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Regulating platform competition in two-sided markets under the O2O era

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ABSTRACT

Online-to-offline (O2O) services permeate our daily life and consumption along with the advanced technology in e-commerce. In this study, motivated by taxi-hailing market case, we analyze the effect of government regulations on competition in two-sided markets featured network externality under the O2O era. First, a model with Hotelling specification is formulated to describe the competition in taxi-hailing markets using subsidies as decision variables. In the model, platforms subsidize two sides agents labeled drivers and passengers, and the subsidies are given based on whether a state of membership or every transaction. Second, government regulations are introduced into the model by adding corresponding modification into agents' utility, and new consequent market equilibriums are compared with the benchmark status. Major findings of this work include: i) the effects of price adjustments regulation depend largely on relative size of mutual network externalities, which causes a negative impact on social welfare except for extreme size level; ii) butt joint with official platforms brings down platforms' cost in both sides so that companies make more profits, where social welfare including consumer surplus and profits increases; iii) forbiddance setting in time limited usage scarifies a little economic effectiveness to ensure better safety.

1. Introduction

In recent years, the advanced mobile technology has led us into an online-to-offline (O2O) community, where the mobile payment technology plays an increasingly important role. O2O refers to an integration of offline commercial opportunities into online operation and services. An example of O2O is the popularity of taxi-hailing applications (apps), mobile software that matches drivers and passengers online to build offline connections. In addition, the advent of O2O has increasingly promoted transformation in many industrial sectors, most of which feature the characteristics of two-sided markets. Rather than going out to specific functional zones for services, customers now can enjoy services delivered to them at almost anytime and anywhere, so the way of bridging the supply chain from suppliers to customers has been changed (Xu et al., 2009; Wu and Olson 2008; Wu et al., 2009). Various platforms are established to serve as intermediaries for ordering goods and service, e.g., clothing websites, online cosmetic retailers, and take-out delivery service. In all these cases, cross-group externalities exist, i.e., a platform connects two groups of agents and whether one group of agents attend and enjoy a platform or not relys on how the platform performs on attracting the other group of agents. For example, the take-out service platform will attract more customers if more restaurants would settle in. And restaurants are willing to participate into the platform if the platform shows its potential to have a large number of customers.

The definition of two-sided market can be given from two angles. Kaiser and Wright (2006), Rochet and Tirole (2006) propose that two-sided platforms cater to two groups of agents, where the trade volume is sensitive to the distribution of the prices for both sides agents, but not only the sum of the two prices. Different from the definition with price structure, Armstrong (2006) gives an intuitional instruction from the perspective of network externality. A two-sided market involves two groups of agents that are connected through a platform, where the number of one group has a large impact on the utility of the other group. Payment card market typically operates in this way that the cards are more valuable for consumers if more business accepted them as one of the payments (Hunt, 2003). Further, Weyl (2010) concludes three features of two-sided market: multi-product firm, cross network effects and bilateral market power.

The regulating problem rose along with the development of two-sided markets. To the best of our knowledge, however, there is few published papers focusing on quantitative analysis for policy evaluation. This paper, motivated by the popularity and growth of O2O mode in China and the competition between platforms appeared in taxi-hailing apps market, is devoted to policy performance based on game theoretic

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method of modeling. Taxi-hailing app is mobile software connecting drivers and passengers through online platform to enhance the offline service efficiency. In 2014, taxi-hailing apps penetrated the large Chinese market, and two leading firms, i.e., Didi and Kuaidi, competed through price, precisely subsidy given to both sides – drivers and passengers. Fig. 1 shows the Baidu Search Index of 'taxi-hailing apps' from 2012 to 2015 (Baidu Search Index is produced by Baidu, a widely used search engine in China, to reflect trends in specific key words search frequencies).

Fig. 1 implies that attention to taxi-hailing apps boomed at the beginning of year 2014 in China. A few weeks later, the search amount and frequency fell down along with people's awareness of this new taxiing way and the acceptance to it. The popularity and wide-ranging usage of taxi-hailing apps can be evidenced by China's smart travel data report issued by Didi research and CBN Data. According to the report, smart travel platforms serve 300 million registered passengers and 10 million registered drivers up to the end of 2015. In 2015, the number of registered taxi-hailing app users increases at an average rate of 13% per month. This explosive growth in a two-sided market breeds problems in various aspects. In this example of taxi-hailing apps market, the business model challenges the licensing system in traditional taxi industry, and leads to safety risk because drivers need to pay attention to the phone when driving. Besides, the growth tendency in this market shows a potential in becoming a monopoly market form when people get more stick to a platform because of the network externality. Therefore, regulations are required, and as expected, this dramatically increasing competition in taxi-hailing apps market does not last for long time due to the intervention of Chinese government, and local governments propose various ways of regulations. This paper discusses about effects of several government regulations of the above problem. Although the problem is explored with detailed setting in model, the analysis of this paper is representative because different industries are with similar developing patterns. For instance, the take-out services and bicycle sharing industry are currently experiencing what taxi-hailing market experienced years ago, where platforms offer discounts to compete for a higher share of consumers. A theoretical explication in the impact of government regulation to the taxi industry can provide guideline to the development in many other industries.

The remainder of this paper is organized as follows. Section 2 provides the literature review. The model to describe taxi-hailing apps market based on the model built by Armstrong (2006) is formulated in Section 3. Regulations carried out by local governments are analyzed in Section 4. At last, in Section 5, we conclude the paper and detail some discussions.

2. Literature review

In this section, the literature review is conducted from two aspects.

The first aspect is the price strategy in the competition in a two-sided market and also the welfare situation. Large amount of research integrates practical complexity when exploring corporations' logic of business, impact factors and new competition modes. Caillaud and Jullien (2003) study the existence of effective equilibrium when group of agents is exclusive to one platform or multi-homing. When platforms are indifferent, one platform attracts all agents is efficient. Rochet and Tirole (2003) research on the logic behind platform's strategy of making profit from one side to subsidize the other side and impact factors, including platform management, difference in platforms and their pricing ability based on amount. Armstrong (2006) discovers that the price structure is largely affected by cross externality, the fixed or per-transaction types of fee, and whether agents are exclusive to one platform or not. He shows that platforms would charge high from multi-homing agents to compete for those single-homing customers. Different from Armstrong's (2006) focus on the membership externality, Rochet and Tirole (2006) reveal the difference between membership and usage externality and bring both into analysis. After considering the proceeding basic problems containing effectiveness, profit mechanism, types of externalities, researchers begin to take different scenarios into account. Complements are made to enrich the solutions to applications in various market forms. Armstrong and Wright (2007) allows different degrees of product differentiation existing in two sides, and multi-homing as well. When sellers regard platforms as identical and buyers not, the result in equilibrium reveals platforms' focuses on buyers yet leaves sellers no gains from transactions. Azevedo and Leshno (2014) integrate heterogeneity preferences into the model for two-sided matching markets, and consider the continuum of traders, giving price-theoretic analysis of school competition. Jullien (2011) applies Stackelberg game and the result shows the leader will restrain trade with one side to moderate competition. Rysman (2004) studies detailed real case of Yellow Pages directories market resulting in a preference to competitive market pattern.

Little current research brings subsidy into consideration that means consumers are offered discounts to choose a platform instead of being charged for a certain price, which is a frequently used strategy in this competition. However, Amelio & Jullien (2012) use tying as the implicit mechanism to subsidy, which results in more participation from two sides and agents gaining profit in monopoly platform situation. Jay Pil Choi (2010) analyzes the welfare result of tying when allowing multi-homing in platforms. Markus Reisinger (2014) considers the heterogeneity in trading behaviors of both two sides of platforms under the two-part tariffs price form, which cannot be distinguished by platforms in advance. This can realize equilibrium uniqueness. McCabe and Snyder, (2016) study the problem in the two-sided market for academic journals involving free subscription fees when traditional way changes to open-access journal. The efficiency and profitability are analyzed and the result shows that the new way can be profitable for a commercial journal since the other authors' side can compensate the loss in the reader side. Market equilibriums are widely discussed but much fewer researches concern the topic of variation in social welfare.

The other aspect is regulation in two-sided markets, which mostly aims at antitrust cases. Economides (2004) points out that competition and antitrust law act with the mission of efficiency maximization. However in two-sided markets, there shows more concerns with dynamic

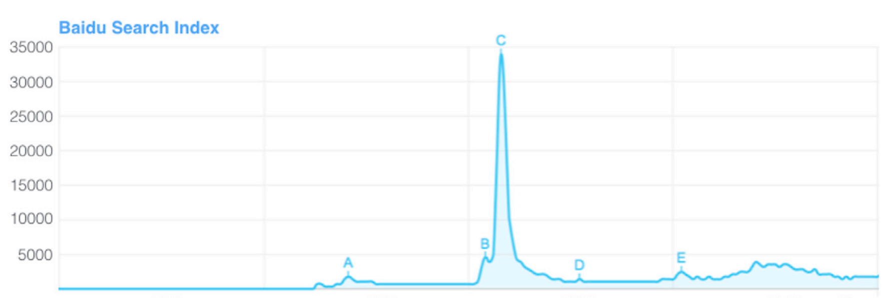

Fig. 1. Baidu Search Index of 'taxi-hailing apps'.

efficiency rather than the efficiency in production and distribution. Evans's (2003) analysis gives five aspects containing marketing power, entrance barrier, predatory pricing, market delineation and assessment for market efficiency that need sufficient concerns. In Roson's (2005) opinion, antitrust law is lack of the update understanding of two-sided markets, resulting some problems. Researchers commonly apply qualitative methods to draw conclusions about features and impacts of antitrust actions in two-sided markets. Wright (2004) analyzes real regulation policies for credit markets in the UK and Australia. Similarly, this paper collects real regulations that governments brought forward and analyzes with game theoretic method without an antitrust focus. Economides and Tåg (2009) consider net neutrality regulation that means no charge to content providers in two-sided markets. In monopoly market, whether the net neutrality regulation induces positive change in industry surplus or not largely depends on the parameter ranges. In duopoly market, this regulation increases surplus if content providers multi-home and customers single-home. Kim (2016) researches on the two-sided market with a monopolistic media platform in theoretical framework. He analyzed how the factors like matching technology, prosumer policy and advertising technology impact on the social welfare, and policy tools are suggested.

Current research on the subject of two-sided markets commonly emphasizes the competition and the antitrust regulations as above. Therefore, this paper tries to make a complement in exploring several other real regulations within the scope of two-sided market and makes an assessment, to give lights to recognize government's impact. Taxi-hailing apps market is an instance we choose to realize this disquisition under this O2O era.

3. The model

In this section, a model of two-sided markets with two platforms competing with each other is formulated. The model comprises two types of agents served by platforms as intermediaries to build interactions between the two groups of agents. In the example of taxi-hailing apps market, drivers and passengers are the two groups of agents connected by the apps. In the model, consumers are supposed to be exclusive to one platform, which does not mean they only install one app but they compare both platforms and choose one to use at a time, because usually apps of the platforms are free to download. This is different from situation in digital media market, where considering multi-homing is meaningful because usually consumers pay fees to obtain the membership for exclusive content. However, in this taxi-hailing market, the zero cost for downloading an app makes the choice between services operates the same way as what people do in selecting which to buy between two things. So for this paper, the assumption is that all the agents are able to get access to the two platforms easily and free, and they are fully sensitive to prices without loyalty to specific platforms. One point worth noting is that this assumption dose not lose much generality because many two-sided markets under the O2O era share the same features with taxi-hailing apps market. Consumers can easily, especially freely acquire the apps and then make a choice, where the content are of a low level of exclusiveness.

The two groups of agents are indexed by $k = 1, 2$. For concreteness, we label drivers as 1 and passengers as 2. It is assumed that they care about the number of the other side agents, but are careless about how many people from the same side participate into this platform. There is a tradeoff if we consider the effect brought by agents from the same side. On one hand, agents wish more participation on the same side so that more agents on the other side can be expected. On the other hand, the competition relationship among them decreases agents' enthusiasm in calling on more same side agents to take part in. The two opponent effects counteract much leaving it reasonable for this paper to suppose only cross-group externality as most papers do. The two platforms are indexed by i, j.

3.1. Passengers

The reality of taxi-hailing apps market shows that the software providers do not charge agents for using the app, instead, they give coupons to both sides of agents to encourage usage. This paper adopted Hotelling model to characterize product differentiation. As assumed, the two platforms are located at the two ends of a line with length of 1, and agents of each side, are normalized to 1 with uniform distribution along the line. The platform $i(j)$ gives coupons to passenger, the value of which is denoted by $t^i(t^j)$. A coupon can be used when the passenger has a transaction with a driver by matching a taxi ride through the platform. When a passenger opens the app and looks for a taxi, there is a possibility p that he is successfully matched to a driver, which is largely depend on the number of drivers on this platform. The form is assumed to be $p(n_1^i) = \alpha_2 n_1^i$, where n_1^i denotes the number of drivers on the platform i and α_2 measures network externality, or intuitively the increase in possibility when adding one more driver. The transaction meets the car using demand of a passenger, which averagely brings utility to him, denoted by v_1.

So the utility of the passenger who located at point x participates into platform i is given by:

$$u_2^i = \alpha_2 n_1^i (v_1 + t^i) - \tau_2 x \tag{1}$$

where the point x refers to the position on the line distances x to the end platform i located at. And the utility of the passenger when choosing platform j is given similarly:

$$u_2^j = \alpha_2 n_1^j (v_1 + t^j) - \tau_2 (1 - x) \tag{2}$$

where τ_2 in both (1) and (2) is 'transportation' parameter under Hotelling specification, depicting the distance between the real product and the ideal one for agents along with x.

More details in explanation are necessary for a better understanding of this model formulation. The distance between the two platforms is a description on their product differentiation in the Hotelling specification. The notation x is defined to spot the location of a consumer according to his distance to one platform in the line, assumed platform i here. It is easier to understand the disutility of choosing a platform if we make an analogy and regard the distances in model as in the real geography and space. The consumer needs to walk a distance of x to arrive at platform i and reach the product, while he walks $(1 - x)$ distance to arrive at the position of platform j. What he spends in walking to access a platform brings him disutility in proportion to distance, which is denoted by $\tau \cdot x$ and referred as 'transportation' cost. Therefore, back to the product differentiation context of model in this paper, $\tau \cdot x$ and $\tau \cdot (1 - x)$ refers to the disutility for the consumer to use platform i and j. We mention the real product and ideal product to offer a substitute explanation to the 'transportation' cost. The ideal platform for a consumer positioned at x distance to platform i, if exists, should be the one positioned where he is, which means he has no disutility for using it. Platform i is a real platform in the market different from the ideal platform, and the difference between them is described as the distance between them. τ denotes the disutility per unit distance, which is multiplied with the distance to denote the whole disutility.

Coupons are not given to all the passengers, so here we assume a passenger gets a coupon for a ride with possibility μ. The size of possibility is assumed to be determined exogenously. Otherwise, when considering endogenous control of the possibility, platforms' strategies can be more complicated like targeted coupons to agents who is close to them or making price discrimination. For simplicity, these are not included in this model. Then for those who do not get a coupon, the utility is given by

$$u_2^i = \alpha_2 n_1^i v_1 - \tau_2 x \tag{3}$$

$$u_2^j = \alpha_2 n_1^j v_1 - \tau_2(1-x) \tag{4}$$

3.2. Drivers

Platforms offer subsidies to drivers in a different way, which depend mostly on overall performance in a period of time like a month instead of one transaction. For example, the platform sets up prize rules for drivers in light of their performances, indicated by the rate of good reviews from passengers, the number of orders per month. Thus, the 'price' for drivers, denoted by s shows a feature of membership fee rather than per transaction fee, which should be added into their utility function in a relatively fixed way:

$$u_2^i = \alpha_1 n_2^i v_2 + s^i - \tau_1 x \tag{5}$$

When the driver located at point x participates into platform i. And

$$u_1^j = \alpha_1 n_2^j v_2 + s^j - \tau_1(1-x) \tag{6}$$

if she or he participates into platform j. Similarly, τ_1 also means 'transportation' cost, same as τ_2 but is for drivers. All the parameters in the paper are non-negative.

3.3. Market equilibrium

To obtain the market equilibrium state, this section first deal with the demand on both sides and then solve for profit maximization, followed with analysis in consumer surplus and social welfare. We begin with spotting the location of indifferent consumer, who has the same incentive to join either platform because he receives equivalent utility from two platforms. There are four categories of passengers considering whether passengers get coupons from platforms. One category receives no coupon, another refers to those receive coupons from both two platforms, and the last two categories contain those receive one coupon from a platform.

Among all the passengers, $(1-\mu)^2$ of them do not get any coupon from platforms, so the location of the passenger indifferent between platforms i, j is given by:

$$m_1 = (1-\mu)^2 \cdot \frac{\alpha_2 v_1 \left(2n_1^i - 1\right) + \tau_2}{2\tau_2} \tag{7}$$

$$s = \frac{-1}{\tau_2(-2+\mu)^2}\left\{\tau_1\tau_2(-2+\mu)^2 + \tau_2^2\mu^2 + 2(-1+\mu)(T_2+\alpha_1 v_2)[T_2\mu - \alpha_2(-2+\mu)v_1 + \alpha_1\mu v_2] - \tau_2\left[T_1(-2+\mu)^2 + \mu(T_2(-2+3\mu) - \alpha_2(-2+\mu)v_1 + \alpha_1(-2+3\mu)v_2)\right]\right\} \tag{15}$$

Equation (7) also implies the number of passengers who participate in platform i because passengers who are closer to platform i than indifferent one would obviously choose i. The proportion of the passengers who get coupons from both platforms is μ^2, so as above, the position of indifferent passenger implies the number of passengers of this type who participate in platform i:

$$m_2 = \mu^2 \cdot \frac{\alpha_2 n_1^i (v_1 + t^i) - \alpha_2 n_1^j (v_1 + t^j) + \tau_2}{2\tau_2} \tag{8}$$

The proportion of passengers who get coupons only from platform i is $\mu(1-\mu)$, and then the number of those participating in platform i is given by:

$$m_3 = \mu(1-\mu) \cdot \frac{\alpha_2 v_1 \left(2n_1^i - 1\right) + \alpha_2 n_1^i t^i + \tau_2}{2\tau_2} \tag{9}$$

The proportion of passengers who get coupons only from platform j is $(1-\mu)\mu$, and the number of those participating in platform i is:

$$m_4 = (1-\mu)\mu \cdot \frac{\alpha_2 v_1 \left(2n_1^i - 1\right) - \alpha_2 t^j \left(1 - n_1^i\right) + \tau_2}{2\tau_2} \tag{10}$$

Therefore, the total number of passengers participating in platform i, denoted by n_2^i is given by

$$n_2^i = m_1 + m_2 + m_3 + m_4 \tag{11}$$

Drivers do not need to be classified into several categories because they do not receive subsidies upon an exogenous possibility. Except for this, the same way can be utilized to imply the number who participate into platform i, denoted by n_1^i:

$$n_1^i = \frac{\alpha_1 v_2 \left(2n_2^i - 1\right) + s^i - s^j + \tau_1}{2\tau_1} \tag{12}$$

Platforms benefit from attracting agents, in forms like the discount today of more future revenues in advertisements, and the enormous profit regarding subsequent mobile payment habit establishment. All these are assumed to a value of T_1 for one driver and T_2 for one passenger. Profit has the denotation of $\pi^i(\pi^j)$, so the two platforms solve the profits maximization problems:

$$\underset{s^i, t^i}{Max}\ \pi^i = (T_1 - s^i)n_1^i + T_2(m_1 + m_4) + \left(T_2 - \alpha_2 n_1^i t^i\right)(m_2 + m_3) \tag{13}$$

$$\underset{s^j, t^j}{Max}\ \pi^j = (T_1 - s^j)n_1^j + T_2(1 - \mu - m_1 - m_3) + \left(T_2 - \alpha_2 n_1^j t^j\right)(\mu - m_2 - m_4) \tag{14}$$

In the symmetric equilibrium, two platforms choose identical value of $s^i(s^j)$ and $t^i(t^j)$ which means $s = s^i = s^j$ and $t = t^i = t^j$. The optimal result is given by:

$$t = -\frac{2(-\tau_2 + T_2 + \alpha_1 v_2)}{\alpha_2(-2+\mu)} \tag{16}$$

$$n_1^i = n_2^i = n_1^j = n_2^j = \frac{1}{2} \tag{17}$$

Then the two platforms gain the same size of agents and also profits, denoted by $\pi_0 = \pi^i = \pi^j$:

$$\pi_0 = \frac{1}{2\tau_2(-2+\mu)^2}\left\{\tau_1\tau_2(-2+\mu)^2 + \tau_2^2\mu(1+\mu) + (-1+\mu)(T_2+\alpha_1 v_2)[3T_2\mu + 4\alpha_2 v_1 - 2\alpha_2\mu v_1 + 3\alpha_1\mu v_2] + \tau_2\left[T_2\left(4 - 2\mu - 3\mu^2\right) + \mu(\alpha_2(-2+\mu)v_1 + 2\alpha_1(1-2\mu)v_2)\right]\right\} \tag{18}$$

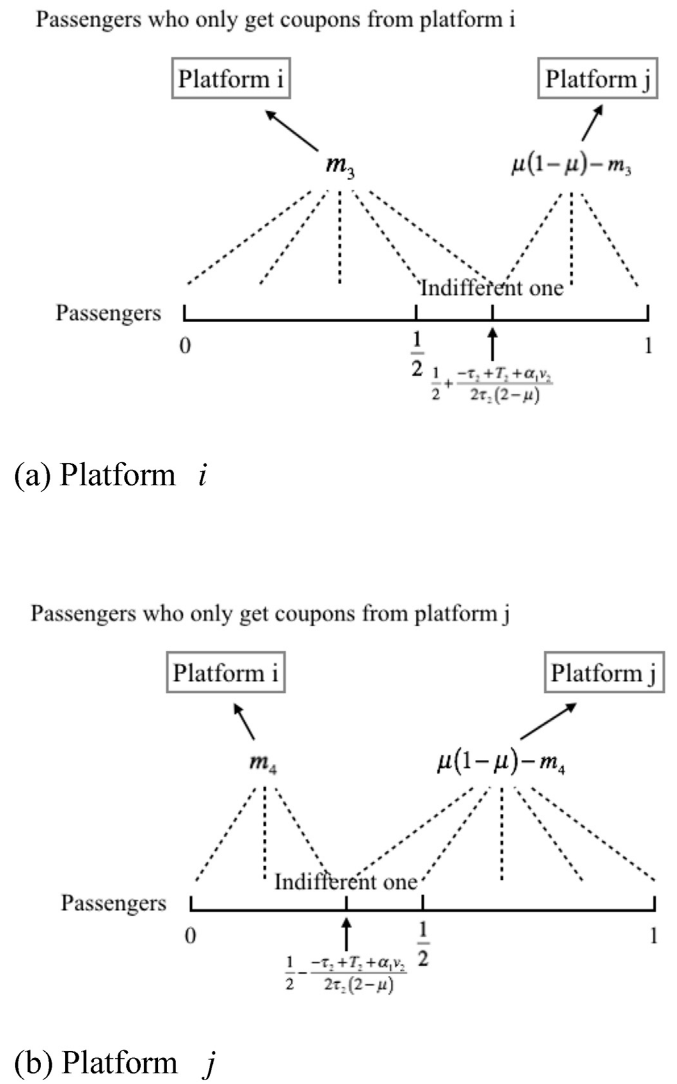

Fig. 2. Choices of passengers who only get coupons from (a) platform i and (b) Platform j.

As for consumer surplus, we first consider the passengers' side. It can be divided into two parts according to passengers' utility functions (1), (3).

One part (positive item) is the utility of getting rides and coupons through platforms, and the other (negative item) is the loss in distances between agents and platforms, or to say the dissatisfaction of platforms, which in this Hotelling framework is called 'transportation' cost (see Subsection 3.1). Correspondingly, the positive utility part, i.e., the positive item would increase with t, the value of a coupon, and the costs are concerned with positions of agents choosing platform i. In this symmetric equilibrium, because of the uniformity distribution assumption, the results show that among the first and second types of passengers who get the coupons from both platforms or get no coupons from any platform, half of them participate into platform i, and the other half in platform j. Specifically, each platform attracts $\frac{1}{2}\mu^2+\frac{1}{2}(1-\mu)^2$ number of passengers from the two groups. While for the third type who only get one coupon, the indifferent agent locates no longer at the center of the line. Substituting t into (9) and (10), we can have the expression of m_3 and m_4 with only exogenous parameters:

$$m_3=\mu(1-\mu)\left[\frac{1}{2}+\frac{-\tau_2+T_2+\alpha_1 v_2}{2\tau_2(2-\mu)}\right] \tag{19}$$

$$m_4=\mu(1-\mu)\frac{-\frac{1}{2}\alpha_2 t+\tau_2}{2\tau_2}=\mu(1-\mu)\left[\frac{1}{2}-\frac{-\tau_2+T_2+\alpha_1 v_2}{2\tau_2(2-\mu)}\right] \tag{20}$$

Hence, for agents who only get coupons from platform i, the indifferent passenger is positioned at $\frac{1}{2}+\frac{-\tau_2+T_2+\alpha_1 v_2}{2\tau_2(2-\mu)}$ distance away from platform i. It is symmetric for agents who only get coupons from platform j. This can be put clearly in Fig. 2.

According to Fig. 2, it can be observed that m_3 will increase with t because the increase of coupon value makes the platform more attracting for the passenger who only gets a coupon from this platform (indifferent point moves to the right). Passengers further away are now able to get reached by platform i, while the total 'transportation' costs get larger. These two adverse effects leave the gross consumer surplus ambiguous, but the increase in 'transportation' costs brings real loss in efficiency. Symmetrically, a platform loses attractiveness to those who only get coupons from the other platform. When t increases, the platform is only able to reach a smaller range of passengers. Since this group does not get coupons from the near platform, the change in coupon value has no effect except for the number decrease of this type of passengers. Then the surplus for this group decreases.

Platforms give coupons to drivers in a different way from passengers, so in the equilibrium, platforms attract half drivers respectively and the driver indifferent between two platforms is always in the central position of the line. So surplus of the whole drivers' group is monotone to the subsidy s that platforms offer.

The consumer surplus can be calculated separately. Passengers' surplus in benchmark is denoted by CS_2^0, where subscript 2 stands for consumers and superscript 0 for benchmark. Drivers' surplus is denoted by CS_1^0.

$$\begin{aligned}CS_2^0=&(1-\mu)^2\left[\int_0^{\frac{1}{2}}\left(\frac{1}{2}\alpha_2 v_1-\tau_2 x\right)dx+\int_{\frac{1}{2}}^1\left(\frac{1}{2}\alpha_2 v_1-\tau_2(1-x)\right)dx\right]\\&+\mu^2\left[\int_0^{\frac{1}{2}}\left(\frac{1}{2}\alpha_2(v_1+t)-\tau_2 x\right)dx+\int_{\frac{1}{2}}^1\left(\frac{1}{2}\alpha_2(v_1+t)-\tau_2(1-x)\right)dx\right]\\&+(1-\mu)\mu\left[\int_0^{m_3}\left(\frac{1}{2}\alpha_2 v_1-\tau_2 x\right)dx+\int_{m_3}^1\left(\frac{1}{2}\alpha_2 v_1-\tau_2(1-x)\right)dx\right]\\&+\mu(1-\mu)\left[\int_0^{m_4}\left(\frac{1}{2}\alpha_2(v_1+t)-\tau_2 x\right)dx+\int_{m_4}^1\left(\frac{1}{2}\alpha_2(v_1+t)-\tau_2(1-x)\right)dx\right]\end{aligned} \tag{21}$$

$$CS_1^0=\int_0^{\frac{1}{2}}\left(\frac{1}{2}\alpha_1 v_2+s-\tau_1 x\right)dx+\int_{\frac{1}{2}}^1\left(\frac{1}{2}\alpha_1 v_2+s-\tau_1(1-x)\right)dx \tag{22}$$

The social welfare consists of consumer surplus and company profits, and the superscript 0 in the denotation represents the benchmark situation. The weight is assumed to be identical so the expression can be denoted as:

$$W^0=CS_1^0+CS_2^0+2\pi_0 \tag{23}$$

Conditions are required to ensure the meaningful results. Indifferent agents, who obtain the lowest utility among their types, must receive a non-negative utility to guarantee all the agents attend platforms. Relying on different types of passengers, four conditions are given in sequence for passengers who do not get any coupons, get both coupons, get only coupons from platform i, and get only coupons from platform j.

$$\alpha_2\cdot\frac{1}{2}\cdot(v_1+t)-\frac{1}{2}\tau_2\geq 0 \tag{24}$$

$$\alpha_2 \cdot \frac{1}{2} \cdot v_1 - \frac{1}{2}\tau_2 \geq 0 \tag{25}$$

$$\alpha_2 \cdot \frac{1}{2} \cdot (v_1 + t) - \frac{\frac{1}{2}\alpha_2 t + \tau_2}{2\tau_2} \cdot \tau_2 \geq 0 \tag{26}$$

$$\alpha_2 \cdot \frac{1}{2} \cdot v_1 - \frac{-\frac{1}{2}\alpha_2 t + \tau_2}{2\tau_2} \cdot \tau_2 \geq 0 \tag{27}$$

The four inequalities (24), (25), (26), (27) can reduce to the following condition which we assume to hold throughout the paper:

$$\alpha_2 v_1 \geq \tau_2 \tag{28}$$

4. The analysis of government regulations

Chinese government took actions when several taxi-hailing apps appeared in China and competed for share in this emerging market by giving out large amount of subsidies to attract drivers and passengers. Many local governments announced various temporary provisions intending to control this situation. This paper chooses three types of regulations and makes assessment based on the framework of preceding model. The first one aims to transfer price between the platform and two sides' agents. The second one asks for butt joint or to say cooperation with official platforms. The last one is absolute forbiddance for some periods of time like morning peaks to avoid phone usage of drivers.

4.1. Price adjustments

Price adjustments refer to the regulation that a passenger is required to pay a mandatory dispatch fee to a driver when they are matched through the taxi-hailing app. Before this regulation, the taxi-hailing platforms did not charge dispatch fees as official platform did, and the regulation is mainly aimed for reducing impulsion the strong price competition brought to the official platform. Actually the service of booking a taxi existed before the private business of taxi-hailing apps became popular in China, which was usually supported by local government. People can call into an official line and ask a taxi for an immediate use or making an appointment. People usually need to pay for the arrangement as well as the lack in publicity result in the limited popularity of this service. This painstaking operation got worse when private taxi-hailing apps service rose. So when government requires passengers to pay an extra fee for the usage of taxi, they adjust the price passengers faced with, and also what drivers face if the fees are transferred to them totally. Precisely, we denote the dispatch fee as p for every ride through taxi-hailing apps. The fee is assumed to transfer completely to drivers.

This changes agents' utility functions, which can be given by:

$$u_1^i = \alpha_1 n_2^i (v_2 + p) + s^i - \tau_1 x \tag{29}$$

$$u_2^i = \alpha_2 n_1^i (v_1 + t^i - p) - \tau_2 x \tag{30}$$

$$u_2^i = \alpha_2 n_2^i (v_1 - p) - \tau_2 x \tag{31}$$

When the extra fee is transferred directly to drivers, platforms' profit functions remain unaltered. The same method solving for equilibrium is applied and the results are given by:

$$\begin{aligned} s_1 = &\frac{-1}{\tau_2(-2+\mu)^2}\{-4\tau_2 T_1 + 4\alpha_2 p T_2 + \tau_1\tau_2(-2+\mu)^2 + 2\alpha_2\tau_2 p\mu + 4\tau_2 T_1\mu \\ &+2\tau_2 T_2\mu - 6\alpha_2 p T_2\mu - 2T_2^2\mu + \tau_2^2\mu^2 - \alpha_2\tau_2 p\mu^2 - \tau_2 T_1\mu^2 - 3\tau_2 T_2\mu^2 + \\ &2\alpha_2 p T_2\mu^2 + 2T_2^2\mu^2 - 4\alpha_2 T_2 v_1 - 2\alpha_2\tau_2\mu v_1 + 6\alpha_2 T_2\mu v_1 + \alpha_2\tau_2\mu^2 v_1 - 2\alpha_2 T_2\mu^2 v_1 \\ &+\alpha_1\left[(\tau_2(2-3\mu) + 4T_2(-1+\mu))\mu + 2\alpha_2(2-3\mu+\mu^2)(p-v_1)\right](p+v_2) \\ &+2\alpha_1^2(-1+\mu)\mu(p+v_2)^2\} \end{aligned} \tag{32}$$

$$t_1 = -\frac{2[-\tau_2 + T_2 + \alpha_1(p + v_2)]}{\alpha_2(-2+\mu)} \tag{33}$$

$$\begin{aligned} \pi_1 = &\frac{1}{2\tau_2(-2+\mu)^2}\{4\tau_2 T_2 + \tau_1\tau_2(-2+\mu)^2 + \tau_2^2\mu - 2\tau_2 T_2\mu - 3T_2^2\mu + \tau_2^2\mu^2 - 3\tau_2 T_2\mu^2 \\ &+3T_2^2\mu^2 + \alpha_2(-2+\mu)(2T_2(-1+\mu) - \tau_2\mu)(p - v_1) + 2\alpha_1[\mu(\tau_2 + 3T_2(-1+\mu)) \\ &-2\tau_2\mu^2 + \alpha_2(2-3\mu+\mu^2)(p-v_1)](p+v_2) + 3\alpha_1^2(-1+\mu)\mu(p+v_2)^2\} \end{aligned} \tag{34}$$

The subscript 1 of s_1, t_1, π_1 is labeled for this first kind of regulation. By comparing the new equilibrium with the benchmark, changes values denoted with Δ are given by:

$$\begin{aligned} \Delta s_1 = &\frac{1}{\tau_2(-2+\mu)^2} p\{-\alpha_2(-2+\mu)[2T_2(-1+\mu) - \tau_2\mu] - 2\alpha_1^2(-1+\mu)\mu(p+2v_2) \\ &+\alpha_1\left[\mu(-2\tau_2 + 4T_2 + 3\tau_2\mu - 4T_2\mu) - 2\alpha_2(2-3\mu+\mu^2)(p - v_1 + v_2)\right]\} \end{aligned} \tag{35}$$

$$\Delta t_1 = \frac{2\alpha_1 p}{\alpha_2(2-\mu)} \tag{36}$$

$$\begin{aligned} \Delta\pi_1 = &\frac{1}{2\tau_2(-2+\mu)^2} p\{\alpha_2(-2+\mu)[2T_2(-1+\mu) - \tau_2\mu] + 3\alpha_1^2(-1+\mu)\mu(p+2v_2) \\ &+2\alpha_1\left[\mu(\tau_2 + 3T_2(-1+\mu) - 2\tau_2\mu) + \alpha_2(2-3\mu+\mu^2)(p - v_1 + v_2)\right]\} \end{aligned} \tag{37}$$

Table 1
Parameter settings for Δs_1.

(a) Parameters in Baseline										
Δs_1	Denotation	α_1	α_2	T_1	T_2	v_1	v_2	τ_1	τ_2	μ
Baseline	F1	1.3	1	0.7	0.8	1	0.8	0.7	0.7	0.6
	F2	1.3	1.5	0.7	0.8	1	0.8	0.7	0.7	0.6

(b) Variations in Parameters				
	$\alpha_2 = 1$		$\alpha_2 = 1.5$	
T_2 increases	F3	$T_2 = 1$	F4	$T_2 = 1$
τ_2 increases	F5	$\tau_2 = 0.8$	F6	$\tau_2 = 0.8$
μ increases	F7	$\mu = 0.7$	F8	$\mu = 0.7$
μ decreases	F9	$\mu = 0.5$	F10	$\mu = 0.5$
v_1 increases	F11	$v_1 = 1.2$	F12	$v_1 = 1.2$
v_2 increases	F13	$v_2 = 1$	F14	$v_2 = 1$

All the parameters are positive and the possibility μ satisfies $0 < \mu \leq 1$, so we can derive $\Delta t_1 > 0$. The intuition behind is that, compared to the benchmark, platforms give more subsidies to passengers to keep their attractiveness against the mandatory extra fees. Combine the regulation impacts and platforms' responses, a passenger receives a change in subsidy from t to t_1 but pays p more, so the net change can be given by:

$$\Delta_1 = \Delta t_1 - p = \frac{2\alpha_1 - \alpha_2(2-\mu)}{\alpha_2(2-\mu)} p \tag{38}$$

Whether it is positive or not depends on the sign of $2\alpha_1 - \alpha_2(2-\mu)$. Specifically, when the condition $\frac{\alpha_1}{\alpha_2} > \frac{2-\mu}{2}$ satisfies, $\Delta_1 = \Delta t_1 - p > 0$ holds. And we know $\frac{1}{2} \leq \frac{2-\mu}{2} < 1$, so if $\frac{\alpha_1}{\alpha_2} \geq 1$, we can derive $\Delta_1 = \Delta t_1 - p > 0$, and passengers surely benefit from this regulation because platforms compensate passengers with more subsidies covering the dispatch fees. Since α_1, α_2 measure the degree of network externality, $\alpha_1 \geq \alpha_2$ implies passengers exert a larger externality toward drivers, which reveals the importance for platforms to retain the passengers' side. Therefore, platforms put more effort on this side, resulting in passengers benefit from this seemingly adverse regulation.

The changes of subsidies for drivers and platforms' profit are hard to derive, so figures with numerical values are used to obtain instructive results.

The software Mathematica is used to produce figures, presenting the relation between Δs_1 and p, and how it changes with parameters. Concerning the relative size of α_1 and α_2, the discussion is divided into two parts that contain α_1 is larger than α_2 and the opposite. Denote the two baseline situations with F1 and F2 (all the parameters are set as Table 1 (a)).

The only difference between F1 and F2 is the size of α_2. Under the two sets of parameters, Fig. 3 shows how Δs_1 varies with p. Then we set two series of parameters conditioning on the different size of α_2 that are shown in Table 1(b).

Fig. 3 shows the drivers' subsidy change respect to transfer price, and four subfigures represent (a) the baseline only, (F1, F2), (b) baseline with changes in T_2 or τ_2, (F1, F2, F3, F4, F5, F6), (c) baseline with changes in μ, (F1, F2, F7, F8, F9, F10), (d) baseline with changes in v_1 or v_2, (F1, F2, F11, F12, F13, F14) respectively.

Focusing on whether Δs_1 is positive or not, we should pay attention to the relative position of the Δs_1 line and the 0 value horizontal line. The $\alpha_2 = 1$ group and $\alpha_2 = 1.5$ group present apparent distinction. When α_1 is larger than α_2, there is much more possibility that appears $\Delta s_1 > 0$, which means the transfer p will lead to an increase in the subsidy to drivers from platforms.

The derivative of Δs_1 by α_1 and α_2 are:

$$\frac{\partial \Delta s_1}{\partial \alpha_1} = -\frac{1}{\tau_2(-2+\mu)^2} p\{2\alpha_2(2-3\mu+\mu^2)(p-v_1+v_2) + \mu[\tau_2(2-3\mu) + 4(-1+\mu)(\alpha_1(p+2v_2)+T_2)]\} \tag{39}$$

$$\frac{\partial \Delta s_1}{\partial \alpha_2} = -\frac{p\{2(-1+\mu)[T_2 + \alpha_1(p-v_1+v_2)] - \tau_2\mu\}}{\tau_2(-2+\mu)} \tag{40}$$

Equations 39 and 40 imply that when $p - v_1 + v_2 > 0$ holds, the sign of $\frac{\partial \Delta s_1}{\partial \alpha_1}$ largely depends on the size of α_2 and μ, and besides $\frac{\partial \Delta s_1}{\partial \alpha_2} < 0$. The intuition behind is that relatively large α_1 implies a large externality that the passengers' side acts on the drivers' side, so when the requirement of transfer p appears, platforms lose attractiveness to passengers, and then drivers as well because of externality. Passengers' large influence on drivers enlarges the possible loss in drivers' number, stimulating platforms' incentive to invest more on drivers. If drivers are not that sensitive to passengers, which is implied by a relatively small α_1, then there is no need for platforms to subsidy drivers much since they already benefit from the transfer while the harmful impact on passengers do not influence drivers much. Adversely, large α_2 means drivers are able to influence passengers a lot, and then platforms can respond in making a less adjustment because now drivers can play some role in getting back passengers who are unpleasant with the transfer.

Meanwhile, the two sets both show that Δs_1 are more likely to be positive when p is small. This makes sense as the preceding explanation. If more transfers are given to drivers, less compensation are needed to offer by platforms. All these can be analyzed from the tradeoff that drivers are faced with. The transfer p satisfies drivers in a positive way, but displease passengers, which exerts a negative influence to drivers through network externality. The negative effect will increase when the externality is large, and the positive effect will decrease with p, which explains what figures present.

The value of Δs_1 shows the size of the effect this regulation has, and it fluctuates with parameters. Derivatives can be calculated by:

$$\frac{\partial \Delta s_1}{\partial T_2} = -\frac{2p(-1+\mu)[\alpha_2(-2+\mu) + 2\alpha_1\mu]}{\tau_2(-2+\mu)^2} \tag{41}$$

$$\frac{\partial \Delta s_1}{\partial v_1} = \frac{2\alpha_1\alpha_2 p(-1+\mu)}{\tau_2(-2+\mu)} \geq 0 \tag{42}$$

$$\frac{\partial \Delta s_1}{\partial v_2} = -\frac{2\alpha_1 p(-1+\mu)[\alpha_2(-2+\mu) + 2\alpha_1\mu]}{\tau_2(-2+\mu)^2} \tag{43}$$

The effect of drivers' value on passengers is determinately positive. And when $\alpha_2(-2+\mu) + 2\alpha_1\mu \geq 0$, we have $\frac{\partial \Delta s_1}{\partial T_2} \geq 0$, $\frac{\partial \Delta s_1}{\partial v_2} \geq 0$. When a driver can bring more value to a passenger, the change in subsidy after this regulation is larger than he who has a lower value of v_1. To be specific, the requirement of transfer p may cause a driver receive a larger size of subsidy from the platform, and then if the driver's value to a passenger lies in a higher level, he will enjoy a higher change in subsidy than the lower value situation. Identically, if the transfer brings to the driver a loss in subsidy, then for a higher value driver, he would suffer a less loss in subsidy. Therefore, to some extent, a higher value that a driver can bring

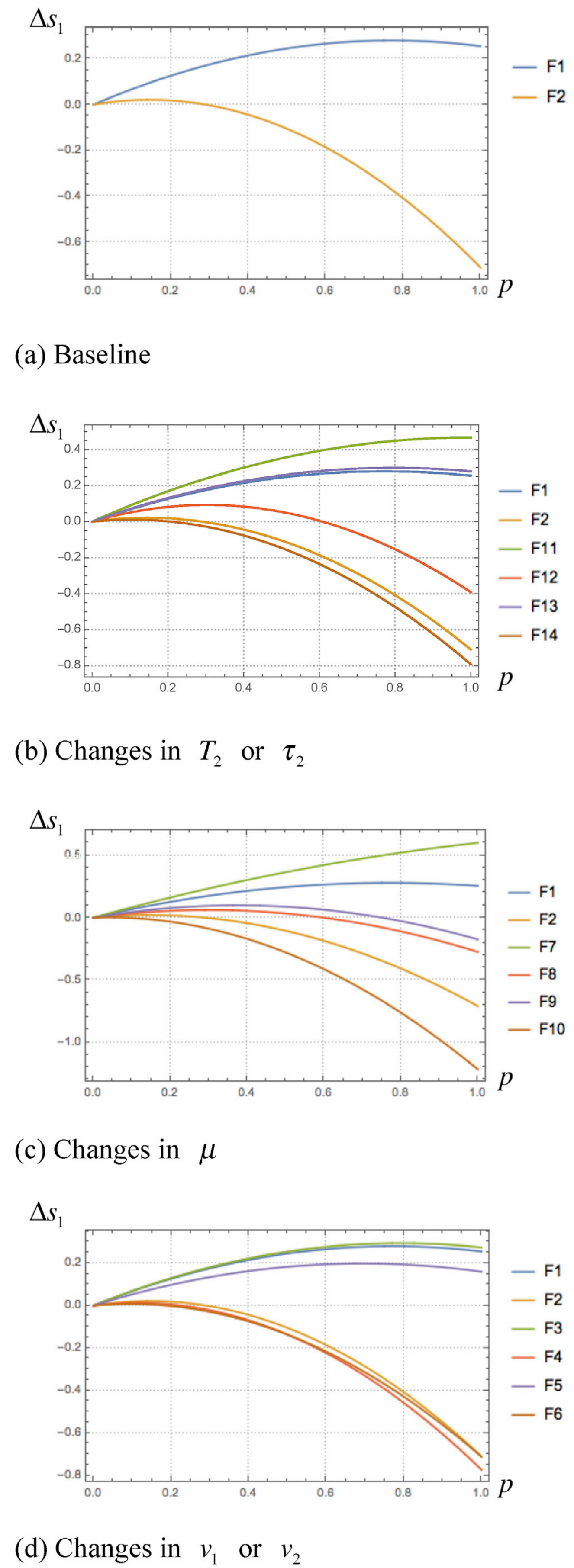

Fig. 3. Drivers' subsidy change respect to transfer price. (a) Baseline; (b) Changes in T_2 or τ_2; (c) Changes in μ; (d) Changes in v_1 or v_2.

to a passenger is beneficial. T_2 and v_2 refer to values a passenger for a platform and a driver, and $\frac{\partial \Delta s_1}{\partial T_2} \geq 0$, $\frac{\partial \Delta s_1}{\partial v_2} \geq 0$ share a parallel explanation with the former one.

Same baseline settings are adopted to explore the profit variation. The discussion is also divided into two parts that α_1 is larger than α_2 and the opposite. Denote the baseline two situations with W1 and W2, where all the parameters are set in Table 2 (a).

Under the two baseline sets of parameters, Fig. 4 shows how $\Delta\pi_1$ changes with p. Then we set two series of parameters conditioning on the different size of α_2 that are shown in Table 2(b).

Fig. 4 shows platforms' profit change respect to transfer price, and four subfigures present (a) the baseline only, (W1, W2), (b) baseline with changes in T_2, (W1, W2, W3, W4), (c) baseline with changes in v_1 or v_2, (W1, W2, W5, W6, W7, W8), (d) baseline with changes in μ, (W1, W2, W9, W10).

From Fig. 4, we can observe that under the set value in Table 2, when α_1 is relatively smaller than α_2, there is more possibility to have $\Delta\pi_1 > 0$, and in most situations listed, lines that represent the larger α_2 position higher. Among the numerical examples, the only situation where $\Delta\pi_1 > 0$ is that α_2 is large and μ is small. The appearance of transfer price harms passengers' utilities so that platforms are supposed to increase coupons' value to maintain attractiveness. A small μ implies that a small amount of passengers have the chance to obtain coupons, resulting in less money put in the passengers' side and room for profits. The expression of Δt_1 implies that when $\frac{\alpha_1}{\alpha_2}$ is relatively large, this price adjustments regulation will drag the profit because platforms' costs increase a lot on defraying more subsidies to passengers. Thus, only when $\frac{\alpha_1}{\alpha_2}$ is not that large, the possibility exists that platforms benefit from the regulation. The intuition behind is explicable by looking over drivers' tradeoff. On one hand the mandatory extra fees reduce platforms' attractiveness to passengers, which also let drivers down because of network externality; on the other hand, the transfer in price from passengers benefits drivers in a direct positive way. Only when α_1 is relatively small, the negative effect that passengers bring to drivers will not balance out the positive effect by introducing transfer fees, can platforms be able to offer less to drivers and gain more profits.

Derivatives of $\Delta\pi_1$ on T_2, v_1, v_2 are calculated:

$$\frac{\partial \Delta\pi_1}{\partial T_2} = \frac{p(-1+\mu)[\alpha_2(-2+\mu)+3\alpha_1\mu]}{\tau_2(-2+\mu)^2} \tag{44}$$

$$\frac{\partial \Delta\pi_1}{\partial v_1} = -\frac{\alpha_1\alpha_2 p(-1+\mu)}{\tau_2(-2+\mu)} \leq 0 \tag{45}$$

$$\frac{\partial \Delta\pi_1}{\partial v_2} = \frac{\alpha_1 p(-1+\mu)[\alpha_2(-2+\mu)+3\alpha_1\mu]}{\tau_2(-2+\mu)^2} \tag{46}$$

Influences of these three parameters are similar to those in Δs_1, and the influence of v_1 to $\Delta\pi_1$ is definite. Discussion about Δs_1 has shown that when a driver's value for a passenger increases, platforms would carry a smaller size of adjustment in drivers' side to react to the regulation. Since the change in profit depends on the variation of t and s, and given that Δt_1 expression does not contain a v_1 item, the change in profit decreases when a driver weighs more value for passengers through the influence on s. Both the signs of $\frac{\partial \Delta\pi_1}{\partial T_2}$ and $\frac{\partial \Delta\pi_1}{\partial v_2}$ depend on the term $\alpha_2(-2+\mu)+3\alpha_1\mu$. When $\frac{\alpha_1}{\alpha_2} > \frac{2-\mu}{3\mu}$ satisfies, $\frac{\partial \Delta\pi_1}{\partial T_2} \leq 0$ and $\frac{\partial \Delta\pi_1}{\partial v_2} \leq 0$. Therefore the variation of a passenger's value for a platform, as well as his value for a driver can exert an influence on the intensity of the regulation.

As for consumer surplus, we analyze passengers and drivers separately. Drivers' surplus varies with the subsidies given by platforms. Comparing the two equilibriums, we find out that each driver does not change his choice for platforms. Because in both equilibriums, two platforms have the same strategy and offer an identical value of subsidy, so that half drivers participate platform i and the other choose platform j.

Hence, the increase in s_1 will raise each driver's utility, so does the surplus of the whole group.

Passengers are divided into four types according to the number and type of coupons they receive. For those getting coupons from two platforms, only when $\Delta_1 = \Delta t_1 - p > 0$, everyone at the same position as in benchmark can obtain more utility. Now that indifferent passenger positioned at center of the line, we can infer this type of passengers' surplus increases. For those who do not get any coupon, things remain as benchmark but an extra payment of p, so the surplus decreases. Many changes happen to passengers who get one coupon from a platform. Take passengers who only get coupons from platform i as the example. When the net change of subsidies minus dispatch fee is positive, that is $\Delta_1 > 0$, the change of platforms' offers fully covers the transfer price, and then a passenger's utility increase compared with benchmark. The expression of m_3 implies platforms are able to reach passengers farther away, which brings up 'transportation' costs. Symmetric setting shows the more this type of passengers are attracted, the less passengers who only get coupons from the other platform are attracted. So apparently the whole consumer surplus heavily relies on the parameters of α_1, α_2, μ.

Denote passengers' and drivers' consumer surplus with CS_1^1 and CS_2^1 respectively, and the welfare situation under this regulation is W^1. Then we have:

$$\begin{aligned} CS_2^1 = (1-\mu)^2 & \left[\int_0^{\frac{1}{2}}\left(\frac{1}{2}\alpha_2(v_1-p)-\tau_2 x\right)dx + \int_{\frac{1}{2}}^1\left(\frac{1}{2}\alpha_2(v_1-p)-\tau_2(1-x)\right)dx\right] \\ & +\mu^2\left[\int_0^{\frac{1}{2}}\left(\frac{1}{2}\alpha_2(v_1+t-p)-\tau_2 x\right)dx + \int_{\frac{1}{2}}^1\left(\frac{1}{2}\alpha_2(v_1+t-p)-\tau_2(1-x)\right)dx\right] \\ & +\mu(1-\mu)\left[\int_0^{m_3}\left(\frac{1}{2}\alpha_2(v_1+t-p)-\tau_2 x\right)dx + \int_{m_3}^1\left(\frac{1}{2}\alpha_2(v_1-p)-\tau_2(1-x)\right)dx\right] \\ & +(1-\mu)\mu\left[\int_0^{m_4}\left(\frac{1}{2}\alpha_2(v_1-p)-\tau_2 x\right)dx + \int_{m_4}^1\left(\frac{1}{2}\alpha_2(v_1+t-p)-\tau_2(1-x)\right)dx\right] \end{aligned} \tag{47}$$

$$CS_1^1 = \int_0^{\frac{1}{2}}\left(\frac{1}{2}\alpha_1(v_2+p)+s-\tau_1 x\right)dx + \int_{\frac{1}{2}}^1\left(\frac{1}{2}\alpha_1(v_2+p)+s-\tau_1(1-x)\right)dx \tag{48}$$

$$W^1 = CS_1^1 + CS_2^1 + 2\pi_1 \tag{49}$$

Compared to welfare in benchmark, the effect on welfare induced by this regulation can be calculated, shown in (50).

$$\begin{aligned} \Delta W^1 &= W^1 - W^0 \\ &= \frac{1}{2\tau_2(-2+\mu)^2}p\{-\alpha_2\tau_2(-2+\mu)^2 + \alpha_1\left[4T_2(-1+\mu)\mu - 4\tau_2^3(-1+\mu)^2\mu^2\right. \\ &\left. +4\tau_2^2T_2(-1+\mu)^2\mu^2 - 2\tau_2^5(-1+\mu)^3\mu^3 + 2\tau_2^4T_2(-1+\mu)^3\mu^3 + \tau_2(4-3\mu^2)\right] \\ &+\alpha_1^2(-1+\mu)\mu\left[2+2\tau_2^2(-1+\mu)\mu + \tau_2^4(-1+\mu)^2\mu^2\right](p+2v_2)\} \end{aligned} \tag{50}$$

Simplifying the expression we obtain that the sufficient conditions for $\Delta W^1 \le 0$ are

$$1 + \tau_2^2(-1+\mu)\mu \ge 0 \tag{51}$$

$$\alpha_1 \le 4\alpha_2 \tag{52}$$

This delivers that when passengers' 'transportation' cost is not that large and the relative size between cross-group externalities remains at a reasonable level, this price adjustments regulation will have a negative impact on social welfare. Oppositely, when passengers' external effect on drivers is much higher than drivers' attractiveness to passengers, the equilibrium before regulation requires platforms subsidy passengers a lot to maintain their attractiveness but less attention on drivers' side because they can largely be driven by the increase in passengers' number. Under this scenario, the mandatory price transfer from passengers to drivers serves as a tool to balance the heavy bias in platforms' subsidies to drivers and passengers, which makes it possible to increase social welfare. Normally, the welfare decreased by the price adjustments is reasonable when the transfer fee p is small. First we are aware that platforms choose the benchmark equilibrium even though they are able to imitate this regulation by reducing a same value of subsides for passengers and transferring them to drivers, which implies that they prefer the benchmark more. Thus, platforms receive a down slope in profits after responding to the regulation, by increasing their subsidies towards passengers, which brings up a platform's attractiveness to those who only receive one coupon from this platform. The capability that a platform can reach further customers results in a loss in efficiency because of the disutility generated by 'transportation' costs that cannot be compensated somewhere else. Nevertheless, when the dispatch fee is large and the price transfer cannot be realized at the initial stage by platforms' own choice, it could be possible that the government regulation serves to a higher level of social welfare.

Proposition 1. *Price adjustments lift platforms' subsidies to passengers. When $\frac{\alpha_1}{\alpha_2} > \frac{2-\mu}{2\mu}$ is satisfied, passengers' extra pay of the mandatory fees can be covered by platforms' increase in coupons but causing efficiency loss. The relative size of mutual network externalities exerts an impact on the positive or negative effect of this regulation, and the intensity of the regulation largely depends on the level of a customer's value. Platforms are easier to gain more profit when α_1 is relatively smaller than α_2 since less subsidies are offered to drivers. While the whole customer surplus is vague, if the two sufficient conditions $1 + \tau_2^2(-1+\mu)\mu \ge 0$ and $\alpha_1 \le 4\alpha_2$ holds, the regulation brings negative impact on social welfare.*

Table 2
Parameter settings for $\Delta\pi_1$.

(a) Parameters in Baseline										
$\Delta\pi_1$	Denotation	α_1	α_2	T_1	T_2	v_1	v_2	τ_1	τ_2	μ
Baseline	W1	1.3	1	0.7	0.8	1	0.8	0.7	0.7	0.6
	W2	1.3	1.5	0.7	0.8	1	0.8	0.7	0.7	0.6

(b) Variations in Parameters	$\alpha_2 = 1$		$\alpha_2 = 1.5$	
T_2 increases	W3	$T_2 = 1$	W4	$T_2 = 1$
v_1 decreases	W5	$v_1 = 0.8$	W6	$v_1 = 0.8$
v_2 decreases	W7	$v_2 = 0.6$	W8	$v_2 = 0.6$
μ decreases	W9	$\mu = 0.4$	W10	$\mu = 0.4$

4.2. Butt joint with official platforms

The regulation of butt joint between private taxi-hailing apps and official platforms is what government did to enforce corporation between them, which means they share customers and information. We assume no market share for public platform in this paper because their size is quite small compared to the private apps. To put it in detail, when a passenger calls for a taxi no matter through the private apps or the official platform, this information goes to an overall dispatching center, and then a driver matches to a passenger probably from the other platform but submitting to a kind of priority that agents from the same platform enjoy a higher possibility to be matched with each other. The feasibility is based on that every taxi in operation is installed with the equipment through which the official platform is able to get access to any taxi and make dispatchment. Making the private taxi-hailing apps get butt joint with official platforms is aimed at a higher level of control by government. Given the model specification, this regulation means a driver who participates in platform i is now able to get access to all passengers including those who choose the platform j, and the symmetric things also apply to passengers. It is reasonable to assume the drivers' side benefit more from passengers sharing the same platform than those from the other platform because of the priority. The utility function of the agent located at x distance from platform i is thereby rewritten as below in (53), (54), (55).

$$u_1^i = \left(\alpha_1 n_2^i + \beta_1 n_2^j\right) v_2 + s^i - \tau_1 x \tag{53}$$

$$u_2^i = \alpha_2 n_1^i (v_1 + t^i) + \beta_2 n_1^j v_1 - \tau_2 x \tag{54}$$

$$\Delta\pi_2 = \frac{1}{2\tau_2(-2+\mu)^2}\{\beta_2(-2+\mu)v_1[2T_2(-1+\mu) - \tau_2\mu + 2(\alpha_1-\beta_1)(-1+\mu)v_2] \\ +\beta_1 v_2[2\tau_2(-1+2\mu)\mu - (-1+\mu)(2\alpha_2(2-\mu)v_1 - 3(-2\alpha_1+\beta_1)\mu v_2 + 6T_2\mu)]\} \tag{61}$$

$$u_2^i = \alpha_2 n_1^i v_1 + \beta_2 n_1^j v_1 - \tau_2 x \tag{55}$$

$$\Delta s_2 = \frac{1}{\tau_2(-2+\mu)^2}\{-\beta_2(-2+\mu)v_1[2T_2(-1+\mu) - \tau_2\mu + 2(\alpha_1-\beta_1)(-1+\mu)v_2] \\ +\beta_1 v_2\left[\tau_2(2-3\mu)\mu - 2\alpha_2\left(2-3\mu+\mu^2\right)v_1 + 2(-1+\mu)(2T_2\mu + (2\alpha_1-\beta_2)\mu v_2)\right]\} \tag{62}$$

where β_1, β_2 share similar implications with α_1, α_2, and they denote the externality induced by agents of the other side and from the other platform. It is assumed that $\alpha_1 > \beta_1$, $\alpha_2 > \beta_2$. Now that platforms still give out coupons to agents on them, their profit functions do not change and still hold the expression of (13) and (14). The results of this new equilibrium are given with subscript 2:

$$s_2 = \frac{1}{\tau_2(-2+\mu)^2}\{-\tau_1\tau_2(-2+\mu)^2 + T_1\tau_2(-2+\mu)^2 - [-2T_2(-1+\mu) + \tau_2\mu \\ -2(\alpha_1-\beta_1)(-1+\mu)v_2][\mu(\tau_2 - T_2 - v_2(\alpha_1-\beta_1)) + (-2+\mu)v_1(\alpha_2-\beta_2)]\} \tag{56}$$

$$t_2 = -\frac{2[-\tau_2 + T_2 + (\alpha_1-\beta_1)v_2]}{\alpha_2(-2+\mu)} \tag{57}$$

$$\pi_2 = \frac{1}{2\tau_2(-2+\mu)^2}\{\tau_1\tau_2(-2+\mu)^2 + \tau_2^2\mu(1+\mu) + (-1+\mu)[T_2 + (\alpha_1-\beta_1)v_2]\cdot \\ [3T_2\mu - 2\beta_2 v_1(2-\mu) - 2\alpha_2(-2+\mu)v_1 + 3\mu v_2(\alpha_1-\beta_1)] + \tau_2\cdot \\ \left[T_2\left(4-2\mu-3\mu^2\right) + \mu((\alpha_2-\beta_2)(-2+\mu)v_1 - 2(\alpha_1-\beta_1)(-1+2\mu)v_2)\right]\} \tag{58}$$

Compared to the benchmark in section 2, variations expressions are shown in (59), (60), (61):

$$\Delta s_2 = \frac{1}{\tau_2(-2+\mu)^2}\{-\beta_2(-2+\mu)v_1[2T_2(-1+\mu) - \tau_2\mu + 2(\alpha_1-\beta_1)(-1+\mu)v_2] \\ +\beta_1 v_2[\tau_2(2-3\mu)\mu + 2(-1+\mu)(2T_2\mu - \alpha_2(-2+\mu)v_1 + (2\alpha_1-\beta_2)\mu v_2)]\} \tag{59}$$

$$\Delta t_2 = \frac{2\beta_1 v_2}{\alpha_2(-2+\mu)} \tag{60}$$

It can be easily proved that $\Delta t_2 < 0$. The expression of Δs_2 can be changed to:

Assume $2\alpha_1 \geq \beta_2$, then based on conditions including $0 < \mu \leq 1$, $\alpha_1 > \beta_1$ and the non-negativity of parameters, we can obtain that if $\tau_2(2-3\mu)\mu - 2(-1+\mu)\alpha_2(-2+\mu)v_1 < 0$ holds, $\Delta s_2 < 0$. Then using the condition (28), we have

$$\tau_2(2-3\mu)\mu-2(-1+\mu)\alpha_2(-2+\mu)v_1\leq\tau_2(2-3\mu)\mu-2(-1+\mu)(-2+\mu)\tau_2 \\ =-5\tau_2\left(\mu-\frac{4}{5}\right)^2-\frac{4}{5}\tau_2<0 \tag{63}$$

Therefore, $\Delta s_2<0$ can be derived.

The expression of $\Delta\pi_2$ can be transformed to:

$$\Delta\pi_2=\frac{1}{2\tau_2(-2+\mu)^2}\{\beta_2(-2+\mu)v_1[2T_2(-1+\mu)-\tau_2\mu+2(\alpha_1-\beta_1)(-1+\mu)v_2]+\beta_1v_2\cdot \\ [2\tau_2(-1+2\mu)\mu-(-1+\mu)2\alpha_2(2-\mu)v_1-(-1+\mu)(-3(-2\alpha_1+\beta_1)\mu v_2+6T_2\mu)]\} \tag{64}$$

Conditions $0<\mu\leq1$, $\alpha_1>\beta_1$ and the non-negativity of parameters imply that if $2\tau_2(-1+2\mu)\mu-(-1+\mu)2\alpha_2(2-\mu)v_1>0$, we have $\Delta\pi_2>0$. Using the condition (28), it can be induced that

$$2\tau_2(-1+2\mu)\mu-(-1+\mu)2\alpha_2(2-\mu)v_1\geq2\tau_2(-1+2\mu)\mu-(-1+\mu)2\tau_2(2-\mu) \\ \geq6\tau_2\left(\mu-\frac{2}{3}\right)^2+\frac{4}{3}\tau_2>0 \tag{65}$$

Therefore, we can derive $\Delta\pi_2>0$ which means platforms gain more profits after this regulation.

The regulation of cooperation allows one platform to get access to agents in the other platform, which draws down their incentives to cost a lot in attracting agents. Whereas, this cooperation increases platforms' attractiveness to agents because agents are no longer forced to give up significant match possibility in choosing between platforms. Therefore, platforms respond in reducing coupons and realize higher profits. Things are quite symmetric in the drivers' side.

Consumer surplus for drivers and passengers are calculated, where the subscript 1,2 represent drivers and passengers respectively, and the superscript 2 represents the second scenario of regulation:

$$CS_1^2=\int_0^{\frac{1}{2}}\left(\frac{1}{2}(\alpha_1+\beta_1)v_2+s-\tau_1x\right)dx+\int_{\frac{1}{2}}^1\left(\frac{1}{2}(\alpha_1+\beta_1)v_2+s-\tau_1(1-x)\right)dx \tag{66}$$

$$\begin{aligned}CS_2^2=&(1-\mu)^2\left[\int_0^{\frac{1}{2}}\left(\frac{1}{2}\alpha_2v_1+\frac{1}{2}\beta_2v_1-\tau_2x\right)dx+\int_{\frac{1}{2}}^1\left(\frac{1}{2}\alpha_2v_1+\frac{1}{2}\beta_2v_1-\tau_2(1-x)\right)dx\right]\\&+\mu^2\left[\int_0^{\frac{1}{2}}\left(\frac{1}{2}\alpha_2(v_1+t)+\frac{1}{2}\beta_2v_1-\tau_2x\right)dx+\int_{\frac{1}{2}}^1\left(\frac{1}{2}\alpha_2(v_1+t)+\frac{1}{2}\beta_2v_1-\tau_2(1-x)\right)dx\right]\\&+\mu(1-\mu)\left[\int_0^{m_3}\left(\frac{1}{2}\alpha_2(v_1+t)+\frac{1}{2}\beta_2v_1-\tau_2x\right)dx+\int_{m_3}^1\left(\frac{1}{2}\alpha_2v_1+\frac{1}{2}\beta_2v_1-\tau_2(1-x)\right)dx\right]\\&+(1-\mu)\mu\left[\int_0^{m_4}\left(\frac{1}{2}\alpha_2v_1+\frac{1}{2}\beta_2v_1-\tau_2x\right)dx+\int_{m_4}^1\left(\frac{1}{2}\alpha_2(v_1+t)+\frac{1}{2}\beta_2v_1-\tau_2(1-x)\right)dx\right]\end{aligned} \tag{67}$$

Therefore, we have social welfare with superscript 2 in the denotation to represent this second type of regulation:

$$W^2=CS_1^2+CS_2^2+2\pi_2 \tag{68}$$

And the variation in social welfare compared to the benchmark equilibrium is:

$$\Delta W^2=W^2-W^0 \\ =\frac{1}{2\tau_2(-2+\mu)^2}\{\beta_2\tau_2(-2+\mu)^2v_1+\beta_1v_2[\tau_2(\mu-2)^2+ \\ (-1+\mu)\mu(2\tau_2-2T_2-2\alpha_1v_2+\beta_1v_2)\left(1+\left(\tau_2^2(-1+\mu)\mu+1\right)^2\right)]\} \tag{69}$$

The implied condition from expression (57) of t_2 provides

$$-\tau_2+T_2+\alpha_1v_2-\beta_1v_2>0 \tag{70}$$

Then we can obtain

$$\Delta W^2>0 \tag{71}$$

Cooperation between official platform and private companies brings a positive impact on social welfare. The logic behind is that consumers including passengers and drivers both benefit from the capability of accessing more agents on the other side. Under the view of social welfare, their loss in subsidies from platforms can be covered by increase in platforms' profits. The decreases in subsidies for passengers influence the positions of indifferent passengers. Specifically, platform *i* loses part of consumers who receive only coupons from platform *i* but locate far away with high 'transportation' costs. For a passenger who locates more than $\frac{1}{2}$ distance away from platform *i* and is closer to platform *j*, it is more efficient for her or him to attend platform *j* because of the 'transportation' cost. Hence, after this regulation, more passengers choose the closer platform, causing less efficiency loss for the whole society, and the result in social welfare change is positive under this regulation.

Proposition 2. *Cooperation between private taxi-hailing apps and official platforms connect both platforms with each other through sharing customers and information, so that passengers enjoy more drivers and platforms profit from less cost spending in coupons to maintain attractiveness to passengers. Subsidies to drivers decrease when passengers have a high possibility of getting coupons. The whole society benefits from this regulation and reaches a higher level of welfare.*

4.3. Forbiddance setting

The usage of mobile phones installed with these apps during driving

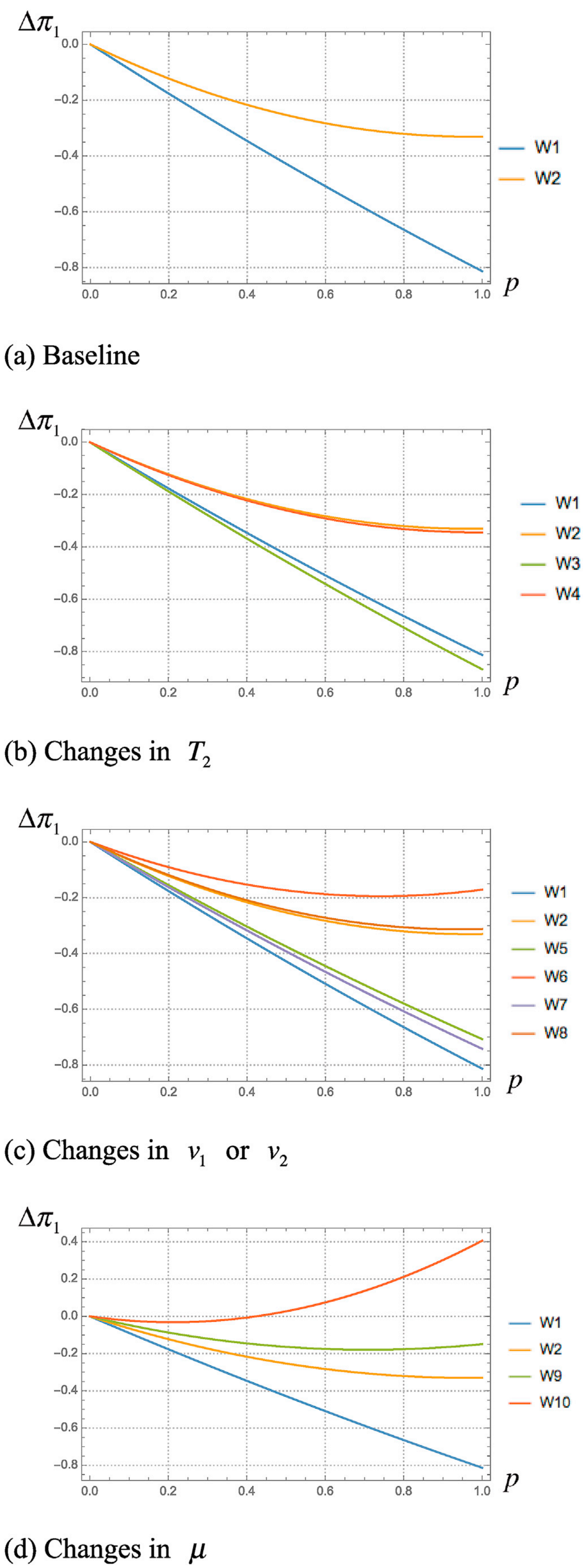

Fig. 4. Profit change with respect to transfer price. (a) Baseline; (b) Changes in T_2; (c) Changes in v_1 or v_2; (d) Changes in μ.

creates large traffic risk. Road condition is complicated in morning and evening peak periods, and it surely will grow worse if taxis need to find specific passengers they match in apps. Therefore, in some regions, local governments forbid the usage of taxi-hailing apps during special time period as morning and evening peaks. This regulation also contains the consideration for some senior citizens who have trouble in new technologies.

When considering the intention of this regulation, it is supposed to take into account of agents' benefit in a safer traffic environment if it is the basic motivation when evaluating the effect. However, this kind of effect is hard to evaluate, and we could try to ignore this impact first to analyze the influence within the framework of model. Without the usage of apps, both sides of agents can still get utility from getting matched offline, but their utilities get hurt in the aspect that they are not able to use coupons to save costs. Meanwhile, platforms are not willing with the software getting aside in that they cannot be alive without agents' usage. So this forbiddance setting harms both customers and platforms.

As a consequence, restrictions in usage time bereave of the agents' utilities gaining from participating in platforms and platforms' ability of making profit from getting used. This is scarified to serve for the safety of transportation environment, which lies at a higher priority in government targets.

5. Conclusions

This paper studies the effect of government regulation on competition in two-sided markets featured network externality under the O2O era. In particular, a model describes platforms competition with Hotelling specification is formulated and we made analysis by incorporating regulations into this framework. Except for the results of current policies, the work can also be applied for further assessment of similar market and regulations.

The topic is motivated by the popularity and growth of O2O in China and the case of competition between taxi-hailing platforms along with local government regulations in recent years. Among various regulating ways, this paper explores three typical of them, including price adjustments, butt joint with official platforms and forbiddance setting. The results indicate that the effects of price adjustments are greatly relying on network externalities and coupons distribution probability. Platforms would definitively offer more subsidies to passengers to maintain their attractiveness to them, but whether the increased subsidies can cover the dispatch fees or not depends on coupons distribution probability. When the externality from drivers to passengers is relatively larger than that from the opposite, there is a higher possibility that drivers can benefit from this regulation and platforms thereby make more profits. Social welfare suffers loss when the two platforms have a low level of differentiation, along with the condition that the externality from passengers to drivers is not greatly larger than that from the opposite. Having private taxi-hailing apps cooperating with official platforms benefits agents by allowing access to more agents from the other side. Thus, platforms cut down their costs in both sides to derive more profits because agents are willing to attend platforms even with low subsidies. Social welfare gains positive effect as well because all groups including passengers, drivers and platforms obtain benefits. And the time limit forbiddance is scarifying agents' utility and platforms' profits for safety consideration among the multiple goals of a government. Many two-sided markets, though in different industries, share the similar features with taxi-hailing apps market under the O2O era. Hence, the analysis and conclusion in this paper do not lose much generality and is revealing to other online-to-offline services such as the competition in take-out delivery service and bicycle sharing industry.

However, there are still a couple of directions this analysis can be extended to. First, other competition modes can be adopted to explore different market forms, like Stackelberg game used by Bruno Jullien (2011) to solve for price strategy. Besides, parameters like the possibility of obtaining coupons by passengers are not endogenously determined by platforms in this model. So extensions could be made in decision variables and control variables as well. Exclusive contracts between agents and platforms are worth discussion about its anticompetitive character and the effects it would realize. In addition, platforms' strategies in discriminating price upon passengers at different time and position is worth exploring for a further disquisition in taxi-hailing market competition.

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