To Root or Not to Root?
The Economics of Jailbreak

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Abstract

We construct a structural model that allows us to jointly estimate the demand for smartphones and paid apps using a Bayesian approach. Our data comes from more than 500 college students in Hong Kong and Shanghai. We find that the moral cost rather than the monetary cost of jailbreaking smartphones determines its prevalence. Users mainly jailbreak smartphones to use paid apps for free, a reason more important among Android users than iPhone users. Paid apps contribute the lion's share of the profits (between 53% and 71%) for both the Android and iPhone. Strictly prohibiting jailbreaking would decrease the aggregate market share of smartphones in the cell phone market. Apple, however, would sell even more iPhones at the expense of Android smartphones.

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1 Introduction

Jailbreaking is a process that unlocks restrictions on smartphones imposed by either the manufacturers or carriers.[1] Jailbreaking enables the user of a smartphone to personalize the phone settings (e.g., the strength of the Wifi antenna). Users of jailbroken iPhones can also sideload unauthorized apps, legal or illegal, from platforms other than the iTunes App Store. Jailbreaking can be deemed a violation of the 1998 Digital Millenium Copyright Act (DMCA). In 2010, the U.S. Library of Congress granted an exemption to jailbreaking from the DMCA. In 2012, the exemption was renewed. During the hearings and public comments surrounding the 2012 exemption, the Joint Creators, composed of app developers such as the Association of American Publishers, opposed the renewal of the exemption based on the ground that it may facilitate app piracy.

What drives users to jailbreak their smartphones? How does a change in copyright policy on jailbreaking affect the smartphone market? Would the effects differ between Apple and Android smartphones? We address these problems by constructing a random-coefficient discrete-choice demand model of smartphones and apps. Within the model, consumers choose whether to jailbreak the smartphones of their choice. Jailbreaking a smartphone within our model enables users to download, install and use paid apps for free and unofficial apps not endorsed by either Apple or Google. We estimate the model using a unique dataset collected from more than 500 college students in Hong Kong and Shanghai through conjoint surveys, and find several interesting results.

First, paid apps contribute significantly to the market shares of smartphones. While varying their prices is inconsequential, the availability of paid apps matters significantly to the smartphones' market shares. Second, because paid apps are important to smartphone users, using paid apps for free is a main reason for jailbreaking, a reason more decisive among Android users than Apple iPhone users. Third, the monetary cost of jailbreaking a smartphone plays a much smaller role than the moral cost in explaining its prevalence. Fourth, strictly prohibiting jailbreaking would bring down the aggregate market share of smartphones. More people would switch back to using traditional cell phones. However, Apple's

[1] "Jailbreaking" is a term applied to Apple's iOS devices such as the iPhone. A similar term for Android smartphones is "rooting." We use the two terms interchangeably in this paper.

sales of iPhones would surprisingly strengthen at the expense of Android smartphones, and Apple would make even more profit. This suggests that Apple should have tried its best to fight the exemption and make it costly to jailbreak not only iPhones but also Android smartphones. This result is at odds with Apple's lack of effort in objecting against the 2012 renewal of the DMCA exemption.

A caveat of our study should be stated up-front. While we acknowledge that the smartphone industry is two-sided (strictly speaking, it is richer than that), we do not study the changes in app supply across different copyright regimes for two reasons. First, we do not have data that would allow us to account for the app developers' responses to different hypothetical copyright regimes. In particular, app developers' responses are inherently dynamic. Changes in the copyright regimes, smartphone demand, app demand and jailbreaking propensity are all factors that enter into the calculation of app developers when they decide whether to develop apps. Not only would the data be hard to come by, but these dynamic responses would be extremely difficult to model. Second, we find it is important to single out the responses of consumers and how phone producers respond to them. Without addressing app developers' responses, we would not be able to estimate the overall profit of phone producers, as the important component of app income would be missing.

Our paper relates to studies on the effect of counterfeits and digital goods piracy on legitimate markets. Grossman and Shapiro (1988a) and Grossman and Shapiro (1988b) are the first to analyze this issue. There have also been numerous studies on the effect of music piracy on album sales. Most have found that music piracy has a significantly negative effect on album sales,[2] with the exception of Oberholzer-Gee and Strumpf (2007). However, with the exception of Leung (2013a), which quantifies the effect of music piracy on iPod sales, none of these studies has examined the effect of piracy in a two-sided market framework.

Some papers have examined counterfeit and piracy in China. For instance, Qian (2008) shows that in the Chinese shoe industry, firms with less government protection differentiate their products through innovation, self-enforcement and subtle high-price signals to decrease counterfeit sales. Bai and Waldfogel (2012) conduct surveys in China and find that unpaid movie consumption comprises about 75% of Chinese respondents' movie consump-

[2]See Blackburn (2004), Hui and Png (2003), Leung (2013a), and Rob and Waldfogel (2006).

tion (compared with approximately 5% reported in the U.S. sample). Further, they find that sales displacement is far smaller for the Chinese sample than U.S. sample.

Our study also contributes to the growing literature on the complementarity between apps and smartphones. Waterson and Doyle (2012) look into eBay auctions on iPhone 4 in the U.K. and show that transaction prices are higher when the phone is unlocked and can be sold overseas. Sun (2012) estimates a consumer demand for the smartphone and app supply and shows that apps contribute to the growing value of smartphones. Kim (2012) estimates consumer demands for both smartphones and apps and shows that Apple provides more app benefits to its users and that Android's stronger sales come entirely from advantages in the price-adjusted quality of its hardware. Our study differs by looking into the effects of jailbreaking on the joint demand of smartphones and apps.

In the next section, we describe the background of the DMCA exemption and the smartphone industry and explain the concept of jailbreaking in more detail. Section 3 describes the data. Section 4 details the model and explains that the conjoint survey provides it with identification by exogenously varying the different prices and attributes of smartphones. Section 5 discusses the results. Section 6 discusses counterfactuals that correspond to different prices, availability of paid apps and that correspond to different copyright regimes.

2 Jailbreaking Smartphones under the Digital Millennium Copyright Act

Introducing apps, a move Apple first made in the summer of 2008, is key to the iPhone's success. The average quarterly worldwide sales of iPhones before apps were born were approximately $1.2 million. On July 10, 2008, Apple launched the App Store, which sells pre-approved apps. In the following year, the average quarterly sales surged to over $5 million. Apps are also key to the skyrocket sales of Android smartphones.

Despite the App Store's huge success, some people embrace the idea that once a customer has purchased a durable good, she should have all of the property rights associated with it. The idea implies that a car owner has the right to choose where to change tires and parts,

or that an apartment owner has the right to decide to whom the apartment is leased or sold. Restricting users to obtaining apps from the App Store is analogous to restricting car owners to purchasing tires from designated stores only. Thus, the concept of jailbreaking emerges.

Jailbreaking is a process that unlocks the restrictions on a smartphone imposed by either the manufacturer or carrier. The restrictions are software codes hidden somewhere in the operating system. For example, the non-jailbroken iPhones can only download pre-approved apps from Apple's App Store. Their users cannot tweak their iPhones to alter the speed of the GPU or the strength of the Wifi antenna. They may be stuck at one carrier. If they switch to another carrier or move to another country, they must obtain another phone.[3] However, jailbreaking is not costless. There are certain risks involved. One may "brick" her phone, meaning a "total loss" of the phone. An Apple fan may also feel as if she is betraying Steve Jobs, in which case she suffers morally. One may also have to take certain steps that many may find incomprehensible, tedious and time consuming. If someone else does it for her, she must pay a certain amount in service fees.

Jailbreaking imposes serious legal implications that the DMCA, which was signed by President Bill Clinton in 1998, was not originally intended to deal with. The DMCA implements certain provisions of the World Intellectual Property Organization (WIPO) Copyright Treaty and WIPO Performances and Phonograms Treaty. It amends Title 17 of the United States Code, in which Chapter 12 (section 1201) prohibits "the circumvention of certain technological measures employed by or on behalf of copyright owners to protect their works."

Section 1201(a)(1) of the DMCA requires the Library of Congress to grant exemption from the prohibition when the access-control technology has a substantial adverse effect on people's ability to make non-infringing uses of copyrighted works. Between 2000 and 2012, the Copyright Office approved 23 exemptions (two in 2000; four in 2003; six in 2006; six in 2010 and five in 2012). In each case, the public submitted an exemption proposal to the Registrar of Copyrights that initiated a process of hearings and public comments. The Registrar then

[3]The technical terminology can be even more confusing than economics jargon. First, the term "jailbreaking" is mostly applied to Apple iPhones. The term "root," however, is mostly applied to Android smartphones. While the terms refer to slightly different things, they both refer to freeing the restrictions imposed by smartphone manufacturers and carriers. Second, the term "unlocking" now refers specifically to freeing up a smartphone's carrier-imposed restriction imposed. Thus, jailbreaking should have already implied unlocking but not the reverse.

made a recommendation and the Librarian issued the final rule.

While Apple has never liked the idea of jailbreaking, some groups, most notably the Electronic Frontier Foundation (EFF), have actively sought for the legal right of users in the U.S. to jailbreak their iPhones. The EFF argues that the intended use of jailbreaking, i.e. "to render certain lawfully acquired applications interoperable with the handset's software," is fair and that the access controls imposed by smartphone developers adversely affects that use. Because jailbreaking enables users to "circumvent a technological measure that effectively controls access to a work protected" by the Copyright Act, according to Section 1201(a)(1)(A), it requires an exemption or could be deemed a violation of the DMCA. The fight ended when an explicit exemption of the DMCA was granted by the U.S. Copyright Office in 2010.[4] The exemption officially says that jailbreaking one's iPhone is not an imprisonable offense in the U.S.

As the exemption of jailbreaking expired in 2012, the EEF along with New America Foundation, Open Technology Initiative, New Media Rights, Mozilla Corporation, the Free Software Foundation, and several hundred individual supporters requested its continuation. Their argument was the same as that put forward by the EEF in 2009: "jailbreaking a smartphone to lawfully acquire apps inter-operable with the smartphone was fair use."

Apple did not file an objection this time. Instead, trade groups representing app developers such as the Association of American Publishers, the American Society of Media Photographers, the Business Software Alliance, the Entertainment Software Association, the Motion Picture Association of American, the Picture Archive Council of America and the Recording Industry Association of America challenged the EEF's proposal. They argued that jailbreaking "increases piracy of applications and is detrimental to the secure and trustworthy innovation platforms that mainstream consumers demand."

While app piracy is widespread, the Copyright Office wrote in the Final Report that renewed the exemption in 2012 that the trade groups "did not demonstrate any significant relationship between jailbreaking and piracy." Indeed, they pointed out one major difficulty that we fully acknowledge but do not intend to tackle in our paper: even the trade groups

[4]Apple opposed the proposal at the time. Their main argument against the granting of the exemption was that jailbreaking would breach the integrity of its iPhones' "ecosystem," and that unauthorized uses would diminish the value of the copyrighted works to Apple.

representing the app developers themselves cannot come up with evidence showing exactly how jailbreaking would injure their businesses, let alone prove that app piracy activities have increased (for app developers not represented by those trade groups) because of jailbreaking.

3 The Data

Jailbreaking an iPhone enables the user to install unapproved (and possibly illegal) apps. The resulting less-restrictive set of property rights associated with buying an iPhone would in principle make it more appealing to smartphone users. Because the exemption makes it legal to jailbreak, all else being equal, the demand for iPhones should increase.

Of course, all else is never equal. The whole analysis becomes complicated when Apple does not monopolize the market. In fact, the exemption also means that Android users can legally jailbreak (root) their Android smartphones. It makes it difficult to predict whether iPhone sales and profits would truly increase because of the exemption.

To address these issues, we designed a conjoint survey to collect a unique dataset on the consumption of different smartphones. We collected our survey data from Hong Kong and Shanghai. There are several reasons for using Chinese data. First, the smartphone market in China is huge. According to UMeng, a Chinese marketing analysis firm specializing in smartphones and the apps market, the number of smartphone users has grown exponentially in recent years, reaching 200 million in October 2012. Second, app piracy is rampant in China. MadFinger Games, a small Czech Republic-based company, said that its Shadowgun had a 39% piracy rate on the iOS platform and a nearly 100% piracy rate on the Android platform in China. It is thus interesting to compare the jailbreaking behavior between Hong Kong, in which intellectual property rights are better enforced, and Shanghai, in which the piracy problem is more serious.

The survey data comprise responses from 328 college students in Hong Kong and 242 students in Shanghai. Students answered two types of questions. First, they provided information on their demographics, the brands of cellphones they used, and whether they had jailbroken their smartphones. Second, they indicated their choices of smartphone in 16 hypothetical tasks. In each of the 16 tasks, factors including smartphone prices, the prices of

paid apps, and costs of jailbreaking of different smartphones were exogenously randomized within a pre-specified range.

This exogenous randomization provides identification for our random-coefficient discrete-choice demand model. We follow Rossi, Allenby, and McCulloch (2005) to set up a hierarchical Bayesian discrete demand model for smartphones, with a mixture of normal priors. The implementation of the posterior inference takes the form of a hybrid of Gibbs sampling and the Metropolis-Hasting algorithm. We then use the estimates to conduct counterfactuals to evaluate the effectiveness of various copyright regimes.

The lack of real market data on jailbreaking led to the conjoint analysis approach adopted in this paper. There are several advantages to using conjoint survey data instead of real market data in this research. First, real market data on the consumption of smartphones and jailbreaking are difficult to come by, and conjoint surveys are possibly the only way to create a panel dataset. To the best of our knowledge, no study has constructed such a panel dataset.

Second, a conjoint survey analysis provides good instruments. There are two potential problems inherent in using real market price data. First, prices are endogenous. As Berry, Levinsohn, and Pakes (1995) and Nevo (2000) illustrate, prices can be a function of unobserved product characteristics and can be correlated with unobserved product heterogeneity. This leads to biased estimation. Second, the actual price variation is small for jailbreaking and apps. A conjoint survey analysis can circumvent these problems because it draws prices as a product attribute exogenously and independently (using the orthogonality principle described in the next subsection). Moreover, as the designers of the survey, we could vary the prices within a pre-specified range to ensure sufficient variations.

However, a conjoint survey has limitations. For instance, a conjoint analysis requires quantifiable attributes. Some attributes such as the availability of free apps are difficult to quantify. These attributes are absorbed in the brand fixed effect in our estimation.

Moreover, one may prefer real market data over conjoint survey data. After all, a revealed preference sounds more reliable. However, various studies in marketing and economics have applied the conjoint survey technique and shown that it can yield reliable demand estimates. Green and Rao (1971) are the first to apply conjoint analysis in marketing science. Since then, there is compelling evidence showing that conjoint survey data can generate reliable demand

estimates. Carlsson and Martinsson (2001) collect both real market data and conjoint survey data on donation choice. Their estimates are statistically the same across the two data sources. Hensher, Louviere, and Swait (1999) arrive at the same conclusion in a freight shipper choice problem. Finally, Leung (2013a) and Leung (2013b) extend the application of the conjoint analysis to the study of piracy.

3.1 Details of the Conjoint Survey

We follow Louviere and Woodworth (1983) by using an choice-based conjoint analysis to collect our data. We conducted the survey in Fall 2012 at the Chinese University of Hong Kong and Shanghai Jiao Tong University. The survey was administered during the last 15 minutes of classes. In total, 570 students returned their completed surveys (328 from Hong Kong and 242 from Shanghai).

Before the survey, we conducted a pilot study using a sample of 20 undergraduate students. We included their three most popular cell phones in the survey (Google Galaxy Nexus, Samsung Galaxy S3, and iPhone 5). To determine a viable range of cell phone and app prices, we asked students to state the maximum price they would be willing to pay for a 4G cell phone, a 2G cell phone and an app. From the results, we identified HK$1,500 to HK$7,500 as a feasible range for a 4G cell phone, HK$100 to HK$2,000 as a feasible range for a 2G cell phone, and HK$0 to HK$30 as a feasible range for each app.

We also asked students to indicate the two most important attributes when choosing a cell phone. Based on their answers, we selected five attributes to construct the conjoint profiles: (1) the price of the cell phone; (2) the price per paid app; (3) the price of jailbreaking; (4) the display resolution (pixel per inch (PPI)); and (5) the camera configuration (megapixels). At the beginning of the study, participants were given the survey containing a sequence of 16 individualized choice sets and definitions of the five attributes. Each choice set had four cell phones, described using the five attributes.[5] A participant has to choose one option from each choice set (none is permitted) and indicates whether he would jailbreak his chosen smartphone. Note that the students were told to interpret jailbreaking as a process that

[5]For other cell phone features the participants may have considered, they were told to assume that those features were the same as in the market.

enabled them to download paid apps for free. Figure 1 presents a sample of a conjoint task in our survey.[6]

Figure 1: A Sample Conjoint Task

	Nokia 5000 (2G)	**Google Galaxy Nexus (4G)**	**Samsung GS3 (4G)**	**iPhone 5 (4G)**
Price	$2000	$1500	$4500	$6000
Price per paid app	NA	$0	$9	$14
Price of jailbreaking	NA	$30	$40	$85
Display	120 PPI	350 PPI	190 PPI	250 PPI
Camera	0.8 megapixels	8 megapixels	12 megapixels	3 megapixels

I choose:

None	**Nokia**	**Nexus**	**GS3**	**iPhone**

Jailbreak your cell phone? ☐*Yes*/☐*No* (You don't need to answer if you choose None or Nokia)

We constructed four versions of the survey for our study. In each version, the order of the alternatives in each choice set were different. The first alternatives within each choice set represented a 16-profile, orthogonal array with five alternatives and four attribute levels (see Addelman (1962)). We then followed Bunch, Louviere, and Anderson (1994)'s approach to use cyclic designs to generate the other alternatives in each choice set. In particular, we constructed subsequent alternatives by adding cyclically generated alternatives to each set.

[6]When we conducted the survey in Shanghai, we converted the nominal value by using the exchange rate at HK$100 = RMB80.33, which is the central parity rate on November 26, 2012.

The attribute level of a new alternative added one to the level of the previous alternative. If the previous alternative was at the highest level, the assignment re-cycled to the lowest level. This construction method satisfied the three properties of efficient choice design (see Sawtooth Software (2008)): (i) minimal overlap; (ii) orthogonality; and (iii) level balance.

In specifying the attribute levels, we divided the range of each attribute into "low," "medium low," "medium high," and "high" categories. Table 1 presents the ranges of all of the attributes. We randomly selected a value from the corresponding range for each attribute level appearing in each cell phone option.

Table 1: Specification of Attribute Levels

	Cell Phone Price (HK$)	Paid App Price (HK$)	Jailbreak Price (HK$)	Camera (megapixels)	Display (PPI)
Low	1,500-3,000 [100-500]	0	0	3 [0.3]	150-200 [80]
Medium Low	3,000-4,500 [500-1000]	1-10	5-30	5 [0.5]	200-250 [100]
Medium High	4,500-6,000 [1,000-1,500]	11-20	35-60	8 [1.5]	260-300 [120]
High	6,000-7,500 [1,500-2,000]	21-30	65-90	12 [2]	310-350 [140]

The ranges in brackets are for 2G cell phones.

3.2 Summary Statistics

Table 2 describes the demographics and some of the behavior of the students in the sample. The Hong Kong students' demographics are similar to those from Shanghai. They share similar ages (averaging 20.57 and 23.08 in Hong Kong and Shanghai, respectively). Males compose a slight majority of the sample (59% in Hong Kong and 54% in Shanghai).

Table 2: Summary Statistics

	Hong Kong			Shanghai		
	Mean (s.d.)	Min	Max	Mean (s.d.)	Min	Max
Age	20.57 (1.59)	17	27	23.08 (2.48)	18	38
Male	0.59 (0.49)	0	1	0.54 (0.50)	0	1
Have Used BT Recently	0.61 (0.49)	0	1	0.71 (0.46)	0	1
Hours Spent on Internet/Day	4.80 (3.62)	1	24	5.18 (2.91)	0.3	20
Jailbreak	0.13 (0.34)	0	1	0.29 (0.45)	0	1

Almost all of the students had access to the Internet, and spent approximately 5 hours per day browsing. Most also had access to pirating technology. In Hong Kong, 61% of the students had recently used BitTorrent (BT), an application used to share (mostly illegal) files

on the Internet. BT was more prevalent among the Shanghai students, more than 71% of whom had experience with BT. Consistently, Shanghai students were more likely to jailbreak their smartphones (29% did so) compared with Hong Kong students (13%).

To understand the underlying demographics of jailbreakers, we run separate logit regressions for the Hong Kong and Shanghai students. As Table 3 shows, students who have recent BT experience are more likely to jailbreak their smartphones. While students with higher family incomes are also more likely to engage in jailbreaking, income does not correlate with jailbreaking behavior in Hong Kong. Further, although it is marginally insignificant, male Shanghai students tend to be more likely to jailbreak their smartphones, there is no significant difference in jailbreaking behavior across genders in Hong Kong.

Table 3: Logit Regression of Jailbreaking[a]

	Hong Kong	Shanghai
Age	-0.02	0.08
	(0.12)	(0.07)
Male	0.08	0.44
	(0.35)	(0.31)
Live with	-0.43	-0.20
family	(0.38)	(0.34)
Income	-0.11	0.17*
(1-6)	(0.10)	(0.10)
BT	1.11***	0.91**
	(0.34)	(0.38)
Internet	-0.01	-0.02
	(0.03)	(0.05)
N	328	242

[a] Standard errors are reported in brackets. ***, **, and * indicate significance at the 1%, 5% and 10% levels.

4 The Demand Model and Estimation

We build a demand model for cell phones following Iyengar, Jedidi, and Kohli (2008).

First, let $\mathbf{x}_j$ be a vector of non-price attributes associated with cell phone j where the first entry is 1. Consumer $i \in \{1, \ldots, I\}$ chooses cell phone j among J choices. She can choose not to consume any of the J choices (with $j = 0$). $\hat{u}_{ij}$ denotes the attribute-based utility, which

does not depend on price, for consumer i, where

$$\hat{u}_{ij} = \alpha_i \mathbf{x}_j. \tag{1}$$

We assume that consumer i can at most choose one cell phone. She has a budget w_i that she can spend on cell phones, apps (which we denote as n_{ij}), and an individual-specific composite (outside) good (which we denote as z_{ij}).

There are two prices for cell phone j depending on whether consumer i jailbreaks the cell phone. If she does not jailbreak the cell phone, she pays f_j^a for the cell phone itself. If she jailbreaks the cell phone, she pays $f_j^a + f_j^b$, where f_j^b is the monetary price for jailbreaking. There is also a (fixed) utility cost, ρ_{ij}, of jailbreaking. Whereas the price for each legal app in cell phone j is p_j^a, the price for each app after jailbreak is p_j^b (which we assume to be zero). The price of the individual-specific composite good is w_i, which is normalized at one.

The budget constraint for consumer i choosing cell phone j is

$$p_i^w z_{ij} + \mathbf{1}\{\text{jailbreak} = 0\}(f_j^a + p_j^a n_{ij}^a) + \mathbf{1}\{\text{jailbreak} = 1\}(f_j^a + f_j^b + p_j^b n_{ij}^b) = w_i. \tag{2}$$

We model the individual utility using the nested logit framework by nesting both the "no jailbreak" and "jailbreak" options of each cell phone j. In particular, we assume that the utility shock for i choosing cell phone j with jailbreak option k is $\zeta_{ij} + (1 - \sigma_i)\epsilon_{ijk}$. We assume ϵ_{ijk} to be distributed i.i.d. extreme value and that ζ_{ij} has a distribution that depends on σ_i such that $\sigma_i \in [0, 1]$ and assume $\zeta_{ij} + (1 - \sigma_i)\epsilon_{ijk}$ to be distributed extreme value. Thus, the utility of consumer i choosing cell phone j with jailbreak option k is

$$u_{ij}^k = \hat{u}_{ij} + \beta_{i1} n_{ij}^k + \beta_{i2}(n_{ij}^k)^2 + \beta_{i3} z_{ij}^k - \mathbf{1}\{k = b\}\rho_{ij} + \zeta_{ij} + (1 - \sigma_i)\epsilon_{ijk}, \tag{3}$$

where

$$\begin{aligned} z_{ij}^a &= w_i - f_j^a - p_j^a n_{ij}^a; \\ z_{ij}^b &= w_i - f_j^a - f_j^b - p_j^b n_{ij}^b. \end{aligned}$$

We can determine the number of apps that consumer i would download from the first order conditions with respect to n_{ij}^k that maximize (3) subject to (2):

$$n_{ij}^{a*} = \max\{\frac{\beta_{i3}p_j^a - \beta_{i1}}{2\beta_{i2}}, 0\}, \tag{4}$$

$$n_{ij}^{b*} = \max\{\frac{\beta_{i3}p_j^b - \beta_{i1}}{2\beta_{i2}}, 0\}. \tag{5}$$

We can express the utility for consumer i choosing cell phone j with jailbreak choice k as

$$\begin{aligned} u_{ij}^k &= \hat{u}_{ij} + \beta_{i1}n_{ij}^{k*} + \beta_{i2}(n_{ij}^{k*})^2 + \beta_{i3}z_{ij}^{k*} - \mathbf{1}\{k=b\}\rho_{ij} + \zeta_{ij} + (1-\sigma_i)\epsilon_{ijk} \\ &\equiv \bar{u}_{ij}^k + \zeta_{ij} + (1-\sigma_i)\epsilon_{ijk} \end{aligned} \tag{6}$$

Let $\mathbf{P} = [p_1^a; \ldots; p_J^a; p_1^b; \ldots; p_J^b; f_1^a; \ldots; f_J^a; f_1^b; \ldots; f_J^b]$ be a vector of prices and $\Theta = [\alpha_i; \beta_{i1}; \beta_{i2}; \beta_{i3}; \rho_i; \theta_i; \sigma_i]$ be a vector of parameters. Integrating out the individual taste shock, we can derive the following expression for consumer i's demand for cell phone j with jailbreak choice k:

$$D_{ij}^k(\mathbf{P}|\Theta) = \frac{\exp\left(\frac{\bar{u}_{ij}^k}{1-\sigma_i}\right)}{\mathbf{G}_j^{\sigma_i}\left[\sum_j \mathbf{G}_j^{(1-\sigma_i)}\right]}, \tag{7}$$

where $\mathbf{G}_j = \sum_{k=a,b} \exp\left(\frac{\bar{u}_{ij}^k}{1-\sigma_i}\right)$.

4.1 Estimation

To exploit the panel structure of our data, we follow Rossi, Allenby, and McCulloch (2005) and use a hierarchical Bayesian model with a mixture of K components of normal priors to flexibly estimate the random coefficients. In addition to the *hyperparameters* that describe the distribution of the heterogeneity, the hierarchical Bayesian approach can also make an inference on the *individual-level* parameters as follows.

In the survey, we asked students to provide demographic information. Therefore, we include aspects of that information to control for observed heterogeneity across students. We define Z_i as a $1 \times n_z$ vector of observable characteristics of i, which has n_z elements, and Z as an $n_i \times n_z$ matrix. Following Rossi, Allenby, and McCulloch (2005), we assume that the

unobserved heterogeneity is distributed as a K mixture of normal. The demand model can therefore be expressed as follows:

$$\begin{aligned} D_{ij}(\mathbf{P}|\Theta) &= \prod_t D_{ijt}(\mathbf{P}_t|\Theta), \\ \Theta_i &= Z_i\triangle + u_i, \\ u_i &\sim N(\mu_{ind_i}, \Sigma_{ind_i}), \\ ind_i &\sim \text{Multinomial}_K(\gamma), \end{aligned}$$

where γ is a vector giving the mixture probabilities for each of the K components. $\triangle$ is an $n_z \times 6$ matrix of parameters that determines the effects of demographics on each utility coefficient. We define $\delta = \text{vec}(\triangle)$ for ease of illustration. The individual-level demand parameters for student i, Θ_i, is therefore a function of her demographics (including family income, recent BT experience and age) and an unobserved factor, u_i. The unobserved factor, u_i, is drawn from a K-component mixture of normal distributions. The set of hyperparameters that describes the distribution of the heterogeneity includes δ (the demographics parameters), γ (the mixture probabilities for each of the K components) and μ_k and Σ_k (the mean and variance-covariance matrix of the kth-component of the distribution of the unobserved heterogeneity, u_i).

The complete specification with priors over the hyperparameters, including the mixture probabilities (τ), the demographic coefficients ($\bar{\delta}$ and a_δ^{-1}), the means of the unobserved heterogeneity ($\bar{\mu}$ and a_μ^{-1}) and the covariance matrices for the unobserved heterogeneity (v and V), can be taken in convenient conditionally conjugate forms:

$$\begin{aligned} \delta &\sim N(\bar{\delta}, a_\delta^{-1}), \\ \gamma &\sim Dirichlet(\tau), \\ \mu_k|\Sigma_k &\sim N(\bar{\mu}, \Sigma_k \times a_\mu^{-1}), \\ \Sigma_k &\sim IW(v, V), \\ \{\mu_k, \Sigma_k\} & \quad \text{independent}, \end{aligned}$$

where the joint prior on μ_k and Σ_k is independent conditional on γ.

We follow the standard Bayesian estimation of the multinomial logit model as in Rossi, Allenby, and McCulloch (2005) except for several differences. First, we do not observe n^k and thus need to calculate its value using the draws of $\beta_{i1}, \beta_{i2}, \beta_{i3}, \theta_i$ from each MCMC draw. Second, to ensure the quasi-concavity of the utility function, we put the following restrictions on the parameters: $\sigma_i < 1$, $\beta_{i2} < 0$, and $\beta_{i3} > 0$. We enforce the restrictions by reparametrizing $\sigma_i = 1 - \exp(s_i)$, $\beta_{i2} = -\exp(b_{i2})$, and $\beta_{i3} = \exp(b_{i3})$, where s_i, b_{i2}, and b_{i3} are unconstrained individual-level parameters.

5 Estimation Results

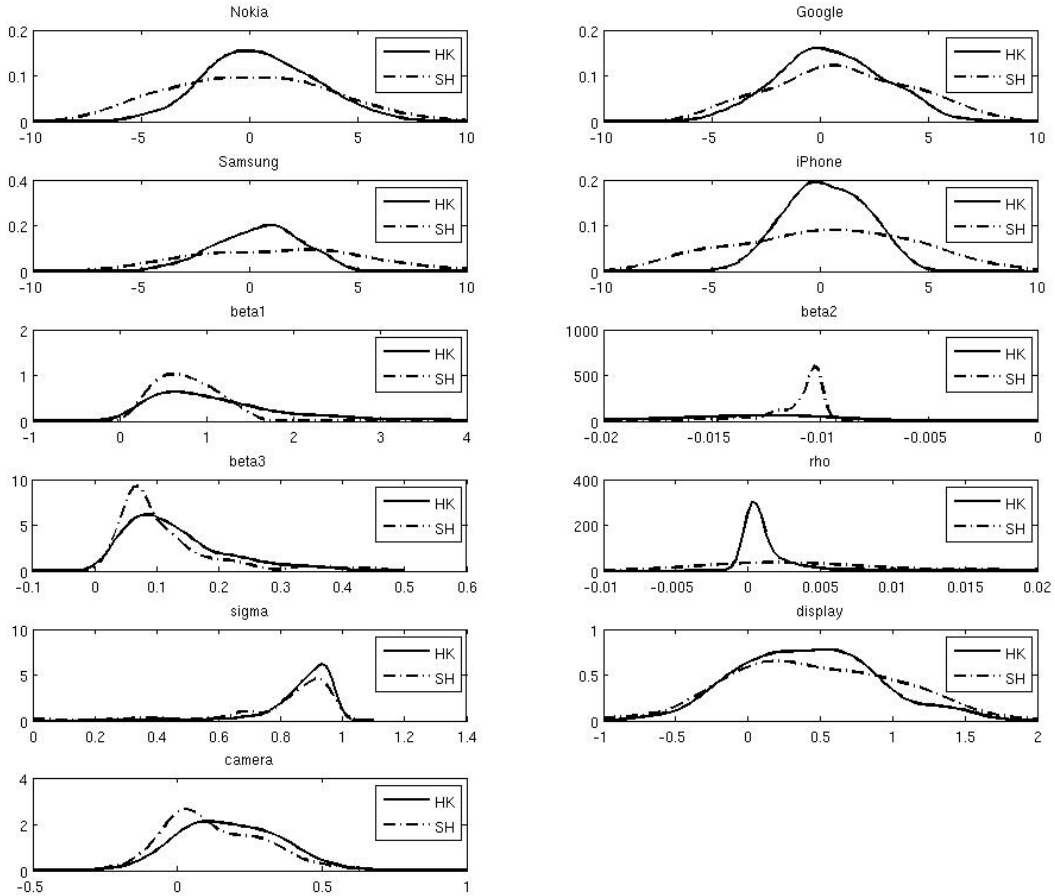
Figure 2 displays the kernel density of the individual-level coefficients from the two-component model. There are several things to note. First, in both cities, the distributions of the dummy coefficients for Nokia are not very different from those of other smartphones. This indicates that the availability of apps contributes significantly to the higher market shares of smartphones.

Second, σ is smaller and more spread out in the Shanghai sample, which indicates that ζ_{ij} is a stronger driving force for smartphone choices in Hong Kong than in Shanghai. In other words, Hong Kong students have a stronger brand preference than Shanghai students. Copyright policies on jailbreaking, therefore, may have a bigger effect in Shanghai than in Hong Kong. We test this in Section 6.

Third, the price coefficients are smaller in Shanghai. The parameter β_3 for Hong Kong students is higher than for Shanghai students, perhaps because most college students in Shanghai do not earn a living working part-time jobs. This indicates that Shanghai students may be less sensitive to price changes in phones. To test this observation, we compute the price elasticities of the various cell phones.

Table 4 reports the estimates of the price elasticities. The elasticity estimates are at brand level, i.e., the percentage change in the demand for the brand (jailbroken and non-jailbroken) in terms of a 1% increase in the prices of various brands. The upper (lower) panel displays the demand elasticities from the Hong Kong (Shanghai) sample. In both samples, the own price elasticities of all of the smartphones (Google, Samsung, and iPhone) are reasonable.

Figure 2: Kernel Density of Coefficients Estimates



They are all above one, indicating a positive marginal cost according to the inverse elasticity rule. The demand for Nokia is inelastic, with elasticities of -0.28 and -0.3 in Hong Kong and Shanghai, respectively.

Hong Kong students are more price sensitive. When the price of Samsung goes up by 1%, Hong Kong students' demand for Samsung drops by 2.66%, and Shanghai students' demand drops by only 2.02%. When the price of the iPhone goes up by 1%, Hong Kong students' demand for the iPhone drops by 2.85%, and Shanghai students' demand drops by only 2.32%.

In both samples, the smartphones are closer substitutes among themselves than for Nokia,

Table 4: Own Price Elasticities

	Hong Kong			
with respect to	Nokia	Google	Samsung	iPhone
Nokia's price	-0.28	0.06	0.02	0.02
	[-0.32, -0.23]	[0.05, 0.07]	[0.01, 0.02]	[0.02, 0.03]
Google's price	1.11	-1.31	1.07	0.98
	[0.90, 1.32]	[-1.42, -1.19]	[0.96, 1.18]	[0.86, 1.12]
Samsung's price	0.19	0.62	-2.66	0.83
	[0.14, 0.24]	[0.53, 0.71]	[-2.94, -2.43]	[0.72, 0.95]
iPhone's price	0.20	0.52	0.76	-2.85
	[0.15, 0.26]	[0.45, 0.59]	[0.63, 0.91]	[-3.13 , -2.59]

	Shanghai			
with respect to	Nokia	Google	Samsung	iPhone
Nokia's price	-0.30	0.03	0.01	0.02
	[-0.38, -0.23]	[0.02, 0.04]	[0.01, 0.02]	[0.01, 0.03]
Google's price	0.99	-1.22	0.89	0.74
	[0.72, 1.35]	[-1.37, -1.08]	[0.77, 1.01]	[0.61, 0.88]
Samsung's price	0.27	0.74	-2.02	0.94
	[0.17, 0.38]	[0.59, 0.89]	[-2.32, -1.74]	[0.78, 1.13]
iPhone's price	0.24	0.40	0.62	-2.32
	[0.13, 0.37]	[0.31, 0.51]	[0.42, 0.93]	[-2.70 , -2.01]

The 5th and 95th percentiles of the estimates are reported in brackets.

the only 2G cell phone in the study. Judging from the cross-price elasticities, students are more likely to substitute an iPhone for another smartphone like a Google phone, rather than a Nokia. For instance, a 1% increase in the iPhone's price in Hong Kong (Shanghai) would lead to an approximate 0.5%-0.7% increase in demand for the Google phone and Samsung, but only an approximate 0.2% increase in demand for the Nokia.

Table 5 reports the variations of the coefficient estimates that are explained by the demographics. Several things are noteworthy. First, age does not explain much of the coefficient variation, probably because it does not vary much among the college students.

Second, the price coefficient (β_3) is correlated with some of the demographics. For instance, the male students in both cities are (statistically) more price sensitive with a higher price coefficient (β_3). Further, students with a higher family income tend to have a smaller price coefficient (β_3) and are therefore less price sensitive.

Third, the psychological cost of jailbreaking (ρ) is correlated with some of the demographics. Male students in both Hong Kong and Shangai have a lower utility cost of jailbreaking (ρ). Whereas Hong Kong male and female students do not differ significantly, Shanghai male students are statistically more likely to jailbreak than their female counterparts. Further, stu-

Table 5: Coefficients Explained by Demographics

	Hong Kong										
	Nokia	Google	Samsung	iPhone	$\log(\beta_1)$	$\log(-\beta_2)$	$\log(\beta_3)$	ρ	$\log(1-\sigma)$	Display	Camera
Age	-0.19	-0.14	-0.01	-0.05	0.01	-0.14	-0.01	0.60	0.11	0.03	-0.01
	(0.14)	(0.15)	(0.14)	(0.14)	(0.04)	(0.16)	(0.02)	(0.24)	(0.05)	(0.03)	(0.01)
Male	-0.29	0.05	-0.25	-0.39	-0.19	-0.61	0.24	-0.28	0.28	0.06	0.02
	(0.42)	(0.45)	(0.43)	(0.44)	(0.13)	(0.36)	(0.05)	(0.43)	(0.16)	(0.11)	(0.02)
Live with	-0.97	-0.71	-0.61	-0.55	0.22	1.28	0.20	0.42	-0.27	0.26	0.07
Family	(0.46)	(0.48)	(0.48)	(0.49)	(0.17)	(0.56)	(0.07)	(0.53)	(0.20)	(0.11)	(0.03)
Income (0-6)	0.45	0.50	0.41	0.42	-0.02	-0.03	-0.04	0.20	-0.03	-0.01	-0.01
	(0.13)	(0.12)	(0.12)	(0.13)	(0.04)	(0.15)	(0.02)	(0.17)	(0.05)	(0.03)	(0.01)
BT	-0.38	-0.33	-0.58	-0.23	-0.22	-0.98	-0.09	-1.87	-0.20	-0.12	-0.03
	(0.49)	(0.46)	(0.48)	(0.47)	(0.13)	(0.43)	(0.05)	(0.54)	(0.17)	(0.11)	(0.02)
Internet	-0.03	-0.01	-0.02	-0.02	-0.02	-0.10	-0.01	-0.09	-0.01	0.01	-0.01
Per Day	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.04)	(0.01)	(0.07)	(0.01)	(0.01)	(0.01)
	Shanghai										
	Nokia	Google	Samsung	iPhone	$\log(\beta_1)$	$\log(-\beta_2)$	$\log(\beta_3)$	ρ	$\log(1-\sigma)$	Display	Camera
Age	-0.24	-0.15	0.13	-0.19	0.01	-0.18	-0.02	0.20	-0.01	-0.01	0.01
	(0.13)	(0.13)	(0.15)	(0.13)	(0.03)	(0.16)	(0.02)	(0.10)	(0.04)	(0.03)	(0.01)
Male	-1.82	-1.32	-1.11	-0.54	0.01	0.77	0.17	-1.35	0.08	0.01	-0.01
	(0.46)	(0.43)	(0.45)	(0.44)	(0.09)	(0.46)	(0.07)	(0.34)	(0.17)	(0.12)	(0.03)
Live with	0.18	0.59	-0.48	0.32	-0.05	-1.78	-0.04	-0.01	-0.07	-0.28	-0.02
Family	(0.54)	(0.52)	(0.54)	(0.65)	(0.11)	(0.74)	(0.08)	(0.40)	(0.20)	(0.12)	(0.03)
Income (0-6)	-0.07	-0.21	-0.20	-0.14	-0.01	-0.50	-0.08	0.22	-0.07	0.01	0.01
	(0.23)	(0.23)	(0.23)	(0.22)	(0.03)	(0.20)	(0.02)	(0.14)	(0.06)	(0.04)	(0.01)
BT	-0.80	-2.30	-1.75	-0.54	0.36	1.77	-0.06	-0.35	-0.05	0.34	0.05
	(0.59)	(0.58)	(0.53)	(0.61)	(0.11)	(0.42)	(0.09)	(0.40)	(0.23)	(0.14)	(0.03)
Internet	-0.01	0.22	0.08	-0.13	-0.13	-0.03	-0.27	0.02	0.02	-0.07	-0.01
Per Day	(0.11)	(0.11)	(0.10)	(0.15)	(0.02)	(0.11)	(0.01)	(0.09)	(0.03)	(0.02)	(0.01)

The standard deviations of the estimates are reported in brackets.

dents with recent experience using BitTorrent (BT) have a lower utility cost of jailbreaking. This relationship is more significant in Hong Kong.

6 Counterfactuals

We conduct several counterfactuals to examine the importance of paid apps and the effects of different copyright regimes. Table 6 describes the current regime in both Hong Kong and Shanghai.

We calculate the predicted market shares and profits of the different smartphones and the predicted prevalence of jailbreaking in seven regimes. Among each of these, the users' choice of phones, whether they would jailbreak, the number of paid apps demanded, and the

Table 6: Current Cellphone Market

	Google	iPhone	Samsung	Nokia
Price (HK$)	3,698	5,588	5,598	620
Paid Apps Price (HK$)	20	11	20	NA
Jailbreak Price (HK$)	50	50	50	NA
Display (PPI)	316	326	306	200
Camera (megapixel)	5	8	8	1.3

corresponding profit-maximizing prices of the phone manufacturers are all endogenously determined.

6.1 Do Paid Apps Determine Jailbreaking?

Apps are key to smartphones. Table 7 reports the estimated market shares of various smartphones in four different regimes. These regimes differ in the price of paid apps and their availability across the different platforms. The first three columns show the market shares of the three smartphones (Google, iPhone, and Samsung) in different regimes. Columns 4-6 show the expected profits per student for the three smartphones. Column 7 computes the corresponding prevalence of jailbreaking among smartphone users. Row 1 shows those of the current regime for ease of comparison.

Free Apps Regime. Under this regime, we set the price of all of the paid apps (for both Android and Apple) to zero. A few results emerge; we stress two that at first glance may appear to contradict to each other. First, the *price* of paid apps is not a crucial determinant of the market shares (and therefore the profits) of different smartphones. This suggests that some other factors are more important in determining users' demand for smartphones, such as, free apps, the design, the brand, etc.[7] Does that mean that paid apps are therefore not important? The second result suggests otherwise. Column 7 shows that the prevalance of jailbreaking falls significantly (from 65.4% to 18.7% in Hong Kong and from 74.7% to 23% in Shanghai). This suggests that *consuming* paid apps must be an important factor in determining smartphone demand. When prices rise, more people choose to jailbreak their smart-

[7]However, there are only slight changes in the market shares and profits of smartphones. This is likely driven by σ being close to one in both places, suggesting that students have a high brand loyalty. This means they would substitute a jailbroken iPhone (or Google or Samsung) with a non-jailbroken iPhone (or Google or Samsung).

Table 7: Market Shares, Profits, and Overall Jailbreaking Percentage under the Different Regimes

	Hong Kong						
	Market Shares (%)			Profit/Student (HK$)			Jailbreaking (%)
	Google	iPhone	Samsung	Google	iPhone	Samsung	All Brands
Current	44.7	14.8	17.1	1,128	274	322	65.4
	[42.1 ,47.1]	[13.2, 16.3]	[15.4, 18.9]	[1,063, 1,189]	[245, 302]	[289, 355]	[63.0, 67.7]
Free Apps	46.2	14.7	17.5	1,166	257	333	18.7
	[43.5, 48.7]	[13.2, 16.2]	[15.7, 19.3]	[1,099, 1,230]	[230, 283]	[299, 367]	[17.7, 19.8]
Free Android Apps	46.6	13.1	18.0	1,202	225	354	26.2
	[44.0, 49.3]	[11.7, 14.8]	[16.3, 19.7]	[1,133, 1,271]	[199, 252]	[322, 389]	[24.9, 27.6]
Free iPhone Apps	44.0	15.9	16.8	1,106	333	309	57.6
	[41.3, 46.4]	[14.0, 17.8]	[14.8, 18.6]	[1,039, 1,167]	[291, 371]	[273, 344]	[55.4, 59.8]
No Apps	16.2	3.6	5.1	306	78	119	0
	[14.4, 18.1]	[2.8, 4.4]	[3.9, 6.3]	[271, 341]	[61, 95]	[91, 148]	[0, 0]
	Shanghai						
	Market Shares (%)			Profit/Student (HK$)			Jailbreaking (%)
	Google	iPhone	Samsung	Google	iPhone	Samsung	All Brands
Current	42.6	16.1	25.5	1,261	366	631	74.7
	[40.5 ,44.8]	[12.6, 20.4]	[21.5, 28.6]	[1,197, 1,326]	[287, 465]	[532, 708]	[71.8, 77.4]
Free Apps	44.1	16.0	26.1	1,303	351	646	23.0
	[41.9, 46.3]	[12.6, 20.2]	[22.2, 29.1]	[1,241, 1,370]	[277, 443]	[551, 722]	[21.8, 24.0]
Free Android Apps	44.8	13.8	26.9	1,359	310	695	31.3
	[42.6, 47.1]	[11.0, 17.4]	[23.6, 29.7]	[1,291, 1,427]	[247, 389]	[612, 768]	[29.2, 33.6]
Free iPhone Apps	41.8	18.1	24.6	1,227	452	597	64.6
	[39.7, 43.9]	[14.2, 22.8]	[20.4, 27.9]	[1,167, 1,291]	[355, 571]	[496, 678]	[61.5, 67.7]
No Paid Apps	17.5	5.7	10.4	461	128	326	0
	[14.9, 20.1]	[3.6, 8.4]	[7.9, 12.8]	[393, 532]	[79, 186]	[249, 404]	[0, 0]

The 5th and 95th percentiles of the estimates are reported in brackets.

phones. The estimate suggests that raising the prices of paid apps from $0 to the current prices would lead to three times the amount of jailbreaking.

The total market shares of smartphones (the sum of the three smartphones examined in this study) increase by only 1.8% and 2% in Hong Kong and Shanghai, respectively. This reflects the low substitutability between smartphones and Nokia, as shown in Table 4. The small increases in the total market shares lead to small changes in the total profits of smartphones. The total profits of all smartphones increase slightly in Hong Kong (HK$32 per student) and in Shanghai (HK$42 per student). However, there are slight differences among Apple and Android phones. Whereas the market shares and profits of the Android phones (Google and Samsung) increase, those of the iPhone suffer. This suggests that making all paid apps free would increase the competitiveness of Android smartphones over that of the

iPhone.[8]

Free Android/iPhone Apps Regime. In the case where either Android or Apple's apps become free, the total market share and profits of smartphones would also increase, at the expense of the smartphones that still charge their apps at a positive price. However, they would not change much.

The more important result, however, comes from comparing the figures in Column 7. Setting HK$0 for Android paid apps alone would significantly lower the prevalence of jailbreaking compared with setting a HK$0 amount for iPhone paid apps. This suggests that using Android paid apps for free would be a more important driver for jailbreaking than using iPhone paid apps for free. Another interpretation is that iPhone users are less likely to jailbreak their phones because they have to pay for paid apps, which are cheaper in iPhones relative to Android phones.

No Paid Apps Regime. The availability of apps is key to the success of smartphones. We assess the importance of paid apps in the No Paid Apps Regime by setting the prices of paid apps at a high level such that no one would purchase any app.[9] The total market shares of smartphones in the No Paid Apps Regime would decrease dramatically from 76.6% to 24.9% in Hong Kong, and from 84.2% to 33.6% in Shanghai. The total expected profits would also drop significantly (HK$1,221 per student in Hong Kong, and HK$1,343 per student in Shanghai). Paid apps contribute a lion's share of the smartphone profits (71% in Hong Kong and 59% in Shanghai). If there were no paid apps, the free apps would not be enough to make smartphones sufficiently attractive. Our results reflect that the worldwide sales of iPhones have increased four times since the opening of the App Store in 2008.

6.2 Effects of Alternative Copyrights Policies

To assess the effects of different copyright policies, we evaluate the market shares of smartphones in three different regimes. Table 8 reports the results.

Free Jailbreak. If the DMCA exemption were to draw the monetary cost of jailbreaking

[8]This may relate to the price decline in apps for Android phones being larger than that of the iPhone.

[9]To shut down the option of using paid apps, we must also shut down the option to jailbreak smartphones. If a paid app were sufficiently expensive, everyone would start jailbreaking their smartphones to gain access. Column 7 would therefore become irrelevant.

Table 8: Market Shares, Profits, and Overall Jailbreaking Percentage under Different Copyright Regimes

	Hong Kong						
	Market Shares (%)			Profit/Student (HK$)			Jailbreaking (%)
	Google	iPhone	Samsung	Google	iPhone	Samsung	All Brands
Current	44.7	14.8	17.1	1,128	274	322	65.4
	[42.1 ,47.1]	[13.2, 16.3]	[15.4, 18.9]	[1,063, 1,189]	[245, 302]	[289, 355]	[63.0, 67.7]
Free Jailbreak	44.9	14.8	17.2	1,134	275	323	66.1
	[42.3, 47.3]	[13.3, 16.3]	[15.4, 19.0]	[1,069, 1,196]	[246, 303]	[290, 356]	[63.7, 68.3]
Free Jailbreak	46.1	14.7	17.4	1,162	257	332	76.9
($\rho = 0$)	[43.4, 48.5]	[13.2, 16.2]	[15.7, 19.2]	[1,096, 1,225]	[230, 283]	[298, 366]	[75.0, 78.8]
No Jailbreak	32.5	18.5	11.2	779	466	248	0
	[29.1, 35.8]	[16.1, 21.0]	[9.6, 13.3]	[695, 857]	[405, 530]	[206, 283]	[0, 0]
	Shanghai						
	Market Shares (%)			Profit/Student (HK$)			Jailbreaking (%)
	Google	iPhone	Samsung	Google	iPhone	Samsung	All Brands
Current	42.6	16.1	25.5	1,261	366	631	74.7
	[40.5 ,44.8]	[12.6, 20.4]	[21.5, 28.6]	[1,197, 1,326]	[287, 465]	[532, 708]	[71.8, 77.4]
Free Jailbreak	42.8	16.1	25.5	1,265	366	632	75.1
	[40.6, 45.0]	[12.6, 20.4]	[21.5, 28.6]	[1,201, 1,330]	[287, 465]	[533, 708]	[72.2, 77.8]
Free Jailbreak	43.8	15.9	25.9	1,295	352	645	84.9
($\rho = 0$)	[41.7, 46.1]	[12.6, 20.1]	[22.1, 29.0]	[1,232, 1,361]	[278, 444]	[549, 720]	[83.0, 86.7]
No Jailbreak	29.7	21.0	18.2	941	863	536	0
	[27.4, 32.0]	[17.0, 25.7]	[14.7, 21.3]	[869, 1,016]	[697, 1,055]	[433, 629]	[0, 0]

The 5th and 95th percentiles of the estimates are reported in brackets.

down, we would expect the monetary cost to be very small.[10] However, it is unclear whether a lower monetary cost would be the only effect. It may also significantly lower users' psychological cost of jailbreaking. Users may believe that if were not appropriate, the Library of Congress would not have given it the "go-ahead."

In the first two regimes, therefore, we set the price of jailbreaking at zero. The first regime differs from the second in that in the second regime, both the monetary cost of jailbreaking and the utility cost, ρ, are set at zero.

In both regimes, the prevalence of jailbreaking rises. The utility cost of jailbreaking, ρ, has a much larger effect on users' decisions to jailbreak. The percentage of jailbreaking increases more than 10% when both the monetary and utility costs of jailbreaking are set at zero. However, it increases by only less than 1% when only the monetary cost of jailbreaking is set at zero.

[10]This is perhaps because more technical experts are willing to engage their time in breaking the software code restrictions. Their effort may lead to much user-friendly software that helps users jailbreak their smartphones.

Therefore, moral cost is a more important determinant of jailbreaking than monetary cost. This implies that smartphone manufacturers should combat the problem of jailbreaking by raising the moral cost instead. The iPhone's major sales strategy relies consistently on one single person: the legendary Steve Jobs, who introduced every iPhone that was on the market when he was alive. Some Apple fans who fell for his charm perceive jailbreaking an iPhone as betraying their idol.

This also suggests that when the exemption of the DMCA was up for renewal in 2012, Apple should have fought hard on it instead of being silent. While Steve Jobs had already passed away, Apple would have appealed to his fans, and protested against the exemption and tried hard to link jailbreaking emotionally to the betrayal of the deceased iconic figure. Doing so would not have overturned the Library of Congress's decision, but it would have made a difference to iPhone users.

No Jailbreak. What would happen if jailbreaking were prohibitively expensive? This case corresponds to a hypothetical situation in which the copyright policies strictly prohibit jailbreaking and are perfectly enforced.

To address this question, in the preceding regime, we shut down the option by raising the monetary cost of jailbreaking to a level such that no one would choose to jailbreak. The results are consistent with the prediction that depriving the right to choose which complementary products (in our case, apps) to use is going to decrease the attractiveness of smartphones. The total market shares of smartphones would drop dramatically in both Hong Kong (to only 14.4%) and in Shanghai (to only 15.3%).

It is also worth noting that iPhone's market share would increase in both markets (from 14.8% to 18.5% in Hong Kong, and from 16.1% to 21.0% in Shanghai) even if iPhone users were prohibited from jailbreaking their smartphones. If jailbreaking were not an option for Android users, some of those who still wanted to purchase a smartphone would switch to an iPhone, which offers cheaper paid apps. The iPhone's profit would increase as a result (from HK$274 to HK$466 in Hong Kong, and from HK$366 to HK$863 in Shanghai.)

7 Conclusion

While jailbreaking can hurt revenue income from the apps market, it may enhance the value of and demand for smartphones. In this paper, we attempt to quantify the gains for smartphone sales in the presence of jailbreaking. We designed a conjoint survey to collect a unique dataset on the consumption of different smartphones, and use it to set up and estimate a random-coeffcient discrete demand model for smartphones.

We obtain several results. First, applications and smartphones are close complements to each other. When paid apps are not available, the total market shares of smartphones drop from 74.7% to 21.9% in Hong Kong and from 80% to 33.7% in Shanghai. The total profits of all of the smartphones also drop significantly in both samples (71% in Hong Kong and 53% in Shanghai). Second, because paid apps are important to smartphone users, installing paid apps for free is an important reason for users to jailbreak. Third, while the monetary cost of jailbreaking is a determinant, it is much less important than the psychological cost users perceive. Fourth, there are heterogeneous effects on smartphone suppliers when the copyright regime shuts down jailbreaking completely. While the total market shares and profits of smartphones would decrease if jailbreaking were not possible, Apple's iPhone profits would increase 36% in Hong Kong and 84% in Shanghai.

Our results provide policy and managerial implications. First, policymakers can not only raise the monetary cost of jailbreaking (such as by penalty) as a deterrent, but also deter jailbreaking by raising its stigma through promoting copyright awareness. Second, the importance of moral cost in jailbreaking suggests that Apple should liken jailbreaking to an emotional betrayal of Steve Jobs or the entire Apple creative team as a deterrent instead of reiterating the pros and cons rationally. Finally, as consumers are less likely to jailbreak under a better enforced copyright regime, firms should focus on their price advantage in the apps market to maintain the market shares of their smartphones. We leave the app developers' responses to alternative copyright regimes to future research.

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