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The Optimal Pricing Strategy of a Mobile Payment Service in a Two-sided Market

Completed Research Paper

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Abstract

Acknowledging the high penetration rate of mobile devices, mobile payment is currently a hot topic and is expected to reach the tipping point of rapid growth. For such a nascent market, how to run a successful mobile payment platform remains unanswered. Therefore, we devote this study to investigate the pricing strategy of proximity mobile payment. Mobile payment serves as a two-sided platform connecting merchants and customers. By leveraging the emergent mobile payment knowledge, we present a game-theoretic model featuring network externality. In the short run, we find the platform will have incentives to apply "divide and conquer" strategy by subsidizing customers to adopt the mobile payment service at the beginning of the business. After the ignition, the platform then becomes profitable by charging per transaction fee from the merchants. In the long run, the subsidization strategy is suggested to be applied when the bank is not taking too much processing fee and leaves sufficient market share to the mobile payment platform. In terms of contributions to practice, this study offers a step forward of method to identify this promising market for mobile payment executives, financial institutes and all others ecosystem.

Keywords: Mobile payment, platform strategy, pricing strategy, game theory

Introduction

The rapid evolution of technology has affected human beings' daily behavior and altered the methods of commerce. From telegraphs, telephones to nowadays mobile phones which most modern people claim cannot live without, communication devices have shortened the time and cost of people to interact with others to a blink of eye. However, mobile phone in today's digital era is not only a communication device but a door to access all variety of services, including information exchange, entertainment, and commerce. According to Forrester (2016), more than 4.8 billion individuals were using a mobile phone at the end of 2016. Data from KPCB (2016) reveal that mobile devices have eclipsed desktop computers as the primary method of Internet access for users globally. The same report shows adults in average spend roughly three hours per day on a mobile device in the United States. As this enormous and potential growth that mobile devices present, it comes with no surprise to see that the battlefield of commerce has extended from e-commerce to so-called m-commerce (mobile commerce). Originally introduced in 1997 by Kevin Duffey at the launch of the Global Mobile Commerce Forum, e-commerce means "the delivery of electronic commerce capabilities directly into the consumer's hand, anywhere, via wireless technology."[1]

[1] For more details, please refer to Global Mobile Commerce Forum 1997 https://cryptome.org/jya/glomob.htm

As this trend evolves, Gartner (2015) predicts that revenue from m-commerce will equal 50% of all digital commerce in the United States by 2017. A recent World Payments report by Capgemini (2015) claims that an annual growth of 60.8% through 2015 as mobile devices have become common devices for shopping online. Nearly 80 million U.S. consumers, corresponding to half of digital buyers in the U.S., are expected to make purchases using mobile devices. Acknowledging the high penetration rate of mobile devices, mobile payment is currently a hot topic and is expected to reach the tipping point of rapid growth.

Mobile payment, also referred to as mobile wallets, mobile money, or mobile money transfer, is widely defined as a transfer of funds in return for a wide range of services and digital or hard goods, where the mobile phones are involved in both the initiation and confirmation of the payment operated under financial regulation. The location of the payer and supporting infrastructure is not important: she may or may not be “mobile” or “on the move” or at a Point of Sale (POS); the money may be paid by credit cards or by a prepaid wallet (Pandy, 2014). Mobile payment is a new form of value transfer, similar to other payment instruments that consumers can use. However, it relies more on the advanced features of mobile phones and the tokenization of a consumer’s financial credentials.

Based on the location of firms and consumers, mobile payment may be remote or proximity. By adopting *remote mobile payment*, the parties and entities involved in the authorization and transaction process are not physically close to each other. As remote mobile payment has been established in the e-commerce market for years, its market structure and architecture are relatively mature. In contrast, thanks to the modern wireless communication technology, *proximity mobile payment* lets consumers use their phones to pay for goods or services at a physical POS or with a mobile POS device at the merchant.[2] According to PwC (2016), in 2014, the transaction volume in the global proximity mobile payment market was valued at $4.6 billion and it is expected to exceed $300 billion by 2020, with a 5-year CAGR of 85.9%.

Mobile payment ecosystem is diverse and complex. Many different kinds of firms are involved, ranging from mobile network operators (MNOs) and financial institutions to software and hardware providers. Therefore, inter-firm collaboration is especially crucial for the development and commercialization of this new market. However, the conflicting interests and different roles played by the firms in the system make it hard to reach a universal agreement on a new market architecture. This leads to a variety of models of mobile payments platform, differentiated by technology implementation (NFC, QR Codes), location (remote or proximity), and various stakeholders (financial institutions, mobile network operators, phone providers, regulators) each with their own motivations, expectations and capabilities (Dennehy and Sammon, 2015; Pandy, 2014).

For a promising payment services markets with a history of numerous tried and failed solutions, how to run a successful proximity mobile payment platform remains unanswered (Dahlberg et al., 2008b). Therefore, we devote this study to investigate a business model of proximity mobile payment, whose development is currently still constraint by technology of end devices and immature market policies.

Mobile payment serves as a two-sided platform connecting merchants and customers. As a platform, successful ignition relies on it installed base, and user benefit of using the platform increases as the number of users increases. This is known as the so-called *positive cross-side network externality*, which is the extra utility one earns by interacting with members at the other side of the platform. The more members at the other side, the more utility one gains. For a mobile payment provider, it faces the challenge of attracting enough merchants to provide goods and services to attract customers, and vice versa. To incentivize merchants and customers to adopt the mobile payment service, pricing (and subsidization) is obviously the key. The platform also needs to profit from the registration fees of both customers and merchants and transaction fee in each payment to make itself financially sustainable. Consequently, in this study we investigate a mobile payment platform’s pricing strategy and the impact of technology options. We hope our study may explain the rationale behind the selection of pricing strategies adopted by mobile payment platforms in industry. Moreover, we may provide a step forward of method to understand this new market that is full of potential.

To this aim, we build a game-theoretic model featuring network externality and consider mobile payment business settings under different technologies. Game theory is a major method used in economics, business, and social science for modeling behaviors of interacting agents (Shapiro, 1989). One particular application is for studying two-sided platforms (Caillaud and Jullien, 2003; Armstrong,

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[2] For more details, please refer to Smart Card Alliance http://www.smartcardalliance.org.

2006). This research method usually focuses on looking for sets of strategies known as "solution concepts" or "equilibria", under a common assumption that players act rationally. The most famous of these is the Nash equilibrium, in which each player's strategy represents a best response to the others' strategies. Researchers analyze behaviors of players to discover economics and business insights.

In this research, three types of players are in the market: a firm constructing the mobile payment platform, a group of potential consumers, and a group of potential merchants. The major purpose of our work is to study the profitability of feasible pricing strategies and figure out factors that affect the platform's equilibrium choice. To focus on the pricing strategies of the platform and the interdependency between merchants and customers, we assume that the decisions of the rest of the players (e.g., banks) are fixed or less flexible to be changed.

In the next section, we review some related works about mobile payment ecosystem, network externality and multi-sided platforms, and mobile payment platform. We then develop our model to address the interaction among the mobile payment platform, customers, and merchants. Our analysis and findings then follow.

Literature Review

Since Dahlberg et al. (2008b), several literature reviews about mobile payments have been written. Hedman and Henningsson (2012) set up a framework to identify the decision makers of this market and their roles. They point out that digitalization of payments has caused ecosystem instability by impacting the competitive and collaborative dimensions of ecosystems. In other words, this digitalization creates a new arena for competition. In the study on how nascent mobile payment markets emerge, Ozcan and Santos (2015) argue, as the potential partners hold dominant positions in different markets, cooperation between two parties are difficult and may lead to a vicious circle and potential markets are lost due to turf wars.

Apart from discussion about the turf war of different players, Ondrus et al. (2015) investigate the impact of openness in mobile payment platform on market potential by examining openness at three levels: the provider, technology, and user levels. As the platform is launched, players as decision makers need to adopt an appropriate openness strategy to achieve the minimum market potential to support platform ignition and hence the likelihood of success. This study contributes to the understanding of the causes that have hindered the developments of mobile payments over the year, and why most mobile payment initiatives have failed before reaching consumers and merchants.

The chicken-or-egg analogy is perfectly used to describe the mobile payment ecosystem challenge facing merchants' and consumers' adoption issues. The more consumers adopting the mobile payment method, the higher the incentives for merchants and agents to join the system. On the other hand, more merchants accepting mobile payment of course also attract more consumers to use it. This is called positive cross-side network effect. The presence of network externality is viewed as an important property of a "two-sided market" (Caillaud and Jullien, 2003; Armstrong, 2006). According to Hagiu and Wright (2015), multi-side platforms not only enable direct interactions between two or more distinct sides, but also affiliate each side of the platform. In a mobile payment business model, the key terms of the interaction could be the pricing, consuming, and delivery of the goods or services. "Affiliation" is defined as users on each side consciously make platform-specific investments that are necessary in order for them to be able to directly interact with each other. For example, in a mobile payment ecosystem, the investment could be a fixed access fee (e.g., POS setup fee or registration fee of mobile payment platform), expenditure of resources (e.g., developing cost of applications using the iPhone's APIs), or an opportunity cost (e.g., paying by cash, joining a loyalty program). These dimensions significantly affect the adoption of multi-sided models.

Caillaud and Jullien (2003) propose a framework to analyze intermediation service providers' pricing strategies under imperfect competition with a consideration of cross-side network externalities, and point out that Internet platform are mostly nonexclusive, where users are said to engage "multihoming". By adopting "divide-and-conquer" strategies, where one side of the platform is subsidized (divide) and profits are made on the other side (conquer), users are absorbed to join in the market at the beginning of the business. When the market size reaches the minimum to support platform ignition, platform can then become profitable. Similar strategies are analyzed in model of payment card system as well (Baxter, 1983; Rochet and Tirole, 2002; Schmalensee, 2002; Wright, 2004). We follow this stream of literature to adopt game theory as our way of examining our research questions.

To the best of our knowledge, few research articles provide theoretical investigation on mobile payment and platform pricing strategy. Zhan and Qiao (2015) construct a game-theoretic pricing model of trusted service manager (TSM) in a mobile NFC payment industry. Chaix and Torre (2010) classify four types of possible economic business models according to the degree of involvement of two main partners, bank(s) and mobile network operator(s). Nevertheless, both studies fail to answer how the platform should determine its pricing or subsidization strategy by their theoretical model. Our study contributes to the literature by explicitly characterizing the mobile payment platform's optimal pricing strategy by considering network externality.

Model

We formulate a stylized model integrating the essential features of a mobile payment platform considering settings under different mobile payment technologies. A mobile payment platform is a service offered to two parties, the customers (for each of them, she) and the merchants (for each of them, he), by a mobile payment platform operator.

Customer. To join the platform, a customer pays a registration fee f_C to the mobile payment platform. It is noted that f_C is not necessarily positive since negative registration fee can be viewed as subsidization. After joining the platform, she may pay with her mobile phone in merchants allowing the service. In each transaction, an exogenous cost of using the mobile payment service $c \geq 0$ occurs. The value of c is determined jointly by the easiness-to-use, security, and usefulness of the service.

As a two-sided platform, the more merchants adopting the mobile payment method, the higher the incentives for customers to join the system. That is, the payment service quality depends on the number of merchants on the platform in equilibrium, which determines the degree of convenience to use the mobile payment service. Let n_M be the number of merchants on the platform, we denote a customer's perceived service quality by general consumption frequency $h(n_M)$, where $h'(n_M) > 0$ and $h''(n_M) < 0$, i.e., increasing the number of merchants is attractive, but the marginal attractiveness decreases. The shape of $h(n_M)$ is further visualized in Figures 1 and 2. If we zoom in the beginning part of Figure 1, the curve can be well approximated as a straight line as shown in Figure 2. In other words, in the nascent market of mobile payment, the number of merchants approximately affects the customers' willingness-to-use linearly. Therefore, we set $h(n_M) = n_M$ in the short run and consider $h(n_M)$ as a general concave function of n_M in the long run.

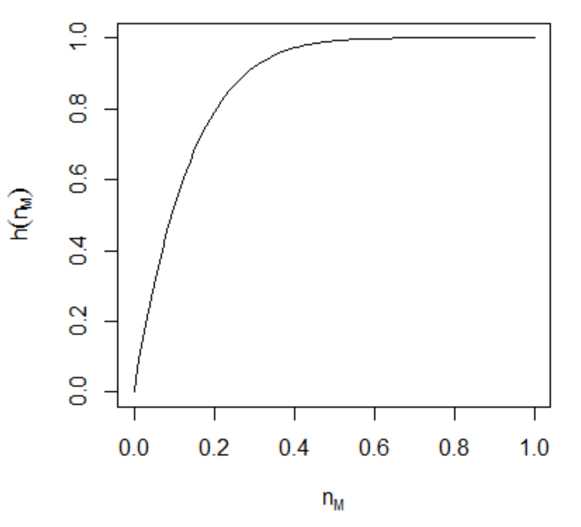

Figure 1. $h(n_M)$

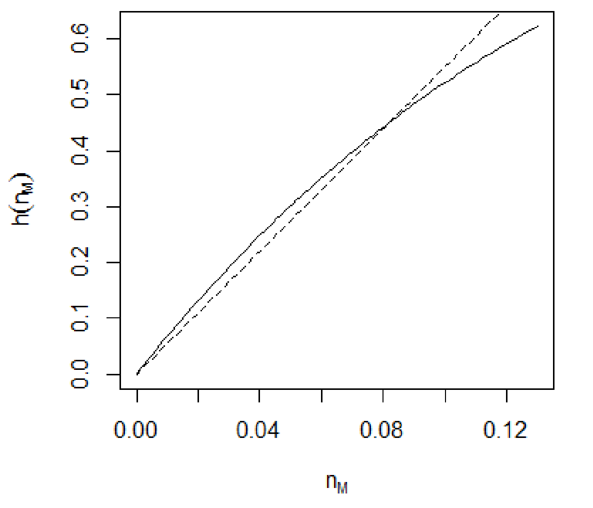

Figure 2. $h(n_M) = n_M$

It is natural that customers differ in their willingness to use a mobile payment service. For example, some customers have a low value of time of going to get cash before shopping, while others may consider carrying coins are inconvenient and transaction speed is important. Therefore, we assume that customers are heterogeneous on their willingness-to-use θ, which is uniformly distributed in $[0,1]$. The net benefit obtained in a transaction is then $\theta - c$. Suppose that a customer in expectation uses the mobile payment service $N > 0$ times, a type-θ consumer's utility in a membership period is thus

$$u_C = Nh(n_M)(\theta - c) - f_C, \tag{1}$$

i.e., the total amount of benefit obtained through using mobile payment $Nh(n_M)(\theta - c)$ minus the membership fee f_C per membership period.

Merchants. Let $p > 0$ be the exogenous average price of products in a mobile payment transaction. When a customer makes a purchase at the merchant, the merchant is charged by the mobile payment platform operator at a rate r_M. That is, he earns only $p(1 - r_M)$ in each transaction. Without loss of generality, we normalize p to 1 throughout this study. We still include p in expressions when that makes the exposition clearer.

We consider merchants to be heterogeneous on their willingness to adopt mobile payment as well. Some merchants may believe that introducing mobile payment can speed up transactions and capture more transaction details for future analysis at the same time. On the contrary, some merchants just dislike mobile payment due to, for example, the resistance to new technology. Therefore, we denote the (physical or mental) cost of performing a mobile payment transaction by η, which distributes uniformly within 0 and 1, to capture the heterogeneity among merchants. A merchant's net earnings per transaction is thus $p(1 - r_M) - \eta$.

Similar to customers, merchants have more incentive to join the platform when more customers sign up on the platform. Let n_C be the number of customers of the mobile payment platform. There will be Nn_C transactions made in one membership period. Given that there are n_M merchants in the market adopting mobile payment, each merchants will receive $\frac{Nn_C}{n_M}$ transactions in expectation. Consequently, a type-η merchant's utility is

$$u_M = \frac{Nn_C}{n_M}(p(1 - r_M) - \eta). \tag{2}$$

Market segmentation. A customer will join the platform if her $u_C \geq 0$, and a merchant will do the same thing if his $u_M \geq 0$. Thus, following our model setting, there exists a critical value θ^* that divides customers into two group: A customer uses the mobile payment service if and only if her $\theta > \theta^*$. Similarly, we can find a critical value η^* such that a merchant will join the platform if and only if his $\eta < \eta^*$. In our notation, this means

$$n_C = 1 - \theta^* \text{ and } n_M = \eta^* \tag{3}$$

An illustration of the market segmentation is provided in Figure 3.

Figure 3. Customer and merchant segmentation

Mobile payment platform. The platform's problem is to maximize its profit

$$u_W = n_C f_C - n_M(-s) + Nn_C p(r_M - b) \tag{4}$$

where $s \geq 0$ is a system installation cost paid by the platform to include a merchant and $b \in [0, 1]$ is an exogenous payment processing fee rate charged by banks. A system installation cost in real world cases can be hardware cost such as POS device set-up fee or staff training cost to adopt new payment method. As we mentioned in the first section, different mobile payment techniques lead to different set-up cost. Payment processing fee is determined by the financial institutes. For example, in an NFC-SIM based system, banks are unwilling to let mobile operators keep in charge of the business and thus reflect their power on charging a high payment processing fee per transaction. On the contrary, in an NFC-HCE based system, banks charge a relatively low processing fee due to the absence of mobile operator, shortening the time to market. The platform profits from the registration fee of customers and transaction fee in each payment. In other words, it looks for f_C and r_M to maximize its profit u_W.

Throughout this study, we impose the assumption $c < p(1-b)$ to be satisfied for all b, c and p. This assures that the cost will not be greater than the profit from the system's perspective. As we normalize p to 1, this assumption means $b + c < 1$.

The sequence of events is as follows. First, the mobile payment platform decides the per transaction fee rate r_M and the registration fee f_C. Second, each potential merchant and customer observes the fees and consider his or her own willingness of adopting mobile payment and decides whether to join the platform or not independently. The sizes of the two groups will then be realized, and the platform earns its profit. A list of notations is provided in Table 1.

Decision variables	
r_M	Merchant's transaction fee rate
f_C	Customer's registration fee
Parameters	
n_C	Number of customers using mobile payment
n_M	Number of merchants using mobile payment
θ	Customer's willingness to use mobile payment
η	Merchant's per transaction cost of using mobile payment
N	Number of transactions of a customer in a membership period
c	Customer's cost of using mobile payment
p	Average price of a transaction
s	System installation cost at the merchant side
b	Payment processing fee charged by banks
$h(n_M)$	General consumption frequency

Table 1. List of decision variables and parameters

Strategy in the Short Run

In this section, we analyze the optimization problem of the mobile payment platform. In this section, we study the basic case, where $h(n_M) = n_M$, which represents the short-run situation faced by the platform. In the next section, we will further discuss the model under the general consumption frequency $h(n_M)$ settings in the long-run.

We first derive the profit function of the platform. Given r_M and f_C, (1), (2), (3), and $h(n_M) = n_M$ together imply that

$$f_C = N(1-r_M)(\theta^* - c) = 0 \quad \text{and} \quad \frac{Nn_C}{n_M}(1 - r_M - \eta^*) = 0, \tag{5}$$

where the former and latter are for the type-θ^* customer's and type-η^* merchant's utilities to be 0, respectively. By solving the system, we get a unique solution of θ^* and η^* as

$$\theta^* = \frac{f_C}{N(1-r_M)} + c \quad \text{and} \quad \eta^* = 1 - r_M. \tag{6}$$

Substituting θ^* and η^* into (4), we have the platform's profit function as

$$u_W = \left(1 - \frac{f_C}{N(1-r_M)} - c\right)\left(f_C + N(r_M - b)\right) - s(1 - r_M) \tag{7}$$

which is a maximization problem of a platform with decision variables $f_C \in \mathbb{R}$ and $r_M \in [0,1]$. The optimal solution of this problem is characterized in Proposition 1.

Proposition 1. *The optimal registration fee and transaction fee rate are*

$$r_M^* = \frac{1+c+b}{2+c} \quad \textit{and} \quad f_C^* = \frac{Nc}{2+c}(b-1) \tag{8}$$

Moreover, for all values of b, *c, s, and N, we have* $r_M^* > 0$ *and* $f_C^* < 0$.

Proposition 1 shows that it is of the platform's best interest to adopt the "divide-and-conquer" strategy, as suggested by Caillaud and Jullien (2003), to subsidize customers and make profits from merchants. Because $f_C^* < 0$, a customer who uses the mobile payment service, instead of paying a registration fee when joining the platform, may receive coupons or discount codes from the platform as a joining gift. With this "promotion," the customer then has more incentive to adopt the mobile payment service at the stores. In the following paragraph, this negative registration fee is termed as "subsidy" for more intuitive understanding, where $|f_C|$ is the magnitude of the subsidy. On the contrary, when transactions are made, the platform charges a per transaction fee rate $r_M^* > 0$ from the merchants to generate revenue. While increasing the per transaction fee rate r_M discourages merchants from joining the platform, the platform would also increase the subsidy to customers $|f_C|$ to enlarge the number of customers and keep the platform being attractive to merchants. In fact, it can be shown that the platform should keep increasing r_M and $|f_C|$ until all customers join the platform (cf. Proposition 3 below).

As we observe in practice, there are several mobile payment platform operators come up with similar pricing strategies to help uptake of latest devices and increase customer acquisition and retention. Samsung's latest offer gives new Samsung Pay users 20 US dollar in gift card credit after they successfully complete their first purchase (Grush, 2016). China UnionPay gives away lucky red packets (hong bao) randomly from 6 to 666 RMB to new users (Yeshb, 2016). These evidences again support the implementation of the subsidization strategy in the mobile payment ecosystem.

We may plug in f_C^* and r_M^* back to (7) and obtain the platform's equilibrium profit

$$u_W^* = \frac{1-b}{2+c}(N-s). \tag{9}$$

We then inspect how the parameters affect the platform's profit and the amounts of subsidy and transaction fee rate in equilibrium. The result is summarized in the next proposition and Table 2.

Proposition 2. *Under the platform's optimal pricing plan:*

1. *The profit of the mobile payment platform u_W increases as each of b, c, s decreases or as N increases.*
2. *The subsidy per customer $|f_C^*|$ increases as each of c, and N increases or as b decreases.*
3. *The transaction fee rate r_M^* increases as b or c increases.*

	N	b	c	s
u_W	↗	↘	↘	↘
$\|f_C\|$	↗	↘	↗	-
r_M	-	↗	↗	-

Table 2: Parameter comparison

In the first part of Proposition 2, it is indicated that the profit of mobile payment platform is better off when the costs of running the business are lower and customers' adoption frequency are higher. This result is intuitive as the platform operator can accordingly earn more transaction fee under a greater market size. However, when the banks are no longer supportive and charge higher payment processing fee, the profitability of the platform shrinks. If the system installation cost is high, since in our model setting no registration fee is charged to merchants, the expense directly reflects on the mobile payment platform's profit.

We then take further look into the influences of the factors to the pricing strategy. With a greater size of the market (N is larger), the mobile payment platform is more willing to give away more subsidy to customers. Moreover, when the cost of customer using mobile payment c is higher, or in other words, the user experience for adoption this payment method is lower, the amount of subsidies to customers should be consequently higher in order to motivate new users to join. Yet the platform then has to turn to the merchants and charge higher transaction fee to cover their subsidies expense.

As for higher processing fee b in each transaction, the platform will response by uprising the transaction fee rate charged from merchants. Correspondingly, only merchants with low costs will adopt the mobile payment service, and thus the platform no longer needs to subsidize those customers whose willingness to use mobile payment is low. Hence, subsidies go down as the processing fee goes up.

To further examine the impact of parameters on the user sizes of the platform in equilibrium, we substitute θ^* and η^* back into (3) and obtain the results in Proposition 3.

Proposition 3. *Under the platform's optimal pricing plan:*

1. *All customers use the mobile payment service, i.e.,* $n_C = 1$.
2. *Some merchants do not use the mobile payment service, i.e.,* $n_M \in (0,1)$. *Moreover,* r_M *increases as b or c decreases.*

According to our analysis, the platform's optimal strategy is to incentivize all the customers to join the platform by subsidization. As the platform profits from the merchants by charging transaction fees, those merchants with high costs will be excluded from the platform.

Discussions

The results above help explain some observed examples in practice. The wireless transmission technology of proximity mobile payments can be categorized into three communication protocols: NFC-based (Near Field Communication), QR code-based, and other contactless technology such as MST-based (Magnetic Secure Transmission). QR code method has low entry barrier compared to the others. Merchants can save cost by not having to invest in expensive equipment and adherence to restrictive rules. That is, in expression of our study, s is low. As Proposition 2 indicates that the platform earns a higher profit with a lower s, it is no wonder that the QR code method is a popular form of electronic mobile payment adopted by many mobile payment operators.

However, convenience brings fraudulent activities and thus the cost for customers to use the QR code method is relatively high. The NFC-based or MST-based method, on the other hand, provides a higher degree of security and allows its users to have no Internet access to make in-time transaction. Proposition 2 shows that higher customer cost c leads to a higher subsidy r_M, which is well observed. In Taiwan, several new mobile payment platform operators are introduced about the same time, but the promotions offered by QR code-based platforms are usually deeper. "GOMAJI Pay" and "All Pay" wallet, for example, give every new user 100 NT dollar that can be used all stores cooperated. Meanwhile, LINE Pay new customers can receive not only LINE Points but also limited edition LINE stickers. But other non-QR code wallet such as "T wallet" or "*friDay*" only offer discounts on limited stores.

In the NFC-SIM based model, payment credential is written on the SIM card and needs authorization of its SIM-card provider, the MNO, to access. That is, the mobile payment service would be controlled by the mobile operator while banks lose their negotiation privilege in this situation. Consequently, due to the unwillingness of other market player to invest the nascent market, banks tend to set a high payment processing fee to hinder the MNOs and meanwhile invest in alternative architectures within their own industry. As for the embedded SE or HCE model or QR code model, financial institutions are allowed to negotiate the relationship with handset manufacturers or the platform operator directly and equally to continue to own the responsibility over financial transactions. Their payment processing fee is thus lower. Proposition 2 again bespeak the difficulty of NFC-SIM based model to be profitable, argued also by Ozcan and Santos (2015).

Strategy in the Long Run

In this section, we generalize the consumption frequency to $h(n_M)$, where $h(n_M)$ is a general concave function. The platform's objective function can then be formulated as

$$u_W = (1 - \frac{f_C}{Nh(1-r_M)} - c)(f_C + N(r_M - b)) \tag{10}$$

Through a derivation similar to that in the short run, we have the optimal amount of registration fee $f_C = \frac{N}{2}((1-c)h(n_M) - (r_M - b))$. The first-order derivative of u_W with respect to the transaction fee rate r_M under the optimal way of charging the registration fee (or giving out subsidies) is thus

$$\frac{\partial u_W}{\partial r_M} = s + \frac{N}{4(1-h(n_M)^2} H(r_M), \tag{11}$$

where

$$H(r_M) = [(1-c)h(n_M) + (r_M - b)][2h(n_M) + h'(n_M)((r_M - b) - (1-c)h(n_M))]. \quad (12)$$

In this case, $\frac{\partial u_W}{\partial r_M} > 0$ is not always true. Therefore, we are interested in understanding when the optimal in the short run, i.e., offer subsidies to include all customers and profit from merchant by setting the highest possible r_M, can still be applied. In particular, we are curious about how the shape of H affects the optimality of such a strategy.

To conduct an investigation, we set $h(n_M) = n_M^t$, where $0 < t \leq 1$, in the sequel. We first conduct numerical experiments to see whether $\frac{\partial u_W}{\partial r_M} > 0$ is true for all $r_M \in [0,1]$ under each parameter combination. The results of our experiments are illustrated below in Figure 4. For each of four different values of $t \in \{0.05, 0.1, 0.2, 0.3\}$, we draw a curve that separate the reasonable parameter region (under the line $b + c = 1$ due to our assumption $b + c < 1$) into two parts. To the left of the curve, we have $\frac{\partial u_W}{\partial r_M} > 0$; to the right of it, we do not. It can be easily observed that the region of $\frac{\partial u_W}{\partial r_M} > 0$ enlarges as t increases. In other words, the strategy optimal in the short run is more likely to remain optimal in the long run when t is close to 1, i.e., when H is "not too concave". This is trivial, as in that case the situation is close enough to the short run. It can also be observed that the strategy is more likely to be optimal if b is small and c is large. We analytically confirm these observations in the following proposition.

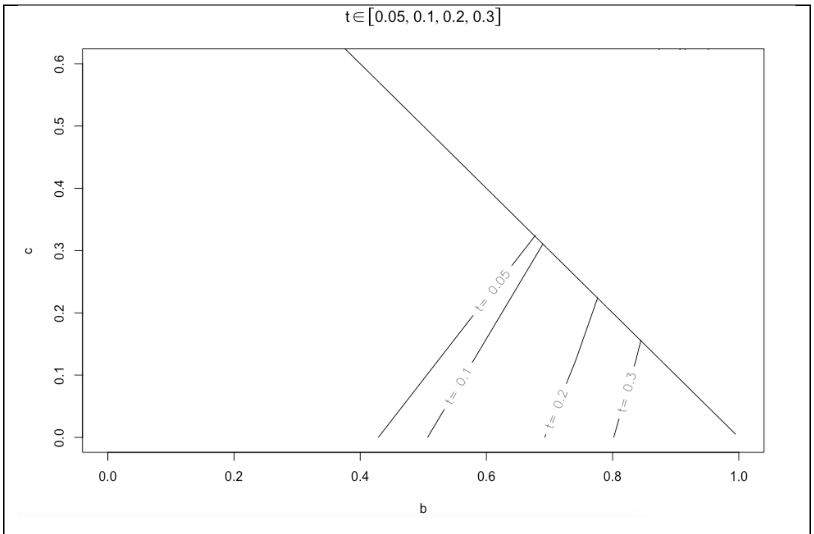

Figure 4. Results of Numerical Experiments

Proposition 4. *For all* $t \in (0,1]$, *there exists a cut-off value* $\hat{b}(t) \in (0,1)$ *such that for all* $b < \hat{b}(t)$, *there exists another cut-off value* $\hat{c}(t,b) \in (0,1)$ *such that for all* $c > \hat{c}(t,b)$ $\frac{\partial u_W}{\partial r_M} > 0$ *is true for all* r_M *within* 0 *and* 1.

Proposition 4 indicates that as long as the payment processing fee b is small enough, and the customer's marginal cost c is large enough, we have $\frac{\partial u_W}{\partial r_M} > 0$ for all $r_M \in [0,1]$. To understand this, note that if the bank is not charging a too high processing fee, it is easier for the mobile payment platform to profit from the merchants. Moreover, if the marginal cost for the customers to use the platform is high, the subsidization strategy for customers will be more needed to incentivize the customers to join the problem. In either case, the original strategy retains its advantages and remains optimal.

Conclusions

By leveraging the emergent mobile payment technology, we present a game-theoretic model featuring network externality to study a mobile payment platform's pricing strategy. In the short run, we find the platform will have incentives to apply the "divide and conquer" strategy by having the merchants cross subsidizing customers to adopt the mobile payment service. This allows the platform to utilize the cross-side network externality to charge per transaction fees from the merchants. With different technologies adopted, the implementation of this pricing strategy alters a little but is still in the same direction. In the long run, the subsidization strategy is suggested to be applied when the bank is not taking too much processing fee, customers do not have a too high marginal cost of using the service, and the marginal consumption frequency does not increase slowly in the number of merchants. We hope these findings can provide a step forward of method to identify this new and promising market.

Our study certainly has its limitations. First, it will be interesting to consider customer's heterogeneity in the numbers of transactions made through mobile payment. The subsidization strategy may need be to tailored for different types of customers. Second, since the role played by banks may affect more than payment processing fee, their strategic decisions should also be taken into consideration. We also have not considered how competition among multiple wallet platforms may change the equilibrium. These extensions of our study call for future investigation.

Appendix

Proof of Proposition 1. The derivative of (7) with respect to f_C can be deduced as

$$\frac{\partial u_W}{\partial f_C} = -\frac{2f_C}{N(1-r_M)} - \frac{r_M - b}{1-r_M} + 1 - c,$$

which implies that an optimal solution must satisfy $\frac{\partial u_W}{\partial f_C} = 0$, i.e., $f_C = \frac{N}{2}(1 - 2r_M - c + r_M c + b)$. We substitute this into (7) and then differentiate it with respect to r_M to obtain

$$\frac{\partial u_W}{\partial r_M} = s + \frac{N}{4(1-r_M)^2}(1 - c + r_M c - b)(1 + c - r_M c - b).$$

As $b + c < 1$, $\frac{\partial u_W}{\partial r_M} > 0$ is always true, which implies that r_M should be set as large as it can reach. We know $n_C = 1 - \theta^* = 1 - c - \frac{f_C}{N(1-r_M)}$, which can be expressed as

$$n_C = 1 - c - \frac{1 - c - 2r_M + cr_M + b}{2(1 - r_M)}.$$

After we replace f_C by $\frac{N}{2}(1 - 2r_M - c + r_M c + b)$. As n_C is bounded above by 1, we obtain $r_M^* = \frac{1+c+b}{2+c}$ as the maximum possible value. It can be easily verified that $0 < r_M^* < 1$. Therefore, our optimal pricing strategy will be $r_M^* = \frac{1+c+b}{2+c}$ and $f_C^* = \frac{Nc}{2+c}(b-1)$.

Proof of Proposition 2. To prove this proposition, all we need is to look at the sign of the first derivatives of r_M, $|f_C|$, and u_W with respect to each parameter. While almost all the signs of the first derivatives can be found trivially through direct observations, here we investigate only r_M with respective to b and $|f_C|$ with respective to c. First, we have $\frac{\partial r_M}{\partial b} = \frac{1-c}{(2+b)^2} > 0$; second, we have $\frac{\partial |f_C|}{\partial c} = \frac{2(1-b)}{(2+b)^2} > 0$. This completes the proof.

Proof of Proposition 3. We plug in f_C^* and r_M^* into (6) and obtain $n_C = \frac{1}{2}\left(1 - c + \frac{(1+c+b)-(2+b)b}{1-b}\right) = 1$ and $n_M = \frac{1-b}{2+c} \in (0,1)$.

Proof of Proposition 4. To examine $H(r_M)$ in (11) is positive when c is sufficiently large and b is sufficiently small, we put $c = 1$ and $b = 0$ into (11) to obtain $H(r_M) = r_M\big(2h(n_M) + r_M h'(n_M)\big)$, which is positive for all $r_M \in [0,1]$. We may then prove that $\frac{\partial u_W}{\partial r_M} > 0$.

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