RIETI Discussion Paper Series 21-E-060

Horizontal Foreclosure with Vertically Shared Large Value:
Qualcomm's License Fee Contracts and Anti-Monopoly Decisions by Government in China's Smartphone Integrated Circuits Market, 2011-2014

WATANABE, Mariko
Gakushuin University

RIETI
Research Institute of Economy, Trade & Industry, IAA
The Research Institute of Economy, Trade and Industry
https://www.rieti.go.jp/en/

RIETI Discussion Paper Series 21-E-060
July 2021

Horizontal Foreclosure with Vertically Shared Large Value:

Qualcomm's License Fee Contracts and Anti-Monopoly Decisions by Government
in China's Smartphone Integrated Circuits Market, 2011-2014

Mariko WATANABE*
Gakushuin University

In 2015, the Chinese competition authority announced a sanction against Qualcomm, a leading semiconductor manufacturer in the United States. This study investigates whether Qualcomm's pricing strategy limited competition with its rivals. The study estimated two demand functions for handsets and integrated circuit (IC) chips, as well as the marginal cost of smartphones. It then factored in the price of IC chips. Based on the estimated prices of chips and demand parameters, the study identified the competitive relationship regarding the IC chips at the product level.
The following were the results of the analysis; the cost of smartphone handsets with Qualcomm's chipset installed is lower than those of rival products. Meanwhile, Qualcomm's chip generates a higher willingness to pay (WTP) by engaging in transactions with increasing numbers of handset assemblers. Qualcomm did not commit vertical foreclosures since its products are not exclusive but the company expanded their customer bases and contributed to the improvement of their customers' ability to set higher WTP and higher prices for their products. However, the company committed horizontal foreclosures, as evident from the pricing of its licensing, where Qualcomm limits competition by raising the cost for rivals; this observation is consistent with the authority's determination. This form of anti-competitive conduct is most severe in the CDMA2000 market in China.

Keywords: vertical transaction, demand estimation, IC chip industry, horizontal foreclosure
JEL classification: Q12, L22, O13

*Gakushuin University, 1-5-1 Mejiro, Toshima, Tokyo 171-8588, Japan. Phone: +81-3-5992-3075, Fax: +81-3-5992-1002, E-mail:mariko.watanabe@gakushuin.ac.jp
Acknowledgment: This study is conducted as a part of the Project "Empirical Analysis of Corporate Global Activities in the Digital Economy" undertaken at the Research Institute of Economy, Trade and Industry (RIETI), headed by Eiichi Tomiura. RIETI allowed the author to use GfK data for this project. The author thanks Ryuhei Wakasugi, Fujio Kawashima, Takashi Yunogami, Fumitake Mieno, Yoshiharu Shimizu, Professor Noriaki Matsushima, Professor Makoto Yano and Masayuki Morikawa for guidance regarding the legal literature, business issues, and theoretical and empirical literature. Kensuke Kubo provided substantial advice for the overall structure of analysis. All remained errors belong to author.

1 Introduction

In February 2015, the National Development and Reform Commission (NDRC hereafter), a Chinese authority on competition policy, issued an administrative sanction decision and found that Qualcomm, an American semiconductor manufacturer, violated the anti-monopoly law of China. Qualcomm holds standard-essential patents (SEPs) for CDMA technologies and substantial shares of the baseband chip in technology sales. The company has had lawsuits filed against it and been charged huge fines in markets such as the EU, Japan, and Korea.

This study ascertains whether Qualcomm's pricing limited competition in the smartphone integrated circuit (IC) chipset market regarding licensees of Qualcomm's SEPs.

Analytics of this study is done by the structural estimation method started from Berry, Levinson and Pakes (1994). With regard to focus on vertical relationship, this study is related to Villas-Boas(2007), Draganska, Klapper and Villas-Boas, Lee(2013) and Collard-Wexler, Gowrisankaran, Lee(2019), although this study apply monopolistic pricing approach, not Nash bargaining model between the assembler and vendors.

This study found the following:

(1) Qualcomm had a highly concentrated market share in the CDMA, CDMA2000, WCDMA and LTE/TD/FD markets. However, regarding vertical transaction relationship, Qualcomm is open and has many transaction partners, committed no foreclosures. The company does not limit the entry of smartphone assemblers. In addition to this, according to the estimated distribution of values, their products enabled the smartphone assembler to generate a high value products.

(2) However, regarding horizontal relationship, it is likely that the company limited competition with chip processor vendors. Estimated cross-price elasticities in 2014, when the NDRC started investigation, showed that Qualcomm's product is monopolistic in CDMA2000 markets, is substitutive with the products of several processor-manufacturers, MediaTek., and Hisilicon but not with Spreadtrum and Leadcores in the LTE or WCDMA markets.

(3) There is a substantial difference in the cost of smartphones which installed Qualcomm products and that installed their rivals in the CDMA and CDMA2000 markets, where Qualcomm holds SEPs and charges license fees to rivals. However, WCDMA and TD-SCDMA markets do not find a significant difference between the costs of using Qualcomm

or rival products. The SEPs license fees charged by Qualcomm might have contributed to raise rival's costs.

This paper is organized as follows: Section 2 summarizes the development of the case against Qualcomm and the management strategy of the company. Section 3 presents empirical questions and reviews the literature. Section 4 describes the economic models employed; then, Section 5 explains the empirical method for the study. Sections 6 and 7 show estimated results of demands and marginal cost and price elasticities. Section 8 then summaries the findings and concludes.

2 The Qualcomm case

2.1 Competitive Strategy of Qualcomm and rivals in China market

Qualcomm was incorporated by Arwin Jacobs in California, United States, in 1995. The company maintained a strong competitive advantage in both technological innovation and business models. The current CEO, Paul Jacobs, describes their management strategy as consisting of the following pillars: First, the company is open to providing their license to all customers. The licensing agreement is also open to all the patents Qualcomm hold and is not limited to their SEPs. Second, due to this open access licensing policy, their pricing is computed based on the total revenue of final products. They understand that this pricing policy is fair regarding risk and profit-sharing. Third, they choose to stay as a fabless company. They prefer not to invest in a factory (Nikkei BP, 2006).

This open licensing policy will enable a huge number of assemblers to enter the smartphone market. Qualcomm is not the only semiconductor company that assumes this open licensing policy in the Chinese market. MediaTek, a Taiwanese fabless semiconductor manufacturer, has a similar business model and succeeded in expanding the GSM market in China.

Qualcomm is the patent holder for CDMA and CDMA2000 and charges license fees for them. However, TD-SCDMA is the standard proposed by Chinese entities, Qualcomm did not committed the development. WCDMA are the standard co-developed by telecommunication manufacturers and other chipset vendors, who are the main patent holders. Although Qualcomm holds several SEPs for the standard, too, Qualcomm is charged a license fee to use these technologies, as summarized in Table (1).

Table 1: **Types of Telecommunication Digital Standards**

Digital standard	Main Patent Holders
2G	
GSM(Global System for Mobile communications)	Nokia
3G	
CDMA (Code Division Multiple Access)	Qualcomm
CDA2000	Qualcomm
WCDMA （Wide band Code Division Multiple Access）	Docomo, Nokia, Ericsson
TDSCDMA (Time Division Synchronous Code Division Multiple Access)	Datang, Huawei
4G	
LTE(Long Term Evolution)	Qualcomm

Source International Telecommunication Union

Table 2: **Types of Competitive Strategies of IC chip Vendors**

Transaction Strategy	Name of Vendors
Chip + Handset Integration	Apple, Samsung, Huawei(Hisilicon)
Share Revenue Contract	Qualcomm
Independent Vendors	MediaTek, Braodcom, Samsung and Spreadutrum others.

Source Authors

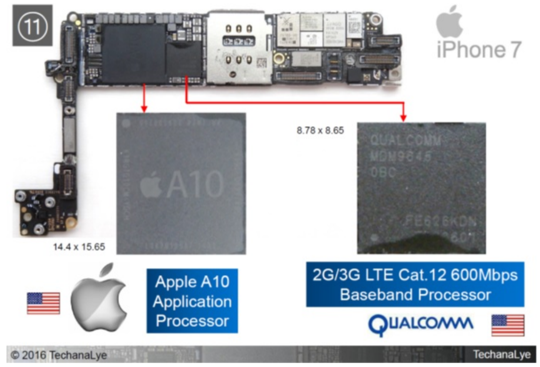
Three types of transaction contracts exist in the Chinese market. The first is Qualcomm's share revenue contract. The second is the conventional independent sales of chipsets to handset manufacturers, of which MediaTek, Spreadtrum, Broadcom belong. The third is the integration of the chipset design process by handset manufactures, of which Apple, Hisilicon (a subsidiary of Huawei), and Samsung belong.

2.2 The case development

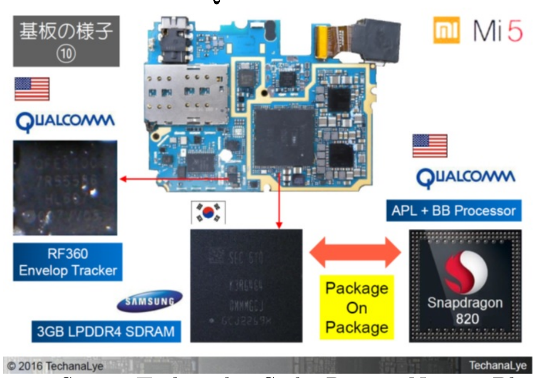
China is not the first country to issue a sanction decision regarding the abuse of monopoly power by Qualcomm. In 2005, six rival IC chip vendors (Nokia, Ericsson, NEC, Panasonic, Broadcom, and Texas Instruments) filed a suit against Qualcomm to the EU commission. Japan's Fair Trade Commission started an investigation in 2009 and is yet to conclude. Japanese cases mainly focus on their cross-license clause, one of which prohibits renegotiations on conditions of the license fee contract. The Korean Fair Trade Commission issued a decision against Qualcomm in 2009 and 2016 (Kawashima, 2016; Wakebe, 2016; Cheng 2016)

Figure 1: IC Chips on Smartphone in China

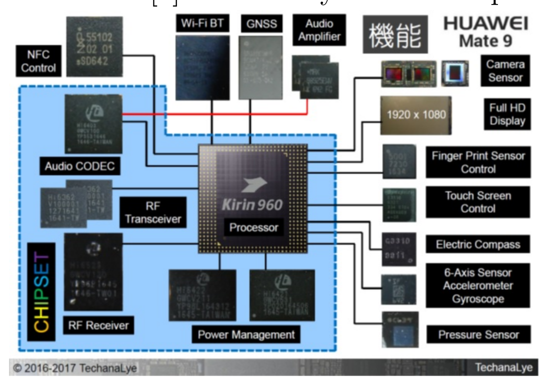
[1] iPhone 7: Separate BB and APL chips



[2] Xiaomi: System on Chips from Qualcomm



[3] Huawei: System on Chips



Source Techanalye Sight Report No.33, iPhone 7, Mi5: No 101, Hisilicon Kirin 960 (2016)

In February 2015, NDRC, China's competition policy regulator, imposed a fine on Qualcomm of 6.088 billion Chinese Yuan, approximately 975 million US dollars, which is the largest in the history of Chinese competition law enforcement (NDRC, 2015).

Bundling with SEP and other products Most of the competition authorities highlighted the bundling of SEPs and the supply of IC chips as anti-competitive conduct. Horizontal foreclosure is a condemned action. However, Qualcomm's share revenue contract and deep devotion to the product development of customer-handset makers are famous as its competitive strategy. The strategy generates a higher WTP of the handset product, to which their IC chip products were supplied. Thus, share revenue contracts might contribute to lower retail prices and improve consumer surplus simultaneously. Whether the vertical or horizontal foreclosures with SEPs took place in the smartphone chip set markets in China is the questions to be explored in this study.

2.3 Structure of the Decision and Qualcomm's response.

NDRC's decision NDRC's decision covers a wider range than Japan's FTC cases. In addition to a renegotiation free cross-license clause, NDRC found three other points, as highlighted below. It finds evidence of (1) charge of loyalty over expired patents, (2) bundling with SEP and non-SEP, and (3) an "unfairly high" license fee is (NDRC, 2015: Kawashima, 2016).

NDRC's decision consists of the following argument;

ND (1) : NDRC confirmed that Qualcomm has a monopolistic power in SEPs regarding CDMA, WCDMA, LTE, and its baseband chipset market. The decision explicitly describes Qualcomm's market shares of CDMA, WCDMA, and LTE as respectively 93.1 percent, 53.9 percent, and 96 percent, with reference to an article of Strategy Analysis.

ND(2) : NDRC claims that the company abuses the monopolistic power confirmed in 1 as follows. a) Qualcomm required smartphone handset assembler to pay a license fee of the parts with expired intellectual property rights. b) The company has a free cross-license free and offered a non-renegotiation condition to customers(**horizontal relationship**). c) The company bundle sales of SEPs and non-SEPs. d) The company's price-setting policy is based on retail device prices(**vertical relationship, share revenue contract**).

ND(3) : Given the abuse confirmed above, the company has maintained an "unfairly high license fee" to smartphone assemblers, which has adversely affected the profits of smartphone handset assemblers, such as Huawei, ZTE, or Xiaomi.

Generally, NDRC accused Qualcomm of setting an "unfairly high license fee" and judged that the company had violated the anti-monopoly law of China (17 Clause 1-1 and 2) (NDRC, 2015; Kawashima, 2016; Wakabe, 2016) Cheng (2016) claims that NDRC's explanation is insufficient and requires further elaboration, although the decision is rational.

Qualcomm's rectification plan On the day the NDRC made the announcement, Qualcomm issued a statement on rectification. They revealed that that the NDRC accepted their "Rectification Plan."

The rectification plan consists of the following items;

Q(1) Qualcomm will offer a license to its current 3G and 4G essential Chinese patents separately from licenses to other patents (**Unbundling of SEPs and other products**).

Q(2) Regarding a reduction of the reference price for computing license fees, the company announced that it would reduce the basis of the license fee computation from 100 percent of the reference price to 65 percent, which is a 35 percent reduction of the license fee. Qualcomm charged 5 percent for 3G and 3.25 percent for 4 G of the reference price as their license fee (**Share revenue contract**).

Q(3) Qualcomm will not condition the sale of baseband chips on the chipset customer signing a license agreement with terms that NDRC found to be unreasonable (**Unbundling of SEPs and other products**).

According to a revised pricing policy that Qualcomm announced, license fees were reduced from approximately five percent of the net price of devices to 3.25 (= 5 percent x 0.65) percent of that for 3G baseband chip and 3.5 percent to 1.95 percent for 4G baseband chips.

Moreover, Qualcomm also announced that it would keep contributing to the growth of the mobile and semiconductor industries in China in the following ways: (1) It would provide extensive engineering assistance to China's mobile operators and roll out their 4G and LTE networks in China. (2) It would assist the Semiconductor Manufacturing International Corporation (SMIC), one of China's largest and most advanced semiconductor foundries, in producing high-performance, low-power mobile processors using advanced 28 nm technology.

To this development, A expressed their complaint to the rectification is insufficient to as follows : "Notably, under the rectification plan Qualcomm unilaterally set the 5 percent and 3.5 percent royalty rates as well as selected the base of 65 percent of the net selling price of the device No declaration or statement by any administrative body has found these terms to be consistent with Qualcomm's obligations to grant licenses to SEPs on FRAND terms (Apple, 2017: 204).

3 Theories on Foreclosure and share revenue Contract

Anti-competitive Factor of Foreclosure The anti-competitive nature of a foreclosure is a classic topic in the theory of market regulation. Rey and Tirole (2007) provide a good theoretical ground to argue on this issue.

They present arguments for the kind of conditions in which foreclosure works against competition. They classify the problem into two possible types of monopolies: vertical foreclosure and horizontal foreclosure.

First, *vertical foreclosure* may arise when (1) a firm controls an input that is essential for a potentially competitive industry. The input is called a bottleneck and (2) the bottleneck owner can then alter competition by denying and limiting access to its input.

Second, when the bottleneck goods is not an input, *horizontal foreclosure* may arise when firms somehow bundle the potentially competitive good and the bottleneck goods. Horizontal foreclosure is basically a predation problem: (1) the bottleneck input firm will bundle with competitive goods to deter the entry of competitors whol also supplies the bottleneck inputs, if the bundling exists. Raising rivals cost (Salop and Scheffman, 1983), Naked Exclusion (Rasmusen, Ramseyer and Wiley, 1991) are the examples (2) lower the current profit to compel competitors to exit the market. Predatory Pricing is the case. Thus, horizontal foreclosure is identified when the bottleneck owner deter the entry of rivlas(Rey and Tirole, 2007: 2153).

Regarding the Qualcomm case, Qualcomm can commit both vertical and horizontal foreclosure. Qualcomm provides the SEP for CDMA, WCDMA, and LTE. Therefore, the company is the bottleneck owner.

Claiming the company has committed vertical foreclosure requires verification that (1) the company holds a monopoly state (related to **ND(1)**), and (2) the company is denying or limiting access of input by customers in general, and transaction is exclusive to the limited customers, and alters competition condition (**vertical forclosure**). This will be the first empirical question of this paper.

Horizontal foreclosure occurs when Qualcomm bundles the SEP, a bottleneck input, with potentially competitive products, non-SEPs. This is related with **ND(3)-b** and **ND(3)-c** in the Decision by NDRC. Claiming that a company has committed horizontal foreclosure requires verifications of either **predatory pricing** or **raising rivals' cost**.

Claiming the predatory pricing situation, you need verify that (1) there is bundling with bottleneck and potentially competitive products, and (2) the company has engaged in predatory conduct by lowering current profits to induce rivals to exit the market, after which they raise the price again. In this action, the bottleneck owner decreases their profit in the short run, but will gain their profit in the long run after they raises the price later.

If you claim the raising rivals' cost occurs, you need to verify that (1) there is bundling with bottleneck and potentially competitive products, and (2) the rival's cost is raised due to the bottleneck owner's conduct.

I regards that this raising rivals' cost action is relevant to the Qualcomm's case in this study. This relationship is related to their share revenue pricing contract in the next section. I will describe it in detail in section 4 and empirically investigated in sections 6 and 7. This is the second and main empirical question of this study.

Share revenue pricing, integration vs double marginalization In the Qualcomm case, the raising rivals' cost strategies is related to a share revenue pricing contract that offered by the Qualcomm.

Chinese authorities found that the company abuses their monopolistic power by its license fee setting policy (**NF(3)-d)**).

The share-revenue type contract is a very classic case of a contract for risk-sharing and incentive provision. Pricing on total revenue is a mechanism called risk share contract in contract theory. This mechanism is prevalent in franchise businesses in the world, contracts between head quarters and the franchisee in the convenience stores in Japan, and does not necessarily inhibit competition in the smartphone device market. It does not raise the cost of assembly since it will decrease when the retail price of devices decreases.

Under this share-revenue-type contract, the revenue of the bottleneck owner changes with price development. If the retail price of the device is lowered, the revenue of the bottleneck owner also shrinks, and the magnitude of the abuse of power also shrinks. Thus, this contract mechanism is not anti-competitive.

The contract will realize lower consumer prices than the double marginalization case. subsidization and (4) strategic adopting of inefficient technology. Remedies that the anti-competitive agency can take are (1) ex post enforcement of competition rules on unilateral conduct (2) using merger control rules to level the playing field and (3) exemptions from antitrust liability for SOEs.

Competitive Advantage and Monopoly Power Competitive advantages and competitive strategy must be considered. I assume that , (1) firms will compete by the size of consumer surplus, which is defined as WTP minus price. Moreover, (2) firms may compete with a high WTP, high or average price strategy, low or average WTP, and low price strategy. The former is called **benefit advantage** and the latter, **cost advantage**. Furthermore, (3) faced with consumer price elastic, where it is higher than one, cost advantage firms may employ a strategy to reduce cost and price and expand consumer surplus and sales. A benefit advantage firm will employ a strategy to maintain the price at an average level and raise WTPs to increase consumer surplus and sales.

Even under an oligopolistic environment, in which the IC chipset markets in China belong, the principle holds as above. If the buyer of the market is fully elastic regarding price, the processor manufacturers cannot raise the price easily. Under this environment, share revenue contract may be chosen to realize lower retail price either by cost advantage or for WTP advantage firms as is theories predict.

Questions of thie paper Below are several points that must be empirically tested to evaluate and predict the outcome of the decision by NDRC and the rectification plan by Qualcomm:

Question 1: Does Qualcomm hold a dominant market share the market of CDMA, CDMA2000, WCDMA, and LTE?

Question 2: If the answer of Q1 is yes, does Qualcomm abuse the monopoly power either in line with vertical foreclosure?

Question 3: Regarding horizontal foreclosure, does the company bundles its bottleneck product with potentially competitive one? Specifically, does the company takes a strategy to raise rivals' cost? This is apparent as they supplies both SEPs and chips as described in the section above.

Regarding the claim of **ND(3)**) that the company charged a patent fee on an expired patent, there is nothing to discuss, if true.

Question 4: If the answer to Q3 is yes, does the company's strategy deters the rivals' entry or deteriorates efficiency? This is the main empirical question in this study and will be answered in sections 6 and 7.

According to a revised pricing policy that Qualcomm announced, license fees were reduced from approximately five percent of the net price of devices to 3.25 (= 5 percent x 0.65) percent of that for 3G baseband chip and 3.5 percent to 1.95 percent for 4G baseband chips. This reduction in the license fees results in a fall in retail prices if the assemblers also reduce the retail price. The increase in profit of assemblers occurs if the assembler maintains the retail price, although they enjoy lowered costs. This decision by the assembler will depend on the size of the price elasticity of demand. This study estimates the price elasticities to confirm this point.

To test the market relevance and possible abuse of market power by Qualcomm in the Chinese smartphone market, this study estimated price elasticities and WTP at individual product levels of smartphone and IC chips demand functions with a discrete choice model with unobserved consumer heterogeneity of nested logit models

Question 5 Were prices set by Qualcomm "unfairly high" as NDRC claimed? In other words, does the company simply raising bargaining power or contributing to increase the WTP of products or benefit of trade of the products? This will be discussed based on the empirical findings related to the Question 4 in section 6.

These are the main questions to be investigated in this paper.

4 Model

4.1 Decision making process

In this section, I describe the model. This study specifies a static price decision process of smartphone and processor manufactures. Here, the study considers the set of smartphone manufacturers and processor manufacturers as given and does not model their entry and exit. The study also considers the product portfolio as pre-determined and given.

The pricing decisions of smartphone handset manufacturers and processor chip vendors were specified as follows:

1. Marginal cost of chip product k (mc_{kt}^{chip}) and unobservable cost shock (η_{kt}^{chip}) are realized. Processor brand manufacturers set price of chip k (ψ_{kt}^{chip}) that includes license fee of product k (lf_{kt}) to maximize their expected profit. Marginal costs of chip for integrated processor and smartphone handset are also realized at this time.

2. Given smartphone product portfolio, smartphone manufacturers choose processor chipset product k. Price of chips (ψ_{kt}^{chip}), other than license fee to Qualcomm (lf_{kt}) is realized.

3. Marginal cost (mc_{jmt}^{phone}) and demand shocks (ξ_{jmt}) of every active smartphone product j are realized.

4. Given all of the product portfolio X_{jmt}, handset manufacturers set the price of the smartphone product j (p_{jmt}^{phone}). Simultaneously, the license fee to Qualcomm ($lf_{kt}^{Qualcomm}$) that links to product price (p_{jmt}) is realized.

5. Consumers make purchase decision given the characteristics and prices (X_{jt} and P_{jt}^{phone}) of the available products in the market.

Smartphone and processor manufacturers solve the game backward by first computing payoffs for all possible configurations of the portfolio. The model is detailed below.

4.2 Demand of Smartphone Handset

The study specifies the demand system as follows. Consumers chose a smartphone product j in a given market (=city and year, here) to maximize their utility. We view a product as a particular brand sold in a city market $m = 1, 2, ...M$ (we delete m hereafter simply for convenience). The indirect utility U_{ijt} of consumer i from purchasing brand $j = 1, 2, ...J$ at time $t = 1, 2, ...T$ is,

$$u_{ijt} = -\alpha_i p_{jt} + \beta X_{jt} + \xi_{jt} + \epsilon_{ijt}. \tag{1}$$

p_{jt} denotes the price of product j in market m in time t. Other factors affect product choice, such as the features of product x_{jt}. ξ_{jt} is a product-market specific unobservable factors. ϵ_{ijt} is the random unobservable error. The random coefficients of price are defined as $\alpha_i = \alpha/Y_i$, whereas Y_{it} is the observed income[1].

The mean utility of product[2] j can be rewritten as,

$$\delta_{jt} = -\alpha_i p_{jt} + \beta X_{jt} + \xi_{jt}, \tag{2}$$

[1] We used average income of each city-year segments in this study because we do not have data on individual income, which means $Y_i = Y_{mt} = \sum Y_i/I_{mt}$ and $\alpha_i = \alpha_{mt} = \alpha/Y_{mt}$. I_{mt} is the population at market m and time t. This is the Taylor approximation of $ln(Y_i - p_{ij})$ in Berry, Levinson, and Pakes (1999).

[2] Since this is the mean of utility, the unobserved independent error ξ_{jt} in equation (1) can be regarded as zero.

where ξ_{jt} represents unobservable and time specific characteristics. Each consumer i in market m chooses product j to maximize his or her utility. Therefore, the aggregate market share for product j in market m is the probability that product j yields the highest utility across all products including outside goods 0. Therefore, the predicted market share of product $j = 1, ...J$, s_j is a function of the mean utility δ_{jt} and parameter vector $\theta = (\alpha, \beta)$.If the unobserved error, ϵ_{ijt} in the equation (1) follows independently and identically distributed (i.i.d.) extreme values, this relationship can be rewritten as a logit choice probability as below.

$$\begin{aligned} P_{jt} &= s_{jt}(\delta_{jt}, \theta) \\ &= \frac{e^{u_{jt}}}{\sum_k e^{u_{kt}}} \\ &= \frac{e^{-\alpha_i p_{jt} + \beta X_{jt} + \xi_{jt} + \epsilon_{ijt}.}}{1 + \sum_k e^{-\alpha_i p_{kt} + \beta X_{kt} + \xi_{kt} + \epsilon_{ikt}}} \end{aligned} \tag{3}$$

Here, 1 in the denominator in equation (3) represents the value of the outside option because $exp(u_0) = exp(0) = 1$. The remaining variables in the denominator are the sum of exponential utilities of all the choices in every market.

The market share of the outside option (i.e., the do not buy option) s_{ot} becomes

$$\begin{aligned} s_{ot} &= \frac{1}{\sum_l e^{u_{lt}}} \\ &= \frac{1}{1 + \sum_l e^{-\alpha_i p_{lt} + \beta X_{lt} + \xi_{lt} + \epsilon_{ilt}}} \end{aligned} \tag{4}$$

Incorporating ratio of equation (3) into equation (4), and given logarithm of equation, the demand for handset of smartphone in nested logit format is as follows:

$$ln \frac{(s_{jm})}{(s_{mo})} = -\alpha \frac{p_{jm}}{y_i} + \sum_{j=1}^{J} (\beta_j X_j) + \xi_j$$

4.3 Supply of Smartphone Handset

Marginal Costs of Smartphone Given the marginal cost of smartphone product j, mc_{jt} consists of chipset price ψ_{kt}^{chip} supplied by chipset vendor k and non-chip inputs z_{jt}, as well as unobservable cost shock η_{jkt}. The chip price consists of license fee lf_{kt} and other parts of the price ν_{kt}. Moreover, it is denominated in monetary terms. Non-chip inputs and unobservable cost shocks are denominated in non-monetary terms and described in exponential form.

$$\begin{aligned} mc_{jt} &= exp(ln(\psi_{kt}) + z_{jt} + \eta_{jkt}) \\ &= exp(ln(lf_{kt} + \nu_{kt}) + z_{jt} + \eta_{jkt}) \end{aligned} \tag{5}$$

Relationship of charge and payment of the license fee is described as follows

$$lf_{kt} = \begin{cases} \theta p & \text{if CDMA or CDMA2000, or WCDMA or LTE and chip is supplied by Non-Qualcomm} \\ 0 & \text{if CDMA, CDMA2000, WCDMA, LTE and chip is supplied by Qualcomm.} \\ l & \text{if TDSCDMA .} \end{cases} \tag{6}$$

The price of processor chipset is as follows:

$$\psi_{kt} = \begin{cases} \theta p + \nu_{jt}^{Non-Qualcomm} & \text{if CDMA or CDMA2000 or WCDMA or LTE chip by Non-Qualcomm} \\ \nu_{kt}^{Qualcomm} & \text{if CDMA or CDMA2000 or WCDMA or LTE and chip by Qualcomm.} \\ l + \nu_{kt} & \text{if TDSCDMA.}^{3} \end{cases} \tag{7}$$

Pricing of Smartphone Handset Denote the set of handset maker n's product as J_{nt}. Given the chipset price ψ_{jkt} and other parts of the marginal cost z_{jt}, handset maker n sets retail price of the smartphone $p_{jt}, \forall j \in J_{nt}$, to maximize its profit.

$$\sum_{j \in J_{nt}} (p_{jt} - \psi_{jt} - z_{jt}) s_{jt}, \tag{8}$$

where s_{jt} is market share of product j in time t.

Equilibrium retail prices satisfy the following first order condition:

$$s_{jt} + \sum_{j' \in J_{nt}} (p_{j't} - \psi_{j't} - z_{jt}) \frac{\partial s_{j't}}{\partial p_{jt}} = 0, \forall j' \in J_{nt}. \tag{9}$$

In vector notation, the vector of the handset price p satisfies

$$p - \psi - z = (L * \Delta)^{-1} s, \tag{10}$$

where L is a $|J_t| \times |J_t|$ product origin matrix ($L_{jj'} = 1$ if both j and j' belong to J_{nt}, and 0 otherwise), $\Delta_{jj'}$ is the derivative of the demand for j' with respect to the price of j, and * represents the element-wise product.

The price of IC chips becomes a function of the handset price when the chip is manufactured by the non-Qualcomm chip maker for CDMA, CDMA2000, WCDMA, and LTE as in equation (7),

Equilibrium prices of handsets satisfies following condition.

$$(L * \Delta)^{-1} s = \begin{cases} p - z - \theta p - \nu & \text{if CDMA or CDMA2000 or LTE and chip by Non-Qualcomm} \\ p - z - \nu & \text{if CDMA, CDMA2000, WCDMA, LTE and chip by Qualcomm.} \\ p - z - l - \nu & \text{if TDSCDMA regardless of chip vendor}^4 \end{cases} \tag{11}$$

4.4 Demand for Chipset

I set up a demand function of chipset based on the utility based approach, not simple input outpu profit function. Chipset is a substantial input for handset manufacturers. Capacity of chipset does not only control the cost of handset, but it does affect the willingness to pay of the consumers. I assume that the handset manufacturers take into account its impact of raising WTP when they choose the chipset.

The utility for the IC chipset product k for smartphone product $j$is

$$u_{jkt} = -\alpha_{jk}\psi_{kt} + \beta Z_{kt} + \xi_{kt} + \omega_{jkt}.$$

The demand for the chipset k is

$$\frac{ln(s_{jkt})}{ln(s_{ot})} = -\alpha_{jk}\psi_{kt} + \beta Z_{kt} + \xi_{kt} + \omega_{jkt}. \tag{12}$$

4.5 Supply of Chipset Vendors

Here, the study formalizes the supply behavior of chipset vendors. Non-Qualcomm chipset vendors must pay a license fee to use the SEP if they use Qualcomm's digital standard, as the company does not participate in the patent pool but charge the fee. On the contrary, Qualcomm does not only receive a license fee revenue for CDMA, CDMA2000, WCDMA, and LTE but also is not charged a fee to the purchases of their own supplied chipsets. This situation is the proclaimed source of the anti-competitive conduct of Qualcomm, which is formalized as follows.

Pricing Function of Chipset Vendors Denote the set of chip vendor v's product as K_{vt}. Given the chipset price ψ_{kt}, license fee payment or revenue from the digital standard is lf_{jt}, chipset vendor v sets price of chipset $\psi_{jt}, \forall j \in J_{nt}$, to maximize its profit. License fee lf_{jt} becomes positive when it is received and becomes negative when it is paid. ν_{kt} is the non-license fee part of the processor price.

The profit function of the chipset vendors is

$$\sum_{k \in K_{vt}} (\psi_{jkt} - \nu_{kt} + lf_{jkt}) s_{kt}, \tag{13}$$

where s_{kt} is the market share of chipset k in time t.

In case the handset maker produces CDMA, CDMA2000, WCDMA, or LTE handsets, the profit function of Qualcomm is as follows;

$$\sum_{k \in K_{vt}} (\psi_{jkt} - \nu_{kt} + \theta p_{jt}) s_{kt}. \tag{14}$$

For non-Qualcomm chipset vendors, the profit function for CDMA, CDMA2000, WCDMA or LTE handsets, is as follows;

$$\sum_{k \in K_{vt}} (\psi_{jkt} - \nu_{kt} - \theta p_{jt}) s_{kt}, \tag{15}$$

When handset makers produce handsets of TD-SCDMA, the profit function for both Qualcomm and Non-Qualcomm chipset vendors become,

$$\sum_{k \in K_{vt}} (\psi_{jkt} - \nu_{kt}) s_{kt}. \tag{16}$$

The equilibrium chipset prices $\psi_{j'k't}$ satisfy the following first order condition:

$$s_{kt} + \sum_{k' \in K_{vt}} (\psi_{j'k't} - \nu_{k't} + lf_{jt}) \frac{\partial s_{k't}}{\partial \psi_{kt}} = 0, \forall k' \in K_{vt}. \tag{17}$$

For Qualcomm, their profit maximum principle and marginal cost of chips ν can be described as below in vector notation

$$\psi - \nu_{kt} + \theta p \quad = \quad (L * \Delta)^{-1} s_k, \tag{18}$$

$$\nu_{kt} = \psi - (L * \Delta)^{-1} s_{kt} + \theta p, \tag{19}$$

Here, θ is positive for Qualcomm, negative for Non-Qualcomm chip vendors, zero for TD-SCDMAs.

5 Identification and Data

This section discusses the identification of demand and supply models.

5.1 Identification of Demand

The study estimates the demand models using the generalized method of moments (GMM) following the work by BLP and the subsequent literature. We estimate demand and supply in two steps.

Instruments for Demand Models Estimation of the model employed here is performed using IV or GMM vis instruments for p_{jt}. Instruments z_{jt} are correlated to p_{jt} but are independent of ϵ_{ijt}. In this case, candidates of instruments mainly come from the following four sources: (1) cost shifters. (2) Prices of the same products of the same brand in other cities (the study assumes that price differences for the same products across cities reflect only demand factors, and the prices of the same products in other cities are correlated with price via cost factors only, as per Berry, Levinson and Pakes, 1995; Hausman, 1996; Nevo, 2001). (3) Price of the same type of products by competitor brands in the same city (Berry, Levinson and Pakes, 1995). Finally, (4) product characteristics (it is natural to assume that the characteristics of products are designed and planned before the price is fixed). Exploiting this natural assumption, we use the characteristics of products as instruments that predetermined the price. Any of the four types of instruments were tried. (i) The first type of "quality" dummy is the sum of the index of characteristics within one's own brand. (ii) The second type of this category's IV is the sum of the characteristics of other products of rival firms. (iii) The third is the sum of the characteristics of other products of their own firms (see Grigolon and Verboven, 2011; Verboven,1996). (iv) The fourth is the average index of the characteristics of a competitor.

Candidates of the instruments variable are as follows. (1) The cost shifter, which is the number of products (no_product); (2) the price of the same products in other cities (

i_price_othermkt), (3) the price of the same type of products by competitors in the same market (i_price_rivals), and (4) the sum of the quality of rivals index in the same market (displaysize_own, displaysize_rivals).

5.2 Identification of Price of IC chips

The study identified the price of the IC chips in a non-parametric way. It transformed equation (20) into the estimation equation of the marginal cost of smartphones by taking the logarithm.

$$\begin{aligned} mc_{jt} &= exp(\beta_{\psi} ln(\psi_{kt}) + \beta^{jt} z_{jt} + \eta_{jkt}) \\ ln(mc_{jt}) &= ln(\psi_0) + \beta^{\psi}_{kt}(d^{processor}_{kt} \times time) + \beta^{jt} z_{jt} + \eta_{jkt}. \end{aligned}$$

where η_{jt} is unobservable. The study computed the prices of chip ψ_{kt} non-parametrically computed as follows:

$$\psi_{kt} = exp(ln(\psi_0) + \beta^{\psi}_{kt}(d_{kt} \times time)) \tag{20}$$

As a reference ψ_0, the study set the price of the A4 processor to that of Apple. The price of the product in 2010 is 35 US dollors = 231 RMB (iSuppli).

5.3 Identification of Competitive Position

Willingness to pay of a consumer i to a product j is a sum of price and consumer surplus. Consumer surplus of a consumer i is, by definition, the utility in monetary term, u_{ij} that the consumer receives from the product j.

However, the researcher cannot observe actual utility u_{ij} as whole. Instead, the researcher can observe indirect utility $v_{ij} = -\alpha_i p_j + \beta_{ij} X_j + \lambda_j + \rho ln(s_{j|k})$ and and assume the distribution of the remained unobservable part $\xi_{ij} + \epsilon_{ij}$. With regard to unobservable characteristics of product xi_{ij}, we can capture by model dummies, λ_j which connected with consumer attributes directly here. With this information, the researcher can calculate the expected consumer surplus (Train, 2009).

$$\begin{aligned} E(CS_{ij}) &= \frac{1}{\alpha_i} E[max_j \ u_{ij}] \\ &= \frac{1}{\alpha_i} E[max_j(\ v_{ij} + \epsilon_{ij})] \end{aligned} \tag{21}$$

If the researcher assume that ϵ_{ij} follows independently and identically distributed, the expected utility of consumer i to product j becomes:

$$E(CS_{ij}) = \frac{1}{\alpha_i}\ ln(\Sigma_{j=1}^{J} e^{v_{ij}})^5.$$

For nested logit model, the expected utility of consumer i from product j in nest k becomes as follows (See Ivaldi and Verboven(2005) and Train (2009))

$$E(CS_{ijk}) = \frac{1}{\alpha_i}\ ln(1 + \Sigma_{k=1}^{K} D_k^{1-\rho}) \tag{22}$$

where

$$D_k = \Sigma_{j=1}^{J} e^{\frac{v_{ij}}{1-\rho}}.$$

Once CS_{ij} for product j is estimated from the demand function, we can compute the value of WTPs, or willingness to pay of consumer i to product j, B_{ij}.

$$B_{ij} = CS_{ij} + Price_{ij} \tag{23}$$

Willingness to pay, B_{ij}, of consumer i to product j is thus computed.

6 Data and Results

6.1 Data on Smartphone and Processor Markets

I used GfK's market audit data of 22 cities including on-line store for 2011 to 2014 of Chinese smart phone market[6]. It has information of number of unit sold, price and attributes of smart phone by product level. Attributes are number of camera, number of slots for sim-card, types of OS, processor numbers, processor brand, types of digital stand, types of display technology, whether GPS hardware or near field communication (NFC) functions are installed.

With regard to data on integrated circuit chip , I need to note the following. What I can observe are (1) digital standard that individual smartphone model employed and (2) processor number of calculation processing unit (CPU), not the base band chip. CPU and based band chip holds different function, and used to be physically in separate. However, along with technological progress, processor chip and base band chips are tend to be integrated as System on Chip (SOC). Thus, I regard that CPU processor number is the identifier of base band chip, and estimate the price of processor chip as the integrated price of CPU and base band chip.

As a whole, the smartphone and its IC markets consists of 555 smart phone brands, 4851 products, 21 processor brands, and 275 processor products appeared in the data set. Huge numbers of brands and products are peculiarity of smart phone market in China.

As number of chip set vendors is substantially smaller than that of smart phone assemblers, I assume that chip set vendors hold the barganing power except Apple, Samsung and Huawei, who integrated IC chip design function by themselves.

In the modelling in this study, I assume that smarphone assembler are the price taker in terms of the chip set. except the case the assembler use the chip set their own designs.

6.2 Estimation Results

Demand for Smartphone Instrument variables such as rivals display size and prices worked (Equation(4) in Table 4). The weak IV test passed as the first stage F value is large, and the Hausman test on orthogonality of IVs also satisfies the condition.

[6] 22 markets contains following cities: Beijing, Changsha, Chengdu, Chongqing, Dongguan, Guangzhou, Harbin, Hefei, Kunming, Nanjing, Nanning, Ningbo, Shanghai, Shenyang, Shenzhen, Shijiazhuang, Suzhou,

Table 3: **Smartphone Market Profile**

year	Smartphone Price (RMB/unit)	Unit	Display size (Inchi)	NFC (Share)	GPS (Share)	Product	Unit /Product
2011							
mean	2,281	4,304	3.3	0.0	0.8	602	88,147
s.d.	1,247	26,334	0.6	0.2	0.4	369	239,484
2012							
mean	1,618	3,155	3.7	0.0	0.9	785	63,453
s.d.	1,189	16,606	0.6	0.2	0.3	633	164,930
2013							
mean	1,260	2,685	4.1	0.1	0.8	1,211	54,295
s.d.	1,070	15,339	0.7	0.2	0.4	1,033	152,809
2014							
mean	1,135	2,498	4.4	0.1	0.8	1,675	49,340
s.d.	1,103	23,008	0.7	0.3	0.4	1,496	155,463
Total							
mean	1,340	2,799	4.1	0.1	0.8	1,292	56,104
s.d.	1,160	19,977	0.8	0.3	0.4	1,236	163,650

Source: GfK

Marginal Cost Function of Smartphone The marginal cost function is estimated by the GLS function. Independent variables in the function were selected by the LASSO estimator.

Demand for Chipset Demand for the chipset is estimated by using the same IVs used in the smart-phone demand. The Hausman test on orthogonality did not pass; however, the over-identification test passed.

Tianjin, Xiamen and Xian and online.

Table 4: **Demand function for Smart-Phone**

	(1) OLS	(2) IV: Rivals' displaysize	(3) Rivals' price	(4) Rivals' price and display size
$\frac{price}{wage}$	-12.266***	-266.750***	-87.912***	-164.554***
	(0.502)	(48.952)	(8.981)	(15.396)
Display size	0.595***	2.756***	1.354***	1.884***
	(0.011)	(0.384)	(0.070)	(0.112)
OS: Android is the reference				
NOKIA/SYMBIAN	-2.670***			
	(0.089)			
PALM OS	-4.371***	-8.519***	-5.031***	-8.011***
	(0.848)	(2.374)	(1.420)	(0.913)
S40 AHA TOUCH	-2.395***	-2.926***	-0.850***	-1.544***
	(0.138)	(0.588)	(0.159)	(0.199)
TIZEN	-0.481	-0.783	-0.762*	-0.896*
	(0.506)	(0.602)	(0.462)	(0.514)
Selected Processor brand: Firm A is the reference				
B	-4.497***	-6.442***	-4.622***	-5.500***
	(0.395)	(1.388)	(0.626)	(0.868)
D	-3.860***	-4.345***	-4.146***	-4.348***
	(0.406)	(1.310)	(0.626)	(0.889)
E	-4.513***	-2.318*	-3.553***	-2.997***
	(0.401)	(1.340)	(0.627)	(0.915)
J	-4.474***	-5.707***	-4.232***	-4.917***
	(0.394)	(1.352)	(0.622)	(0.865)
L	-5.006***	-3.054**	-3.802***	-3.463***
	(0.398)	(1.311)	(0.622)	(0.900)
M	-5.089***	-3.676***	-4.080***	-3.852***
	(0.418)	(1.309)	(0.635)	(0.905)
N	-4.087***	-11.532***	-7.531***	-9.480***
	(0.629)	(1.913)	(0.876)	(1.135)
QUALCOMM	-4.633***	-5.471***	-4.346***	-4.862***
	(0.394)	(1.326)	(0.620)	(0.866)
O	-4.465***	0.165	-2.789***	-1.573
	(0.397)	(1.539)	(0.641)	(0.973)
P	-4.013***	-5.664***	-3.709***	-4.603***
	(0.396)	(1.397)	(0.625)	(0.866)
R	-4.868***	-6.110***	-4.509***	-5.264***
	(0.399)	(1.365)	(0.625)	(0.867)
T	-2.749***	-3.912***	-3.546***	-3.797***
	(0.431)	(1.337)	(0.658)	(0.913)
S	-5.418***	-3.814***	-4.319***	-4.123***
	(0.395)	(1.299)	(0.619)	(0.892)
Selected smartphone brand				
A	0.000	15.339***	4.937***	8.297***
	(.)	(3.172)	(0.842)	(1.881)
H	2.396***	2.416***	2.429***	1.3672
	(0.197)	(0.554)	(0.247)	(1.203)
M	3.563***	5.609***	4.139***	3.755***
	(0.207)	(0.688)	(0.265)	(1.298)
O	3.216***	7.113***	4.426***	4.563***
	(0.200)	(0.923)	(0.283)	(1.376)
S	3.645***	8.451***	4.972***	5.413***
	(0.196)	(1.107)	(0.303)	(1.426)
V	3.012***	6.079***	3.961***	3.864***
	(0.200)	(0.804)	(0.271)	(1.338)
Z	1.628***	1.123**	1.509***	0.299
	(0.197)	(0.564)	(0.248)	(1.184)
2012	-0.620***	-4.234***	-1.568***	-2.913***
	(0.030)	(0.734)	(0.140)	(0.256)
2013	-1.251***	-6.949***	-2.792***	-4.768***
	(0.031)	(1.142)	(0.213)	(0.380)
2014	-2.036***	-9.467***	-4.095***	-6.607***
	(0.033)	(1.474)	(0.273)	(0.487)
Constant	-11.045***	-9.867***	-11.175***	-9.083***
	(0.554)	(1.455)	(0.671)	(0.826)
N	130516	130516	130516	130516
R^2	0.405	.	0.260	.
$WeakIV : FvalueatFirststage$	-	37.76	356.3	187.901
$Exogeneity : GMMCstatistics$	-	6.7e-10	1.7e-10	5.9e-10
p-value		1	1	1

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
F value at first stage tests weakness of instruments. GMM C statistics tests exogeneity of IVs
I have processor and handset brands except several selected ones anonymous.

Table 5: Marginal Cost Function of Smartphone

	ln_cost
Displaysize	0.439***
	(0.011)
CDMA	-0.258*
	(0.132)
GSM	-0.145***
	(0.022)
TDSCDMA	-0.347***
	(0.019)
Two Simcards	0.202***
	(0.013)
(Reference= Android)	
iOS	2.823***
	(0.309)
Linux	0.318***
	(0.113)
Nokia/Symbian	0.369***
	(0.141)
Windows Phone	0.349***
	(0.048)
No Camera	-1.477***
	(0.245)
Single Camera	-0.314***
	(0.015)
Smartphone Brand Dummy	
H	0.981***
	(0.171)
M	0.971***
	(0.192)
O	2.007***
	(0.176)
S	1.758***
	(0.171)
V	1.644***
	(0.168)
Z	0.545***
	(0.167)
Constant	3.798***
	(0.446)
Processor Product Dummy	Yes
Processor Product Dummy × Year dummy	Yes
City Dummy	Yes
N	116,769
Number of groups	4,716
R^2	
Within	0.5226
Between	0.6751
Overall	0.6935

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

GLS regression. I have processor and handset brands except several selected ones anonymous.

Table 6: **Demand for Chipset**

	$ln(s_k) - ln(s_o)$
$\frac{processor\_price}{smartphone\_price}$	-19.449***
	(1.194)
Digital Standard	
(2.X CDMA ONE: reference)	
2.X CDMA+GSM	-5.507***
	(1.287)
3.X CDMA20001XE	-2.310***
	(0.826)
3.X TD-SCDMA +2	1.978**
	(0.901)
3.X WCDMA	-1.554*
	(0.836)
3.XCDMA+WCDMA+T	2.394***
	(0.909)
3.XCDMA20001XE+	-3.022***
	(0.854)
4.XTD+3.XW	-2.607***
	(0.828)
4.XTD+FD+3.XTD	-2.303**
	(1.041)
WCDMA + GSM	-82.624***
	(5.553)
Processor Brand	
(A: reference)	
E	36.563***
	(3.433)
J	56.463***
	(4.239)
L	38.270***
	(3.402)
QUALCOMM	41.157***
	(3.456)
O	29.835***
	(3.201)
P	40.016***
	(3.565)
R	35.616***
	(3.596)
Smartphone Brand	
A	-12.543***
	(1.340)
H	2.699***
	(0.518)
M	0.302
	(0.378)
O	-0.951**
	(0.382)
S	-1.388***
	(0.382)
V	-0.734*
	(0.380)
Z	0.611
	(0.376)
Constant	37.761***
	(3.202)
Processor product dummy	YES
Year dummy	YES
N	126,269
Hansen J	4.8e-10 (p = 1.0000)
GMM c	1.1e+09 (p = 0.0000)
$WeakIV : FvalueatFirststage$	563.9

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

I have processor and handset brands except several selected ones anonymous.

7 Estimated Profile of Market Outcome

7.1 Foreclosures?: Descriptive Data

Q1-Q4: No vertical foreclosure, but horizontally, yes Whether Qualcomm holds a substantially significant share in the market as connected to their abuse of power? In order to answer this question, I observed market share data for horizontal relationship and number of customers for vertical relationship. My data set confirmed that the company has more than an 80 percent share in the CDMA and LTE markets(Table 7), as NDRC Decision suggests. Regarding the WCDMA baseband chip market, the share is less than 50 percent, which is lower than the 80 percent that the NDRC decision suggests (Table A.4). Qualcomm's market share in the markets are high enough to abuse their power except TD-SCDMA market, which is the digital standard promoted by the Chinese government(Table A.5). Meanwhile, Qualcomm's transaction partner is very diversified (Table 8). As a whole market, number of smartphone models that smartphone brands supplied on the market are increased (Figure 2). Variety of smartphone products for consumers increased between 2011 to 2014.

Table 7: **Horizontal Status of Qualcomm share:2011-2014**

Digital standard	**Market share in the standards**			
	2011	2012	2013	2014
2G				
GSM	0.031	0.015	0.007	0.007
3G				
CDMA	0.978	0.685	0.411	0.533
CDA2000	0.675	0.794	0.779	0.858
WCDMA	0.390	0.415	0.370	0.371
TDSCDMA	0.021	0.074	0.156	0.092
4G				
LTE/TD/FD			0.941	0.554

Source GfK.

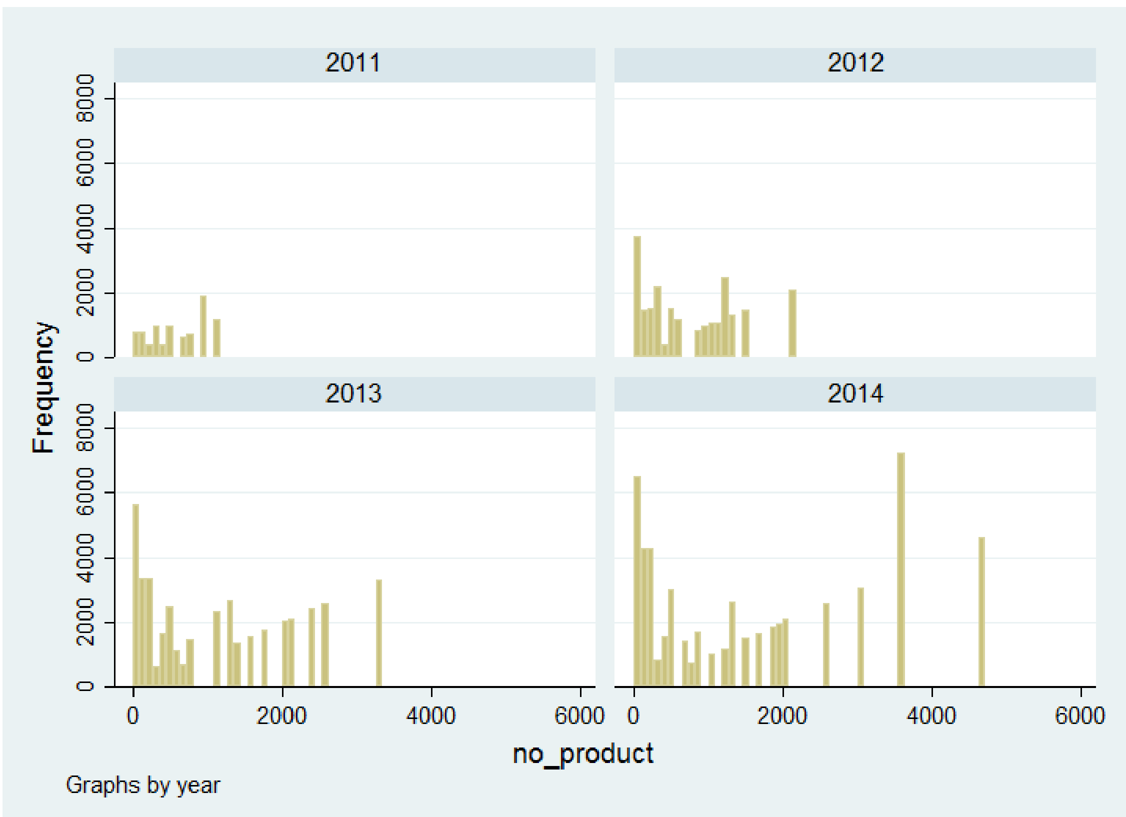
Note SEP for CDMA and CDMA2000 is held by Qualcomm

Table 8: **Vertical Status of Qualcomm: Number of customers**

	2011	2012	2013	2014
Number of customer brand	61	119	148	198
Total number of smartphone brand	97	300	446	481
Price of Smartphone with Qualcomm (mean:RMB)	2104	1533	1301	1196
Price of Smartphone with Qualcomm (sd:RMB)	1057	1038	1172	1203

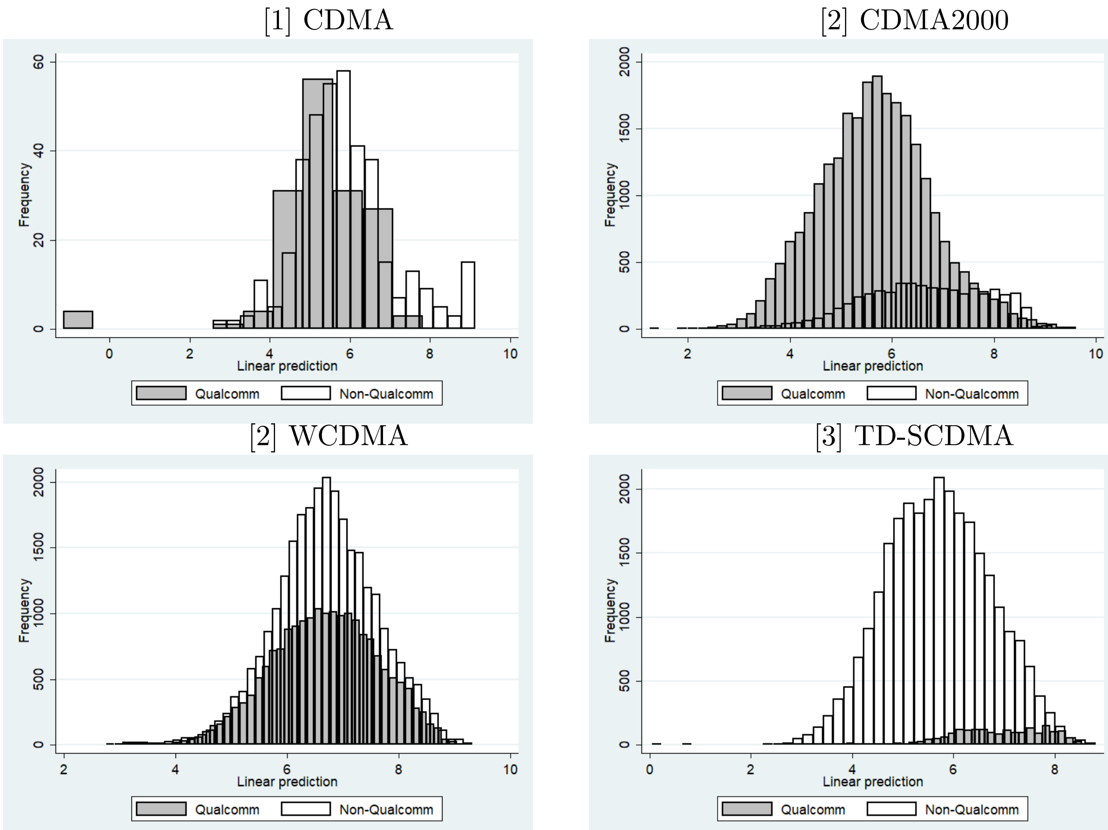
Source GfK

Figure 2: **Number of products by brand**



Source: GfK

Figure 3: **Marginal Cost of Smartphone : Qualcomm-installed vs Non-Qualcomm model**



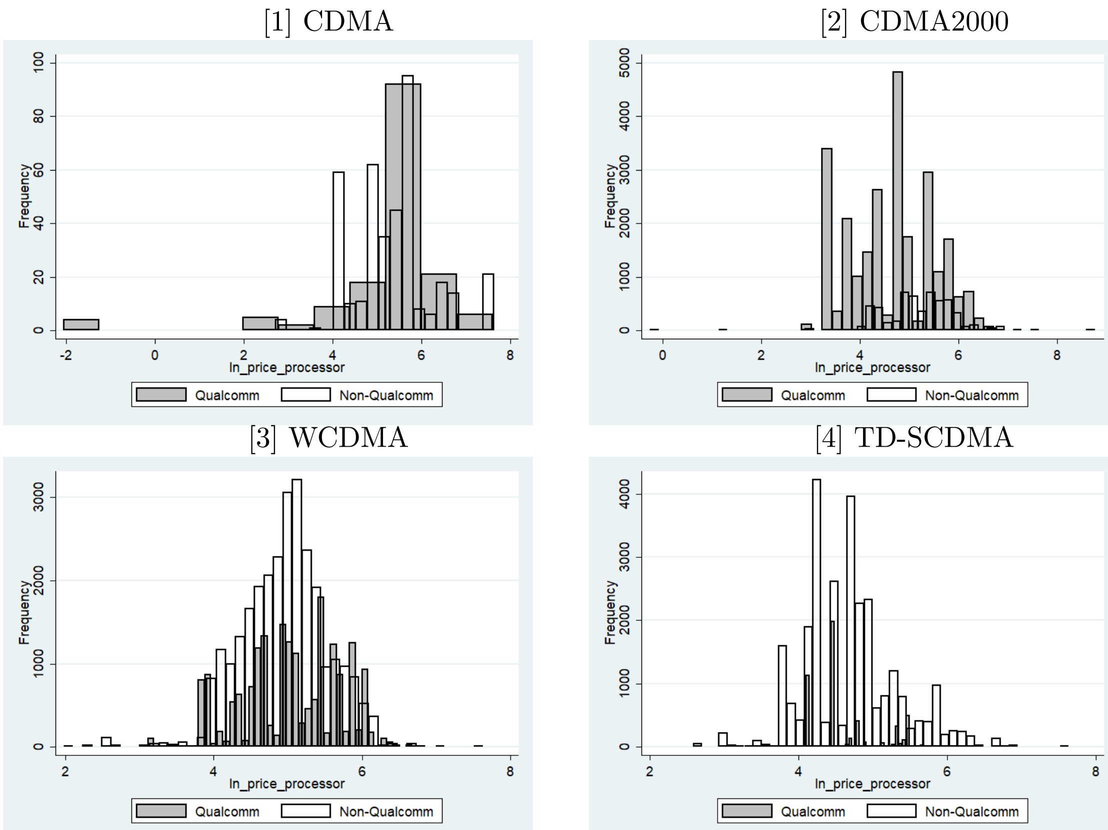
Source: Author's estimation

7.2 Marginal Cost of Smartphone and Price of Chip Sets

Figure 3 compares the estimated marginal costs of Qualcomm-chip-installed smartphone and non-Qualcomm-chip-installed ones. The costs of Qualcomm-installed handsets in the WCDMA and TD-SCDMA categories are higher than non-Qualcomm-installed handsets. The cost difference of the handset models for CDMA2000 and CDMA is not clear.

Figure 4 compares the distribution of the estimated price of processor chips between Qualcomm and Non-Qualcomm vendors. In the CDMA and CDMA2000 standards, prices of the Qualcom chips are lower than their rivals. There is no clear difference between WCDMA and TD-SCDMA.

Figure 4: Price of Chip Sets: Qualcomm Chip vs Non-Qualcomm Chip



Source: Author's estimation

7.3 Price elasticities

Price elasticities identify competitive relationships among the processor brands.

Tables 9. 10 and 11 show the mean own and cross price elasticities by the processor brand. Price elasticities in the row shows competitive relationship with the individual brands. If the cross price elasticities of brand on the column is more than one, it means the brand in column is substitutive relationship with the row brand. In the CDMA2000 market, there is no processorbrand who is substitutive to Qualcomm other than A and E, both are integrated chip vendors. Qualcomm is the monopolistic price leader in this market.

On the contrary, the WCDMA and LTE markets are more competitive. In addition to Qualcomm, J and O present a large cross-price elasticity. Even for Qualcomm, J, shows a cross-price elasticity of 2.2 for WCDMA and 4.8 for LTE, is substitutive.

Table 9: **Cross and Own Price Elasticities : CDMA2000, mean, 2014**

	A	B	D	E	F	I	J	L	QUALCOMM	O	P	Q	S	UNKNOWN
A	-0.7337	0.0005	0.0002	0.0272	0.0002	0.0002	0.0045	0.0021	0.2966	0.0190	0.0000	0.0035	0.0053	0.0117
B	0.0567	-3.0346	0.0001	0.0111	0.0001	0.0001	0.0018	0.0008	0.1212	0.0078	0.0000	0.0014	0.0022	0.0048
D	0.0697	0.0002	-3.9949	0.0136	0.0001	0.0001	0.0022	0.0010	0.1488	0.0095	0.0000	0.0017	0.0026	0.0059
E	0.1343	0.0005	0.0002	-2.3569	0.0002	0.0002	0.0043	0.0020	0.2868	0.0184	0.0000	0.0034	0.0051	0.0113
F	0.0403	0.0001	0.0000	0.0079	-2.4884	0.0000	0.0013	0.0006	0.0860	0.0055	0.0000	0.0010	0.0015	0.0034
I	0.0385	0.0001	0.0000	0.0075	0.0001	-2.5307	0.0012	0.0006	0.0822	0.0053	0.0000	0.0010	0.0015	0.0032
J	0.1636	0.0006	0.0002	0.0321	0.0003	0.0002	-1.8240	0.0024	0.3495	0.0224	0.0000	0.0041	0.0062	0.0138
L	0.0775	0.0003	0.0001	0.0152	0.0001	0.0001	0.0025	-1.4253	0.1656	0.0106	0.0000	0.0019	0.0029	0.0065
QUALCOMM	**5.5203**	0.0186	0.0063	**1.0814**	0.0091	0.0066	0.1774	0.0823	-1.9149	0.7564	0.0005	0.1385	0.2098	0.4662
O	0.2836	0.0010	0.0003	0.0556	0.0005	0.0003	0.0091	0.0042	0.6058	-1.8316	0.0000	0.0071	0.0108	0.0240
P	0.0133	0.0000	0.0000	0.0026	0.0000	0.0000	0.0004	0.0002	0.0284	0.0018	-2.2797	0.0003	0.0005	0.0011
Q	0.0177	0.0001	0.0000	0.0035	0.0000	0.0000	0.0006	0.0003	0.0377	0.0024	0.0000	-1.9987	0.0007	0.0015
S	0.2549	0.0009	0.0003	0.0499	0.0004	0.0003	0.0082	0.0038	0.5444	0.0349	0.0000	0.0064	-2.1950	0.0215
UNKNOWN	0.1968	0.0007	0.0002	0.0385	0.0003	0.0002	0.0063	0.0029	0.4203	0.0270	0.0000	0.0049	0.0075	-2.9923

Source: Author's estimation

Table 10: **Cross and Own Price Elasticities : WCDMA, mean, 2014**

	A	U	B	E	H	I	J	L	M	QUALCOMM	O	P	R	T	S	UNKNOWN
A	-0.7513	0.0186	0.0328	0.0445	0.0258	0.2368	0.3616	0.0014	0.0002	0.2134	0.3010	0.0076	0.0160	0.0010	0.0032	0.0601
U	0.4350	-2.0532	0.0271	0.0367	0.0213	0.1955	0.2985	0.0011	0.0001	0.1761	0.2485	0.0062	0.0132	0.0009	0.0026	0.0496
B	0.4865	0.0171	-1.6306	0.0410	0.0238	0.2186	0.3338	0.0013	0.0001	0.1970	0.2779	0.0070	0.0147	0.0010	0.0029	0.0555
E	0.3874	0.0136	0.0241	-2.6752	0.0189	0.1741	0.2658	0.0010	0.0001	0.1569	0.2213	0.0056	0.0117	0.0008	0.0023	0.0442
H	0.1652	0.0058	0.0103	0.0139	-2.0018	0.0743	0.1134	0.0004	0.0001	0.0669	0.0944	0.0024	0.0050	0.0003	0.0010	0.0188
I	0.1800	0.0063	0.0112	0.0152	0.0088	-1.8655	0.1235	0.0005	0.0001	0.0729	0.1028	0.0026	0.0055	0.0004	0.0011	0.0205
J	**5.5371**	0.1950	0.3444	0.4672	0.2708	**2.4883**	-1.7055	0.0144	0.0017	**2.2419**	**3.1632**	0.0794	0.1677	0.0110	0.0332	0.6312
L	0.2632	0.0093	0.0164	0.0222	0.0129	0.1183	0.1805	-2.1479	0.0001	0.1065	0.1503	0.0038	0.0080	0.0005	0.0016	0.0300
M	0.0589	0.0021	0.0037	0.0050	0.0029	0.0265	0.0404	0.0002	-2.1214	0.0239	0.0337	0.0008	0.0018	0.0001	0.0004	0.0067
QUALCOMM	**7.4313**	0.2617	0.4622	0.6270	0.3635	**3.3395**	**5.0985**	0.0193	0.0023	-1.7859	**4.2453**	0.1065	0.2251	0.0147	0.0445	0.8471
O	**1.0842**	0.0382	0.0674	0.0915	0.0530	0.4872	0.7439	0.0028	0.0003	0.4390	-1.8620	0.0155	0.0328	0.0022	0.0065	0.1236
P	0.0435	0.0015	0.0027	0.0037	0.0021	0.0195	0.0298	0.0001	0.0000	0.0176	0.0248	-2.0290	0.0013	0.0001	0.0003	0.0050
R	0.3740	0.0132	0.0233	0.0316	0.0183	0.1681	0.2566	0.0010	0.0001	0.1514	0.2137	0.0054	-2.0488	0.0007	0.0022	0.0426
T	0.0504	0.0018	0.0031	0.0043	0.0025	0.0227	0.0346	0.0001	0.0000	0.0204	0.0288	0.0007	0.0015	-1.3159	0.0003	0.0057
S	0.5399	0.0190	0.0336	0.0455	0.0264	0.2426	0.3704	0.0014	0.0002	0.2186	0.3084	0.0077	0.0163	0.0011	-1.8120	0.0615
UNKNOWN	0.4787	0.0169	0.0298	0.0404	0.0234	0.2151	0.3284	0.0012	0.0001	0.1938	0.2735	0.0069	0.0145	0.0010	0.0029	-2.2151

Source: Author's estimation

Table 11: **Cross and Own Price Elasticities : LTE, mean, 2014**

	A	E	I	J	L	QUALCOMM	O	P	UNKNOWN
A	-0.6226	0.5712	0.2290	0.8071	0.0108	**2.4940**	0.0259	0.0004	0.0316
E	**2.5906**	-1.9767	0.5135	1.8102	0.0242	**5.5935**	0.0581	0.0010	0.0710
I	0.4630	0.2290	-1.9113	0.3235	0.0043	0.9997	0.0104	0.0002	0.0127
J	**2.2328**	1.1041	0.4426	-1.9111	0.0208	**4.8209**	0.0501	0.0008	0.0612
L	0.2134	0.1055	0.0423	0.1491	-1.9615	0.4608	0.0048	0.0001	0.0058
QUALCOMM	**12.2348**	**6.0503**	**2.4253**	**8.5491**	0.1141	-1.4073	0.2746	0.0045	0.3352
O	0.2308	0.1141	0.0458	0.1613	0.0022	0.4984	-1.5542	0.0001	0.0063
P	0.0067	0.0033	0.0013	0.0047	0.0001	0.0145	0.0002	-7.9138	0.0002
UNKNOWN	0.2051	0.1014	0.0407	0.1433	0.0019	0.4428	0.0046	0.0001	-2.1535

Source: Author's estimation

Table 12: **Value Distribution of CDMA2000, RMB, mean**

	WTP	Price of smartphone	Cost of mobile	Price of processor	MC for chip	MC after lf reduction
A	8005	4756	3897	174	-138	-213
B	4222	3575	3194	575	305	253
D	3374	2238	2706	528	221	195
E	3784	1603	1391	226	124	96
F	1301	594	230	190	93	83
I	1487	1042	333	147	57	42
J	3037	1081	712	124	59	40
L	4578	2738	1894	207	55	15
QUALCOMM	2535	959	527	143	108	123
O	5927	3892	2802	339	32	-24
P	2572	1509	725	175	83	62
R	4080	1894	1723	196	77	49
S	3108	1639	964	205	68	49
UNKNOWN	1758	1040	572	183	71	59
Total	2707	1139	677	156	101	109

Source: Author's estimation
I have processor and handset brands except several selected ones anonymous.

7.4 Distribution of Value between Smartphone assembler and Chipset Vendors

In order to answer the fifth question above, that is, whether Qualcomm charged "unfairly high price", information on value distribution between smartphone assembler and chip vendors is instructive. I present the value distribution between consumer, smartphone manufacturers and chip vendors.

Here, I present Willingness to pay (WTP), price of mobile, estimated cost of mobile, estimated processor price and estimated marginal cost of processors. Willingness to pay of certain smartphone model, is the maximum of source of value that processor chip set can share revenue .

Figures 5, 6, 7 visualize value distribution between smartphone manfacturers and chipset vendor by types of competitive strategies of transaction partners: (1) Large independent smartphone manufacturers, that is, M (2) Middle sized smartphone manufacturers, O and V (3) Chip + Handset Integrated manufacturers, H and S.

For WDCMA market, M and O, and V's handsets that installed Qualcomm processor generates higher value in terms of WTP and price of mobile phone than the hands set installed the rivals processors brand J. O and V do not supply CDMA2014 products.

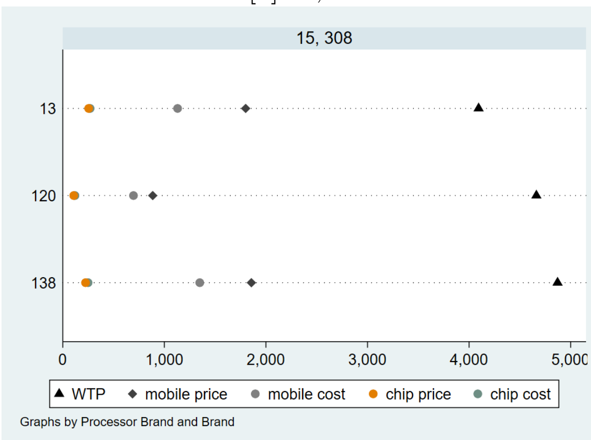
Interestingly, the handset assembler who also integrated the processor design such as S and H, shows a contrasting feature in their product portfolio. Both S and H installed their own processors for higher WTP and price products. For S and H, Qualcomm's processor installed in middle and low WTP and handset price category.

Possible interpretation are as follows: For the price taker-assembler such as M or O, V, value of transaction with Qualcomm is higher although the bargaining power belongs to the Qualcomm. This implies share revenue contract nature of license fee of SEP might be related and that vertical foreclosure with customer may not exists against the decision by NDRC.

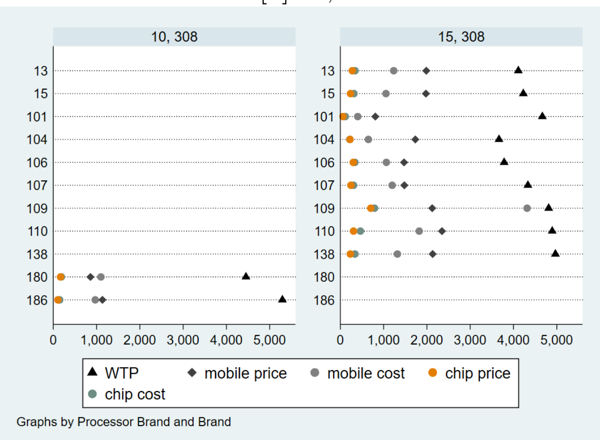
Product portfolio of S and H allow us to have consistent interpretation with above. Due to the nature of share revenue contract on license fee, the assembler who has their own source of chip set avoid installing it on the higher priced hand set model in order to reduce the license fee payment to Qualcomm.

Figure 5: WTP price, cost Map: M, O, V and S

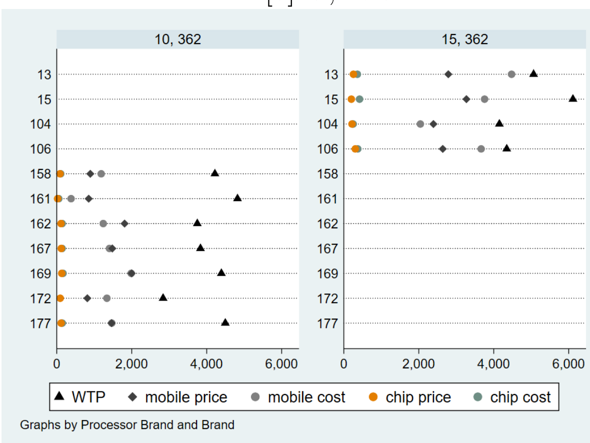
[1] M, CDMA2000



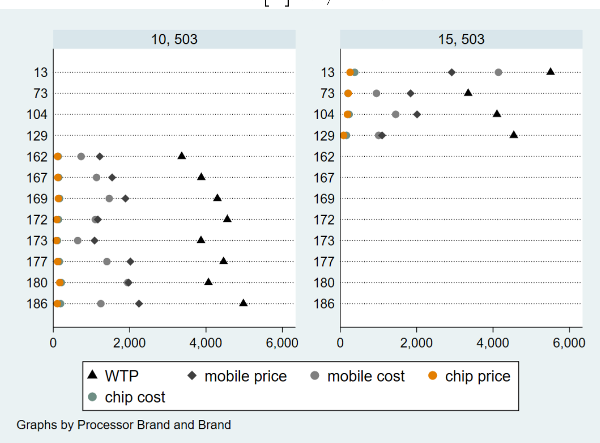
[2] M, WCDMA



[3] O, WCDMA



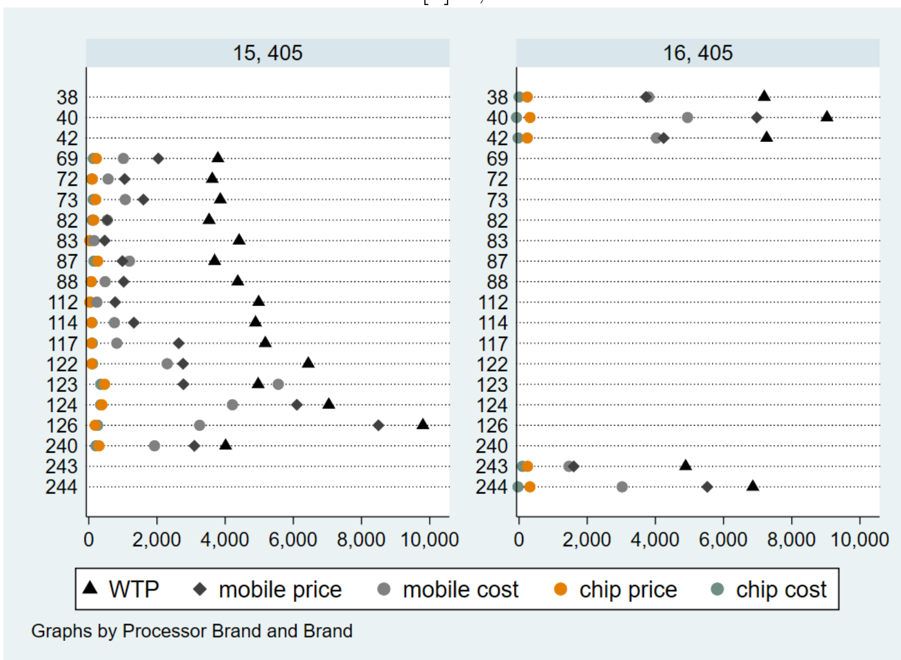
[4] V, WCDMA



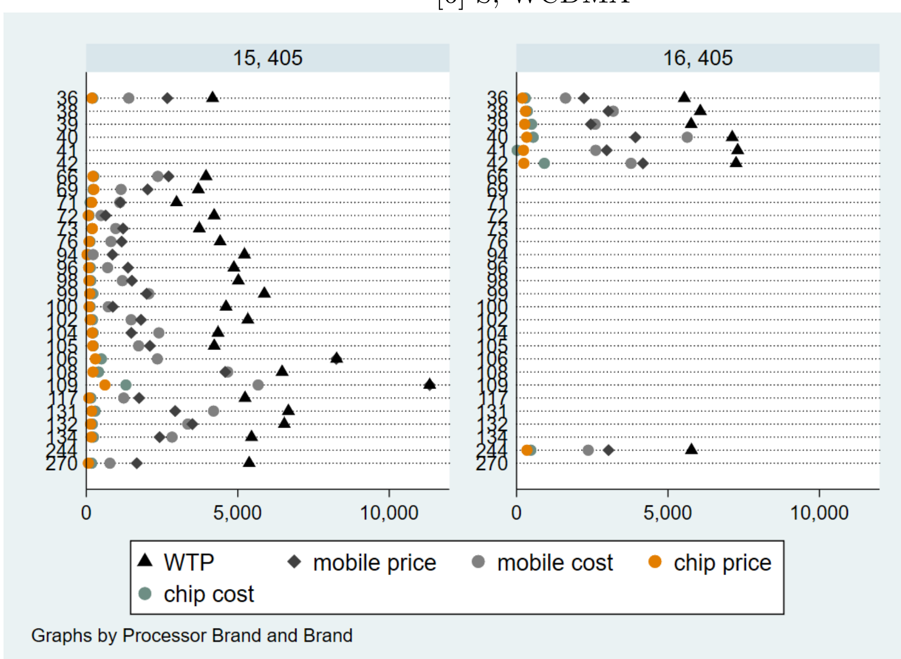
*Source:*Author's estimation
*Notes:*15, 10 are id of processor brands. 308, 362, 503 are ids of smart-phone brands

Figure 6: WTP price, cost Map(2) : S

[5] S, CDMA2000



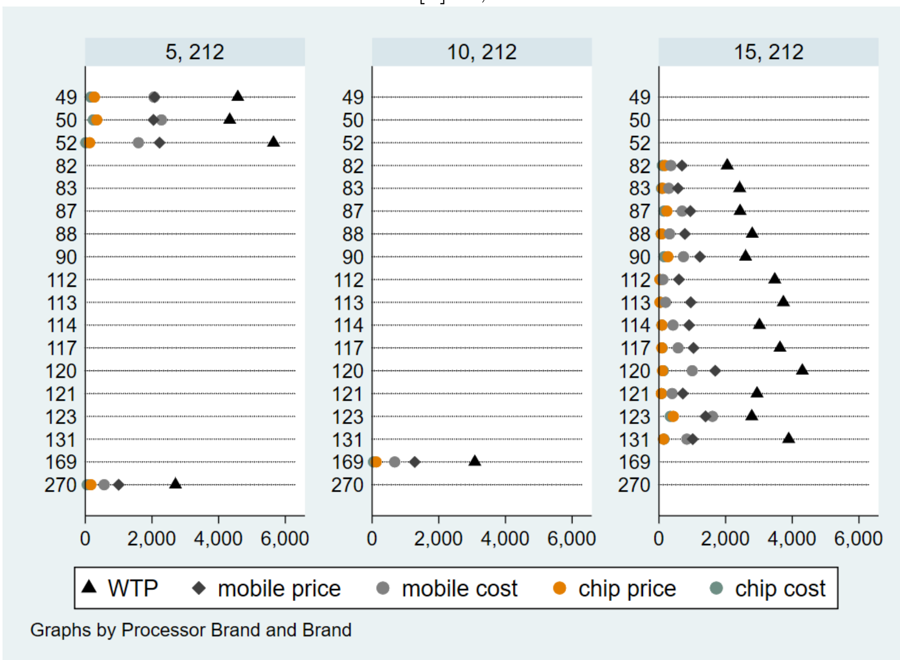
[6] S, WCDMA



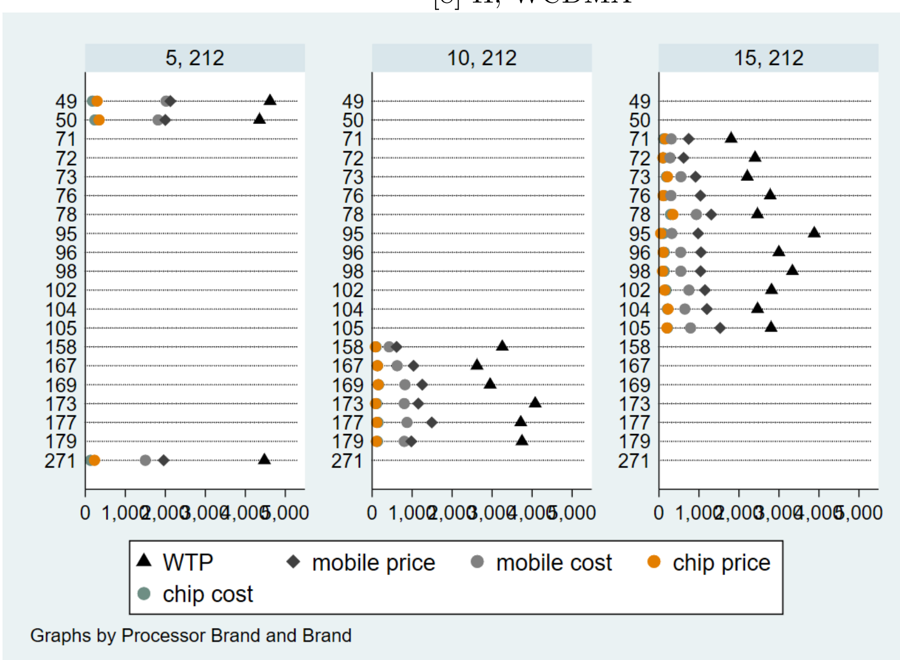
*Source:*Author's estimation
*Notes:*15, 16 are ids of processor brands. 405 is the id of smart-phone brands

Figure 7: WTP price, cost Map(3) : H

[7] H, CDMA2000



[8] H, WCDMA



Source: Author's estimation
Notes: 15, 10 are ids of processor brands. 212 is id of smart-phone brands

8 Discussion and Conclusion

The answers to the five empirical questions are summarized as follows:

First, Qualcomm holds a large substantial share of the CDMA, WCDMA, and LTE baseband chip market.

Second, regarding vertical foreclosure, Table (8) shows evidence that supports the claim that the company does not suppress competition. A substantial share of smartphone brands in China uses Qualcomm's input, instead of limiting the use to a particular partner. Moreover, the average retail price of smartphones using the company's input is decreasing.

Third, regarding the horizontal foreclosure that NDRC found, the company agreed not to bundle the 3G and 4G SEPs with other patents. The bundling existed. Moreover, claiming that a company has committed horizontal foreclosure requires verification that the company has engaged in predatory conduct by lowering current profits to induce rivals to exit the market, after which they raise the price again. The company announced that they would lower the license fee in their rectification plan instead of raising the price.

Regarding the impact of the decision by the NDRC, it will generate a positive-sum outcome, both to Chinese consumers and Qualcomm. Qualcomm may have an incentive to increase the supply of the license provision and baseband chips. It cannot be claimed that Qualcomm abused its monopoly power, at least in terms of the reduction of the production quantity. However, the company may have an incentive to increase production. The management strategy of Qualcomm needs to be more carefully examined.

This paper found that (1) Qualcomm holds a substantial share of the markets, as NDRC found. (2) However, their price-setting mechanism is not necessarily to hinder competition. Particularly in the smartphone device market, the company plays a role as a "technological enabler," and this can be seen in the rapid increase in the number of products in the smartphone market in China. Meanwhile, the retail net price of a smartphone has rapidly decreased. Consumer surplus keeps increasing. (3) On the contrary, Qualcomm may increase their income when they reduced the reference price for computing license fees. The impact of the decision of the NDRC against Qualcomm does not harm the profit of the company but may prompt the growth of the mobile phone industry in China.

References

Apple Inc. (2017) , APPLE INC.'S AMENDED COMPLAINT CASE NO. 17-cv-0108-GPC-MDD.

Ackerberg, Daniel A. and Gregory S. Crawford (2009) "Estimating Price Elasticities in Differentiated Product Demand Models with Endogenous Characteristics," mimeo, 2009.

Ackerberg, Daniel A., Gregory S. Crawford and Hahn, Jinyong (2011) "Orthogonal Instruments: Estimating Price Elasticities in the Presence of Endogenous Product Characteristics" Working Paper, University of Warwick.

Berry, Steven (1994) "Estimating Discrete-Choice Models of Product Differentiation" *Rand Journal of Economics*, 25 (2) 242–262

Berry, Steven, James Levinson and Ariel Pakes (1995) "Automobile Prices in Market Equilibrium" *Econometrica*, 63 (4) 841–890.

Berry, Steven and Philip A. Hale (2015) "Identification in Differentiated Products Markets" Cowles Foundation Discussion Paper No. 2019, Yale University

Collard-Wexler, Allan, Gowrisankaran, Gautam, Lee, Robin S (2019) ."Nash in Nash Bargaining: A Microfoundation for Applied Work" *Journal of Political Economy*, 01 February 2019, Vol.127(1), pp.163-195

Thomas K Cheng (2016) " The PRC NDRC Case against Qualcomm: A Misguided Venture or Justified Enforcement of Competition Law?" *Journal of Antitrust Enforcement*, 5 (1) 76—-99 ($doi10.1093/jaenfo/jnw005$)

Crawford, Gregory (2012) "Endogenous Quality Choice: A Progress Report" *International Journal of Industrial Organization*, 30 (3) 315–320

Draganska, Michael D.l Klapper, S. Villas-Boas (2010) "A Larger Slice or a Larger Pie? An Empirical Investigation of Bargaining Power in the Distribution Channel". *Marketing Science*, 29(1):57-74

Grigolon, Laura and Franc Verboven (2011) " Nested Logit or Random Coefficient logit? A Comparison of Alternative Discrete Choice Models of Product Differentiation" Center for Economic Studies, Discussion Paper Series 11–24.

Gandhi, Amit and Jean-Francois Houde (2016), "Measuring Substitution Patterns in Differentiated Products Industries," Working Paper. NBER Working Paper Series 26375 for 2020 version.

Hausman, Jerry (1996) "Valuation of New Goods under Perfect and Imperfect Competition," in *The Economics of New Goods*, ed. by T. Bresnahan, and R. Gordon. Chicago: University of Chicago Press.

Japan Fair Trade Committee (2009), "A Cease and Desist Order on Qualcomm Inc." 30 September, 2009. $http : //www.jftc.go.jp/houdou/pressrelease/h21/sep/09093001.html$

Kawashima Fujio (2016) "Comments on Lecture on Professor Wang Xianlin". The 39th Open Seminar at Research Center of Competition Policy.

Miller, Nathan H. and Matther Weinberg (2017), "Understanding the Price Effects of the MillerCoors Joint Venture," *Econometrica*, 85 (6), 1763-1791.

Michel, Christian and Stefan Wiergraeber (2018) "Estimating Industry Conduct in Differentiated Products Market: The Evolution of Pricing Behavior in the RTE Cereal Industry"

National Development and Reform Committee (2015) "NDRC China's Decision on Anti Monopoly Law of Qualcomm" 9th February, 2015.

Nevo, Aviv (2001) "Measuring Market Power in the Ready-To-Eat Cereal Industry," *Econometrica*, 69 (2) 307–342.'

Eric B. Rasmusen, J. Mark Ramseyer, and John S. Wiley Jr. (1991) "Naked Exclusion" *The American Economic Review*, Vol. 81, No.5 (Dec., 1991). Pp.1137-1145.

Rey, Patrick and Jean Tirole (2007) "A Primer on Foreclosure" in Armstrong M. and R. Porter ed., *Handbook of Industrial Organization, Volume 3* 2007, Elsevier

Steven C Salop and David T. Shceffman (1983) "Raising Rivals' Costs", *The American Economic Review*, Vol.73, No.2 (May 1983), pp. 267-271

Stock, James and Motohiro Yogo (2005) "Testing for Weak Instruments in Linear IV Regression" *book* Chapter 5, Andrews DWK *Identification and Inference for Econometric Models*. New York: Cambridge University Press; pp. 80–108.

Train, Kenneth E. (2009), *Discrete Choice Methods with Simulation* second edition, Cambridge University of Press, Nyew York.

Villas Boas, Sohia (2007) "Vertical Relationships Between Manufacturers and Retailers: Inference With L imited Data," *The Review of Economic Studies*, 2007, Vol. 74, 2, pp. 625-652.

Wakebe Yusuke (2016) "Development of Regulation on Abuse of Intellectual Property Right in China" The 42nd Open Seminar at Research Center of Competition Policy

Table A.1: GSM Base Band Market:2011-2014

processorbrand	**market share**			
A			0.7639	
U	0.0211	0.0083	0.0022	0.0004
B	0.0268	0.0111	0.0066	0.0089
D	0.6683	0.3523	0.0850	0.0120
H	0.0051	0.0013	0.0153	0.0002
I	0.0390	0.0051	0.0142	0.0012
J	0.0105	0.4321	0.5380	0.0881
K		0.0001	0.0014	0.0001
M	0.0000			
N	0.0003	0.0000	0.0000	
QUALCOMM	0.0311	0.0149	0.0066	0.0713
O	0.0021	0.0015	0.0009	0.0001
P	0.0052	0.0467	0.0096	
R	0.0000			
T	0.0224	0.0067	0.0044	0.0016
UNKNOWN	0.1733	0.1612	0.2786	0.0427

Source GfK

Table A.2: **CDMA Baseband Market:2011-2014**

processor brand	**market share**			
	2011	2012	2013	2014
A		0.4261	0.4160	
H		0.0000	0.0000	
J		0.0000	0.0000	0.0183
QUALCOMM	0.9781	0.6853	0.4108	0.5330
O	0.0151	0.2989	0.1270	0.0293
S	0.0001	0.0155	0.0354	0.0024
UNKNOWN	0.0067	0.0003	0.0006	0.0010

Source GfK

Table A.3: **CDMA2000 Baseband Market:2011-2014**

processor brand	**market share**			
	2011	2012	2013	2014
A		0.0609	0.0645	0.0654
B	0.0027	0.0043	0.0014	0.0004
D	0.0033	0.0014	0.0002	0.0003
E	0.0024	0.0002	0.0338	0.0274
F		0.0016	0.0010	0.0002
I	0.0078	0.0010	0.0001	0.0000
J	0.0000	0.0075	0.0196	0.0103
L	0.0073	0.0083	0.0060	0.0018
QUALCOMM	0.6752	0.7943	0.7794	0.8549
O	0.0838	0.0263	0.0676	0.0335
P		0.0001	0.0000	0.0000
R	0.0055	0.0104	0.0008	
T	0.1477	0.0790	0.0142	0.0031
UNKNOWN	0.0699	0.0097	0.0018	0.0020

Source GfK

Table A.4: **WCDMA Baseband Market:2011-2014**

processor brand	**market share**			
	2011	2012	2013	2014
A	0.1262	0.1374	0.1686	0.1797
U	0.2271	0.0386	0.0064	0.0045
B	0.0348	0.0662	0.0461	0.0255
E		0.0031	0.0147	0.0097
H		0.0001	0.0025	0.0097
I	0.0087	0.0098	0.0082	0.0200
J	0.0146	0.1386	0.2160	0.2734
L	0.0083	0.0222	0.0071	0.0014
M	0.0044	0.0058	0.0010	0.0021
N	0.0000		0.0000	0.0000
QUALCOMM	0.3900	0.4148	0.3689	0.3717
O	0.0241	0.0812	0.1203	0.0745
P			0.0000	0.0038
R	0.0047	0.0218	0.0174	0.0075
T	0.0285	0.0060	0.0008	0.0002
S	0.0802	0.0403	0.0146	0.0033
UNKNOWN	0.0484	0.0139	0.0074	0.0128

Source GfK. *Note* IOS is excluded.

Table A.5: **TD-SCDMA Baseband Market:2011-2014**

processor brand	**market share**			
	2011	2012	2013	2014
B	0.0041	0.0050	0.0116	0.0013
D	0.0651	0.0023	0.0001	0.0000
E		0.0006	0.0121	0.0087
H	0.0038	0.0003	0.0022	0.0002
G	0.0011	0.0233	0.0515	0.0301
I	0.5160	0.4531	0.0664	0.0356
J	0.0014	0.0951	0.3235	0.6211
L	0.0118	0.0399	0.0302	0.0468
M		0.0033	0.0006	0.0000
QUALCOMM	0.0211	0.0744	0.1562	0.0901
O	0.0475	0.0693	0.0474	0.0194
P		0.1092	0.2477	0.1112
R	0.0798	0.0389	0.0105	0.0009
S	0.1920	0.0679	0.0200	0.0016

Source GfK

Table A.6: LTE TD FD Base Band Market:2011-2014

processorbrand	**market share**	
	2013	2014
A		0.1486
E	0.0012	0.1066
I	0.0054	0.0637
J		0.1228
L	0.0528	0.0017
QUALCOMM	0.9406	0.5536
O		0.0020
P		0.0000

Source GfK

Table A.7: WTP, Price, Cost Map: CDMA2000, 2014

processor brand	WTP	price	mobile cost	processor price	chip cost
A	9,032	4,303	2,593	141	192
B	4,290	2,984	1,990	456	340
D	3,459	1,287	1,184	297	229
E	4,858	1,748	1,467	220	528
F	1,447	444	49	52	34
I	1,485	848	141	78	54
J	3,590	1,075	505	105	41
L	5,077	1,999	1,051	145	58
QUALCOMM	2,779	673	164	62	63
O	7,359	3,436	2,091	234	314
P	2,532	1,033	481	125	83
R	4,642	1,577	1,100	160	69
S	3,458	928	345	78	36
UNKNOWN	1,685	557	138	68	34
Total	2,895	704	180	78	63

Source: Author

Table A.8: Estimated WTP, Price, Cost Map: WCDMA, 2014, mean

processor brand	WTP	price	mobile cost	processor price	chipt cost	
A	9,010	4,408	2,840	149	195	191
B	4,293	2,944	2,029	456	323	308
D	3,717	1,474	1,214	297	231	221
E	4,607	1,683	1,251	217	2,275	2,268
F	1,469	505	90	62	39	37
I	2,009	791	155	87	52	49
J	3,610	1,110	543	113	42	39
L	5,116	2,295	1,367	173	58	53
QUALCOMM	3,000	875	322	88	87	90
O	6,881	3,784	2,270	222	262	255
P	2,557	1,071	448	125	78	74
R	4,707	1,614	1,136	160	56	51
T	3,637	1,151	456	113	-302	-305
UNKNOWN	1,855	672	199	88	34	32
Total	3,150	990	408	95	97	99

Source: Author

Table A.9: Estimated WTP, Price, Cost Map: WCDMA 2014, mean

processor brand	WTP	price	mobile cost	processor price	chipt cost	
A	9,195	3,981	2,714	147	149	144
U	3,768	1,362	646	130	27	23
B	3,683	940	432	73	102	100
E	5,212	1,793	1,345	243	354	346
H	5,691	1,410	769	138	51	47
I	4,289	945	419	88	45	42
J	3,566	1,044	503	79	79	76
L	4,613	1,549	843	144	74	70
M	4,010	1,362	532	129	69	65
QUALCOMM	4,156	1,344	731	105	105	108
O	6,752	2,448	2,013	214	217	210
P	3,509	424	109	38	19	17
R	3,994	1,165	576	108	-0	-4
T	4,302	1,662	658	111	37	33
S	4,382	1,682	833	142	56	52
UNKNOWN	2,771	974	301	71	94	92
Total	4,046	1,283	687	99	94	93

Source: Author