

Effects of cooperative mechanisms in mobile commerce value chain

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Abstract: In order to analyze the effects of different cooperative mechanisms between a mobile device manufacturer and a mobile network operator (MNO), a Stackelberg structure is constructed. The manufacturer acts as a leader, while the MNO acts as a follower, i. e., a traditional retailer. Three cooperative mechanisms are considered: the manufacturer does not invest in developing the propriety function and software to support the infrastructure capacity of the MNO; the manufacturer invests in the development; the MNO offers a subsidy to encourage the manufacturer to invest in development. The results reveal that investing in the development can increase the profits of both the manufacturer and the MNO. Furthermore, if the MNO shares certain investment costs with the manufacturer, the MNO may charge higher prices of mobile connection services and mobile value-added services, and the profits of the two players may be enhanced.

Key words: mobile commerce; supply chain model; pricing; game theory

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Due to the development of 3G-related technologies, the mobile commerce (m-commerce) value chain has become more complex; an increasing number of players enter the m-commerce industry fulfilling one or several roles in the value chain and new business opportunities are also created for these participants^[1]. Kuo and Yu^[2] proposed an overall definition of the m-commerce. Through any highly mobile device and wireless communication network, activities related to commerce transaction, data access, network service, and so on, and processed without any boundaries of time and space are within the coverage of mobile commerce. Porter^[3] pointed out that the value chain is the linkage and integration of a series of activities in which enterprises deliver the created and valued products or services to customers.

In today's volatile mobile commerce industry environments, the increase in new companies that enter the m-commerce market makes the market become more competitive. This raises an important issue in the area of the m-commerce value chain. Which is the most effective and efficient cooperative mechanism among the participants? Many researchers studied this issue from the basic m-commerce value chain theory perspective and developed a number of business model frameworks for describing the actors and their roles in the value chain, as well as the corresponding sources of revenue^[2,4-16]. However, the main focuses of these papers are

different. Based on a description of the major players in the m-commerce value chain, Kuo and Yu^[2] pointed out that MNOs are the most critical ones among the participants in the m-commerce value chain, so they mainly investigated the roles that MNOs played on the m-commerce value chain. Tsalgaidou et al.^[4-5] attempted to study the underlying business model of the key actors. How the value is added in the stream of activities involved in providing m-commerce to customers was considered by Barnes^[6]; Olla and Patel^[7] focused on customer value consisting of value strategy and positioning and value production and coordination; the possible interaction between the main participants was studied by Varshney and Vetter^[8]. How the m-commerce value chain evolution leads to the success of the m-commerce application was analyzed in Ref. [9].

Few of these articles, however, study cooperative mechanisms among these participants from a quantitative analysis point of view. This paper offers a simple analytical model to study the effects of different cooperative mechanisms between a mobile device manufacturer and a MNO in the m-commerce value chain.

We assume that, in this paper, consumers, who purchase mobile devices from MNOs acting as traditional retailers, must promise to subscribe to the mobile network for a period of time, and also decide whether or not to use the value-added services. The MNOs, here, differ from traditional retailers. That is, they can generate revenue from both the mobile connection services and the mobile value-added services; i. e., the MNOs may gain the primary revenue from selling access to mobile communication networks and increase their profits by attracting more subscribers to use mobile value-added services. The usage of the value-added services may be affected by the function of the mobile device; thus, the mobile device manufacturer is supposed to be involved in quality investment. A Stackelberg structure is constructed between the manufacturer and the MNO. In the first stage, the manufacturer determines the wholesale price to the MNO, as well as the investment level of developing the propriety function and software to support the infrastructure capacity of the MNO; in the second stage, the MNO sets the price of mobile connection services and the price of value-added services simultaneously. In this paper, we consider three cooperative mechanisms: 1) The manufacturer does not invest in developing the propriety function and software to support the infrastructure capacity of the MNO (N-FS); 2) The manufacturer invests in developing the propriety function and software to support the infrastructure capacity of the MNO (FS); 3) The MNO offers a subsidy to encourage the manufacturer to invest in developing the propriety function and software to support its infrastructure capacity (E-FS). Infrastructure capacity, here, refers to base stations, glass fiber cables, microwave transmitters, the net-

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work system and additional transmission equipment rather than to radio spectra^[17].

1 Model

We assume a mobile commerce market in which all the activities occur within a single period and consider an m-commerce value chain consisting of a mobile device manufacturer and a retailer, the MNO. The interaction mechanism between the manufacturer and the MNO is assumed to be the manufacturer-Stackelberg process. The mobile device manufacturer acts as a leader, who sets a wholesale price to the MNO, and decides whether it invests in developing the propriety function and software to support the infrastructure capacity of the MNO. The MNO, whose revenues come from selling the access to a mobile communication network and value-added services, chooses the price of mobile connection services and the price of value-added services.

In the following section, we will develop two-stage m-commerce value chain models with a mobile device manufacturer and an MNO, which can tell both the manufacturer and the MNO how to make their decisions in different collaborative relationships.

1.1 The model of N-FS

Now, consider a value chain model where the mobile device manufacturer sets the wholesale price w to the MNO and does not invest in developing the propriety function and software to support the infrastructure capacity of the MNO; then the MNO determines the price of mobile connection services and the price of value-added services.

We assume that in this scenario, the MNO faces the following linear demand function:

$$q_1 = a - p_1, \quad q_2 = a - p_1 - p_2 = q_1 - p_2 \quad (1)$$

where a is the market scale; p_1 represents the retail price of mobile connection services; p_2 is the retail price of value-added services; q_1 is the total number of subscribers to mobile network per period; q_2 represents the market demand of value-added services. The demand function means that if the customers pursue mobile devices from the MNO, they should subscribe to the network for a period of time and choose whether or not to access the value-added services; i. e., the original market scale of q_2 equals q_1 .

The profit of the MNO from subscribing to the network is

$$\pi_{r1} = (p_1 - w)q_1 - c_r$$

where w is the unit mobile device wholesale price; c_r measures the fixed cost of the MNO to invest in building network infrastructure.

The profit of the MNO from value-added services is

$$\pi_{r2} = p_2 q_2$$

Thus, the total profit of the MNO is

$$\pi_r(p_1, p_2) = \pi_{r1} + \pi_{r2} = (p_1 - w)q_1 + p_2 q_2 - c_r \quad (2)$$

The profit of the mobile device manufacturer is

$$\pi_m(w) = (w - c)q_1 = (w - c)(a - p_1) \quad (3)$$

where c represents the unit production cost of the mobile device ($a > c$).

Proposition 1 The total profit of the downstream retail, the MNO, is a concave function of p_1 and p_2 . The optimal price of mobile connection services and the optimal price of mobile value-added services are

$$p_1^* = \frac{1}{3}(a + 2w), \quad p_2^* = \frac{1}{3}(a - w) \quad (4)$$

Proof For a given w , the MNO will maximize the total profit function $\pi_r(p_1, p_2)$. Solving the first-order condition of $\pi_r(p_1, p_2)$ for p_1 and p_2 , we have $p_1^* = \frac{1}{3}(a + 2w)$, and $p_2^* = \frac{1}{3}(a - w)$. Here the pair (p_1^*, p_2^*) is a unique stationary point of the function $\pi_r(p_1, p_2)$. It follows the Hessian matrix,

$$\begin{bmatrix} \frac{\partial^2 \pi_r}{\partial p_1^2} & \frac{\partial^2 \pi_r}{\partial p_1 \partial p_2} \\ \frac{\partial^2 \pi_r}{\partial p_2 \partial p_1} & \frac{\partial^2 \pi_r}{\partial p_2^2} \end{bmatrix} \bigg|_{(p_1^*, p_2^*)} = \begin{vmatrix} -2 & -1 \\ -1 & -2 \end{vmatrix} \bigg|_{(p_1^*, p_2^*)}$$

Let Δ_1 and Δ_2 denote the first- and the second-order principal minors of the Hessian matrix of the total profit of the MNO, $\pi_r(p_1, p_2)$; then, we have $\Delta_1 = -2 < 0$, $\Delta_2 = 3 > 0$. Thus the Hessian matrix of the total profits of the MNO is negative definite; i. e., the second-order necessary conditions of Eq. (2) at the point (p_1^*, p_2^*) are satisfied. Hence, (p_1^*, p_2^*) is the optimal solution of Eq. (2).

For the mobile device manufacturer, we assume that he/she knows the MNO's reaction function given in Eq. (4), for any given w . Thus, the manufacturer's profit is

$$\pi_m(w) = \frac{2}{3}(w - c)(a - w)$$

The second-order condition of the function π_m with respect to w is

$$\frac{\partial^2 \pi_m}{\partial w^2} = -\frac{4}{3} < 0$$

Hence, we can derive that the manufacturer's profit π_m is a concave function with respect to w .

Solving the first-order condition $\partial \pi_m / \partial w = 0$ will give the optimal wholesale price as follows:

$$w^* = \frac{1}{2}(a + c) \quad (5)$$

Combining Eq. (5) with Eqs. (1) to (4) will yield the optimal policies and the corresponding profits of the manufacturer and the MNO.

1.2 The model of FS

In this subsection, we consider a scenario that the manufacturer decides to invest in developing the propriety function and software to support the infrastructure capacity of the MNO, which means that the demand function is different

from the previous one, i. e., Eq. (1). Thus, in this case, the manufacturer not only determines the wholesale price w to the MNO, but also elects the investment level of developing the propriety function and software to support the infrastructure capacity of the MNO; the MNO, in turn, sets the price of mobile connection services and the price of the value-added services.

According to Refs. [18–19], we assume that in this scenario, the demand function of the MNO is changed into

$$q_1 = a - p_1 + \theta\sqrt{s}, \quad q_2 = a - p_1 - p_2 + \theta\sqrt{s} \quad (6)$$

where s represents the investment level of the mobile device manufacturer, and θ measures the demand sensitivity to the function and software that the mobile device provides. In order to ensure the non-negativity of all the decisions, we assume that $\theta \in (0, 2)$ throughout this paper; i. e., the effect of development investment on the market demand is not too large.

The total profit of the MNO now is changed into

$$\pi_r(p_1, p_2) = \pi_{r1} + \pi_{r2} = (p_1 - w)q_1 + p_2q_2 - c_r \quad (7)$$

The profit of the mobile device manufacturer, hence, is changed into

$$\pi_m(w, s) = (w - c)q_1 - s \quad (8)$$

where s is the function and software investment of the mobile device manufacturer.

Proposition 2 The total profit of the MNO is a concave function of p_1 and p_2 , and the optimal price of the mobile connection services and the optimal price of the mobile value-added services are

$$p_1^* = \frac{1}{3}(a + \theta\sqrt{s} + 2w), \quad p_2^* = \frac{1}{3}(a + \theta\sqrt{s} - w) \quad (9)$$

Proof We omit the derivation of the equilibrium since they are similar to the approach used in Proposition 1.

For the mobile device manufacturer, we assume that he/she knows the MNO's reaction function given in Eq. (9) for any given w and s .

Proposition 3 The total profit of the upstream mobile device manufacturer is a concave function of w and s . The optimal wholesale and investment levels are

$$w^* = \frac{3a + (3 - \theta^2)c}{6 - \theta^2}, \quad s^* = \frac{(a - c)^2\theta^2}{(6 - \theta^2)^2} \quad (10)$$

Proof We omit the derivation of the equilibrium since they are similar to the approach used in Proposition 1.

Combining Eq. (10) with Eqs. (6) to (9) will yield the optimal policies and the corresponding profits of the manufacturer and the MNO.

1.3 The model of E-FS

We will discuss the situation that the MNO offers a subsidy to encourage the manufacturer to invest in developing the propriety function and software to support the infrastructure capacity. Thus, we assume that the demand function is the same as in the above scenario, i. e., the demand function faced by the MNO is still Eq. (6).

Similar to Ref. [19], the total profit here of the MNO is changed into

$$\pi_r(p_1, p_2) = \pi_{r1} + \pi_{r2} = (p_1 - w)q_1 + p_2q_2 - ts - c_r \quad (11)$$

where t represents the subsidy rate that the MNO encourages the manufacturer to invest in developing the propriety function and software for the value-added services. In fact, only the parameter term $-ts$ is added into Eq. (7) to obtain Eq. (11), hence, the first-order and the second-order derivatives keep unchanged to ones obtained from Eq. (7); i. e., the optimal price of the mobile connection services and the optimal price of the mobile value-added services here are the same as in Eq. (10).

Assumption 1 The subsidy rate of the MNO satisfies

$$0 < t < \frac{\theta^2(6 - \theta^2)}{3(12 - \theta^2)} < 1 - \frac{\theta^2}{6}$$

The profit of the mobile device manufacturer per period is changed into

$$\pi_m(w, s) = (w - c)q_1 - (1 - t)s \quad (12)$$

For the mobile device manufacturer, we assume that he/she knows the MNO's reaction function given in Eq. (10) for any given w and s .

Proposition 4 The total profit of the upstream mobile device manufacturer is a concave function of w and s , the optimal wholesale and investment levels are

$$w^* = \frac{3a(1 - t) + (3 - 3t - \theta^2)c}{6(1 - t) - \theta^2}, \quad s^* = \frac{(a - c)^2\theta^2}{(6(1 - t) - \theta^2)^2} \quad (13)$$

Proof We omit the derivation of the equilibrium since they are similar to the approach used in Proposition 1.

Combining Eq. (13) with Eqs. (6), (9), (11) and (12) will yield the optimal policies and the corresponding profits of the manufacturer and the MNO.

2 Comparisons of Optimal Solutions for Three Cooperative Mechanisms

Now, we will compare the optimal solutions of the three models presented above. Based on the previous analysis and using straightforward mathematical manipulation, we present the optimal solutions of the three models discussed above in Tab. 1. p_1^* , p_2^* , π_r and π_m in Tab. 1 represent the optimal policy and the maximum profits of the mobile device manufacturer and the MNO, respectively.

Tab. 1 Optimal solutions for three cooperative mechanisms

Models	N-FS	FS	E-FS
p_1^*	$\frac{1}{3}(2a + c)$	$\frac{4a + 2c - c\theta^2}{6 - \theta^2}$	$\frac{4a(1 - t) + 2c(1 - t) - c\theta^2}{6(1 - t) - \theta^2}$
p_2^*	$\frac{1}{6}(a - c)$	$\frac{a - c}{6 - \theta^2}$	$\frac{(a - c)(1 - t)}{6(1 - t) - \theta^2}$
π_r	$\frac{1}{12}(a - c)^2 - c_r$	$\frac{3(a - c)^2}{(6 - \theta^2)^2} - c_r$	$\frac{(a - c)^2(3(1 - t)^2 - t\theta^2)}{(6(1 - t) - \theta^2)^2} - c_r$
π_m	$\frac{1}{6}(a - c)^2$	$\frac{(a - c)^2}{6 - \theta^2}$	$\frac{(a - c)^2(1 - t)}{6(1 - t) - \theta^2}$

Proposition 5 In the three cooperative scenarios, the MNO charges the highest price of the mobile connection services and the highest price of the value-added services in the E-FS scenario, when the manufacturer decides to invest in developing the propriety function and software to support the infrastructure capacity of the MNO; meanwhile, the MNO offers a subsidy to encourage the manufacturer to invest, and the MNO can obtain the largest profits.

Proof For convenience, let p_1^{i*} and p_2^{i*} denote the optimal price policy of the MNO, and π_r^{i*} denotes the maximum profit of the MNO, respectively, under the three cooperative mechanisms. Hence, from Tab. 1, one can easily have

$$\begin{aligned} p_1^{2*} - p_1^{1*} &= \frac{2\theta^2(a-c)}{3(6-\theta^2)} \\ p_1^{3*} - p_1^{2*} &= \frac{4\theta^2t(a-c)}{(6-\theta^2)(6(1-t)-\theta^2)} \\ p_2^{2*} - p_2^{1*} &= \frac{\theta^2(a-c)}{6-\theta^2} \\ p_2^{3*} - p_2^{2*} &= \frac{\theta^2t(a-c)}{(6-\theta^2)(6(1-t)-\theta^2)} \\ \pi_r^{2*} - \pi_r^{1*} &= \frac{\theta^2(a-c)^2(12-\theta^2)}{12(6-\theta^2)} \\ \pi_r^{3*} - \pi_r^{2*} &= \frac{\theta^2t(a-c)^2(3t\theta^2+6\theta^2-36t-\theta^4)}{(6-\theta^2)(6(1-t)-\theta^2)} \end{aligned}$$

Since $a > c$, $\theta \in (0, 2)$, $0 < t < \frac{\theta^2(6-\theta^2)}{3(12-\theta^2)} < 1 - \frac{\theta^2}{6}$, the right-hand sides of the above equations are all positive. It means that all the above equations are more than zero, i. e.,

$$p_1^{1*} < p_1^{2*} < p_1^{3*}, p_2^{1*} < p_2^{2*} < p_2^{3*}, \pi_r^{1*} < \pi_r^{2*} < \pi_r^{3*}$$

The proof of Proposition 5 is completed.

Proposition 6 As for the mobile device manufacturer, he/she can obtain the lowest profit in the N-FS case and the largest profit in the E-FS scenario. It means that, the manufacturer should invest in developing the propriety function and software to support the MNO's network capacity. Furthermore, when the MNO offers a certain subsidy to encourage the manufacturer to invest, the manufacturer gains the highest profit.

Proof It follows steps similar to that of Proposition 5, so the details are omitted.

Indeed, from the propositions discussed above, we can see that the investment cost of the manufacturer can be compensated by the increase in the wholesale price as well as the demand, which means that investing in developing the propriety function and software to support the capacity of the MNO will benefit both the manufacturer and the MNO. Furthermore, if the MNO offers a certain subsidy to the manufacturer, this gives an incentive to the manufacturer and encourages him/her to put more resources to develop the propriety function and software of mobile devices; for the MNO, who connects to customers directly and controls the basic profile and preference information of users, this cooperative mechanism will promote him/her to share user information with the manufacturer to develop the function of mo-

bile devices according to user preferences.

3 Conclusion

As the use of mobile wireless networks becomes popular, customers are asking for higher value-added service levels. In this context, it is particularly important for the MNO providing high quality value-added services; thus, the services should be provided through simple applications interfacing with mobile devices. So, the research and development of the propriety function and software to support the infrastructure capacity of the MNO are critical for providing high quality value-added services. In this paper, we analyze the effects of three cooperative mechanisms between a mobile device manufacturer and an MNO in an m-commerce value chain. The value chain model differs from the traditional supply chain in that, the MNO can charge two kinds of prices to customers, i. e., the price of accessing the network and the price of value-added services. That is, the MNOs gain the primary revenue from selling access to the mobile communication network and increase their profits by enticing subscribers to use mobile value-added services. In future research, we will study the effects of different cooperative mechanisms between a mobile device manufacturer and duopolistic MNOs.

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移动商务价值链中不同合作机制的影响

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摘要:通过建立 Stackelberg 模型,分析了移动装置制造商和移动网络运营商的不同合作机制带来的影响. 移动装置制造商是领头企业,而移动网络运营商是尾随企业,即传统的零售商. 主要研究了移动装置制造商与移动网络运营商的 3 种合作机制:移动装置制造商只开发通用的功能和软件,不针对移动网络运营商的网络特性开发适用的功能和软件;移动装置制造商投资开发适用于移动网络特性的功能和软件;移动网络运营商对移动装置制造商的开发投入进行补贴. 结果显示:移动装置制造商投资开发适用的功能和软件可以同时增加两者的收益,并且当移动网络运营商承担一部分的投资成本时,移动网络运营商可以制定更高的移动连接服务和移动增值服务价格,从而得到更高的收益.

关键词:移动商务;供应链模型;定价;博弈理论

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