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IS "QUANTITY RESTRICTION ORDER" ON SHARING BIKES REASONABLE AND EFFECTIVE? — THE REGULATION ON THE EXCESS OF SHARING BIKES

Abstract. *As a vital component of the ride sharing area in the Chinese sharing economy, the "Internet + Green Transportation" new business form of sharing bikes plays a crucial role in resolving the citizens' problem of "the last kilometer" and contributes greatly to alleviating traffic congestion and reducing air pollution in cities due to its convenience and environmental-friendliness. However, since bike sharing firms compete against each other to capture more market share by launching sharing bikes irrationally, there are excessive quantity of sharing bikes in some cities. Consequently, the excess of sharing bikes exacerbates the negative*

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externalities created by riding sharing bikes, i.e., the adverse impact on the well-being of non-riders when riders ride sharing bikes. The government issues "Quantity Restriction Order" to resolve the problem of bike sharing excess. This paper constructs a theoretical model to analyse the mechanism of the government regulation on launching bike sharing. It shows that the government should consider the trade-off between the harm to non-users represented by the cost of negative externalities created by riding sharing bikes and the benefit to users represented by the user satisfaction when controlling the quantity of sharing bikes for different firms. This result indicates that the reasonable and effective "Quantity Restriction Order" on sharing bikes is not the one that controls the quantities of all firms' sharing bikes but the one that controls the quantities of sharing bikes for different firms stage by stage. The result provides theoretical guidance for the government to solve and avoid the problem of sharing bike excess.

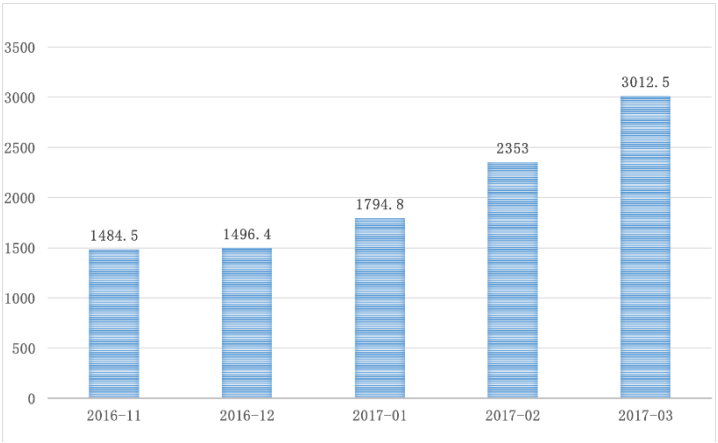
***Keywords**: sharing bike, excess launch, "Quantity Restriction Order", negative externality.*

JEL Classification: L13; L53

1. Introduction

With the rapid development of modern information technology, there has been a new economic mode of sharing economy which takes the integration of social idle resources as the core. With the Internet as the media, the sharing economy can quickly match the information of the suppliers and the demanders, and then by temporarily transferring the right to use, it ensures the highest utilisation rate of the idle resources left around the society (Taeihagh, 2017; Liu, 2017). According to the Report on Sharing Economy Development in China 2017, the market volume of China's sharing economy in 2016 was approximately 3.452 trillion yuan, increasing by 103% from that of 1.6978 trillion yuan in 2015.

As a major component of sharing mobility in China's sharing economy, the bike sharing has been thriving in every major city in recent years. Designed for convenient use and low in price, the sharing bikes are becoming people's first choice to take daily short-distance travel. According to the Research Report on China's Bike Sharing Market in the First Quarter of 2017 released by Big Date Research (a third-party data research institution) in May 2017, the user scale for bike sharing has maintained a trend of fast growth since November 2016 (as is shown in Figure 1). As of March 2017, the user scale for China's sharing bikes had exceeded 30 million. Bike sharing, as an active response to the government's vigorous initiative of "Green Travel", have helped people complete "the last kilometer" of travel in a way that not only eased the traffic congestion, but also greatly reduced the emission of carbon dioxide.



Data Source: Big Data Research

Figure 1. User Scale for Sharing Bikes from November 2016 to March 2017 (Unit: 10 Million Persons)

With the rapid development of the bike sharing market, there are increasing violations of rules and regulations in riding and parking of the shared bikes, which are deteriorating the traffic condition, and increasing the road accidents and the difficulty in traffic management. As a simple non-motorised vehicle, the sharing bikes are highly interchangeable. The price of riding them is very low, with no big price difference among the different types. Thus, people’s choice for bike sharing is largely determined by the availability. That’s why bike sharing companies decided to compete with each other to gain more market share shortly after entering the market by increasing the number of their own bikes within the same area. However, such blind-quantity competition resulted in an oversaturated number of sharing bikes in cities. Such an excess of bike sharing had aggressively occupied the space for public transit, aggravated the problems of illegal parking, and increased the management cost for relevant government departments and bike sharing companies, which was a huge waste of resources and against the principle of sharing economy to increase the utility rate of resources and reduce the social costs. To solve the excess of sharing bikes, the local governments had successively issued a “Quantity Restriction Order” since August 2017. The purpose was to restrict the bike sharing companies from adding new bikes and to bring the total number of sharing bikes under a strict control.

There were two potential problems behind the “Quantity Restriction Order” issued by the local governments to regulate the excess of sharing bikes: (1) the order failed to achieve the expected effect: the actual number of bike sharing restriction was still too much after the restriction; (2) people’s demands for daily short-

distance travel were not satisfied: the number of sharing bikes was too little after the restriction. Therefore, before launching a reasonable and effective "Quantity Restriction Order" on bike sharing, the local governments should first determine the reasonable capacity of sharing bikes in the cities under their respective jurisdiction, respectively, that is, a reasonable and effective "Quantity Restriction Order" should be based on specific quantity restriction plans that vary with different cities.

Focusing on the increasingly prominent excess of sharing bikes, this paper builds a theoretical model to thoroughly analyse the reasons of such excess. The negative externalities resulting from the use of shared bikes generated external social costs and reduced social welfare. Therefore, for the sake of the society as a whole, the proposed optimal quantity of sharing bikes will be the one that can maximise the social welfare, which is consistent with the principle of sharing economy to reduce the overall social costs; while the actual number of sharing bikes will be the result of the competition among the bike sharing companies driven by the purpose of maximising profits. When the actual number of sharing bikes surpasses the proposed optimal quantity, there will be an excess of sharing bikes, which will cause negative externalities during the use of bikes, thus cutting down on the social welfare. To curb such negative externalities, it is imperative for local governments to exert their power and function in allocating resources (Mao, 2007).

The results in this paper show that, before launching regulations to curb or avoid the excess of sharing bikes, the local governments should focus on the different situations of cities under their own jurisdiction, and at different stages. The situations can be boiled down to the damage caused by users to non-users (external social costs generated from the negative externalities resulting from the use of sharing bikes) and the benefits brought to users (the bike sharing user satisfaction) when using the bikes. As the external social costs generated from the negative externalities resulting from the use of sharing bikes increase, the bike sharing companies offering poor user experience will first exceed their optimal level in terms of the number of bicycles placed by them compared with those offering better user experience. Therefore, the launch of the local governments' quantity restriction should be determined by the relationship between the actual number and the proposed optimal quantity of the sharing bikes, to keep the total number of sharing bikes at or below the optimal level.

The main contributions of this paper are as follows; first, this paper proposes a theoretical framework for a thorough analysis of the reasons of the excess of sharing bikes, and a theoretical guidance for the healthy and orderly development of the bike sharing market. Second, this paper studies the mechanism of the local governments' regulation on the excess of sharing bikes based on an analysis of the excess of sharing bikes. Third, this paper, taking the actual data as the numerical examples, illustrates the feasibility of the theories proposed for the regulation on the excess of sharing bikes in practice. Fourthly, the theories proposed in this paper provide a way of thinking for the quantity restriction on other products and services that will also generate negative externalities in the field of sharing economy.

2. Theoretical Model

(I) Basic Framework

Suppose that there are two bike sharing companies in the bike sharing industry: Company 1 and Company 2. The sharing bikes provided by the two companies are highly interchangeable, but the user experience they offer varies with the convenience in finding and unlocking one, and the labour saving and shock absorption effect in riding. These two bike-sharing companies offering different products compete on the quantity they put on the market, namely, they are in a Cournot competition (Singh and Vives, 1984). To facilitate the operation, suppose the unit cost these two companies take to produce bikes is of the same value, which is 0.

The illegal riding and parking of sharing bikes had caused negative externalities, i.e., external costs to the society; but on the other side, the emerge of sharing bikes reduced the use of motor vehicles, facilitating energy conservation and environment protection, thus producing positive externalities, i.e. external benefits to the society(Ayres and Kneese, 1969 ; Dugger, 1985). Unlike the positive externalities, the negative externalities are short-term — the impact on the non-users appeared in a short period of time. Bartelsman et al. pointed out that the short-term externalities caused by the consumer activities have a critical impact on the whole industry (Bartelsman et al., 1994). Therefore, this paper mainly considers the negative externalities resulting from the use of sharing bikes.

The representative consumers in the whole society are divided into two groups: users of sharing bikes and non-users. The utility of the former derives from the consumption of sharing bikes and Hicksian composite commodity[i], while the latter only from that of Hicksian composite commodity. According to Hicks (1959) and Hicksian composite commodity includes all commodities except the target commodity; it depicts a consumer’s consumption of non-target commodities based on his/her set budget constraints. Based on the Spence-Dixit-Stiglitz model (Dixit and Stiglitz, 1977) the utility functions for these two groups of representative consumers can be respectively expressed as:

$$U_u(x_0, x_1, x_2) \equiv x_0 + a_1 x_1 + a_2 x_2 - \frac{1}{2}(x_1^2 + 2\gamma x_1 x_2 + x_2^2), a_1, a_2 \geq 0, \gamma \in (0,1) \quad (1)$$

$$U_{nu}(x_0, x_1, x_2) \equiv x_0 - c(x_1 + x_2), c > 0 \quad (2)$$

Where, x_0 represents Hicksian composite commodity; x_1 and x_2 represent the number of sharing bikes put on market by Company 1 and Company 2,

respectively; a_1 and a_2 represent the uses' experience of using the sharing bikes of Company 1 and Company 2, respectively; γ represents the interchangeability of sharing bikes of Company 1 and Company 2; c represents the unit cost of the negative externalities resulting from the use of sharing bikes. Without loss of generality, this paper assumes that Company 1's sharing bikes provide the users with better experience than Company 2's, namely, $a_1 > a_2$.

(II) Proposed Optimal Quantity of Sharing Bikes

As the use of sharing bikes will cause negative externalities, so for the sake of the whole society, the proposed optimal quantity of sharing bikes shall be determined based on welfare maximisation. Taking the utility of consumers and the profits of bike sharing companies into consideration, the issue of welfare maximisation can be expressed as:

$$\max_{x_1,x_2} \; U_u(x_0, x_1, x_2) + U_{nu}(x_0, x_1, x_2) \tag{3}$$

The solutions to the above equation are the proposed optimal quantities of the sharing bikes of Company 1 and Company 2, respectively:

$$x_1^* = \frac{a_1 - \gamma a_2 - (1-\gamma)c}{1-\gamma^2} \tag{4}$$

$$x_2^* = \frac{a_2 - \gamma a_1 - (1-\gamma)c}{1-\gamma^2} \tag{5}$$

According to Equations (4) and (5), apart from the user experience a_1 and a_2, the proposed optimal quantity of sharing bikes is also related to the unit cost of negative externalities resulting from the use of sharing bikes c. Specifically, as Company 1 provided the users with a better experience, its proposed optimal quantity of sharing bikes increased; while for Company 2 offering poor user experience, its proposed optimal quantity of sharing bikes decreased, and vice versa. That is, $\partial x_i^* / \partial a_i > 0$, $\partial x_i^* / \partial a_{-i} < 0$ where $i = 1, 2$; as the unit cost of negative externalities resulting from the use of sharing bikes increased, the proposed optimal quantities of sharing bikes of both Company 1 and Company 2 decrease, namely, $\partial x_i^* / \partial c < 0$.

(III) Actual Number of Sharing Bikes

The utility of bike-sharing users derives from the use of share bikes and the consumption of Hicksian composite commodity, thus the demands for sharing bikes is the maximum utility of users. The problem of the maximum utility of users for sharing bikes can be expressed as follows:

$$\max_{x_1,x_2} U_u(x_0, x_1, x_2)$$
$$\text{s.t. } x_0 + p_1 x_1 + p_2 x_2 = m \tag{6}$$

Where, p_1 and p_2 represent the prices for riding the sharing bikes of Company 1 and Company 2, respectively; m represents the income of the users. By solving the above equation, two inverse demand functions for the sharing bikes of Company 1 and Company 2 can be obtained, respectively:

$$P_1(x_1, x_2) \equiv a_1 - x_1 - \gamma x_2 \tag{7}$$

$$P_2(x_1, x_2) \equiv a_2 - x_2 - \gamma x_1 \tag{8}$$

Due to the competition between Company 1 and Company 2 to occupy the bike sharing market, the actual number of sharing bikes put on market by the two companies is determined based on profit maximisation. According to Equations (7) and (8), the issue of profit maximisation can be expressed as follows:

$$\max_{x_i} P_i(x_i, x_{-i}) \cdot x_i \tag{9}$$

By solving the above equations, the actual number of sharing bikes put on market by Company 1 and Company 2 can be obtained:

$$\tilde{x}_1 = \frac{2a_1 - \gamma a_2}{4 - \gamma^2} \tag{9}$$

$$\tilde{x}_2 = \frac{2a_2 - \gamma a_1}{4 - \gamma^2} \tag{11}$$

To ensure $\tilde{x}_2 > 0$, suppose that $a_2 > \frac{\gamma}{2} a_1$. According to Equations (10) and (11), the actual number of sharing bikes has nothing to do with the unit cost of negative externalities resulting from the use of sharing bikes c, i.e., $\partial \tilde{x}_i / \partial c = 0$. That's because both Company 1 and Company 2 give no consideration to the negative externalities resulting from the use of sharing bikes to the society when deciding how many sharing bikes they can actually put on market.

(IV) Excess of Sharing Bikes

As mentioned above, given that the bike sharing companies give no consideration to the negative externalities resulting from the use of sharing bikes to the society when deciding how many sharing bikes they can actually put on market, the actual number of sharing bikes may exceed the proposed optimal quantity, leading to an excess of sharing bikes. By comparing the proposed optimal quantity (x_1^*, x_2^*) and the actual number $(\tilde{x}_1, \tilde{x}_2)$, it can be concluded that when $c > c_1$, $\tilde{x}_1 > x_1^*$, where $c_1 \equiv \frac{(2+\gamma^2)a_1 - 3\gamma a_2}{(1-\gamma)(4-\gamma^2)}$; when $c > c_2$, $\tilde{x}_2 > x_2^*$, where $c_2 \equiv \frac{(2+\gamma^2)a_2 - 3\gamma a_1}{(1-\gamma)(4-\gamma^2)}$. Comparing c_1 to c_1, it can be concluded that $c_1 > c_2$.The conclusion is summarised into the following propositions:

PROPOSITION 1:

(1) When $c > c_1$, the actual number of both Company 1 and Company 2 exceeds the proposed optimal quantity, i.e., $\tilde{x}_i > x_i^*$;

When $c_2 < c < c_1$, the actual number of Company 1 is below the proposed optimal quantity, i.e., $\tilde{x}_1 < x_1^*$; while the actual number of Company 2 exceeds the proposed optimal quantity, i.e., $\tilde{x}_2 > x_2^*$;

When $c < c_2$, the actual number of both Company 1 and Company 2 is below the proposed optimal quantity, i.e., $\tilde{x}_i < x_i^*$.

Proposition I indicates that bike sharing companies generally put a redundant number of sharing bikes on market. This conclusion is in line with the ubiquitous phenomenon of the excess of sharing bikes today. Specifically, when the unit cost of negative externalities resulting from the use of sharing bikes is at an

excessively high level ($c > c_1$), the actual number of both Company 1 and Company 2 exceeds the proposed optimal quantity, namely, the excess of sharing bikes is found in both Company 1 and Company 2; when and only when the unit cost of negative externalities resulting from the use of sharing bikes is at a very low level ($c < c_2$), there will be no excess of sharing bikes. As the unit cost of negative externalities resulting from the use of sharing bikes increased, the proposed optimal quantity will decrease to achieve a balance between the benefits to the users and damage to the non-users caused by the users. But the number of sharing bikes the bike sharing companies actually put on market won’t be affected by the increase of the unit cost of negative externalities. In conclusion, as the unit cost of negative externalities resulting from the use of sharing bikes increased, the number of sharing bikes actually put on market by different bike sharing companies will exceed the proposed optimal quantity, leading to an excess of sharing bikes.

What’s more, Proposition 1 also indicates that Company 1 has fewer cases of excess of sharing bikes than Company 2 — the excess of sharing bikes of Company 1 will only occur in Case (1). That’s because Company 1 enjoys a higher level of proposed optimal quantity of sharing bikes than Company 2 ($x_1^* > x_2^*$): Company 1 brings more benefits for the users by offering better user experience at a given unit cost of negative externalities resulting from the use of sharing bikes. Therefore, Company 1 enjoys more space for adding new sharing bikes without exceeding the optimal level.

3. Local governments’ Restriction on the Quantity of Sharing Bikes

As can be seen from the conclusion of Proposition 1 that, the bike sharing companies will excessively add new sharing bikes in order to win more market share than each other, resulting in the actual number of sharing bikes surpassing the proposed optimal quantity. In practice, to solve the excess of sharing bikes, a “Quantity Restriction Order” has been successively issued by the local governments. However, in order to ensure the healthy and orderly development of the bike sharing market, measures should also be taken to prevent the bike sharing companies from aggressively adding new bikes by the local governments. For this purpose, this section will deal with the concrete plans for the local governments to regulate and control the number of sharing bikes, which can serve as a theoretical basis and guidance for the quantity restriction of the local governments to solve the excess of sharing bikes.

When a quantity restriction order is imposed on the bike sharing company i , the profit maximisation problem can be expressed as:

$$\max_{x_i} P_i(x_i, x_{-i}) \cdot x_i$$
$$\text{s.t. } x_i \le x_i^* \tag{10}$$

Under the constraint conditions in the above equation, the number of sharing bikes the bike-sharing companies actually put on market based on profit maximisation will not exceed the proposed optimal quantity. The Lagrange function of such optimisation problem can be expressed as:

$$L_i(x_i, x_{-i}, \lambda_i) = P_i(x_i, x_{-i}) \cdot x_i + \lambda_i \left(x_i^* - x_i\right), \lambda_i \ge 0 \tag{11}$$

Where, λ_i represents the Lagrange multiplier. By solving the Lagrange function, we can obtain:

$$\hat{x}_i = \frac{2\left(a_i - \hat{\lambda}_i\right) - \gamma\left(a_{-i} - \hat{\lambda}_{-i}\right)}{4 - \gamma^2} \tag{12}$$

According to the constraint condition ($\hat{x}_i \le x_i^*$) and the complementary relaxation condition ($\hat{\lambda}_i(x_i^* - \hat{x}_i) = 0$) in the profit maximisation problem, we can obtain the number of sharing bikes the bike sharing companies actually put on market under different unit costs of the negative externalities under the quantity restriction issued by the local governments.

First, let $\hat{x}_i < x_i^*$. From $\hat{\lambda}_i(x_i^* - \hat{x}_i) = 0$, we can obtain $\hat{\lambda}_i = 0$. Substitute $\hat{\lambda}_i = 0$ into the equation, we can obtain $\hat{x}_i = \tilde{x}_i = \frac{2a_i - \gamma a_{-i}}{4 - \gamma^2}$. When $c < c_2$, we can get $\hat{x}_i < x_i^*$

This conclusion can be summarised into the following lemmas:

Lemma 1: where there is a quantity restriction issued by the local government, if $c < c_2$, the actual number of sharing bikes of both Company 1 and Company 2 is below the proposed optimal quantity, i.e., $\hat{x}_i < x_i^*$.

The conclusion of Lemma 1 is consistent with that of Proposition 1 (3). When $c < c_2$, due to the low level of the unit cost of the negative externalities resulting from the use of sharing bikes, the actual number of sharing bikes of both

Company 1 and Company 2 is below the proposed optimal quantity. In which case, no quantity restriction will be issued by the local governments, so the situation under this condition is in conformity with that in which there’s no such quantity restriction.

Second, let $\hat{x}_1 < x_1^*$ and $\hat{x}_2 = x_2^*$. From $\hat{\lambda}_i(x_i^* - \hat{x}_i) = 0$, we can obtain $\hat{\lambda}_1 = 0$ and $\hat{\lambda}_2 \geq 0$. Plug in the equation $\hat{\lambda}_1 = 0$, we can obtain $\hat{x}_1 = \frac{a_1 - \gamma a_2 + \gamma(1-\gamma)c}{2(1-\gamma^2)}$ and $\hat{\lambda}_2 = \frac{3\gamma a_1 - (2+\gamma^2)a_2 + (1-\gamma)(4-\gamma^2)c}{2(1-\gamma^2)}$. After a calculation, when $c_2 \leq c < c_3$ where $c_3 \equiv \frac{a_1 - \gamma a_2}{(1-\gamma)(2+\gamma)}$, we can obtain that $\hat{x}_1 < x_1^*$ and $\hat{\lambda}_2 \geq 0$. This conclusion can be summarised into the following lemma.

Lemma 2: where there’s a quantity restriction issued by the local governments, if $c_2 \leq c < c_3$, the actual number of sharing bikes of Company 1 is below the proposed optimal quantity, i.e., $\hat{x}_1 < x_1^*$; while the actual number of sharing bikes of Company 2 is in line with the proposed optimal quantity, i.e., $\hat{x}_2 = x_2^*$.

The conclusion of Lemma 2 verifies the conclusion of Proposition 1 (2). When $c_2 \leq c < c_3 < c_1$, the actual number of sharing bikes of Company 1 — a company that provides users with better experience is under the proposed optimal quantity, in which case, the local government won’t impose a quantity restriction on Company 1. That is, the actual number of sharing bikes of Company 1 is not subject to the government’s quantity restriction. However, the actual number of sharing bikes of Company 2 — a company that provides users with worse experience when $c_2 \leq c < c_3 < c_1$ is above the proposed optimal quantity. In that case, the local government will impose a quantity restriction on Company 2 to lower the actual number of sharing bikes to the proposed optimal level, i.e., $\hat{x}_2 = x_2^*$.

Similarly, let $\hat{x}_1 = x_1^*$ and $\hat{x}_2 < x_2^*$. From $\hat{\lambda}_i(x_i^* - \hat{x}_i) = 0$, we can obtain $\hat{\lambda}_1 \geq 0$ and $\hat{\lambda}_2 = 0$. Plug in the equation $\hat{x}_1 = \frac{a_1 - \gamma a_2 - (1-\gamma)c}{1-\gamma^2}$ and $\hat{\lambda}_2 = 0$, we can

obtain $\hat{x}_2 = \frac{a_2 - \gamma a_1 + \gamma(1-\gamma)c}{2(1-\gamma^2)}$ and $\hat{\lambda}_1 = \frac{3\gamma a_2 - (2+\gamma^2)a_1 + (1-\gamma)(4-\gamma^2)c}{2(1-\gamma^2)}$. After a calculation, when $c_1 \le c < c_4$ where $c_4 \equiv \frac{a_2 - \gamma a_1}{(1-\gamma)(2+\gamma)}$, we can obtain $\hat{x}_2 < x_2^*$ and $\hat{\lambda}_1 \ge 0$. However, the fact is $c_4 < c_1$, so such situation does not exist. This conclusion verifies the conclusion of Proposition 1. Considering that Company 1 is less prone to the excess of sharing bikes than Company 2, Company 2 is unlikely to be exempted from a quantity restriction imposed by the local government when there's one imposed on Company 1.

At last, let $\hat{x}_i = x_i^*$. From $\hat{\lambda}_i(x_i^* - \hat{x}_i) = 0$, we can obtain $\hat{\lambda}_i \ge 0$. Plug in the equation $\hat{x}_i = \frac{a_i - \gamma a_{-i} - (1-\gamma)c}{1-\gamma^2}$, we can obtain $\hat{\lambda}_i = \frac{\gamma a_{-i} - a_i + (1-\gamma)(2+\gamma)c}{1-\gamma^2}$. After a calculation, when $c \ge c_3$, we can obtain $\hat{\lambda}_i \ge 0$. This conclusion can be summarised into the following lemma.

Lemma 3: when the local government imposes a quantity restriction on the sharing bikes, if $c \ge c_3$, the actual number of sharing bikes of both Company 1 and Company 2 conforms to the proposed optimal quantity, i.e., $\hat{x}_i = x_i^*$.

The conclusion of Lemma 3 verifies the conclusion of Proposition 1 (1). When $c \ge c_3$, both Company 1 and Company 2 are confronted with an excess of sharing bikes due to the extortionate unit cost of negative externalities. In that case, the local government will impose a quantity restriction on both Company 1 and Company 2 to reduce the actual number of sharing bikes of the two companies to the proposed optimal level. What's worth noting is that in Lemma 3, when $c \ge c_3$, Company 1 is confronted with an excess of sharing bikes. On this basis, when $c_3 \le c < c_1$, the actual number of sharing bikes of Company 1 is below the proposed optimal quantity when there's no quantity restriction imposed by the local government, but when there's a quantity restriction imposed by the local government, the actual number of sharing bikes of Company 1 will exceed the proposed optimal quantity and thus be reduced to be at or below the proposed optimal level. That's because when $c_2 < c_3 \le c < c_1$, if there's a quantity restriction imposed by the local government, the actual number of sharing bikes of Company 2

will be restricted at the proposed optimal level, creating more market share for Company 1; consequently, Company 1 will excessively add new bikes. In conclusion, when there’s a quantity restriction imposed by the local government, Company is more prone to the excess of sharing bikes.

In combination with Lemmas 1-3, we can obtain the following proposition.

PROPOSITION 2:

When $c < c_2$, the actual number of both Company 1 and Company 2 is below the proposed optimal quantity, and at this time, the government won’t impose a quantity restriction on either Company 1 or Company 2;

When $c_2 \leq c < c_3$, the actual number of Company 1 is below the proposed optimal quantity, so the government will only impose a quantity restriction on Company 2 to lower its actual number of sharing bikes to the proposed optimal level;

When $c \geq c_3$, the government will only impose a quantity restriction on both Company 1 and Company 2 to lower the actual number of sharing bikes of the two companies to the proposed optimal level.

As can be seen in Proposition 2 that, as the unit cost of negative externalities resulting from the use of sharing bikes increased, the local government will impose a quantity restriction on different bike sharing companies on the basis of the actual situation of each company and at each stage, to ensure that the actual number of sharing bikes of each company is at or below the proposed optimal level (as is shown in Figure 2). In Figure 2, the solid line parallel to the c axis indicates the proposed optimal quantity of sharing bikes of Company 1 and Company 2 under different unit costs of negative externalities, and the height of the shadow zone indicates the actual number of sharing bikes of Company 1 and Company 2 under different unit costs of negative externalities. Specifically, when the unit cost of negative externalities resulting from the use of sharing bikes is at an extremely low level ($c < c_2$), the actual number of sharing bikes of both Company 1 and Company 2 is below the proposed optimal quantity, so the local government won’t impose a quantity restriction on either Company 1 or Company 2 (as is shown in Figure 2 by the transverse line and the shadow area within the interval of $c < c_2$); when the unit cost of negative externalities resulting from the use of sharing bikes is at a relatively high level ($c_2 \leq c < c_3$), Company 2 — a company that provides users with worse experience will be confronted with an excess of sharing bikes, so the local government will impose a quantity restriction on Company 2 (as is shown in Figure 2 by the transverse line and the shadow area within the interval of $c_2 \leq c < c_3$); when the unit cost of negative externalities resulting from the use of sharing bikes is at an excessively high level ($c \geq c_3$), both Company 1 and Company 2 will be confronted with an excess of sharing bikes, so the local government will impose a quantity restriction on both

companies (as is shown in Figure 2 by the transverse line and the shadow area within the interval of $c \geq c_3$). That is because, for one thing, the proposed optimal quantity of sharing bikes will decrease with the increase of the unit cost of negative externalities resulting from the use of sharing bikes; for another, at a given unit cost of negative externalities, the proposed optimal quantity of sharing bikes of a company that provides users with better experience is higher than that of a company provides users with worse experience. Therefore, the problem of the excess of sharing bikes will first occur in Company 2, then in Company 1. The conclusion of Proposition 2 illustrates the mechanism of the government's regulation and control over the number of sharing bikes, thus provides the local government with a theoretical basis for solving the excess of sharing bikes and a theoretical guidance for avoiding such excess.

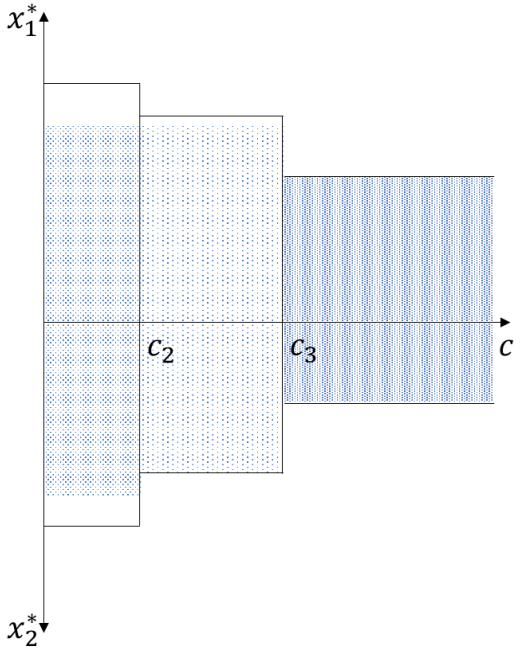


Figure 2. Local Governments' Customised Plans to Regulate the Excess of Sharing Bikes for Different Bike-sharing Companies and Different Situations

To more intuitively compare the conclusion of Proposition 2 to that of Proposition 1, Figure 3 depicts the relationship between the actual number x_i and the proposed optimal quantity x_i^* of sharing bikes of Company 1 and Company 2

under different unit costs of negative externalities and when there is or isn’t a quantity restriction imposed by the local government, respectively.

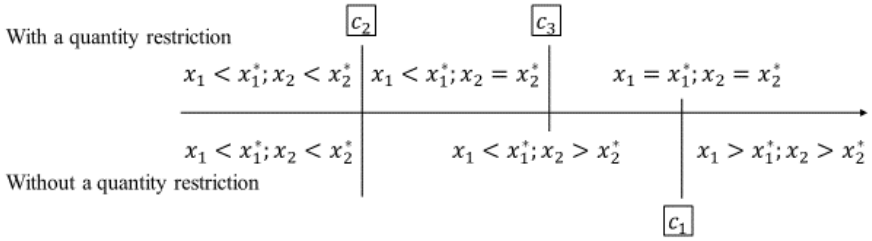


Figure 3. Actual Number of Sharing Bikes with and Without a Quantity Restriction Imposed by the Local Government

4. Discussion

The use of bike sharing induced illegal riding and parking, which generated negative externalities. According to the conclusion of this theoretical research, the negative externalities resulting from the use of bike sharing are the root cause of the excess of bike sharing. To solve and avoid such excess, this section discusses three ways to reduce the negative externalities resulting from the use of sharing bikes, which are corrective taxes, corporate innovation and investigation, and social sanctions.

(I) Corrective Taxes

To solve the excess of sharing bikes induced by the negative externalities resulting from the use of sharing bikes, the local governments can also, based on the market regulation, levy corrective taxes on the bike sharing companies to stimulate them to correct their behaviors in line with the social efficiency. That is, to solve the excess of sharing bikes by the bike sharing companies themselves. Corrective taxes, also called Pigovian taxes, are taxes designed to correct the negative externalities. Specifically, the local governments can levy the corrective taxes on each bike sharing company for each sharing bike they put on market to push them to take the social costs generated by the negative externalities into consideration, namely, to internalise the negative externalities to keep the actual number of their bikes in cities at or under the proposed optimal level.

(II) Corporate Innovation and Investigation

To avoid the excess of sharing bikes, the bike sharing companies can make innovations in their technology and management, to reduce the negative externalities resulting from the use of sharing bikes. For example, by installing a positioning system, the bike sharing companies can determined whether the users reasonably park the bikes at designated sites at the end of riding. They can further, based on the big data technology, lower the credit scores and grades of users who frequently illegally park the sharing bikes. In addition, the other bike sharing companies can learn from the "Chengdu Pattern" of OFO, to vigorously promote the grid operation and maintenance management. They can divide the urban area into several grids, and for each grid, a specially-assigned person is set to correct the illegal parking in time.

Through innovations in technology and management, the bike sharing companies can lower the external costs generated from the negative externalities resulting from the use of sharing bikes, so that they will be allowed a higher level of proposed optimal quantity. In which case, they can enhance their market share and gain more revenues; when the newly added revenues are greater than the innovation costs, they will see an increase in profits, which will in turn continuously promote innovations in technology and management.

(III) Social Sanctions

The excess of sharing bikes can be solved by reducing the negative externalities resulting from the use of sharing bikes under the pressure of social sanctions. The social sanctions mainly refer to the social supervision and norms set for the users and the bike sharing companies. The social sanctions for the bike sharing companies can be divided into two aspects. The first is to supervise and urge the bike sharing companies to intensify their management in bike sharing, such as correcting illegal parking in a timely manner. The second is to normalise the bike sharing companies' monitoring and management of their users, to avoid illegal riding and parking, and other problems. Both can be realised by imposing a fine on the bike sharing companies or confiscating their bikes. The purpose is to prompt the bike sharing companies to internalise the negative externalities resulting from the use of sharing bikes.

5. Conclusion and Enlightenment

This paper thoroughly analyses an increasingly prominent phenomenon of the excess of sharing bikes by building a theoretical model; theoretically illustrates the mechanism of the local governments' regulation on the excess of sharing bikes based on the "Quantity Restriction Order" on the sharing bikes issued by the local governments; verifies the feasibility of the theories proposed in this paper using the numerical examples based on the actual data; discusses three ways to solve the negative externalities resulting from the use of sharing bikes: corrective taxes, corporate innovation and investigation, and social sanctions.

The results show that the excess of sharing bikes is related to the external social costs generated from the negative externalities resulting from the use of sharing bikes as well as the bike sharing user satisfaction. Therefore, the local governments should weigh up the damage caused to the non-users (external social costs generated from the negative externalities resulting from the use of sharing bikes) against the benefits brought to users (bike sharing user satisfaction) before launching a reasonable and effective “Quantity Restriction Order”. Besides, a reasonable and effective “Quantity Restriction Order” should be customised for different bike sharing companies and for different situations. To be specific, when the external costs generated from the negative externalities resulting from the use of sharing bikes are at a relatively high level, the actual number of sharing bikes of bike sharing companies receiving lower user satisfaction will exceed their proposed optimal quantity, and now the local government should impose a quantity restriction on this company; when the external costs generated from the negative externalities resulting from the use of sharing bikes are at an excessively high level, the actual number of sharing bikes of bike sharing companies receiving lower or higher user satisfaction will all exceed their proposed optimal quantity, and now the local government should impose a quantity restriction on each company. That’s because for one thing, the proposed optimal quantity of sharing bikes will decrease with the increase of the external costs generated from the negative externalities resulting from the use of sharing bikes; for another, at a given external cost, the proposed optimal quantity of sharing bikes of a company with higher user satisfaction is higher than that of a company with lower user satisfaction. Therefore, the latter is more prone to the excess of sharing bikes.

The conclusion of this theoretical research not only illustrates the reasons for the prevalent excess of sharing bikes, but also clarifies the mechanism of the local governments’ regulation on the excess of sharing bikes, thus providing a theoretical basis and guidance for the local governments to solve and avoid such excess. With a collection of relevant data, the conclusion of this theoretical research can be applied to measure and calculate the degree to which the actual number deviates from the proposed optimal quantity of sharing bikes of each bike sharing company in each city in China, helping the local governments to formulate their own quantity restriction plans. The conclusion of this theoretical research also opens ways of thinking for the quantity restriction on other products and services that will also generate negative externalities in the field of sharing economy. Similarly, the local governments can refer to the theories proposed in this paper for solving the excess of sharing bikes to solve the excess of other products and services that will also generate negative externalities. Therefore, the principle of sharing economy can be better fulfilled to increase the utilisation rate of resources and to reduce the social costs, and continuous efforts can be made to promote the high-quality development of China’s economy.

REFERENCES

[1] **Taeihagh, A. (2017),** ***Crowdsourcing, sharing economies and development***. *Journal of Developing Societies*, 33 (2), 191-222;

[2] **Liu, G. (2017),** ***Shared economy: The subversion of the traditional economic model.*** *Economist*, (5), 97-104. (in Chinese);

[3] **Mao, M. (2007),** ***Summary of research on government regulation theory***. *Management World (Monthly)*, (2), 137-150. (in Chinese);

[4] **Singh, N., Vives, X. (1984),** ***Price and quantity competition in a differentiated duopoly***. *RAND Journal of Economics*, 15 (4), 546-554;

[5] **Ayres, R.U., Kneese, A.V. (1969),** ***Production, consumption, and externalities***. *American Economic Review*, 59 (3), 282-297;

[6] **Dugger, W.M. (1985),** ***The analytics of consumption externalities***. *Review of Social Economy*, 43 (2), 212-233;

[7] **Bartelsman, E.J., Caballero, R.J., Lyons, R.K. (1994),** ***Customer- and supplier-driven externalities***. *American Economic Review*, 84 (4), 1075-1084;

[8] **Hicks, J.R. (1959),** ***A "value and capital" growth model***. *Review of Economic Studies*, 26 (3), 159-173;

[9] **Dixit, A.K., Stiglitz, J.E. (1977),** ***Monopolistic competition and optimum product diversity***. *American Economic Review*, 67 (3), 297-308.

[i] The price of Hicksian composite commodity is normalized to 1.