The role of a technological platform in facilitating innovation in the global value chain : a case study of China's mobile phone industry

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The Role of a Technological Platform in Facilitating Innovation in the Global Value Chain: A Case Study of China's Mobile Phone Industry

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Abstract

This study investigates the role of a technological platform in facilitating innovation in the global value chain. The literature argues that a technological platform facilitates innovation through its modular architecture. However, in case of China's mobile phone industry, innovation was paradoxically facilitated by the Qualcomm platform with a low degree of modularity. Several reasons are responsible for this phenomenon. First, innovation in the mobile phone industry has altered into a systemic innovation. Second, Qualcomm formulated a strategy that enables deep product differentiation, which precisely satisfied the upgraded domestic demands in China. Third, Chinese firms have accumulated strong capabilities that receive special technical support from Qualcomm. Fourth, stimulated by its unique licensing model, Qualcomm has been strongly motivated to help customers create value. The case of China's mobile phone industry indicates that, under some conditions and institutional arrangements, technological platforms can possibly help firms in developing countries to engage in innovation and create value.

Keywords: technological platform, modularity, systemic innovation, revenue-sharing contract

JEL classification: L20, O10, O30

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1 Introduction

The central topic of a study to investigate global value chain (GVC) is related to the manner in which lead firms and firms in developing countries exchange knowledge and information as well as the influence of this exchange on capability formation, industrial upgrading, and innovation (Gereffi 1999; Gereffi et al. 2005; Morrison et al. 2008; Pietrobelli 2011). Existing studies have focused on the role of global buyers in facilitating learning and innovation in GVCs. However, a growing body of literature suggests that vendors of technological platforms have played an increasingly important role in the development of global high-tech value chains. As demonstrated by the success stories of Microsoft, Intel, and Google, an increasing number of multinational companies have started adopting platform strategies to acquire a dominant share in the global market (Gawer and Cusumano 2002; Gawer 2009a; Cusumano 2011).

By definition, a technological platform could cause a significant impact on GVCs. Gawer and Henderson (2007 p.4) define a platform "owner" as a firm that owns a core element of the technological system that defines its forward evolution. Gawer (2009b, p.57) defined a platform as "building blocks that act as a foundation upon which other firms can develop complimentary products, technologies or services," and Baldwin and Woodard (2009, p.19) defined a platform as "a set of stable components that supports variety and evolvability in a system by constraining the linkages among the other components." These definitions indicate that a technological platform could play a crucial role in GVCs because it owns core technologies, determines design rules, and provides a solid foundation for innovation. A study of the relation between the technological platform and its users in developing countries will help us to gain a profound understanding of the mechanism of learning and innovation in GVCs.

This paper discusses this issue by focusing on the case of China's mobile phone industry, which is a typical platform-driven sector. In the 2000s, the dominant adoption of Taiwanese company Media Tek's (MTK) platform caused homogenous products, grave imitations, and intense competition in China. However, in the 2010s, along with the technological changes in mobile phone industry, the upgrading of China's domestic demands, the accumulation of technological capabilities of Chinese firms, and the introduction of an appropriate institutional arrangement, the technological platform provided by Qualcomm has become a crucial driving force in facilitating innovation and value creation. We thoroughly discuss this phenomenon to clarify the exact role of technological platforms in GVCs.

In the remainder of this paper, Section 2 reviews the literature on platforms and GVCs in the context of developing countries. Section 3 provides a brief introduction of the structural changes in China's mobile phone industry and highlights the crucial role of the Qualcomm platform in bringing about these changes. Section 4 clarifies the mechanism through which Qualcomm facilitates innovation in China's mobile phone sector. Section 5 concludes.

2 Literature review

The literature on platforms in developed countries have argued that a technological platform can facilitate innovation due to its modular architecture (Gawer 2014). It is highlighted that a technological platform must "entail a technological architecture that is modular and composed of a core and a periphery" (Gawer 2014, p.1245). Langlois and Robertson (1992, p.297) first argued about the importance of modularity in facilitating innovation. On the supply side, a modular system has the "potential for autonomous innovation, which is driven by the division of labor and provides the opportunity for rapid trial-and-error learning." On the demand side, the modular system can "fine-tune the product to consumer needs and therefore blanket the product space more completely." Gawer (2014, pp.1242–1243) stressed the fundamental role of an open interface within a platform's modular architecture. An open interface "contains information that is accessible to external agents and usable by them to allow to build complementary innovation that is compatible with this interface." Therefore, the degree of openness of a platform's interface will significantly impact the effect of its role in facilitating innovation.

However, in the literature on developing countries' firms, the roles of the technological platform and its modular architecture were described in a different context. The first line of the literature argued that the technological platform—because of the modular architecture—can help finished products makers in developing countries enter the global high-tech industry with little technological capabilities (Ding 2013). Modular architecture enabled a large number of small assemblers to share the same type of technological platforms to save on significant R&D investment (Watanabe 2014). Modular architecture also helps reduce interdependency and explicit coordination costs between platform vendor and users (Tatsumoto et al. 2009).

The second line of the literature argued that the technological platform and its modular architecture indeed hindered innovation and capability formation in developing countries. Steinfeld (2004, p.1973) pointed out that firms engaging in modular production "have little choice but to compete on the basis of low cost and high volume. They continually run the risk of being unseated by the next low-cost entrant, especially since fully modularized products are easily substitutable from the consumer's perspective." In a study of the technological platform in China's mobile phone industry, Brandt and Thun (2011, pp.173) noticed that "the modular product architecture provides domestic OEMs a shortcut to product upgrading, because the core technology can be outsourced, but this also leads to intense competition within the sector." Yasumoto and Shiu (2007, p.66) highlighted that encapsulation of the technological platform in the mobile phone sector enhanced thorough interfirm modularity between platform vendor and product developer and, "thus, hindered bilateral mutual learning between them."

The literature on platform and firms in developing countries also reached some consensuses. First, the knowledge on a technological platform is highly modularized. There are little knowledge and information flows between platform vendor and its users. Second, platform users in developing countries only manufacture simple finished products. There is little room for product differentiation. Third, platform users in developing countries cannot achieve substantial innovation as they have not accumulated sufficient technological capabilities. From the perspective of value chain governance, these three points lead to a typical "market" governance in a platform-driven GVCs (Gereffi et al. 2005). However, as highlighted by Gereffi et al. (2005), GVC governance patterns are not static, which change overtime along with the changes in technology, market and firm capabilities. That being the case, we would ask a question: if changes occurred, just like what happened in China's mobile phone sector, then, could a technological platform create new opportunities for innovation and value creation in developing countries?

This research question is closely related to the discussion of buyer-driven GVCs. Most literature indicated that global buyers are often reluctant to share knowledge of key technology, design, and marketing to prevent suppliers from becoming competitors (Schmitz and Knorringa, 2000; Bazan and Navas-Aleman, 2004; Morrisson et al., 2008). In line with these micro-level studies, recent studies on trade-in value-added suggested a clear trend: that the value distribution for developing countries' firms became increasingly smaller (Baldwin, Ito and Sato 2014; Dollar et al. 2017, Chapter 2).

Therefore, it is very important to find out a success story in which a technological platform help firms in developing countries to conduct innovation and create value.

3 Structural changes in the mobile phone industry and replacement of leading technological platforms

The mobile phone industry in China has experienced significant structural changes since 2010. Prior to that, this industry was dominated by feature phones and characterized by its low-end segment, the so-called shanzhai sector. Shanzhai firms are small businesses with dozens of employees. The shanzhai value chain is highly disintegrated, with numerous independent firms specializing in narrow production processes. Value chain governance is typically an arm's length market that has the disadvantages of highly homogenous products and grave imitations (Zhu and Shi 2010; Brandt and Thun 2011; Ding and Pan 2014).

Table 1 Shipments of Major Smartphone Makers in the Global Market

	Vendors	2011	2012	2013	2014	2015	2016
1	Samsung	95	198	299	308	320	311
2	Apple	93	136	153	193	232	215
3	Huawei	17	31	52	75	108	139
4	OPPO	-	5	18	31	45	95
5	VIVO	-	3	12	30	44	82
6	Xiaomi	-	7	19	65	73	58
7	LG	19	26	48	59	60	-
8	ZTE	17	31	42	45	51	57
9	Lenovo	4	23	45	-	45	50
10	TCL-Alcatel	3	7	12	41	42	34

Source: Data of Samsung and Apple in 2016: IDC; other data: IHS iSuppli, a market research firm.

However, in recent years, China's mobile phone industry has achieved significant upgrading. In the global smartphone market, Chinese firms matured and rapidly replaced many existing international brands (Table 1). In line with the global market, newly emerged firms have quickly replaced international brands and have become major players in the domestic market. From 2012 to 2016, the list of the top five smartphone brands (regarding domestic shipments) in the Chinese market has changed from Samsung, Lenovo, Apple, ZTE, and Huawei to OPPO, Huawei, VIVO, Apple, and Xiaomi.[1]

Table 2 Market Share of Local Smartphone Brands in China

	2014 Q4			2015 Q3		
	Total	Share of local brands in each segment	Share of local top 3	Total	Share of local brands in each segment	Share of local top 3
High-end (>500$)	16%	-	4.2%	13.5%	-	9.4%
Mid-range (250-500$)	20.4%	76.5%	44.6%	24.8%	81.9%	58.8%
Low-end (<250$)	63.6%	100%	45.4%	61.7%	100%	48%

Source: Authors-calculated, based on GFK market research data.

In the 2000s, Chinese feature phone makers primarily concentrated on the low-end segment of the domestic market (Ding and Pan 2014). In the 2010s, the situation has significantly changed. Data for the period from the fourth quarter of 2014 to the third quarter of 2015 (Table 2) showed that Chinese firms maintained their absolute advantages in the low-end market and acquired certain shares in the mid-range market. Some Chinese firms also began to enter the high-end segment. In particular, the concentration level in the mid-range market has shown a significant increase.

The rising shares of Chinese brands in the middle- and high-end segments have indeed led to value creation. Using the example of the most popular model, OPPO R5 released in 2014, the BOM cost was estimated at $155.6, and the official price was approximately $488.4.[2] In the same year, iPhone 6 was released with a BOM cost of $212 and an unlocked price of $649.[3] Until the third quarter of 2017, data on major

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[1] These data are estimated by IDC, a market research company.

[2] BOM cost is estimated by Fomalhaut Techno Solutions. For data on the new model release, one dollar was equivalent to 6.1405 Yuan.

[3] https://technews.tw/2014/09/23/iphone-6-and-iphone-6-plus-bom-cost, accessed Jan 18, 2018.

smartphone brands' profits were first reported.[4] According to this estimation, the profits per unit of the major brands are as follows: Apple ($151), Samsung ($31), Huawei ($15), OPPO ($14), VIVO ($13), and Xiaomi ($2). Large gaps between Apple and Chinese brands remain in terms of profitability. Given that Apple completely focuses on the high-end market and Chinese brands focus on both the middle- and low-end markets, we at least can confirm that some flagship models of Chinese brands (Huawei, OPPO, VIVO) in the middle-range market have gradually accumulated capabilities to create value. A piece of evidence to support this view is the profit data of Foxconn, the largest original equipment manufacturer (OEM) of iPhone. The profit per unit for iPhone X of Foxconn was reported as $10, including the assembly fee ($ 4.2) and the profits of parts and component ($5.8)[5]. This data clearly revealed the stronger abilities of Chinese mobile phone firms to capture value in GVCs.

In the 2000s, the value chain of feature phones was highly disintegrated. The product development of a mobile phone usually involves two separate processes: the design house and the system integrator (Imai and Shiu 2007, Ding and Pan 2014). Design houses are engaged in PCB hardware design and some software designs. They are also in charge of PCBA (printed circuit board + assembly) production. Generally, system integrators do not have an R&D department and only partially take charge of product definition, supply chain management, project management, and sales (Ding and Pan 2014). However, in the 2010s, an increasing number of vertically integrated firms that had both the design house and the system integrator functions emerged. The number of vertically integrated firms in 2016 was estimated as 30[6].The top five Chinese companies in 2016 (in terms of global shipments)—Huawei, OPPO, VIVO, Xiaomi, and ZTE—are all vertically integrated.

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4 http://www.timesnownews.com/technology-science/article/apple-samsung-vivo-oppo-xiaomi-counterpoint-research-study/182825, accessed Feb. 8, 2018. These data were estimated by Counterpoint, a market research company.

5 http://www.huaxia.com/tslj/flsj/zz/2017/10/5495638.html accessed Feb. 8, 2018.

6 Author interview with Pan Jiutang, former vice president of Huaqiang Electronic Research Institute on Dec. 19, 2016.

These significant structural changes accompanied a drastic replacement of the technological platforms in the mobile phone industry.[7] In the eras of 2G and 3G technologies, MTK succeeded in developing a turnkey solution that includes a platform (baseband IC) that conducts most of the system design and part of the software design, and a reference design that makes most mobile phone components easy to use. This turnkey solution has significantly reduced the technological barriers to entry into the mobile phone sector and has precisely met the requirements of large numbers of China's underserved shanzhai firms. However, only marginal autonomous innovations were allowed on the platform (Wang and Lin 2008; Zhu and Shi 2010; Brandt and Thun 2011; Ding 2014).

MTK maintained its advantage in 3G era but was no longer able to obtain the dominant position when 4G was introduced (Table 3). Instead, Qualcomm, as the world's largest owner of 3G and 4G technology patents, entered the smartphone baseband IC market. Qualcomm's share in China's 4G market (by shipments) accounted for more than 50% in 2015 (Table 3). Of the top ten smartphone makers (in terms of shipments) in the domestic market in 2015, eight are Chinese makers. Among these, five makers primarily adopt Qualcomm's platforms: Xiaomi (No. 1, 70%), OPPO (No. 4, 70%), VIVO (No. 5, 60%), Coolpad (No. 7, 60%), and ZTE (No. 10, 50%).[8] In the third

[7] In the smartphone era, the role of the mobile phone operating system as a software technological platform became increasingly important as well. In China, all of the mobile phone companies chose the Android platform. There are then two directions for the differentiation of smartphones. The first direction is to differentiate a smartphone through application software (Thun and Sturgeon, forthcoming). The most successful case is Xiaomi, which developed its own user interface, MIUI, using the Android platform. However, this software differentiation strategy is easy to copy and, thus, could not establish long-term solid barriers to entry. The second direction is to differentiate a smartphone in terms of hardware (and related software) functionalities, such as a beauty camera, fast-charging, and so on. Different from software, the differentiation of hardware functionality requires much closer collaboration with the platform vendor and key parts suppliers, which is more difficult to imitate. Eventually, most leading Chinese mobile phone companies, including Xiaomi at late stage, have chosen the second direction. This paper thus focused on the relations between hardware platform vendor and mobile phone companies.

[8] These data are estimated by Shenzhen Huaqiang Electronics Industry Research Institute. Huawei's case is unique. The company developed its own baseband IC, Hisilicon, which accounted for 55% of its total shipment in 2015.

quarter of 2017, as the three top Chinese brands (OPPO, VIVO, Xiaomi) are adopting Qualcomm's chipsets in mid-tier and affordable premium smartphones, the company's share in world's smartphone SoC market (by value) reached to 42%, far ahead of Apple (20%), MTK (14%) and Samsung (11%).[9] In contrast, most small firms with poor technological capabilities had to give up the adoption of Qualcomm platforms. In the following sections, we carefully explore how the changes in technology, market and firm capabilities enabled Qualcomm to play such a crucial role in facilitating innovation, creating value, and stimulating industrial upgrading.

Table 3 Shipments of Baseband ICs in China's Smartphone Market (million units)

Platform vendor	2014	2015
3G		
Qualcomm	70	10
MTK	300	210
Spreadtrum	80	95
Total	450	315
4G		
Qualcomm	110	210
MTK	35	140
Hisilicon	15	42
Leadcore	-	11
Spreadtrum	-	12
Marvell	20	5
Total	180	415

Source: Huaqiang Electronic Research Institute.

Pearl River Delta (PRD), having Shenzhen as its central city, is the largest mobile phone industrial cluster in the world. Among the top ten global smartphone companies (Table 1), five of them (Huawei, OPPO, VIVO, ZTE, and TCL-Alcatel) are in PRD. Since 2009, we have made annual visits to Shenzhen to conduct interviews with platform vendors and mobile phone makers. Our focal point is knowledge and information flows along the mobile phone value chain. In recent years, along with the rise of Qualcomm platform, we intensively conducted interviews with managers at

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9 https://www.counterpointresearch.com/global-smartphone-soc-market-crossed-us8-billion-q3-2017-third-quarter-record, accessed Feb 26, 2018.

Qualcomm, managers or engineers at vertically integrated firms and design houses that adopt Qualcomm platform, and various industry analysts in Shenzhen. Meanwhile, from December 2014 to February 2015—at the turning point from 3G to 4G technology—we conducted a questionnaire in Shenzhen and its neighboring areas, investigating the knowledge and information flows between platform vendors and mobile phone companies. The sample size is 56, including 48 companies that primarily manufacture smartphones (the share of smartphones is no less than 50%, the same below) and eight companies that primarily manufacture feature phones. In the remainder of this paper, the analysis is based on the information collected from fieldwork and the questionnaire distributed in PRD. Regarding the questionnaire data, because our motivation is to compare the different roles of two major platforms in the development of the smartphone sector, we thus focus on the data on five smartphone makers that primarily adopt the Qualcomm platform, and 37 smartphone makers that primarily adopt the MTK platform. As previously stated, MTK's strategy is to serve a large number of firms in the middle- and low-end markets that have poor technological capabilities. In contrast, Qualcomm's strategy is to serve with a small number of leading customers in the middle- and high-end markets with strong technological capabilities. Therefore, although the sample size is small, it revealed the exact situation in the smartphone industry.

4 Changing environment and technological platform responses

4.1 Technological changes

The first reason to explain the leading role of the Qualcomm platform is that its strategy has precisely adapted to recent technological changes in the mobile phone sector that transformed innovation in the mobile phone industry from autonomous innovation to systemic innovation and significantly broke down value chain modularity.

The first technological change in the mobile phone sector is that both mobile phone and telecommunication technologies have become increasingly complex. Compared with a feature phone, the smartphone has an independent operating system and application software. All of these generate more bugs and require closer collaboration between the platform vendor and smartphone companies to solve problems. Moreover, in the 4G era, radio frequency technology has become very difficult to standardize and integrate into the baseband IC chipset. A mobile phone company needs to repeatedly communicate with the platform vendor and amplifier and antenna suppliers to make the telecommunication function more stably (Humphrey et al. 2017).

The second technological change is that the life cycle of a mobile phone was shortened considerably. In the eras of the feature phone and 2/3G technology, the lifecycle of a mobile phone was two years, but has been shortened to half a year at present. According to Tasumoto and Shiu (2007, p.64), “novel technology adoption requires product system knowledge of nested modules, … even in modularized interfirm development processes.” To acquire a comprehensive system of knowledge for the development of each new smartphone model, platform vendors must more frequently exchange technological information with their customers.

On the other hand, the R&D cycle of baseband ICs and finished products remain very long in the mobile phone sector. For example, the R&D of a mobile phone processor, which is the core part of the baseband IC chipset, takes two years and the product development of a finished smartphone takes six to twelve months. In this circumstance, a technological platform vendor must precisely predict the market trend two to three years before the release of a new smartphone. For this purpose, the vendor needs to regularly communicate with its customers to obtain accurate consumer-related information.

Tables 4 and 5 indicated these situations. Because of the above-mentioned technological changes, there generated two-way rich technological and market information flows between platform vendors and users, whatever the platform is Qualcomm or MTK[10]. However, Qualcomm platform has shown comparatively lower value chain modularity than MTK. In particular, regarding the question that “are platform vendors proactive at providing technological knowledge and information related to their IC products to your company”, the difference between these two platforms are significant (Table 5).

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[10] This situation was entirely different from the situation in 2000. According to Wang and Lin (2008, p.178), among 266 firms in the ICT industry in Shenzhen and Dongguan “only 12 percent of enterprises considered that R&D cooperation was important and a mere 3 percent considered it very important while as many as 79 percent reported that they had never engaged in such cooperation with other local enterprises.” In line with this statement, 80 percent of the firms did not exchange any R&D-related information or ideas with firms in the same region. It is not clear how many mobile phone firms were included in this survey. However, the paper suggests that mobile phone is a major sector of ICT industry in Shenzhen and Donguan, and it selected 13 mobile phone firms to conduct in-depth interviews that suggest a poor situation with respect to research cooperation.

This point precisely reflected the different platform strategies adopted by Qualcomm and MTK. As a technological leader, Qualcomm is good at exploring new technological frontiers but is not strong at the standardization and modularization of new technologies. Thus, Qualcomm is more used to jointly developing new products and resolve problems with customers through face-to-face communication. This strategy has just been adapted to technological changes in the mobile phone industry.

Usually, before releasing a new platform, Qualcomm closely communicates with customers to reflect as best as possible their requirements for the platform. After a platform has been adopted, individuals are assigned to be responsible for the joint product development of smartphones. Qualcomm provides regular and emergent support to its customers and assists them in conducting co-marketing, often jointly holding product release conferences or introducing overseas carriers to customers. In this way, Qualcomm broadly exchanges technological and marketing information with customers.[11]

Table 4 Frequency of Communication with Technology Platform Vendors

	Almost every day	Several times per week	Several times per month	Several times per year	No communication	Total
MTK users	9	11	5	1	1	27
Qualcomm users	3	2	0	0	0	5

Source: Authors' questionnaire survey data.

Notes:

1) Qualcomm users refer to mobile phone companies that primarily adopt its platforms (the share of Qualcomm is no less than 50%). MTK users refer to mobile phone companies that primarily adopt MTK platforms (the share of MTK is no less than 50%). The same below.

2) This table does not include data of system integrators because they only purchase PCBAs from design houses but do not transact directly with platform vendors.

[11] The author's interview with a manager at Qualcomm Shenzhen (Dec. 20, 2016).

Table 5 Information Flows between Technology Platform Vendors and Smartphone Makers

	Frequent	Sometimes	Occasionally	Never	Total
Does your company ask platform vendors to provide related knowledge, information or solutions when it engaged product development based on the platform and confronts technological problems?					
MTK users	22	2	3	0	27
Qualcomm users	5	0	0	0	5
Are platform vendors proactive at providing technological knowledge and information to your company related to their IC products?					
MTK users	17	6	3	1	27
Qualcomm users	5	0	0	0	5
Are platform vendors proactive at providing market information to you?					
MTK users	14	7	5	1	27
Qualcomm users	2	3	0	0	5
Is your company proactive at providing feedback regarding market information to the baseband IC maker?					
MTK users	14	9	3	1	27
Qualcomm users	3	2	0	0	5

Source: Authors' questionnaire survey data.

Note: This table does not include the data of system integrators, as they only purchase PCBAs from design houses but do not transact directly with platform vendors.

Qualcomm often sends a team to its customers to help it develop new products and resolve problems[12]. The company also allows leading Chinese companies' research teams to visit its headquarters. In these situations, in addition to a technology assistant team and an after-service department, Chinese engineers can engage in face-to-face communication with Qualcomm's core engineers and learn intensively from them. This interaction is very important for the formation of technological capabilities. As Ernst and Kim (2002, p.1425) argued, "in most cases, the acquisition of explicit knowledge alone is not sufficient for the local suppliers to assimilate and use it in production, as the translation of explicit knowledge into actual operations requires a significant amount of tacit knowledge."

12 Author interview with Pan Jiutang on Dec. 19, 2016.

In contrast, MTK is more used to providing codified information through the reference design. MTK's reference design for the smartphone covers the most mature technologies for software (such as the user interface) and hardware. Various solutions for possible problems are also integrated into the reference design.[13] As a result of the lack of face to face communication, MTK users' learning opportunities are significantly limited.[14]

4.2 Upgrading domestic demand

The second reason to explain the leading role of the Qualcomm platform is that the company has formulated various strategies that enable product differentiation at a deep level, thus adapting the significant changes in domestic demand in China.

According to the Chinese government's official statement, the middle-class population reached 400 million in 2018.[15] These people have created a significant market for high-quality products, strong brand image, and good functionalities. The other factor is the rapid development of the mobile Internet in China. Up until February 2017, the number of mobile internet users in China was 1.06 billion, or more than 80% of the total population. Of these, 978 million users are adopting 3G/4G technologies (Ministry of Industry and Information 2017). Given the large number of mobile Internet users, China has fostered various world-class internet platforms and APPs such as WeChat, Taobao, and Didi. The social networking and transaction requirements generated from these platforms and APPs have forced Chinese firms to develop smartphones with faster data transmission speeds, more stable systems, and clearer camera functions.

To respond to these changes in market demand, Qualcomm adopted a strategy that enables platform users to conduct deep product differentiation. As Table 6 suggests, compared with smartphone makers' primarily adopting the MTK platform, smartphone

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[13] Qualcomm has attempted to learn from MTK and provided the Qualcomm Reference Design (QRD) to customers but failed to achieve significant results (the author's interview with a manager at Qualcomm Shenzhen on Dec.20, 2016).

[14] Yasumoto and Shiu (2007) pointed out this problem of the MTK platform in the feature phone era. Smartphones partly broke down the value chain modularity of the MTK platform, but the learning opportunities remain limited relative to Qualcomm as long as a turnkey solution is adopted.

[15] China's top economic official, Mr. Liu He's speech at the Davos Forum 2018.

makers primarily adopting the Qualcomm platform sold more products to China's domestic market and developed country markets, in which demand is more qualified.

Table 6 Market shares of products adopting MTK and Qualcomm platforms

	Total	Chinese Market Average	Developing Countries Average	Developed Countries Average
MTK users	37	39.1%	54.2%	6.6%
Qualcomm users	5	73.0%	11.76%	15.12%

Source: Authors' questionnaire survey.
Note: This table includes all of the data on vertically integrated firms, design houses, and system integrators.

Two methods can be used to enable deep product differentiation. The first method is to substantially open the interface. Qualcomm opened approximately 80% of its hardware driver source code to mobile phone companies, whereas MTK opened a mere 20%.[16] Several patterns define the use of these hardware source codes. The first pattern is that Qualcomm develops special hardware functionality by itself and only allows one company, as the world's first user, to differentiate its product by using this function. For example, Xiaomi 5S first adopted the Sense ID ultrasonic fingerprint function, which was provided and supported by Qualcomm. The second pattern is that smartphone makers independently research a new functionality and develop a smartphone using this function on the basis of Qualcomm's hardware source codes. For example, OPPO Find 7 contains the Voltage Open Loop Multi-Step Constant-Current Charging (VOOC) flash-charging function, which is developed by OPPO and is also a world's first. Although the Qualcomm platform developed its own fast-charging technology, the company still supported the development of OPPO Find 7. The third pattern is that smartphone makers jointly develop a new function with other parts suppliers. VIVO X9 was the first to adopt a front dual camera (using Sony's IMX 376 sensor) function in collaboration with Sony. The development of the X9 was also based on Qualcomm's hardware source codes and is supported by it.

[16] The author's interview with an engineer at a design house (Jan. 10, 2017) who has been engaged in the design of mobile phones using both the Qualcomm and MTK platforms.

Worthy of attention is that the collaboration with Qualcomm helped give Chinese mobile phone makers more opportunities to cooperate with the world's first-class suppliers, which further accelerated the upgrading of Chinese firms. Regarding the aforementioned examples, Xiaomi collaborated with Biel Crystal (for the cover glass) on the development of the Sense ID ultrasonic fingerprint function in the 5S model. OPPO collaborated with Texas Instruments (for the power chip) when developing VOOC flash-charging. In addition to Sony, VIVO also collaborated with ArcSoft (for camera software) for the development of a front dual camera function.

The second method to support deep product differentiation is to allow customers to adjust certain design parameters (such as radio frequency specifications) of the Qualcomm platform, which partially breaks down the platform's product modularity. A good example is VIVO. As one of the largest customers of Qualcomm in China, VIVO is given the most original evaluation report on Qualcomm's new platforms. VIVO can make requests to Qualcomm's product definition department to adjust some parameters of features and performance that go beyond the scope of a standardized Qualcomm platform.[17] In contrast, MTK users were not allowed to do similarly.

In summary, deep product differentiation requires more frequent knowledge and information exchange between platform vendors. As similar as technological changes, deep product differentiations that resulted from the upgraded domestic demands had a strong impact on breakdown in value chain modularity.

4.3 Capability formation

The third reason that explains the leading role of the Qualcomm platform is that some Chinese mobile phone companies have accumulated strong technological capabilities and meet Qualcomm's standard for special technical support.

In the era of the feature phone, given the autonomous nature of innovation, sales volumes for new models were at most two million units. However, regarding the smartphone, innovation was transformed into being systemic and sales volumes for a single model were more than 10 million units. For example, sales volumes of the most popular flagship OPPO and VIVO models—the R9 and X9—amounted to 20 million

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[17] Authors' interview with the person in charge of software development at VIVO (Oct.9, 2016). VIVO can also ask Qualcomm for information on launch dates and the costs of each new platform.

units[18]. These large sales volumes for a single model generated strong scale economies, enabling mobile phone companies to invest heavily in R&D to accumulate technological capabilities. As a result, an increasing number of system integrators began to establish their own R&D department and transformed into vertically integrated firms. The share of mobile phones developed by vertically integrated firms out of Chinese firms' total shipments increased from less than 30% to nearly 50% between 2010 and 2015.[19] To establish an R&D department, Chinese firms not only hired engineers from international mobile phone companies—particularly those from poorly performing companies in China (Motorola, Nokia, HTC, Sony, and so on)—but also fostered their own engineers (Humphrey et al., 2017).

To enjoy strong R&D scale economies, a mobile phone company is also required to possess certain marketing capabilities. In the 2000s, most mobile phone companies relied on independent distributors for sales of their products (Ding and Pan 2014). However, after 2010, some leading mobile phone companies began to establish their own distribution channels. From the first quarter of 2014 to the second quarter of 2015, the share of the top six "retail-focused OEMs" (mobile phone companies that built their own sales network) in the Chinese market increased sharply from 26% to 47%.[20]

Chinese companies' accumulation of capability complies with Qualcomm's technical support standard. Qualcomm usually provides special support for their leading customers. In Qualcomm's monthly global support bandwidth, customers are categorized into five ranks in terms of shipments and product technology. Companies ranked in the top position are given the highest priority for product customization, jointly resolving problems, and receiving new technological information.[21] Currently, only Apple has sufficient technological capability to substantially customize Qualcomm's baseband IC. Chinese firms are only able to adjust certain design parameters of the platform. In comparison, the majority of MTK's users are small firms with poorer capabilities. Except for debug, MTK is more accustomed to providing standardized turnkey solutions for them instead of individual support.

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[18] Author interview with Pan Jiutang on Dec. 19, 2016.

[19] IHS market research data provided by Pan Jiutang.

[20] These data are provided by Pan Jiutang.

[21] This information was cited from Shiu Jingming's presentation at the workshop on "The upgrading of China's industrial agglomeration: An interdisciplinary approach of spatial economics and area-study" (Jan. 2016) at the Institute of Developing Economies.

VIVO, as the third largest smartphone maker and one of Qualcomm's largest customers in China, is a typical case that suggests how a Chinese company achieved innovation and was upgrading by gaining special support from Qualcomm.[22] Initially, VIVO outsourced its R&D department to a design house. VIVO gradually internalized its R&D department, expanding the number of software development engineers from 37 to 700 between 2011 and 2015. VIVO also established 250,000 outlets (some franchised) in China, which allows the company to reach out even to fourth-tier cities.

All of these efforts have significantly strengthened VIVO's relationship with Qualcomm. When VIVO was small, it could not get any support from Qualcomm. Presently, VIVO interacts frequently with Qualcomm at various levels. At the engineer level, more than ten individuals communicate with Qualcomm almost every day. At the middle management level, the person in charge of the R&D department intensively communicates every month with Qualcomm's vice president in the Chinese branch. Regarding top management, the two companies' CEOs, CFOs, and CTOs meet each other several times a year. Moreover, if VIVO has an emergency, Qualcomm mobilizes its global resources to support its customer, including through 30 to 40 engineers from Santiago and Hyderabad. A manager at Qualcomm (Shenzhen) confirmed that VIVO (and Huawei) are particularly good at learning through close interactions.[23]

4.4 Revenue-sharing contract

The fourth reason that explains the leading role of the Qualcomm platform is the company's unique licensing model. As a typical revenue-sharing contract, this licensing model has provided strong incentives at Qualcomm to help customers create value.

Qualcomm collects licensing fees from customers on the basis of the wholesale price of a mobile phone. As the world's largest patent owner of 3G /4G technologies, license fees are the largest revenue stream for Qualcomm. For example, in the 2016 fiscal year, Qualcomm Technology Licensing's (QTL) share accounted for 85% of Qualcomm's total earnings before taxes (EBT).[24] In China's 4G technology market, before 2015, Qualcomm collected 3.5% of the total wholesale revenue of each 4G smartphone model

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[22] Authors' interview with the person in charge of software development at VIVO (Oct.9, 2016).

[23] Author's interview conducted on Dec.20, 2016.

[24] Qualcomm's Fiscal 2016 Results.

as licensing fees and reduced the basis of the fee collection from total to 65% of wholesale revenues after an antitrust investigation was conducted by the Chinese government.

Qualcomm's licensing model is criticized as an abuse of monopoly position for obtaining excessive profits. However, this model also can be regarded as a typical revenue sharing contract, an institutional arrangement for stimulating knowledge sharing. [25] Under this licensing model, Qualcomm has strong incentives to care about both the IC chipsets shipments and the value added created in each mobile phone. Thus, Qualcomm has been strongly motivated to share various technological and marketing knowledge with customers and help them to develop smartphones with high value added.

In contrast, MTK only collects license fees before selling chipsets to their customers regardless of the smartphone's wholesale price, which represents a typical lump-sum contract[26]. Under MTK's licensing model, the company is only concerned with mobile phone shipments. Eventually, MTK chose a strategy that enables a large number of small firms to adopt its platforms.

5 Conclusion

The case of China's mobile phone industry suggests that technological platforms can possibly assist firms in developing countries to engage in innovation and capture value. The value chains driven by the Qualcomm platform have helped China's leading mobile phone companies achieve significant upgrading, conduct active systemic innovations, and engage in more value creation. This finding is different from the finding of existing literature on buyer-driven value chains, platforms in developing countries and trade in value-added. The leading role of technological platforms was enabled by three factors.

The first factor is the breakdown in value chain modularity of the mobile phone industry. Platform literature considered that the technological platform is a stable system and its design architecture is always modular (Baldwin and Woodard 2009, p.19; Gawer 2014,

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[25] This point was inspired by Cheung (1967), which suggested that a share tenancy contract is essentially an institutional arrangement for risk sharing.

[26] Author's interview with a manager at a vertically integrated firms that adopts MTK platform (May 29, 2017).

p.1243).[27] Thus, governance of the value chain between platform vendor and users is naturally modular. However, from the value chain perspective, chain governance patterns are determined by various factors and are always changing, along with changes in these factors (Gereffi et al., 2005). As technology became complex, the codifiability of technology decreases and, as demands are upgraded, transaction complexity increases. Both these factors lead to breakdowns in value chain modularity and, accordingly, closer collaborations and interactions between platform vendors and users.

Value chain governance theory is based on the experience of buyer-driven value chains, but also can be well applied to the explanation of platform-driven value chains. In the mobile phone industry, the emergence of the smartphone and 4G technologies, and upgrading domestic demand have significantly undermined value chain modularity. Qualcomm's platform strategy, including face-to-face special technical support and support for deep product differentiation have well adapted to these changes and have facilitated systemic innovation.

The second factor is that some Chinese firms as platform users have accumulated certain technological capabilities. These capabilities enabled them to meet Qualcomm's standard for special technical support and thus gain important learning opportunities. In the case of China's mobile phone industry, the formation of these capabilities has benefited from human resources accumulated in multinational companies and the scale economy of R&D generated from China's large market. This finding is consistent with the argument in the literature on GVCs and innovation, which suggested that learning from the lead firm alone is insufficient for innovation in GVCs. In addition, firm-level efforts to accumulate capabilities and an innovation system that enables this accumulation are indispensable (Morrison et al., 2008; Pietobelli and Laberroti, 2011; Marchi et al., 2016). We further highlighted that marketing capability is also

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[27] Recent literature on the technological platform argues that the platform is not a stable system but evolves (Gawer 2014). This study focused on changes in the organizational forms of platforms (internal platform, supply chain platform, and industry platform), considering that decisions regarding a platform interface's openness are driving forces for these changes. However, this paper discussed the evolving mechanism of platforms using different logic. We argue that exogenous factors, such as technological and market changes, drive changes in the design architecture and related value chain modularity.

indispensable as it helps enjoy the scale economy of R&D and accumulate technological capabilities[28]

The third factor is appropriate institutional arrangements. According to value chain governance theory, the previously mentioned two factors lead to typical relational inter-firm relations (Gereffi et al. 2005). However, we have observed that the relationships between Qualcomm and Chinese mobile phone companies are different. Although rich knowledge and information flows are generated along the chain, a significant asset specificity problem—a key point of relational governance—has not occurred (Gereffi et al. 2005, p.84). Every month, Qualcomm changes the customers that receive special technical support in terms of their shipments and product technologies. Instead of transaction-specific investments, Qualcomm has chosen a different institutional arrangement to strengthen its relationships with customers. Qualcomm adopted a unique licensing model that is a typical revenue sharing contract. Using this model, Qualcomm is strongly motivated to share knowledge on R&D, design, and marketing with customers and to help them develop smartphones with higher value added. Qualcomm's case indicated that an appropriate institutional arrangement is likely to facilitate the transfer of core knowledge from developed to developing countries. In future research, we need to find out more success stories about such arrangements, not only in the platform-driven value chain, but also in the buyer-driven value chain, so that gain a more profound understanding of global value chains.

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[28] Sako and Zylberberg (2017) regard these investments in capability formation as investments in complementary assets, a key strategy to help firms in developing countries to profit from upgrading. In the case of a platform-driven value chain, however, it is slightly controversial if we can say these assets are "complementary", as there is no significant asset specificity problem along the chain.

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