the exclusivity arrangements on iPhone. This observation also motivates the need to allow for heterogeneity in handset preferences for any service provider as well as heterogeneity in provider preferences for any given handset – a feature that we incorporate into our model.

To supplement our data, we obtain prices and features of the common handsets from Consumer Reports and CNET.com. The carriers subsidized the handsets if they were purchased with a two-year contract. For example, AT&T paid Apple $300 for an iPhone 3G (with 8GB storage), leaving AT&T customers the balance of $199. Verizon paid RIM roughly $200 toward the $399 total price of the BlackBerry Storm, leaving its customers the balance of $199. Even lower-end phones can draw substantial subsidies from carriers. On the other hand, not everyone needs the sophisticated capabilities offered by a smartphone. The market is still dominated by regular cell phones. A regular cell phone is

usually priced less than $50 and often free with a two-year contract. Figure 1 describes the distribution of handset prices to the end consumers.

The prices for carriers' service plans are collected from carriers' websites. For the same carrier, the service plans are essentially the same throughout the country. Therefore we assume that consumers in the U.S. face the same set of prices for wireless services, although the service quality varies across different areas for different service providers. To control for the effects of carriers' signal quality on consumers' choices, we collect data from an online website, www.signalmap.com, which records the signal strength for major wireless carriers reported by consumers throughout the country. The signal strength is reported in a scale from 1 to 5. We calculate the average signal strength for each carrier in different designated market areas (DMAs), and then match the DMA information with the Forrester survey data on where respondents live. Table 4 shows the average signal strength for the four major carriers across markets. AT&T and Verizon appear to provide stronger signals at lower variation across markets than Sprint and T-Mobile.

To illustrate the effect of signal quality on consumer choices, we compare consumers' subscription decisions across DMAs. In Table 5-1, we summarize consumers' carrier choice in markets where AT&T offers superior signals, i.e., AT&T's average signal strength ≥ 3, whereas Verizon's average signal strength ≤ 2. We find that AT&T had a higher market share in these markets, and attracted more customers in 2008. On the other hand, in Table 5-2 we summarize consumers' carrier choices in markets where AT&T offers inferior signals, i.e., AT&T's average signal strength ≤ 2, whereas Verizon's average signal strength ≥ 3. We observe a higher market share and more recruits for Verizon in these markets.

5. The Model

We consider a market with competing service providers and their compatible handsets. We assume that consumers choose service providers and handsets simultaneously, and thus each choice alternative is a bundle of a handset and a two-year contract with a service provider. We assume that a smartphone purchase is always

coupled with a corresponding data plan. The outside option consists of no purchase as well as the wireless service plans without a long term contract such as the prepaid plans.[16]

Consumer Utility Specification

The indirect utility function is defined over a handset and service plan bundle. If choosing handset j and service provider k at time t, a consumer i obtains a utility of

$$U_{ijkt} = V_{ijkt} + \varepsilon_{ijkt},$$

Where the deterministic component of utility is given by;

$$V_{ijkt} = x_{jkt}'\lambda_i + \alpha_{ik} - \beta_i^H p_{jkt}^H - \beta_i^S p_{jkt}^S + \gamma_H I\left\{b_{i,t-1} = b_j\right\} + \gamma_S I\left\{s_{i,t-1} = k\right\} + \xi_{jkt}; \quad (1)$$

$$j = 1,2,...,J;$$
$$k = 1,2,...,K_j.$$

J is the total number of handsets, including both smartphones and regular phones; and K_j is the number of service providers that carry handset j. x_{jkt} is a vector of handset characteristics, including the handset brand and indicator variables for regular phone, smartphone, touch screen, GPS, etc. The intrinsic preference for service provider k is represented by α_{ik}, which is assumed to vary across consumers. p_{jkt}^H is the handset price and p_{jkt}^S is the monthly service fee. We allow the price coefficient to be different across the two prices, because consumers are likely to treat the one-shot handset price and the monthly service price differently.[17] Note that if handset j is a smartphone, then p_{jkt}^S includes the monthly fee for the basic service as well as that for the data plan.

We use two indicator functions to control for potential state dependence in consumer choices of both handsets and service providers. $I\{b_{i,t-1}=b_j\}$ is an indicator function that equals to one if handset j has the same brand as consumer i's previous handset and zero otherwise. Similarly $I\{s_{i,t-1}=k\}$ equals one if consumer i chose k as the service provider in

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[16] Potentially we are able to estimate a model with two separate outside goods – a prepaid plan and no wireless service. Given the limited information about the prepaid plans in the data, we choose to combine these two options as one alternative in the choice set.

[17] Alternatively we can estimate a single price coefficient, but add up the handset price and the discounted flow of monthly service fees, with the discount factor to be estimated as well. In other words,

$$\beta_i^H p_{jkt}^H + \beta_i^S p_{jkt}^S = \beta_i \left(p_{jkt}^H + \sum_{\tau=t}^{t+24} \rho_i^{\tau-t} p_{jk\tau}^S \right).$$ These two alternative treatments are equivalent up to a scaling factor and so none of the other parameter estimates will change.

the last period. ξ_{jkt} represents other characteristics that are unobservable to the researcher but observed by consumers. Finally ε_{ijkt} is a random error that follows a type 1 extreme value distribution.

We use a random coefficients logit model to allow for more flexible substitution patterns across choice alternatives. In particular, we allow certain parameters to vary across consumers according to

$$[\gamma_i^{smart}, \alpha_{i1}, \alpha_{i2}, \alpha_{i3}, \alpha_{i4}]' = \left[\gamma^{smart} + \tau Tech_i, \alpha_1, \alpha_2, \alpha_3, \alpha_4\right] + v_i.$$

γ^{smart} represents a consumer's preference toward smartphones, and α represents her preference toward wireless service providers with subscripts 1-4 indicating AT&T, Sprint, T-Mobile and Verizon respectively. The variable $Tech_i$ represents whether consumer i likes technology or not, as indicated in her responses to the Forrester survey. To allow for correlations between consumer preferences for smartphones and for service providers, we assume that v_i follows a multivariate normal distribution with mean zero and with the following covariance matrix:

$$\begin{bmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} & \sigma_{14} & \sigma_{15} \\ \sigma_{12} & \sigma_{22} & 0 & 0 & 0 \\ \sigma_{13} & 0 & \sigma_{33} & 0 & 0 \\ \sigma_{14} & 0 & 0 & \sigma_{44} & 0 \\ \sigma_{15} & 0 & 0 & 0 & \sigma_{55} \end{bmatrix}.$$

To reduce the number of parameters to be estimated we assume zero correlations between the preferences for different service providers.

The model identification heavily relies on the variation in prices and other characteristics of handsets. The brand preferences for different service providers are identified by the relative market share of the same handset across carriers. Similarly, the brand preferences for handsets are identified by the relative share of the different brands within a carrier after controlling for prices and product characteristics. State dependence can be identified from the extent of switching in the data; and the effects of signal quality off of variation across geographic markets.

Estimation Issues

In the utility specification for a handset and service plan bundle in Equation (1), the handset prices can be correlated with the unobserved product characteristics, such as

stylishness of design. If the resulting endogeneity is not controlled for our parameter estimates will be biased. Therefore we use the control function approach proposed by Petrin and Train (2009) to address this issue. In the first stage we recover the unobserved attributes as a control factor by regressing handset prices on a set of observed exogenous variables and instrumental variables. Then in the second stage we estimate the demand parameters while using the recovered control factor as an extra variable.

Specifically in the first stage we recover $\xi_{jkt}*$, a one-to-one mapping of ξ_{jkt}, through the following regression:

$$p_{jkt}^{H} = \omega z_{jkt} + \xi_{jkt}^{*}.$$

z_{jkt} includes dummy variables for service providers and handset brands, exogenous handset characteristics, and a set of instrumental variables. Similar to Albuquerque and Bronnenberg (2010), Petrin and Train (2009) and Iimi (2005), we use the following instruments: (1) the mean value of each exogenous characteristics across all other handsets of the same brand sold by the same service provider; (2) the mean value of each exogenous characteristics across all handsets of the same brand sold by other service providers; and (3) the mean value of each exogenous characteristics across all handsets of other brands sold by the same service provider.

The mean value of an observed attribute from rival products is used as an instrument since it can be interpreted as the average attractiveness of rival products, which has an impact on the pricing of the focal product. On the other hand such mean value of one attribute is unlikely to be correlated with a firm' decisions on whether to include a different product attribute. Thus we believe these instruments are correlated with handset prices but not with the unobserved attributes.

Likelihood Function

Using the obtained $\xi_{jkt}*$ as a covariate in place of ξ_{jkt} in equation (1), the estimation of demand parameters can proceed via maximizing the following likelihood function:

$$L = \prod_{i} \int \prod_{k} \prod_{j} P_{ijkt}(x, p, \xi, v_i)^{y_{ijkt}} f(v_i) dv_i.$$

P_{ijkt} represents the probability that consumer i chooses handset j from carrier k at time t, and y_{ijkt} is an indicator variable that takes value 1 if that happens..

Because the second stage maximum likelihood estimation uses an estimated ξ_{jkt}^* from the first stage, the standard error of the second stage estimator has to be adjusted accordingly following Petrin and Train (2009).

Pricing Model

In order to conduct counterfactual experiments to examine the welfare consequences of the exclusive contract between Apple and AT&T vis-à-vis the iPhone, we need to simulate what would have happened if the exclusive arrangement did not exist and hence the iPhone was available from all carriers. We first model the handset pricing decisions of handset makers and wireless carriers as a Stackelberg leader-follower game, in which the handset manufacturers set wholesale prices first and the service providers then set retail prices for the handsets to the subscribers. We then recover the margins for handset manufacturers and service providers, which will be used for our counterfactual analysis.

We start from a scenario in which only handset (retail and wholesale) prices are decision variables given service prices. The carrier maximizes its total profits by choosing the optimal retail prices for handsets given monthly service fees.

$$\max_{(p_{jk}^H)} \pi_k = \sum_{j \in J_k} \left[\left(p_{jk}^H - w_{jk} + r_{jk}^S \right) s_{jk} \left(p^H \right) \right],$$

where J_k is the set of product sold by service provider k, w_{jk} is the wholesale price for product j, r_{jk}^S is the margin that the carrier receives on monthly service fees, and $s_{jk}(p)$ is the share of product-service bundle jk. The first order conditions with respect to the handset prices, assuming a pure strategy Nash-equilibrium in prices, are

$$s_{jk} + \sum_{m \in J_k} \left[\left(p_{mk}^H - w_{mk} + r_{mk}^S \right) \frac{\partial s_{mk}}{\partial p_{jk}^H} \right] = 0 . \tag{2}$$

Each handset manufacturer maximizes its profit by choosing the wholesale prices for its handsets, knowing how service providers set retail prices according to Equation (2). The manufacturer's profit function is

$$\pi_w = \sum_{j \in M_w} \sum_k \left(w_{jk} - c_{jk} \right) s_{jk} ,$$

where M_w is the set of handsets produced by manufacturer w. The first order conditions can be written as

$$s_{jk} + \sum_{j \in M_w} \sum_k \left(w_{jk} - c_{jk} \right) \frac{\partial s_{jk}}{\partial w_{jk}} = 0 . \tag{3}$$

As in Villas-Boas (2007), we obtain the following vector expression for service providers' implied price-cost margins and manufacturers' wholesale price-cost margins respectively:

$$p^H - w + r^S = -\left(T_r * \Delta_r \right)^{-1} s\left(p^H \right),$$

$$w - c = -\left(T_w * \Delta_w \right)^{-1} s\left(p^H \right).$$

T_w is a ownership matrix for manufacturers, and T_r is a ownership matrix for service providers. In particular, element (i, j) in T_w equals to one if a manufacturer sells both products i and j, and zero otherwise. Similarly, element (i, j) in T_r equals to one if the service provider sells both products i and j, and zero otherwise. Δ_r represents how demand responds to changes in retail prices of handsets, with element (i, j) defined as $\frac{\partial s_i}{\partial p_j^H}$. Δ_w describes how demand responds to changes in wholesale prices of handsets, with element (i, j) defined as $\frac{\partial s_i}{\partial w_j}$.[18]

Note that the above two equations allow us to calculate the wholesale margins and retail margins. Because we do not have direct observations on any of c, w or r^S, we are not able to identify them separately. However, such separation is not critical for the purpose of predicting retail prices – shifting c, w and r^S by a constant while preserving the margins will lead to the same retail prices. Therefore it is sufficient to recover the wholesale and retail margins in order to perform our counterfactual analysis.

6. Results

We report the estimation results from three alternative models: (1) a logit model with no control for price endogeneity; (2) a logit model with control for price endogeneity; and (3) the proposed random coefficients logit model.

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[18] The details on the calculation of these matrices are provided by Villas-Boas (2007).

For comparison, results for models (1) and (2) are both reported in Table 6. We can see that after controlling for price endogeneity, consumers appear to be more sensitive to handset prices. Estimation results for model (3) are provided in Table 7. First, brand intercepts for top handset brands and for major service providers are reported. The values of these intercepts reflect the relative attractiveness of different brands, after accounting for other effects in the model. We find that Apple and BlackBerry enjoyed the highest preferences among all handset makers, which is consistent with the popularity of the iPhone and BlackBerry handsets. Among the major wireless carriers, Verizon and AT&T appear to be more attractive than Sprint and T-Mobile on average.

Table 7 also shows that the parameters of most product features are of the expected sign and significant. Having features such as touch screen and GPS positively affect the consumers' mean utility for a handset. *Smartphone* and *Contract* are defined as dummy variables indicating a smartphone and a two-year contract respectively. It is interesting to observe that the parameter estimate for the contract subscriptions is negative. Intuitively, a consumer does not prefer to be locked in a two year contract, hence a service provider generally provides price discount for handset to attract potential service subscribers. Smartphone is more attractive than regular phone after controlling for prices and product characteristics. From the interaction effect of technology attitude and smartphone, we find that consumers who are more technology proficient are more likely to subscribe to a smartphone service. Naturally, a stronger signal increases the utility of wireless service.

Next, we turn to the effects of prices on consumers' purchase decisions. In equation (1), we allow the price effects to be individual specific. During empirical estimation, we make these price effects specific to different income levels. The results suggest that lower-income individuals are more price sensitive than higher-income ones. According to the price coefficients, consumers are more sensitive to the monthly service price than the handset price, which is not surprising given that consumers have to sign a two-year contract and pay the monthly service fee for 24 months.

Now we calculate the average price elasticity of demand for handsets. For each household, we calculate price elasticity as the expected percentage change in the purchase probability of a handset relative to one percentage change in the handset price. We find that the average price elasticity for handset is -1.77 across all smartphones. The

price elasticity of iPhone is relatively high with the magnitude of -3.46.[19] For the handset with price equals to zero, we calculate the semi price elasticity. For example, if price of the free handset increase to 10 dollars, then the market share will decrease 15.6% on average.

We find strong state dependence in consumers' choices of handset brands and service providers, which suggests a strong tendency for consumers to stay with their current handset brands and with their current service providers. In terms of the magnitude, the state dependence effect in service provider is much larger than that in handset brand, possibly due to more competition in the handset market.

From the estimates for the covariance matrix for v_i, we observe that there is less heterogeneity in consumer preferences for service providers than for smartphones. In addition, we find significant positive preference correlation between smartphones and Verizon.

From the supply side model, we can solve for the retail margins for service providers and the wholesale margins for handset manufacturers. We then calculate the average margins across all handset-carrier combinations. On average, a carrier's margin is 9.3% and a handset manufacturer's margin is 5.8% of the total revenue including monthly service fees from a two-year contract and handset retail prices.

7. Counterfactual Analysis

Our research objective is to measure the impact of iPhone's exclusive arrangement on consumer welfare. This objective requires us to conduct a counterfactual analysis to find out what would have happened if iPhone were not under the exclusive arrangement and hence available to other wireless carriers as well. We examine two scenarios: (1) iPhone were available to Verizon in addition to AT&T; and (2) iPhone were available to all wireless carriers.

First we assume away any competitive responses and hold all retail prices constant in the market. For other carriers who could also offer iPhone in a counterfactual scenario,

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[19] Scott Cunningham from CoreEconomics used a different approach to calculate elasticity of demand for the iPhone, and found an elasticity of -3.37 for the iPhone.

we assume the same retail price of $199 on the iPhone. The predicted market shares are reported in Table 8. If both AT&T and Verizon carried iPhone, Apple's market share would have been 2.25%, 0.9% higher than the observed 1.35% under the exclusive arrangement. If all carriers could offer iPhone, Apple's market share would have further increased to 3.48%.

To evaluate the welfare loss resulted from the exclusive arrangement between Apple and AT&T, we calculate the compensating variation as a measure of welfare change following Small and Rosen (1981). Based on the estimates of our demand model, the average welfare loss from one consumer due to the exclusive contract is $1.08 for each purchase occasion. Given there were 300 million potential wireless subscribers and 70% subscribed for a two-year contract in the U.S. by the beginning of 2009, the aggregate welfare loss is estimated to be $210 million per year, which accounts for 0.14% of the $145 billion revenues in the U.S. wireless industry in 2008.

In the analysis above, we hold all retail prices constant and focus on the welfare loss due to the absence of valuable choice alternatives. However, in a counterfactual market environment we would expect firms to adjust their prices in response to the different channel structure. Therefore it is important to model the strategic interactions between firms and to account for competitive responses. We assume that handset makers and wireless carriers follow a Stackelberg leader-follower pricing game, in which handset makers set wholesale prices first, whereas wireless carriers set retail prices accordingly.

To make the model tractable we assume that wireless carriers would have kept the current monthly service fees while adjusting handset prices in these counterfactual situations. The proposed model follows Villas-Boas (2007), Chen et al. (2007), Chu et al. (2007) and Asker (2005). By assuming a Stackelberg leader-follower game between handset manufacturers and wireless carriers, we are able to back out the marginal costs for various handsets and then use these cost numbers to predict the retail prices in counterfactual market environments.

We first predict the retail prices of the iPhone from different carriers if it became available from both AT&T and Verizon.[20] The predicted prices and market share are

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[20] Since we do not have the marginal costs of iPhone from other carriers, we assume that their marginal costs are the same as AT&T's, which has been recovered from the supply side model.

reported in the second and third column of Table 9. In the fourth column, we report the predicted prices of iPhone if it became available from all carriers. We find a small change in AT&T's subsidized price of iPhone. The price from Verizon would have been slightly higher, but the smaller carriers would have offered much lower prices. We also find that under the new channel structure, AT&T would have lowered its prices slightly for other handsets[21] while its competitors would have increased prices for other handsets. The intuition is that AT&T would have lost its relative advantage on product selection if iPhone were available from other carriers, and thus might have cut prices on other handsets to stay competitive. By contrast, with the iPhone other carriers might have been less aggressive in their pricing of other handsets. Based on the predicted prices, we calculate market shares and welfare consequences. The market share for the iPhone would have been 4.59%, higher than the 3.48% without accounting for price adjustments. The annual welfare loss is estimated to be $326 million, again higher than the previous estimate primarily due to lower prices from smaller carriers.

8. Conclusions

In this paper we study the welfare consequences of the exclusive arrangement between Apple and AT&T on iPhone. First we estimate consumer demand for wireless services including their choices in both handsets and wireless service providers. Our approach provides a framework to investigate the complex problem of understanding consumers' joint purchases in these closely related product categories. We then model the pricing decisions of handset makers and wireless carriers, in order to predict how they would have adjusted their prices in the counterfactual scenario that iPhone were not subject to an exclusive contract and thus available to all wireless carriers. Our results suggest that the annual welfare loss resulted from the exclusivity agreement observed on iPhone is about $326 million, from which $210 million resulted from restricting consumers' choice set, and the rest due to firms' price adjustments.

Several limitations of our study leave opportunity for future research. First, when iPhone was first launched some consumers might decide to postpone their purchases in

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[21] The price drops $0.41 on average.

expectation of a lower price or more apps for iPhone in the future. In this study, we do not incorporate consumers' forward-looking behavior.

Second, we examine the welfare loss to consumers due to the fact that exclusive arrangements restrict consumer choices. However, major wireless carriers argue that exclusive arrangements allow risk sharing between handset makers and wireless carriers, and hence encourage innovations. This could induce long-term welfare gains to consumers. In this study we abstract away from this aspect of the welfare consequences, and focus on the direct welfare loss due to exclusivity. It may be fruitful for future studies to take a more complete view and examine the long-term effect by taking into account innovations.

Finally, our counterfactual analysis is dependent on several assumptions on the supply-side model. Because we do not have detailed information on production costs of handsets and service costs incurred by service providers, we have to make assumptions on the pricing game played between firms, and rely on the structure of our supply-side model to identify the marginal profits for each player in the game. Again we ignore possible dynamic considerations on the supply side. Given better information on firms' cost structure, we could relax some of the relatively strong assumptions we have to rely on.

In summary, our study is the first step to empirically analyze the issue of exclusive arrangements. We estimate the direct welfare loss resulted from the exclusivity agreement between Apple and AT&T on iPhone, and seek to provide empirical evidence for policy makers. There are several limitations in our study, which we believe to be important and worthwhile for future research to investigate.

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Table 1: Summary of Consumer Handset Purchase Decisions

Brand	2007 (%)	2008 (%)
Carrier's brand	8.57	7.63
Apple	0.35	1.33
BlackBerry	1.69	3.89
HTC	0	0.34
Kyocera	2.34	1.96
LG	14.17	18.66
Motorola	26.13	23.51
Nokia	14.35	11.86
Palm	0.93	0.90
Samsung	12.03	13.43
Sanyo	2.57	1.81
Sony Ericsson	1.87	1.86
Others	2.35	2.26
No Phone	12.68	10.56

Note: Based on the survey responses from 10546 consumers.

Table 2: Summary of Consumer Service Subscription Decisions

	None	AT&T	Sprint	T-Mobile	Verizon	Others	Total (2007)
None	901	103	18	39	72	204	1337
AT&T	54	1378	25	27	84	101	1669
Sprint	14	46	362	16	57	43	538
T-Mobile	15	38	11	363	49	33	509
Verizon	29	90	32	32	1425	67	1675
Others	101	227	72	50	143	1205	1789
Total (2008)	1114	1882	520	527	1830	1653	7526

Note: The numbers in each row represent the number of subscribers in 2007. The numbers in each column represent the number of subscribers in 2008.

Table 3: Handset Choices by AT&T Service Subscribers in 2008

Brand	All Subscribers	Subscribers from Verizon
Apple	5.7%	12.2%
BlackBerry	6.2	10.0
HTC	0.4	3.3
LG	12.2	10.0
Motorola	16.2	11.1
Nokia	18.4	17.8
Palm	0.7	1.1
Samsung	14.8	10.0
Sanyo	0.5	1.1
Sony Ericsson	6.1	4.4
Others	18.8	18.9
Number of subscribers	1882	90

Table 4: Average Signal Strength by Carrier

Carrier	Average Strength	Standard Deviation
AT&T	2.63	0.92
Sprint	2.23	1.17
T-Mobile	2.29	1.16
Verizon	2.59	0.99

Table 5-1: Wireless Subscriptions in Pro-AT&T Markets
(AT&T signal strength ≥ 3 and Verizon signal strength ≤ 2)

	None	AT&T	Sprint	T-Mobile	Verizon	Others	Total (2007)
None	261	32	1	13	14	55	276
AT&T	15	365	6	11	24	23	444
Sprint	4	11	101	6	13	10	145
T-Mobile	3	14	4	143	18	15	197
Verizon	6	27	10	10	358	12	423
Others	27	72	18	20	38	342	517
Total (2008)	316	521	140	203	465	457	2102

Table 5-2: Wireless subscriptions in Pro-Verizon Markets
(AT&T signal strength ≤ 2 and Verizon signal strength ≥ 3)

	None	AT&T	Sprint	T-Mobile	Verizon	Others	Total (2007)
None	147	12	4	5	10	42	220
AT&T	4	193	1	3	11	19	231
Sprint	0	5	62	4	11	4	86
T-Mobile	2	4	1	45	3	6	61
Verizon	6	12	2	5	231	9	265
Others	20	28	8	8	30	310	302
Total (2008)	179	252	78	70	296	290	1165

Table 6: Parameter Estimates (Basic Logit)

Variable	Model (1)		Model (2)	
	Estimate	Std. Err.	Estimate	Std. Err.
Brand intercepts for handsets				
Apple	0.6030	0.1554	0.8414	0.1592
BlackBerry	0.5308	0.0900	1.064	0.0951
HTC	-1.1192	0.1964	-1.0851	0.2065
LG	-0.0441	0.0490	-0.0053	0.0484
Motorola	-0.2429	0.0504	-0.0675	0.0509
Nokia	-0.6623	0.0576	-0.6704	0.0573
Sanyo	-1.8323	0.1045	-1.878	0.1056
Sony	-1.8720	0.0920	-1.9486	0.0933
Palm	-0.6635	0.1556	-0.7183	0.1564
Samsung	-0.6371	0.0518	-0.6692	0.0514
Brand intercepts for carriers				
AT&T	1.0295	0.0562	1.0393	0.0561
Sprint	-0.3363	0.0759	-0.3021	0.076
T-Mobile	0.1556	0.0726	0.0901	0.0731
Verizon	0.9628	0.0577	0.9551	0.0578
Features				
Touch screen	0.5050	0.1098	0.7178	0.1084
GPS	0.9852	0.0797	0.8913	0.0795
Smartphone	1.2960	0. 1908	1.1881	0.1822
Tech * smartphone	0.8338	0.0740	0.8286	0.0744
Contract	-1.0729	0.2221	-1.1273	0.2254
Signal Strength	0.0774	0.0341	0.0926	0.0341
Price coefficients for handsets				
Income group 1 (< $40,000)	-0.0146	0.0007	-0.0178	0.0008
Income group 2 ($40,000~$90,000)	-0.0138	0.0006	-0.0172	0.0006
Income group 3 (> $90000)	-0.0113	0.0007	-0.0149	0.0009
Price coefficients for carriers				
Income group 1 (< $40,000)	-0.0757	0.0058	-0.0732	0.0058
Income group 2 ($40,000~$90,000)	-0.0633	0.0057	-0.0603	0.0057
Income group 3 (> $90000)	-0.0625	0.0057	-0.0593	0.0058
State dependence				
Service	2.3749	0.0315	2.3839	0.0315
Phone	0.5657	0.0339	0.5247	0.0341
Control factor			0.0090	0.0005
Log likelihood	-20696		-20567	
# of observations	7526		7526	

Table 7: Parameter Estimates (Random Coefficients Logit)

Variable	Estimate	Std. Err.
Brand intercepts for handsets		
Apple	0.6992	0.1554
BlackBerry	0.7424	0.0974
HTC	-1.4024	0.2028
LG	-0.051	0.049
Motorola	-0.0608	0.0516
Nokia	-0.6744	0.0574
Sanyo	-1.9407	0.1074
Sony	-2.0212	0.095
Palm	-1.605	0.1682
Samsung	-0.6842	0.0517
Brand intercepts for carriers		
AT&T	1.1100	0.0641
Sprint	-0.1379	0.1341
T-Mobile	-0.3001	0.2274
Verizon	0.8003	0.0711
Features		
Touch screen	1.0194	0.1056
GPS	0.8027	0.0850
Smartphone	0.7694	0.1833
Tech * smartphone	0.8303	0.0765
Contract	-1.3149	0.2910
Signal Strength	0.0746	0.0344
Price coefficients for handsets		
Income group 1 (< $40,000)	-0.0183	0.0008
Income group 2 ($40,000~$90,000)	-0.0177	0.0006
Income group 3 (> $90000)	-0.0154	0.0007
Price coefficients for carrier		
Income group 1 (< $40,000)	-0.0678	0.0075
Income group 2 ($40,000~$90,000)	-0.0550	0.0074
Income group 3 (> $90000)	-0.0543	0.0075
State dependence		
Service	2.4411	0.0328
Phone	0.5305	0.0345
Control factor	0.0092	0.0006
Covariance matrix		
σ_{11}	0.6836	0.1820
σ_{12}	0.0288	0.0404
σ_{13}	0.0189	0.0602

σ_{14}	0.1450	0.1512
σ_{15}	0.2643	0.0820
σ_{22}	0.1530	0.0528
σ_{33}	0.2157	0.1259
σ_{44}	0.7678	0.3704
σ_{55}	0.1935	0.0816
N	7526	
LL	-20474	

Table 8: Predicted Market Shares without Price Adjustments

| Carrier | iPhone for | | |
	AT&T only	AT&T+Verizon	All carriers
AT&T	1.35%	1.34%	1.33%
T-Mobile			0.28%
Sprint			0.23%
Verizon		0.91%	0.90%
Others			0.74%
Total	1.35%	2.25%	3.48%

Table 9: Predicted Retail Prices and Market Shares

| Carrier | iPhone for AT&T & Verizon | | iPhone for all carriers | |
	Predicted Price	Market Share	Predicted Price	Market Share
AT&T	$199.98	1.31%	$199.13	1.31%
T-Mobile			$149.56	0.63%
print			$145.75	0.53%
Verizon	$205.09	0.83%	$205.19	0.81%
Others			$163.37	1.31%
Total		2.14%		4.59%

Figure 1: Frequency Distribution of Handset Prices