



Contents lists available at ScienceDirect

## Journal of Comparative Economics

journal homepage: [www.elsevier.com/locate/jce](http://www.elsevier.com/locate/jce)

## To root or not to root? The economics of jailbreak

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## ARTICLE INFO

## Article history:

Received 8 July 2015

Revised 29 July 2016

Accepted 1 August 2016

Available online 5 August 2016

## JEL Classification:

L14

L86

K42

O34

## Keywords:

Jailbreak

Demand estimation

Smartphones

App demand

## ABSTRACT

**Chao, Hong, Ho, Chun-Yu, Leung, Tin Cheuk, and Ng, Travis**—To root or not to root? The economics of jailbreak

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 utility cost rather than the upfront 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 66% and 59%) 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. *Journal of Comparative Economics* 45 (2017) 481–497. Shanghai Jiao Tong University, China; Wake Forest University, US; The Chinese University of Hong Kong, China; University at Albany, SUNY, USA.

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## 1. Introduction

Jailbreaking is a process that unlocks restrictions on smartphones imposed by either the manufacturers or carriers.<sup>1</sup> 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 Millennium Copyright Act (DMCA). In 2010, the U.S. Library of Congress granted an exemption to jailbreaking from the DMCA, which the Apple Inc tried very hard to lobby against. The exemption was renewed in 2012. 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

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<sup>1</sup> "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.

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.<sup>2</sup>

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 upfront monetary cost of jailbreaking a smartphone plays a much smaller role than the utility cost in explaining its prevalence.<sup>3</sup> 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 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, with the exception of ([Oberholzer-Gee and Strumpf, 2007](#)).<sup>4</sup> However, with the exception of ([Leung, 2015](#)), 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 consumption (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 units. On July 10, 2008, Apple launched

<sup>2</sup> We acknowledge that our sample is not representative. In particular only 39% of all smartphones were owned by people aged below 24 in 2012 according to statistics from Statista.com. Given that college students are more likely than others to jailbreak their smartphones, our results of the impacts of jailbreaking on smartphone sales can be seen as an upper bound of the true ones.

<sup>3</sup> The utility cost in our model captures factors including the hassle in updating the smartphone or the moral cost of jailbreaking.

<sup>4</sup> See ([Blackburn, 2004](#)), ([Hui and Png, 2003](#)), ([Leung, 2015](#)), ([Liebowitz, 2006](#)), ([Peitz and Waelbroeck, 2004](#)), ([Rob and Waldfogel, 2006](#)), and ([Zentner, 2006](#)). [Smith and Telang \(2012\)](#) provide a more recent review of the literature.

the App Store, which sells pre-approved apps. In the following year, the average quarterly sales surged to over 5 million units. 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.

While there is no reliable statistics on jailbreaking, some major events may give us some hints on the prevalence of jailbreaking. In early 2013, a tool called *evasi0n* was available that allows users to jailbreak their devices that run iOS6. Forbes reported that there were more than 7 million downloads within just six days since the tool's release.<sup>5</sup>

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 cannot remove unwanted apps preloaded by either the carrier or the phone manufacturer.<sup>6</sup> They may be stuck at one carrier. If they switch to another carrier or move to another country, they must obtain another phone.<sup>7</sup> However, jailbreaking is not costless. First of all, one has 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. We call this upfront monetary cost. There are also certain risks involved. One may "brick" her phone, meaning a "total loss" of the phone. Also, iPhone users need to re-jailbreak their iPhones every time they update the operating system, iOS. Given that Apple releases major update every year and minor updates almost every month, this creates a significant hassle for iPhone users in jailbreaking their iPhones. In addition, software piracy is a criminal act that infringes on the intellectual property against the app developer and thus may bear the ethical cost for the perpetrators. An Apple fan may also feel as if she is betraying Steve Jobs, in which case she suffers morally. We define all these other costs as utility cost.

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 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.<sup>8</sup> 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 EFF 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 EFF 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 EFF's proposal. They argued that jailbreaking "increases piracy of applications and is detrimental to the secure and trustworthy innovation platforms that mainstream consumers demand."

<sup>5</sup> See (Kosner, 2013).

<sup>6</sup> This motivation was reported by a survey by Tencent. We thank a referee for this pointer.

<sup>7</sup> 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.

<sup>8</sup> 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.

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 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. We acknowledge that students are not the most representative sample of the whole population. Students answered two types of questions. First, they provided information on their demographics, the brands of cellphones they used, whether they had jailbroken their smartphones, and the number of apps in their smartphones.<sup>9</sup> 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 et al., 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 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 et al., 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 et al. (1999) arrive at the same conclusion in a freight shipper choice problem. Finally, Leung (2015) and Leung (2013) extend the application of the conjoint analysis to the study of piracy.

To address the concern that students may not report their true individual preference when there is no reward and questions are hypothetical, we conducted a pilot study to obtain information on student's preferences and acceptable ranges of different covariates.

<sup>9</sup> For the number of apps, students are asked to indicate their apps consumptions in different categories, i.e. 0, 1–15, 16–30, 31–45, and 46 or above.

	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)

Fig. 1. A sample conjoint task.

### 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\$1500 to HK\$7500 as a feasible range for a 4G cell phone, HK\$100 to HK\$2000 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.<sup>10</sup> 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 enabled them to download paid apps for free. Fig. 1 presents a sample of a conjoint task in our survey.<sup>11</sup>

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 et al., 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. 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.

<sup>10</sup> 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.

<sup>11</sup> 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.

**Table 1**  
Specification of attribute levels.

	Cell phone price (HK\$)	Paid app price (HK\$)	Jailbreak price (HK\$)	Camera (megapixels)	Display (PPI)
Low	1500–3000 [100–500]	0	0	3 [0.3]	150–200 [80]
Medium Low	3000–4500 [500–1000]	1–10	5–30	5 [0.5]	200–250 [100]
Medium High	4500–6,000 [1000–1500]	11–20	35–60	8 [1.5]	260–300 [120]
High	6000–7500 [1500–2000]	21–30	65–90	12 [2]	310–350 [140]

The ranges in brackets are for 2G cell phones.

**Table 2**  
Summary statistics<sup>a</sup>.

	Hong Kong			Shanghai		
	Mean (s.d.)	Min	Max	Mean (s.d.)	Min	Max
Age	19.46 (1.36)	16	25	23.08 (2.48)	18	38
Male	0.57 (0.50)	0	1	0.54 (0.50)	0	1
Have used BT recently	0.46 (0.50)	0	1	0.71 (0.46)	0	1
Hours spent on internet/day	4.55 (6.44)	0.5	24	5.18 (2.91)	0.3	20
Jailbreak	0.15 (0.36)	0	1	0.29 (0.45)	0	1
Live with family	0.81 (0.39)	0	1	0.39 (0.49)	0	1
Income (0–6)	3.17 (1.60)	0	6	2.17 (1.44)	0	6

<sup>a</sup> The coding for the variable “Income” is 0 for HK\$0 to 10,000, 1 for HK\$10,001 to 20,000, 2 for HK\$20,001 to 30,000, 3 for HK\$30,001 to 40,000, 4 for HK\$40,001 to 50,000, 6 for HK\$50,001 or above.

### 3.2. Summary statistics

Table 2 describes the demographics and some of the behavior of the students in the sample. Some of the Hong Kong students’ demographics are similar to those from Shanghai. They share similar ages (averaging 19.46 and 23.08 in Hong Kong and Shanghai, respectively). Males compose a slight majority of the sample (57% in Hong Kong and 54% in Shanghai).

However, while most Hong Kong students (81%) live with their family, only 39% of the Shanghai students do. Also, Hong Kong students’ average family income is higher than that of Shanghai students’.

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, 46% 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 (15%). Though the statistics for jailbreak is likely to be lower than it actually is for two reasons. First, students might not want to report that they have actually “broken” the law. Second, many of the students are freshmen in universities and are thus still using old cell phones (which do not have functions of the latest smartphones) purchased by parents. Indeed, in our samples, approximately 1/4 of the students indicated that they were using cell phones such as Sony and Nokia which do not have Apple’s and Android’s operating systems, while more than 40% of iPhones and Samsung Galaxy users have jailbroken their smartphones.

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.

### 4. The demand model and estimation

We build a demand model for cell phones following (Iyengar et al., 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  $i \in \{1, \dots, I\}$  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

$$\hat{u}_{ij} = \alpha_i \mathbf{x}_j. \quad (1)$$

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 upfront monetary price for jailbreaking. There is also a (fixed) utility cost,  $\rho_{ij}$ , of jailbreaking. As described in the previous section,

**Table 3**  
Logit regression of jailbreaking<sup>a</sup>.

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

<sup>a</sup> Standard errors are reported in brackets. \*\*\*, \*\*, and \* indicate significance at the 1%, 5% and 10% levels.

the monetary costs for jailbreaking are varied exogenously in the conjoint survey. This helps us to separately identify the effect of monetary and psychological cost on jailbreaking behaviour. As we mentioned before, the utility cost can capture factors including the hassle in updating the smartphone or the moral cost of jailbreaking.<sup>12</sup> 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  $\epsilon_{ijk}$  to be distributed i.i.d. extreme value and that  $\zeta_{ij}$  has a distribution that depends on  $\sigma_i$  such that  $\sigma_i \in [0, 1]$  and assume  $\zeta_{ij} + (1 - \sigma_i)\epsilon_{ijk}$  to be distributed extreme value. The value of  $\sigma_i$  has implication on the individual’s brand loyalty. If  $\sigma_i$  is close to one,  $\zeta_{ij}$  is a stronger driving force for smartphone choices, indicating a stronger brand preference.

The utility of consumer  $i$  choosing cell phone  $j$  with jailbreak option  $k$  can then be written as

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

where

$$z_{ij}^a = w_i - f_j^a - p_j^a n_{ij}^a;$$

$$z_{ij}^b = w_i - f_j^a - f_j^b - p_j^b n_{ij}^b.$$

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):

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

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

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

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

$$\equiv \bar{u}_{ij}^k + \zeta_{ij} + (1 - \sigma_i)\epsilon_{ijk} \tag{6}$$

Let  $\mathbf{P} = [p_1^a; \dots; p_j^a; p_1^b; \dots; p_j^b; f_1^a; \dots; f_j^a; f_1^b; \dots; f_j^b]$  be a vector of prices and  $\Theta = [\alpha_i; \beta_{i1}; \beta_{i2}; \beta_{i3}; \rho_{ij}; \sigma_i]$  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  $k$ :

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

<sup>12</sup> We do not restrict  $\rho_{ij}$  to be negative. If consumers enjoy the process of jailbreaking,  $\rho_{ij}$  can be positive.

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

#### 4.1. Estimation

To exploit the panel structure of our data, we follow (Rossi et al., 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 et al., 2005), we assume that the unobserved heterogeneity is distributed as a  $K$  mixture of normal. The demand model can therefore be expressed as follows:

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

where  $\gamma$  is a vector giving the mixture probabilities for each of the  $K$  components.  $\Delta$  is an  $n_z \times 6$  matrix of parameters that determines the effects of demographics on each utility coefficient. We define  $\delta = \text{vec}(\Delta)$  for ease of illustration. The individual-level demand parameters for student  $i$ ,  $\Theta_i$ , 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  $\delta$  (the demographics parameters),  $\gamma$  (the mixture probabilities for each of the  $K$  components) and  $\mu_k$  and  $\Sigma_k$  (the mean and variance-covariance matrix of the  $k$ th-component of the distribution of the unobserved heterogeneity,  $u_i$ ).

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

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

where the joint prior on  $\mu_k$  and  $\Sigma_k$  is independent conditional on  $\gamma$ . As in many panel data, there is a subset of students who do not purchase from the complete set of products. Prior about the parameters will be important for this set of students. We follow (Rossi et al., 2005) to use informative priors. For instance, to avoid implausible intercept values of  $-20$  or  $+20$ , we set  $a_\mu$  to  $1/16$ . The prior on  $\Sigma_k$  is also important. A tight prior around a small value would force us to use a large number of components to fit the data. We again follow (Rossi et al., 2005) to use a relatively diffuse prior by setting  $v$  to  $nvar + 3$  and  $V = v\mathbf{I}$ , where  $nvar$  is the number of coefficients.

We follow the standard Bayesian estimation of the multinomial logit model as in Rossi et al. (2005) except for several differences. First, we do not observe  $n^k$  and thus need to calculate its value using the draws of  $\beta_{i1}$ ,  $\beta_{i2}$ ,  $\beta_{i3}$  from each MCMC draw. We use the draws to calculate the values of  $n^k$  using Eqs. (4) and (5), which are then used to compute the demand for cell phone  $j$  in Eq. (7). The exogenous variations in the phone and jailbreak prices bring variations in the consumption of composite good, while the exogenous variations in the prices of paid apps (and the square terms of these prices) bring variations in the consumption of paid apps. These help us to identify  $\beta_{i1}$ ,  $\beta_{i2}$ ,  $\beta_{i3}$ . 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

Fig. 2 displays the kernel density of the individual-level coefficients from the two-component model.<sup>13</sup> There are several things to note. First, in both cities, the distributions of the dummy coefficients for Nokia are not very different from those

<sup>13</sup> We only keep the draws after the 5000th iteration for all the results reported in the paper. In unreported results, we use MCMC convergence to provide some visual diagnostics of our estimation.

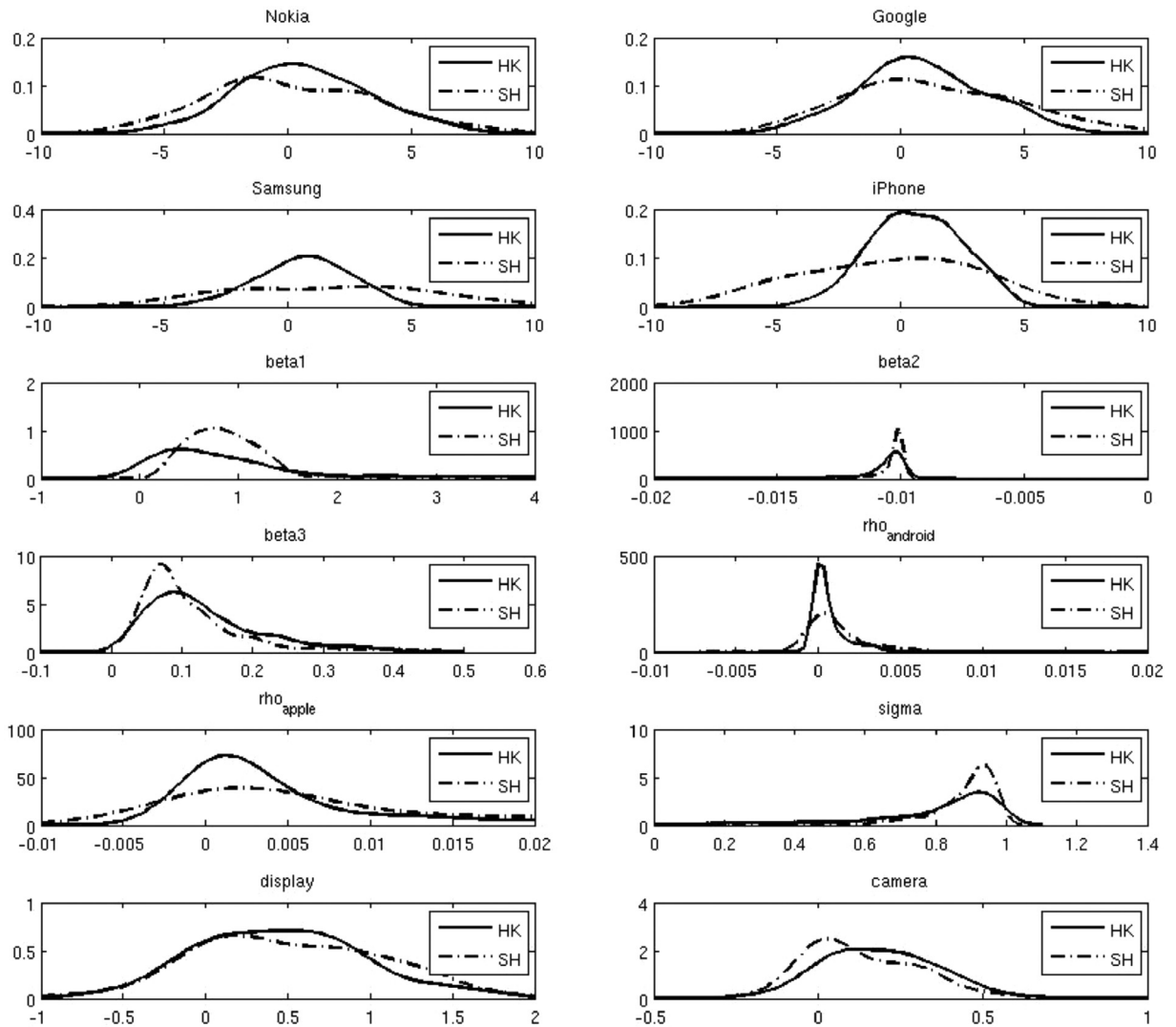


Fig. 2. Kernel density of coefficients estimates.

of other smartphones. This indicates that the availability of apps contributes significantly to the higher market shares of smartphones.

Second, the parameter  $\sigma$  captures the role of brand loyalty played in smartphone choice. In fact, our model nests the random coefficient logit model without a nest, which does not consider brand loyalty in consumers' smartphone choice, by having an extra parameter of  $\sigma$ . Our results show that the parameter  $\sigma$  for both Hong Kong and Shanghai samples are close to one, which suggests that our model is more preferable than the random coefficient logit model without a nest. In other words, brand loyalty plays a role in the smartphone choice of our respondents. However,  $\sigma$  is smaller and more spread out in the Shanghai sample, which indicates that  $\zeta_{ij}$  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.

The estimates of  $\beta_1$  and  $\beta_2$  determine the demand for apps. The estimate of  $\beta_1$  is higher in Shanghai and in Hong Kong. There is a diminishing marginal utility in consuming apps. Table 4 compares the apps demand that the students report in the survey and our estimates. We derive the apps demand from the first order conditions in equations (4) and (5), using the individual-specific demand estimates obtained from the estimation. Our estimates slightly underestimate the apps demand for Hong Kong students: more students would have 0–15 apps in their smartphones in our estimates than in the actual data. And our estimates overestimate the apps demand for Shanghai students: more students would have more than 45 apps in our estimates than in the actual data. However, given that this is not a moment that we try to match in our estimation, our estimates fit the data reasonably well.

**Table 4**  
Apps demand.

	Hong Kong		Shanghai	
	Data	Estimates	Data	Estimates
0–15 apps	39%	50%	32%	32%
16–30 apps	32%	22%	36%	18%
31–45 apps	15%	12%	14%	14%
More than 45 apps	14%	16%	19%	36%

**Table 5**  
Price elasticities.

With respect to	Hong Kong			
	Nokia	Google	Samsung	iPhone
Nokia's price	–0.25 [–0.29, –0.22]	0.06 [0.05, 0.07]	0.02 [0.02, 0.03]	0.02 [0.02, 0.03]
Google's price	0.99 [0.81, 1.18]	–1.26 [–1.38, –1.17]	1.04 [0.92, 1.17]	0.94 [0.81, 1.07]
Samsung's price	0.18 [0.14, 0.22]	0.57 [0.49, 0.65]	–2.68 [–2.94, –2.42]	0.79 [0.70, 0.91]
iPhone's price	0.21 [0.15, 0.28]	0.51 [0.44, 0.60]	0.79 [0.64, 0.97]	–2.77 [–3.02, –2.52]
With respect to	Shanghai			
	Nokia	Google	Samsung	iPhone
Nokia's price	–0.22 [–0.27, –0.17]	0.04 [0.03, 0.05]	0.02 [0.01, 0.02]	0.01 [0.01, 0.02]
Google's price	0.77 [0.59, 0.98]	–1.27 [–1.41, –1.15]	0.86 [0.77, 0.96]	0.72 [0.58, 0.87]
Samsung's price	0.32 [0.24, 0.40]	0.81 [0.70, 0.93]	–1.84 [–2.05, –1.66]	0.81 [0.65, 0.98]
iPhone's price	0.13 [0.08, 0.21]	0.34 [0.27, 0.43]	0.41 [0.31, 0.52]	–2.16 [–2.49, –1.82]

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

To assess the price sensitivity, we see that the price coefficients are smaller in Shanghai. The parameter  $\beta_3$  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 5 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. 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 –0.25 and –0.22 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 2.68%, and Shanghai students' demand drops by only 1.84%. When the price of the iPhone goes up by 1%, Hong Kong students' demand for the iPhone drops by 2.77%, and Shanghai students' demand drops by only 2.16%.

In both samples, the smartphones are closer substitutes among themselves than for Nokia, 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 0.51%–0.79% increase in demand for the Google phone and Samsung, but only an approximate 0.2% increase in demand for the Nokia.

Table 6 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 ( $\beta_3$ ) 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. Further, students with a higher family income tend to have a smaller price coefficient and are therefore less price sensitive.

Third, the utility cost of jailbreaking ( $\rho$ ) is correlated with some of the demographics. Male students in both Hong Kong and Shanghai have a lower utility cost of jailbreaking iPhones ( $\rho_{apple}$ ), and male students in Shanghai have a lower utility cost of jailbreaking both iPhones ( $\rho_{apple}$ ) and Android phones ( $\rho_{android}$ ). Further, Hong Kong students with recent

**Table 6**  
Coefficients explained by demographics.

	Hong Kong											
	Nokia	Google	Samsung	iPhone	$\log(\beta_1)$	$\log(-\beta_2)$	$\log(\beta_3)$	$\rho_{apple}$	$\rho_{android}$	$\log(1 - \sigma)$	Display	Camera
Age	-0.18 (0.22)	-0.09 (0.21)	0.08 (0.19)	-0.00 (0.21)	0.09 (0.06)	0.28 (0.16)	-0.02 (0.02)	0.66 (0.26)	0.41 (0.20)	0.09 (0.06)	0.03 (0.03)	-0.01 (0.01)
Male	-0.65 (0.42)	-0.12 (0.42)	-0.41 (0.45)	-0.54 (0.41)	-0.11 (0.10)	-1.06 (0.36)	0.25 (0.05)	-0.78 (0.51)	0.29 (0.51)	0.33 (0.16)	0.05 (0.10)	0.03 (0.02)
Live with Family	-0.66 (0.54)	-0.56 (0.52)	-0.37 (0.55)	-0.27 (0.52)	0.17 (0.15)	2.72 (0.87)	0.19 (0.08)	0.54 (0.76)	0.30 (0.73)	-0.19 (0.23)	0.27 (0.13)	0.06 (0.03)
Income (0–6)	0.39 (0.13)	0.46 (0.13)	0.33 (0.14)	0.38 (0.14)	-0.03 (0.04)	-0.05 (0.18)	-0.04 (0.02)	0.04 (0.22)	0.10 (0.16)	-0.06 (0.04)	-0.01 (0.03)	-0.00 (0.01)
BT	-0.80 (0.42)	-0.73 (0.41)	-1.13 (0.41)	-0.64 (0.41)	0.21 (0.11)	0.73 (0.38)	-0.06 (0.06)	-1.93 (0.58)	-1.40 (0.45)	-0.27 (0.19)	-0.15 (0.11)	-0.03 (0.02)
Internet Per Day	-0.05 (0.03)	-0.02 (0.02)	-0.04 (0.03)	-0.04 (0.03)	-0.01 (0.01)	-0.01 (0.05)	-0.01 (0.01)	-0.19 (0.08)	-0.17 (0.06)	-0.02 (0.01)	0.01 (0.01)	-0.00 (0.00)
	Shanghai											
	Nokia	Google	Samsung	iPhone	$\log(\beta_1)$	$\log(-\beta_2)$	$\log(\beta_3)$	$\rho_{apple}$	$\rho_{android}$	$\log(1 - \sigma)$	Display	Camera
Age	-0.16 (0.12)	-0.07 (0.12)	0.19 (0.13)	-0.27 (0.17)	-0.00 (0.03)	-0.11 (0.21)	-0.02 (0.02)	0.29 (0.13)	0.12 (0.10)	0.01 (0.04)	-0.02 (0.03)	0.01 (0.01)
Male	-1.35 (0.53)	-0.90 (0.52)	-0.66 (0.45)	0.16 (0.66)	-0.14 (0.12)	-1.39 (0.58)	0.16 (0.07)	-0.93 (0.53)	-1.24 (0.91)	0.15 (0.16)	0.02 (0.11)	-0.02 (0.02)
Live with Family	-0.83 (0.46)	-0.50 (0.52)	-1.48 (0.50)	-0.35 (0.59)	0.06 (0.13)	-1.64 (0.59)	-0.02 (0.08)	1.25 (0.68)	-0.10 (0.62)	0.17 (0.19)	-0.32 (0.12)	-0.02 (0.03)
Income (0–6)	-0.31 (0.21)	-0.47 (0.19)	-0.45 (0.19)	-0.22 (0.22)	0.02 (0.04)	-0.77 (0.25)	-0.09 (0.02)	0.36 (0.20)	0.87 (0.22)	0.07 (0.06)	-0.01 (0.04)	0.00 (0.01)
BT	-0.77 (0.47)	-2.30 (0.40)	-1.80 (0.41)	-0.49 (0.58)	0.23 (0.15)	0.13 (0.84)	-0.08 (0.08)	-1.12 (0.52)	0.64 (0.88)	-0.02 (0.21)	0.36 (0.15)	0.06 (0.03)
Internet Per Day	-0.03 (0.12)	0.20 (0.11)	0.08 (0.12)	-0.17 (0.13)	-0.05 (0.02)	-0.53 (0.18)	0.02 (0.01)	0.14 (0.12)	0.26 (0.12)	0.05 (0.03)	-0.07 (0.02)	-0.00 (0.01)

The standard deviations of the estimates are reported in brackets.

experience using BitTorrent (BT) have a lower utility cost of jailbreaking both iPhones and Android phones, while their Shanghai counterparts have a lower utility cost of jailbreaking iPhones only. Shanghai students who have a higher family income seem to incur a higher utility cost of jailbreaking.

In addition to piracy, there are some non-financial motives for jailbreaking. These include the possibility to unlock certain blocked features and to remove unwanted apps preloaded by smartphones. According to a survey by Tencent, one of the reasons for jailbreaking is the removal of unwanted apps preloaded by the networks.<sup>14</sup> However, the possibility of voiding the warranty may deter people from jailbreaking their smartphones. These incentives and disincentives are different between an iPhone and an Android phone. For instance, the benefit of unlocking an iPhone might be higher than unlocking an Android phone. However, the number of unwanted preloaded apps in Android phones is higher and the harm of losing the iPhone warranty might be higher. It is unclear a priori whether these non-financial factors are more important for iPhones or Android phones. In the results, we found that the ratio of utility cost of jailbreaking Android and utility cost of jailbreaking iPhones ( $\frac{\rho_{android}}{\rho_{apple}}$ ) are below 1 in both Hong Kong and Shanghai, with an average of 0.56 and 0.88, respectively, which indicates that the psychological costs of jailbreaking an iPhone is higher in both cities. We regress this ratio on some demographic variables. Table 7 shows that male students tend to find this more important, and Shanghai students with BT experience (who are more likely to download illegal free apps) tend to find this less important.

## 6. Counterfactuals

We conduct several counterfactuals to examine the importance of paid apps and the effects of different copyright regimes. Table 8 describes the current regime in both Hong Kong and Shanghai.<sup>15</sup>

We calculate the predicted market shares and profits of the different smartphones and the predicted prevalence of jailbreaking in seven regimes.<sup>16</sup> Among each of these, the users' choice of phones, whether they would jailbreak, the number of paid apps demanded, and the corresponding profit-maximizing prices of the phone manufacturers are all endogenously determined.

<sup>14</sup> See <http://www.chinainternetwatch.com/12926/80-china-smartphone-users-rooted/>. We thank a referee for the pointer.

<sup>15</sup> The prices and specifications of the cellphones were obtained on <http://www.price.com.hk/> at the time of the study. The prices of paid apps were obtained at <http://www.canalys.com/newsroom/android-apps-are-too-expensive>. The price of jailbreaking was obtained from our own observations at the stores at the time of the study.

<sup>16</sup> We back out the marginal costs of different smartphones using the elasticities estimates in Table 5 and the inverse elasticity rule.

**Table 7**  
Regression of utility costs of jailbreaking.

	Hong Kong	Shanghai
Age	0.07 [−0.05, 0.20]	−0.05 [−0.12, 0.02]
Male	−0.54 [−0.92, −0.17]	−0.25 [−0.56, 0.05]
Live with family	0.28 [−0.17, 0.73]	−0.74 [−1.09, −0.41]
Income (0–6)	0.02 [−0.09, 0.13]	−0.05 [−0.15, 0.05]
BT	−0.02 [−0.38, 0.35]	0.52 [0.18, 0.87]
Internet per day	−0.01 [−0.03, 0.02]	−0.05 [−0.11, 0.01]
Constant	−0.81 [−3.29, 1.68]	2.46 [0.85, 4.06]
N	321	234

95% confidence intervals are reported in brackets.

**Table 8**  
Current cellphone market.

	Google	iPhone	Samsung	Nokia
Price (HK\$)	3698	5588	5598	620
Paid apps price (HK\$)	30	11	30	NA
Jailbreak price (HK\$)	50	50	50	NA
Display (PPI)	316	326	306	200
Camera (megapixel)	5	8	8	1.3

### 6.1. Do paid apps determine jailbreaking?

Apps are key to smartphones. Table 9 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.<sup>17</sup> Does that mean that paid apps are therefore not important? The second result suggests otherwise. Column 7 shows that the prevalence of jailbreaking falls significantly (from 59.4% to 20.4% in Hong Kong and from 68.6% to 23.7% 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 smartphones. 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 1.2% and 0.9% in Hong Kong and Shanghai, respectively. This reflects the low substitutability between smartphones and Nokia, as shown in Table 5. 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\$25 per student) and in Shanghai (HK\$27 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.<sup>18</sup>

**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.

<sup>17</sup> However, there are only slight changes in the market shares and profits of smartphones. This is likely driven by  $\sigma$  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).

<sup>18</sup> This may relate to the price decline in apps for Android phones being larger than that of the iPhone.

**Table 9**

The effects of apps pricing on market shares, profits, and overall jailbreaking percentage.

	Hong Kong						
	Market shares (%)			Profit/student (HK\$)			Jailbreaking (%)
	Google	iPhone	Samsung	Google	iPhone	Samsung	All brands
Current	44.1 [41.7, 46.3]	14.9 [13.1, 16.7]	16.0 [14.7, 17.4]	1,149 [1,086, 1,208]	284 [250, 318]	300 [274, 325]	59.4 [57.6, 61.3]
Free apps	45.2 [42.9, 47.4]	14.9 [13.2, 16.5]	16.3 [15.0, 17.7]	1,182 [1,123, 1,239]	264 [233, 292]	312 [286, 337]	20.4 [19.4, 21.5]
Free android apps	45.5 [43.3, 47.6]	13.3 [11.8, 14.7]	16.9 [15.7, 18.3]	1,217 [1,158, 1,274]	233 [207, 258]	332 [306, 358]	26.6 [25.4, 27.9]
Free iPhone apps	43.6 [41.1, 46.0]	16.2 [14.1, 18.6]	15.5 [14.0, 16.8]	1,122 [1,059, 1,184]	331 [288, 380]	285 [258, 310]	52.5 [50.8, 54.5]
No paid apps	12.7 [11.1, 14.2]	3.9 [3.0, 4.7]	7.6 [6.1, 9.1]	344 [301, 384]	98 [76, 120]	142 [115, 169]	5.96 [5.17, 6.71]
	Shanghai						
	Market shares (%)			Profit/student (HK\$)			Jailbreaking (%)
	Google	iPhone	Samsung	Google	iPhone	Samsung	All brands
Current	39.9 [37.6, 42.3]	12.5 [10.6, 14.9]	27.5 [25.1, 29.7]	1,129 [1,063, 1,195]	307 [259, 366]	746 [681, 807]	68.6 [66.2, 71.1]
Free apps	40.6 [38.3, 43.1]	12.6 [10.7, 14.9]	27.6 [25.4, 29.7]	1,150 [1,085, 1,219]	302 [257, 357]	757 [696, 815]	23.7 [22.8, 24.5]
Free android apps	41.0 [38.6, 43.4]	11.6 [9.8, 13.8]	28.1 [25.8, 30.1]	1,171 [1,105, 1,241]	275 [232, 329]	777 [714, 833]	30.7 [29.3, 32.2]
Free iPhone apps	39.6 [37.3, 41.9]	13.5 [11.4, 15.9]	27.0 [24.6, 29.2]	1,113 [1,049, 1,178]	341 [290, 703]	728 [663, 789]	60.6 [58.0, 63.3]
No paid apps	15.7 [14.1, 17.4]	3.7 [2.2, 5.3]	16.5 [14.6, 18.3]	443 [398, 793]	94 [56, 136]	444 [393, 492]	8.0 [6.9, 9.2]

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

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 eliminating the options to purchase apps with either non-jailbroken or jailbroken smartphones. The total market shares of smartphones in the No Paid Apps Regime would decrease dramatically from 75% to 24.2% in Hong Kong, and from 79.9% to 35.9% in Shanghai. The total expected profits would also drop significantly (HK\$1149 per student in Hong Kong, and HK\$1201 per student in Shanghai). Paid apps contribute a lion's share of the smartphone profits (66% 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 10 reports the results.

**Cost of jailbreaking** If the DMCA exemption were to draw the upfront monetary cost of jailbreaking down, we would expect the upfront monetary cost to be very small.<sup>19</sup> However, it is unclear whether a lower upfront monetary cost would be the only effect. It may also significantly lower users' utility cost of jailbreaking. Users may believe that if it were not appropriate, the Library of Congress would not have given it the "go-ahead."

In the first five regimes, therefore, we set the various prices of jailbreaking at zero. The upfront monetary cost ( $f_j^{fb}$ ) is set at zero in all five Free Jailbreak regimes except the second one. In the first Free Jailbreak regime, while the monetary cost is zero, the utility costs of jailbreaking are kept as before. The second Free Jailbreak regime reverse the first one, i.e., the monetary cost is kept as before while the utility costs of jailbreaking are set at zero. In the third Free Jailbreak regime, the utility costs of jailbreaking iPhones ( $\rho_{apple}$ ) and Android phones ( $\rho_{android}$ ) are set at zero. In the fourth Free Jailbreak regime, the utility cost of jailbreaking Android phones is set at zero. In the fifth Free Jailbreak regime, the utility cost of jailbreaking iPhones is set at zero.

<sup>19</sup> 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.

**Table 10**  
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	44.1	14.9	16.0	1,149	284	300	59.4
	[41.7, 46.3]	[13.1, 16.7]	[14.7, 17.4]	[1,086, 1,208]	[250, 318]	[274, 325]	[57.6, 61.3]
Free jailbreak (\$=0)	44.3	15.0	16.1	1,155	285	300	60.3
	[41.9, 46.5]	[13.2, 16.8]	[14.8, 17.5]	[1,069, 1,196]	[246, 303]	[290, 356]	[58.5, 62.2]
Free jailbreak ( $\rho_{android} \cdot \rho_{apple} = 0$ )	45.1	15.2	16.3	1,175	273	310	68.6
	[42.7, 47.6]	[13.3, 16.9]	[14.9, 17.7]	[1,086, 1,220]	[235, 289]	[296, 363]	[68.8, 71.9]
Free jailbreak (\$=0, $\rho_{android} \cdot \rho_{apple} = 0$ )	45.5	15.2	16.4	1,187	269	312	71.5
	[43.1, 47.9]	[13.4, 16.9]	[15.0, 17.7]	[1,096, 1,225]	[230, 283]	[298, 366]	[69.8, 73.4]
Free jailbreak ( $\rho_{android} = 0$ )	46.0	13.6	16.9	1,226	233	334	69.5
	[43.7, 48.4]	[12.0, 15.1]	[15.5, 18.3]	[1,096, 1,225]	[230, 283]	[298, 366]	[67.7, 71.3]
Free jailbreak ( $\rho_{apple} = 0$ )	43.6	16.1	15.9	1,140	357	293	64.4
	[41.1, 46.0]	[13.9, 18.5]	[14.5, 17.3]	[1,096, 1,225]	[230, 283]	[298, 366]	[62.1, 66.5]
Higher jailbreak cost ( $\rho_{apple} \times 3$ )	44.3	13.6	16.6	1,178	257	317	57.8
	[42.0, 46.6]	[11.8, 15.2]	[15.2, 17.9]	[1,117, 1,237]	[224, 288]	[291, 343]	[56.0, 60.0]
No jailbreak	31.3	18.4	10.8	776	526	236	0
	[28.8, 33.8]	[16.0, 20.8]	[9.6, 12.0]	[695, 857]	[405, 530]	[206, 283]	[0, 0]
Shanghai							
	Market shares (%)			Profit/student (HK\$)			Jailbreaking (%)
	Google	iPhone	Samsung	Google	iPhone	Samsung	All brands
	Current	39.9	12.5	27.5	1,129	307	746
	[37.6, 42.3]	[10.6, 14.9]	[25.1, 29.7]	[1,063, 1,195]	[259, 366]	[681, 807]	[66.2, 71.1]
Free jailbreak (\$=0)	40.1	12.6	27.5	1,132	307	747	69.4
	[37.8, 42.4]	[10.6, 15.0]	[25.2, 29.8]	[1,067, 1,198]	[260, 366]	[682, 807]	[67.1, 71.9]
Free jailbreak ( $\rho_{android} \cdot \rho_{apple} = 0$ )	40.4	12.5	27.5	1,143	304	754	74.2
	[38.1, 42.8]	[10.6, 14.8]	[25.2, 29.6]	[1,076, 1,210]	[257, 359]	[693, 813]	[73.0, 76.9]
Free jailbreak ( $\rho_{android} = 0$ )	40.5	12.5	27.5	1,145	303	756	76.6
	[38.2, 42.9]	[10.6, 14.8]	[25.2, 29.6]	[1,079, 1,213]	[257, 358]	[695, 814]	[74.1, 78.8]
Free jailbreak ( $\rho_{apple} = 0$ )	40.6	12.3	27.5	1,152	295	761	76.2
	[38.3, 43.0]	[10.4, 14.8]	[25.2, 29.6]	[1,085, 1,218]	[250, 351]	[698, 817]	[73.7, 78.5]
Free jailbreak ( $\rho_{apple} = 0$ )	40.0	12.8	27.5	1,126	317	740	70.0
	[37.7, 42.3]	[10.9, 15.1]	[25.3, 29.8]	[1,061, 1,193]	[270, 375]	[679, 803]	[67.9, 72.4]
Higher jailbreak cost ( $\rho_{apple} \times 3$ )	40.3	11.8	27.6	1,145	277	763	67.6
	[38.0, 42.5]	[9.9, 14.4]	[25.1, 29.9]	[1,078, 1,207]	[232, 338]	[695, 825]	[65.1, 70.1]
No jailbreak	29.2	17.0	20.5	866	747	643	0
	[27.0, 31.7]	[14.2, 19.8]	[18.6, 22.6]	[798, 939]	[622, 872]	[583, 708]	[0, 0]

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

The prevalence of jailbreaking rises in all five Free Jailbreak regimes. The utility cost of jailbreaking,  $\rho$ , has a much larger effect on users' decisions to jailbreak. In both Hong Kong and Shanghai, the percentage of jailbreaking increases more when we inhibit the utility costs of jailbreaking than when we inhibit the monetary cost of jailbreaking.

These suggest that utility cost is a more important determinant of jailbreaking than upfront monetary cost. When both  $\rho_{apple}$  and  $\rho_{android}$  are set at zero, the percentage of jailbreaking increases 11.2% in Hong Kong and 7.2% in Shanghai. As we discussed, the utility costs of jailbreaking can potentially capture various factors. One of the factors is the hassle in dealing with frequent updates. Another factor is the moral cost of jailbreaking; jailbreaking may be perceived as a criminal act against the app developer and some Apple fans who fell for Steve Job's charm perceive jailbreaking an iPhone as betraying their idol.

To assess the importance of the utility cost of jailbreaking iPhones, we hypothetically increase  $\rho_{apple}$  by three times. This can be done by increasing the frequency (and thus the hassle) of updates, or by a marketing campaign emphasizing the morality of not jailbreaking one's iPhone. The overall percentage of jailbreaking decreases 1.6% in Hong Kong and 1% in Shanghai. Apple's profits from iPhones drop HK\$27 (or approximately 10%) in Hong Kong and HK\$30 (also approximately 10%) in Shanghai. Since our analysis does not include the platform's lost loyalty revenue from the app developer's side of the market, the profit impact for Apple can be understood as an lower bound whereas the profit impacts for Google and Samsung can be understood as an upper bound.

**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 upfront 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

**Table 11**  
Profits between jailbreakers and non-jailbreakers under different copyright regimes.

	Non-jailbreak student (Hong Kong)				
	Google's profit	iPhone's profit	Samsung's profit	Smartphone's profit	Consumers' welfare
Free jailbreak ( $\$=0$ )	+0.56%	+0.23%	+0.23%	+0.42%	+3.07%
Free jailbreak ( $\rho_{android} \cdot \rho_{apple} = 0$ )	+3.04%	-5.35%	+4.17%	+1.73%	+6.08%
Free jailbreak ( $\$=0, \rho_{android} \cdot \rho_{apple} = 0$ )	+3.83%	-5.77%	+4.65%	+2.04%	+8.75%
Free jailbreak ( $\$=0, \rho_{android} = 0$ )	+8.37%	-20.17%	+13.28%	+3.56%	+1.65%
Free jailbreak ( $\$=0, \rho_{apple} = 0$ )	-1.31%	+27.43%	-2.90%	+4.24%	+0.35%
Higher jailbreak cost ( $\rho_{apple} \times 3$ )	+3.19%	-10.04%	+6.40%	+1.16%	-3.37%
No jailbreak	-29.59%	+77.24%	-17.76%	-5.22%	-13.87%
Jailbreak student (Hong Kong)					
	Google's profit	iPhone's profit	Samsung's profit	Smartphone's profit	Consumers' welfare
Free jailbreak ( $\$=0$ )	+0.50%	+0.29%	+0.26%	+0.42%	+3.71%
Free jailbreak ( $\rho_{android} \cdot \rho_{apple} = 0$ )	+0.31%	+0.67%	-0.99%	+0.16%	+4.58%
Free jailbreak ( $\$=0, \rho_{android} \cdot \rho_{apple} = 0$ )	+0.19%	+0.84%	-1.28%	+0.01%	+6.94%
Free jailbreak ( $\$=0, \rho_{android} = 0$ )	+1.60%	-1.04%	+1.51%	+1.16%	+1.29%
Free jailbreak ( $\$=0, \rho_{apple} = 0$ )	-0.13%	+4.58%	-3.20%	+2.73%	+0.04%
Higher jailbreak cost ( $\rho_{apple} \times 3$ )	+2.52%	-7.19%	+4.42%	+1.35%	-4.30%
No jailbreak	-42.55%	+156.39%	-27.83%	-7.85%	-28.40%
Jailbreak Student (Shanghai)					
	Google's profit	iPhone's profit	Samsung's profit	Smartphone's profit	Consumers' welfare
Free jailbreak ( $\$=0$ )	+0.31%	+0.02%	+0.03%	+0.17%	+3.32%
Free jailbreak ( $\rho_{android} \cdot \rho_{apple} = 0$ )	+1.19%	-2.06%	+1.57%	+0.85%	+4.01%
Free jailbreak ( $\$=0, \rho_{android} \cdot \rho_{apple} = 0$ )	+1.50%	-2.88%	+1.83%	+1.03%	+5.46%
Free jailbreak ( $\$=0, \rho_{android} = 0$ )	+2.07%	-5.92%	+2.75%	+1.24%	+3.95%
Free jailbreak ( $\$=0, \rho_{apple} = 0$ )	-0.26%	+4.31%	-1.10%	+0.06%	+3.57%
Higher jailbreak cost ( $\rho_{apple} \times 3$ )	+1.49%	-10.89%	+2.76%	+0.28%	-1.20%
No jailbreak	-18.09%	+123.89%	-9.55%	+3.89%	-25.68%
Non-jailbreak student (Shanghai)					
	Google's profit	iPhone's profit	Samsung's profit	Smartphone's profit	Consumers' welfare
Free jailbreak ( $\$=0$ )	+0.28%	+0.05%	+0.07%	+0.17%	+4.25%
Free jailbreak ( $\rho_{android} \cdot \rho_{apple} = 0$ )	+1.23%	+1.39%	-0.07%	+0.66%	+4.53%
Free jailbreak ( $\$=0, \rho_{android} \cdot \rho_{apple} = 0$ )	+1.54%	+1.60%	-0.03%	+0.96%	+5.09%
Free jailbreak ( $\$=0, \rho_{android} = 0$ )	+1.85%	-0.07%	+0.35%	+1.08%	+3.80%
Free jailbreak ( $\$=0, \rho_{apple} = 0$ )	-0.11%	+1.67%	-0.15%	+0.15%	+5.03%
Higher jailbreak cost ( $\rho_{apple} \times 3$ )	+1.37%	-7.54%	+1.23%	-0.06%	-1.35%
No jailbreak	-34.34%	+279.39%	-23.55%	+2.30%	-36.08%

of smartphones. The total market shares of smartphones would drop dramatically in both Hong Kong (from 75% to 60.5%) and in Shanghai (from 79.9% to 66.7%).

It is also worth noting that iPhone's market share would increase in both markets (from 14.9% to 18.4% in Hong Kong, and from 12.5% to 17.0% 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\$284 to HK\$526 in Hong Kong, and from HK\$307 to HK\$747 in Shanghai.) However, to conclude this analysis with a caveat, the fall of Android market shares caused by the no-jailbreak regime can be partly mitigated by the increased entry in the paid apps market, which drives down the apps prices and deters the customers from switching.

### 6.3. Copyright regimes: jailbreakers vs non-jailbreakers

The copyright regimes considered in Section 6.2 might have different impacts on different groups of consumers. In particular, those who are jailbreaking their current smartphones might react differently to those who are not. Because we know the actual jailbreaking behavior from the first part of our survey, we are able to compare the impacts of the various copyright regimes on these two groups of students.

We calculate the changes in profits and consumer welfare from the current regime to other copyright regimes in Table 11.<sup>20</sup> The first two sub-tables compare the non-jailbreak students and jailbreak students in Hong Kong. The last two sub-tables compare the non-jailbreak students and jailbreak students in Shanghai. Under the copyright regimes in which either one or both utility costs of jailbreaking become zero, the changes of consumer welfare between the two groups are similar. However, from the smartphone producers' point of view, the non-jailbreak students (who have higher utility costs on average) have a larger response to these regimes than do the jailbreak students. For instance, when the utility cost of jailbreaking an iPhone becomes zero, the profit per non-jailbreak student goes up by 27% and 4% in Hong Kong and Shanghai, respectively, compared to the 5% and 2% for the jailbreak students.

However, under the "No Jailbreak" regime, jailbreak students have a larger response. The overall profit change for all smartphones combined are similar between the two groups of students, but iPhones' profits increase more among jailbreak students (256% in Hong Kong and 279% in Shanghai) than among non-jailbreak students (175% in Hong Kong and 224% in Shanghai). Also, jailbreak students suffer a larger welfare loss in both cities.

## 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-coefficient 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 75% to 24.2% in Hong Kong and from 79.9% to 35.9% in Shanghai. The total profits of all of the smartphones also drop significantly in both samples (66% in Hong Kong and 59% 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 upfront monetary cost of jailbreaking is a determinant, it is much less important than the utility 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 85% in Hong Kong and 145% in Shanghai.

Our results provide policy and managerial implications. First, the upfront monetary cost of jailbreaking is not an effective deterrent of jailbreaking. Second, the importance of utility cost in jailbreaking suggests that smartphone manufacturers should emphasize software piracy being a criminal act and 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.

## Acknowledgments

Travis Ng would like to acknowledge the financial support from the research committee of the Chinese University of Hong Kong (Direct Grant Project ID: 2021123). Chun-Yu Ho would also like to acknowledge the financial support from the National Natural Science Foundation of China (NSFC, Project No. 71301103).

## Supplementary material

Supplementary material associated with this article can be found, in the online version, at [10.1016/j.jce.2016.08.002](https://doi.org/10.1016/j.jce.2016.08.002)

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<sup>20</sup> We do not show the 5th and 95th percentile estimates for brevity.

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