Government Subsidy Strategies for Biosimilars R&D Based on Dynamic Game Theory

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This work was supported in part by the Ministry of Education of Humanities and Social Science Project under Grant 18YJCZH060, and in part by the Education Department of Liaoning Provincial Project under Grant 2017WZD03.

ABSTRACT In order to develop the biomedical industry, government subsidy of biosimilars is an incentive policy which has been used by the government. Different government subsidy strategies have an impact on drug price, consumer surplus, social welfare, the income of biosimilars enterprises and the demand of biosimilars, which have been deeply analyzed through backward induction of the dynamic game theory. The analysis shows that the price coefficient and the influence of the subsidy on demand will affect the choice of government subsidy strategies. It is concluded that under different subsidy strategies, consumer surplus, social welfare and the income of biosimilars enterprises are positively correlated with the amount of subsidy per unit product. This paper provides a decision-making basis for developing government subsidy strategies scientifically.

INDEX TERMS Biosimilars, subsidy strategy, two-stage game, consumer surplus, social welfare.

I. INTRODUCTION Biosimilars has been defined as a less-costly alternative to special biological products with the same safety and efficacy, including vaccines, somatic cells, gene therapy, blood and its components, tissue and recombinant therapeutic proteins. Biosimilars is similar to primary drugs in quality, clinical efficacy and safety. But the prices will be greatly reduced compared with those of the latter, which improves the accessibility of drugs and better satisfies the demand of patients. On the other hand, with the development of science and technology, especially biotechnology and biosimilars have shown that the irreplaceable role of other drugs in some clinical treatment fields. On the other hand, the patents of a large number of primary biological drugs will expire in 2020. Undoubtedly, the biosimilars will usher in an unprecedented explosive growth, and its proportion in the global pharmaceutical market will be increased significantly. Frost & Sullivan forecasts that the global compound annual growth rate of biosimilars will reach 53.7% in 2016-2021, with sales achieving US $36.6 billion in 2021 [1]. Macquarie Research also predicts that biosimilars will develop rapidly in 2016-2020, with compound annual growth rate reaching 40% [2]. Driven by increased healthcare expenditure, enhanced R&D capacity, positive changes in government policies and increased capital investment, biosimilars will embrace important development opportunities.

China also attaches great importance to biosimilars. For example, the Technical Guideline for the Research, Development and Evaluation of Biosimilars (“Tentative”), the Rules for Naming Principles for Generic Names of Biological Products (Draft for Soliciting Opinions) [3], [4] and other laws and regulations have proposed that the biosimilars not only can directly enter the medical insurance reimbursement list as the primary drugs, but also enjoy a unified generic name. In the meantime, the National Development and Reform Commission clearly stated in the Implementation Plan for Industrialization of High-end Medical Devices and Key Technologies of Drugs [5] that the development and industrialization of biosimilars with patents expired, high clinical value and great market potential shall be encouraged, to improve the production level of biosimilars, enhance production efficiency and product quality. Biomedical industry is the most important and active emerging industry in the 21st century, and it is the main direction of strategic emerging industry, which is of great significance for developing new economy and fostering new growth drivers in China. In order to vigorously promote the development of the biomedical industry, the central and
local government at all levels use a variety of policy means, including strategic planning, government procurement, and financial support. Biosimilars is an important link in the biomedical industry chain, a key step to promote the development of biomedical industry, and the only way to build a “Healthy China”. However, the proportion of biosimilars in pharmaceutical market is very small at the moment, it’s still in the initial stage, facing a shortage of funds, lack of talent and other development obstacles. Under such situation, cities such as Xiamen and Shenzhen took the lead in launching financial subsidies for biosimilars. Therefore, the study about the government subsidy strategies of biosimilars has an important effect on promoting the development of biosimilars and the biomedical industry. Now, the research about the subsidies of biosimilars is still a blank. This paper constructs a two-stage dynamic game model to study the impact of government subsidy on drug price, consumer surplus, social welfare, the income of biosimilars enterprises and the demand of biosimilars, which make up the gap about research on subsidy of biosimilars. Therefore, it is very important to study the subsidy strategies of biosimilars based on dynamic game theory.

II. RELATED STUDIES

Subsidies are gratuitously transferred directly or indirectly by the government to individuals or enterprises. Pigou, a British welfare economist, proposed a solution to solve the problem of externalities through subsidies and taxation, and the government should use subsidy policies to promote the development of enterprises, while enterprises should adjust the corresponding business strategies to obtain more subsidies from the government [6]. Government subsidy strategies are mainly divided into three categories: (1) Subsidy to consumers; (2) Subsidy to manufacturers; and (3) Subsidy to both consumers and manufacturers.

About the study of government subsidy, one way is to use the empirical method [7]–[17], to carry out regression analysis with the help of data statistics, and explain the actual effect of government subsidy. Examples are as follows. Cin et al. Using panel datasets to study public R&D subsidies for Korean manufacturing, it was found that R&D subsidies played an active role in R&D spending and value-added productivity of Korean manufacturing companies, promoting technological progress and economic growth [7]. Buchmann and Kaiser take the German biotechnology industry as an example, they believed that subsidies for R&D projects will increase patent output, companies participating in multiple projects will bring more benefits [8]. Bai et al. used the Tobit model to measure the green efficiency and composition of thermal power companies from 2010 to 2015, the impact of environmental subsidies on green efficiency was studied [13]. Little empirical research carried out in the field of subsidies, which the confidential data is difficult to obtain.

The other way is to explain the behavior of government subsidy by establishing mathematical models [18]–[47]. Most scholars focus on subsidy research in the supply chain. For example, Madani et al established a government-lead competitive mathematical model and a competitive mathematical model with green and non-green supply chains as followers to discuss green in supply chain competition. Strategic and governance pricing issues determine subsidies and tax rates for green and non-green products [18]. Ezimadu et al. studied cooperative advertising decisions in the manufacturer-retailer supply chain, with sethi models and optimal control techniques and stochastic differential games. The theory is that with the increase of subsidies, the efforts of retail advertising are increasing, while the manufacturers are decreasing [19]. Gu et al. proposed new fourth-order electric vehicle manufacturing supply chain model subsidy policy, which between government, electric or gasoline vehicle manufacturers, retailers and ultimate car customers [22]. Liu et al. put forward a three-stage stackelberg game model and use this model for retail-led supply under government subsidies Decision analysis of the problem [23]. Sun also obtained Green Investment Strategy, based on two supply chain manufacturers and material suppliers.In order to determine the optimal decision-making under the government subsidies [25]. In addition, some scholars research subsidy strategies from the perspective of social welfare. For example, MartínHerrán et al. study the optimal strategy of dynamic policy game between regulators and monopolists. Managers choose emission tax to maximize social welfare, while monopolist chooses emission reduction technology output and investment to achieve profit Maximization [26]. Yang et al. used a dynamic control model to solve the steady-state equilibrium under different conditions, and studied the welfare effects of the renewable energy investment subsidy game in two adjacent regions [27]. Nikzad and Atallah introduced a three-stage game model to study the impact of tariffs on R&D expenditures when there is a tariff spillover effect among enterprises [29]. Sølvang et al. studied the stochastic optimization model for designing a single-cycle multi-product multi-level reverse logistics system under government subsidies and low-carbon emission requirements. Conduct numerical tests and finally make recommendations from carbon government subsidies and emission requirements [30]. Zhu et al. analyzed the indirect relationship between electric vehicle sales and electric vehicle charging infrastructure construction, with the context of phasing out of electric vehicle subsidies [31]. Kundu et al. set a example for German rail freight, and discussed the impact of government subsidies for shippers mode conversion behavior. Finally proposed subsidy policy for government departments. From what we have studied, it can be seen that the research on subsidies for medicine is still blank, and focuses on the establishment of mathematical models. The maximization of social welfare through dynamic game models, which provides a good reference for biosimilars subsidies research.

At present, according to the existing literature, no scholars have been involved in the study on the government subsidy strategies for biosimilars. Due to the lack of historical data of biomedical industry, on the basis of the existing literature, this
paper uses the method of establishing mathematical model to study the government subsidy strategies, and constructs a two-stage dynamic game model to study the impact of government subsidy on drug price, consumer surplus, social welfare, the income of biosimilars enterprises and the demand of biosimilars. Which provide decision-making suggestions for the government to make subsidy strategies scientifically.

III. MODEL ESTABLISHMENT AND SOLUTION

A. MODEL DESCRIPTION

In the study of government subsidy strategies, the game object includes the subsidizing party and the subsidized party. By the use of subsidy strategies, the government hopes to have a positive stimulating effect on R&D of enterprises, share enterprises risk, make up for enterprises loss, and promote the development of biomedical industry. Enterprises will benefit from R&D and production of biosimilars and receive as much government subsidies as possible. When an enterprise obtains the subsidy from the government, it is equivalent to reduce the risk of technology R&D. As a result, the enterprises will increase the intensity of technology R&D, and the income of the enterprises will increase, which is conducive to maximize the profit. Consumers as the participants, will receive corresponding subsidies mainly through price changes and direct government subsidies. Both enterprises and government aim to maximize their own interests, and the behavior of one party has an impact on the action strategy of the other party in the next stage.

B. MODEL ASSUMPTIONS

Under the premise of government subsidy, a two-stage dynamic game model between government and biosimilars enterprises is introduced. The game is a non-cooperative and dynamic multi-player game, involving biosimilars enterprises, governments, patients and other subjects. In order to facilitate the study about this problem, some complex conditions are simplified, and the basic assumptions of the model are made as follows:

(1) In the process of the game, only the game between enterprises and the government are considered, while the differences between biosimilars enterprises are ignored, and the differences between the superior and subordinate levels of the government are not taken into account. Both parties, as the participants in the game process, aim to maximize their own benefits.

(2) It is assumed that there is only one manufacturer in the market, the government gives a subsidy of α yuan per each unit product sold, the proportion of subsidies to manufacturers is $t_1$, and the proportion of subsidies to consumers is

$$t_2 \ (t_1 + t_2 = 1).$$

(3) The market conduct between government and enterprises are mainly divided into two stages. In the first stage: the government determines the subsidy rate with the aim to achieve the maximization of social welfare, in which the subsidy rate is $t \ (0 \leq t \leq 1)$; in the second stage: enterprises determine the selling price $p$ with the aim to maximize their own interests. In the context of government subsidies, sales will be increased through subsidizing to consumers. The market demand function can be set as:

$$q = -\pi t + \alpha t + \theta$$ (1)

It is assumed that $\pi$ is the influence coefficient of price on demand, $\alpha$ is the influence factor of subsidy to consumers on demand, and $\theta$ indicates the expected demand of the market.

C. MODEL SOLUTION

Based on the above assumptions, the income function of the enterprises can be obtained, as shown in equation (2):

$$\Pi_m = q \ (1 - a) t$$ (2)

In order to maximize the capital benefit, the government regulates the subsidy proportion to the greatest extent, and in order to facilitate the calculation, the concept of social welfare maximization is introduced. Social welfare is the sum of consumer surplus and the income of biosimilars enterprises minus the government subsidy expenditure. The social welfare is quantified according to reference [48], and its function expression is shown in equation (3):

$$SW = \int_{t_m}^{t} q(p) dp$$ (4)

According to the social welfare, consumer surplus is used as an index to measure the difference between the maximum price consumers can bear and the actual price they pay. The consumer surplus is quantified according to the reference [49], and the function expression is shown in equation (4):

$$CS = \int_{p_m}^{p} q(p) dp$$ (5)

In this paper, a two-stage game model between government and enterprises are constructed, and the equilibrium solution of the game model is solved according to the backward induction. According to the derivation of equation (2), the output under the maximization of the income of biosimilars enterprises is obtained:

$$p^* = \frac{\theta - \pi a (1 - t) + \alpha t a}{2\pi}$$ (5)

$p^*$ is a monotone increasing function when $t \in [0, 1]$, that is, when $t = 1$, the maximum value is $p^*_{\text{max}} = \frac{\theta + \alpha t a}{2\pi}$, when $t = 0$, the minimum value is $p^*_{\text{min}} = \frac{\theta - \pi a + \alpha t a}{2\pi}$, and Proposition 1 is obtained:

Proposition 1: In order to avoid speculation by enterprises, the government will not spend too much on subsidies.

By substituting Equation (5) in Equation (1), the maximum sales volume of the enterprises is obtained:

$$q^* = \frac{1}{2} \left\{ \theta + a (\pi (1 - t) + t a) \right\}$$ (6)
By substituting Equation (5) and (6) in the income function of the enterprises, the maximum income is obtained:

$$\prod_{m}^{*} = \frac{[\theta + a(\pi - \pi t + t\alpha)]^2}{4\pi} \tag{7}$$

According to Equation (4) and (5), the consumer surplus can be obtained:

$$cs = \frac{-\theta^2 - 2\pi^2a^2 - a^2\pi^2a^2 + 2\theta\alpha a}{8\pi} \tag{8}$$

Next, the decision-making of government is analyzed, to determine the subsidy proportion. By substituting $p^*$, $q^*$, and $\prod_{m}^{*}$ into the social welfare, we obtain:

$$SW = \frac{3\theta - a(\pi + \pi t - 3\pi\alpha)]}{8\pi} \tag{9}$$

The first derivative and the second derivative of $SW$ are determined according to Equation (9), respectively. And we obtain:

$$\frac{dSW}{dt} = a[\theta(-2\pi + 3\alpha) + a(\pi^2t + 3\pi\alpha + \pi(\alpha - 4\pi\alpha))] \frac{4\pi}{\pi} \tag{10}$$

$$\frac{d^2SW}{dt^2} = -a^2(\pi - 3\alpha)(\alpha - \pi) \cdot a(\pi^2 - 2\pi\alpha + 3\pi\alpha) \tag{11}$$

By setting $\frac{d^2SW}{dt^2} = 0$ in Equation (11), we obtain:

$$t = \frac{2\theta\pi - 3\theta\alpha - a\pi\alpha}{a(\pi^2 - 4\pi\alpha + 3\pi\alpha)} \tag{12}$$

Since $t \in [0, 1]$, we obtain:

$$2\theta\pi - 3\theta\alpha < a < \frac{\theta}{\pi}$$

When $\alpha < \pi < 3\alpha$, $\frac{d^2SW}{dt^2} < 0$, $SW$ is a convex function about $t$, and the government gets the optimal decision. When $\alpha < \pi < 3\alpha$, $\frac{d^2SW}{dt^2} > 0$, $SW$ is a convex function about $t$, the government can also get the optimal decision.

**Lemma 1:**

When $\alpha < \pi < 3\alpha$, the government subsidizes both enterprises and consumers.

**Proof:** When $\alpha < \pi < 3\alpha$, $\frac{d^2SW}{dt^2} < 0$, $SW$ is a convex function about $t$, and the optimal decision of the government can be obtained. Now we can obtain $t = \frac{2\theta\pi - 3\theta\alpha - a\pi\alpha}{a(\pi^2 - 4\pi\alpha + 3\pi\alpha)}$.

**Lemma 2:**

When $\pi < \alpha$ or $\pi > 3\alpha$, the government will choose to subsidize only the enterprises or the consumers.

**Proof:** When $\pi < \alpha$ or $\pi > 3\alpha$, $\frac{d^2SW}{dt^2} > 0$. $SW$ is a convex function about $t$. At this time, $t = 0$ or $t = 1$, and the government gets the optimal decision. Given: $g(t) = SW$, $g(1) - g(0) = \frac{a[\theta(6\alpha - 4\pi) + a(\pi^2 - 2\pi\alpha + 3\pi\alpha^2)]}{8\pi} \tag{13}$

(a) When $\pi < \alpha$, $6\alpha - 4\pi > 0$, so $\theta(6\alpha - 4\pi) + a(\pi^2 - 2\pi\alpha + 3\pi\alpha) > 0$, and the government chooses to subsidize the patients.

(b) When $\pi > 3\alpha$, $6\alpha - 4\pi < 0$. Since $\alpha < \frac{\theta}{\pi}$, while $\frac{\theta}{\pi} < \frac{2\theta(2\pi - 3\alpha)}{\pi^2 - 2\pi\alpha + 3\pi\alpha}$, $g(1) < g(0)$, the government chooses to subsidize biosimilars enterprises.

When $\alpha > 3\alpha$, patients are more willing to accept lower drug prices. Because of the great difference between $\pi$ and $\alpha$, the influence coefficient of government subsidy to patients on demand is less than that of price on demand. From the perspective of social welfare maximization, the expenditure of government subsidy to patients will be higher than that to biosimilars enterprises. When $\pi < \alpha$, if the influence coefficient of government subsidy to patients on demand is greater than that of price on demand, patients prefer to get a subsidy directly.

**Corollary 1:** The price increases with the increase of subsidy proportion.

**Proof:** $\frac{dp^*}{dt} > 0$ is obtained by calculating the first derivative of equation (5). When $\pi < \alpha$ or $\pi > 3\alpha$, if the government subsidizes patients or subsidizes biosimilars enterprises, the price the patients get will be higher than that of the biosimilars enterprises the government subsidizes. When $\alpha < \pi < 3\alpha$, if the government subsidizes both patients and biosimilars enterprises at the same time, the higher the subsidy proportion for patients, the higher the price patients get.

**Corollary 2:** Under the three subsidy strategies of the government, the demand for drugs always increases with the increase of unit subsidy.

**Proof:** By calculating the first derivative of $a$ and $t$ according to equation (6), we obtain:

$$\frac{dq^*}{dt} = \frac{1}{2\theta\pi - 3\theta\alpha - a\pi\alpha} > 0 \tag{14}$$

$$\frac{dq^*}{dt} = \frac{1}{2a(\alpha - \pi)} \tag{15}$$

When $\pi = \alpha$, the influence coefficient of price on demand is equal to that of government subsidy to patients on demand. No matter what subsidy strategies the government adopts, the sales volume is equal. When $\alpha < \pi < 3\alpha$, the government chooses to subsidize both patients and biosimilars enterprises at the same time. When the subsidy proportion is higher for patients, the sales volume is smaller. When $\pi < \alpha$ or $\pi > 3\alpha$, the government subsidizes only one party, and the sales volume of subsidy to biosimilars enterprises is greater than that to patients.

When the influence coefficient of price on demand is greater than that of government subsidy to patients, in order to stimulate the sales of biosimilars, the government subsidy policy should be tilted to biosimilars enterprises. If enterprises are subsidized at this time, patients will get a lower price. When the influence coefficient of government subsidy to patients on demand is greater than that of price on demand, the government subsidy policy should be tilted to patients. Although the price is higher at this time, the government...
subsidy to patients has a greater impact on demand, and patients who receive subsidies can buy more biosimilars.

**Corollary 3:** No matter what subsidy strategies the government makes, the income of biosimilars enterprises increases with the increase of unit subsidy.

*Proof:* By calculating the first derivative of \( a \) and \( t \) according to equation (7), we obtain:

\[
\frac{d\prod^*}{da} = \frac{[\pi(1-t)+ta]\theta+s(\pi(1-t)+ta)}{2\pi} > 0 \tag{16}
\]

\[
\frac{d\prod^*}{dt} = \frac{a(\alpha-\pi)[\theta+a(\pi(1-t)+ta)]}{2\pi} \tag{17}
\]

When \( \pi = \alpha \), no matter what subsidy strategies the government makes, the incomes of biosimilars enterprises are equal. When \( \alpha < \pi < 3\alpha \), the government chooses to subsidize both patients and biosimilars enterprises. At this time, the higher the subsidy proportion is for patients, the lower the income of biosimilars enterprises is. When \( \pi < \alpha \) or \( \pi > 3\alpha \), the government chooses to subsidize one of the parties. At this time, the income of subsidy to patients is higher than that to biosimilars enterprises. When \( \pi < \alpha \), \( \prod^*(t=1) = \frac{(\theta+a\alpha)^2}{4\alpha} \prod^*_{\alpha} \) is the decreasing function of \( \pi \), so the minimum value is \( \prod^*_{\alpha}(\text{min}) = \frac{(\theta+a\alpha)^2}{4\pi} \). When \( \pi > 3\alpha \), \( \prod^*(t=0) = \frac{(\theta+a\alpha)^2}{4\alpha} \prod^*_{\alpha} \) is the decreasing function of \( \pi \), the maximum value is \( \prod^*_{\alpha}(\text{max}) = \frac{(\theta+3\alpha\alpha)^2}{12\alpha} \), and \( \frac{(\theta+a\alpha)^2}{4\alpha} > \frac{(\theta+3\alpha\alpha)^2}{12\alpha} \), so \( \prod^*(t=1) > \prod^*(t=0) \).

The government can choose a higher unit amount of subsidy to stimulate the enthusiasm of biosimilars enterprises. When the amount of subsidy is fixed, the government needs to consider the influence coefficient of subsidy to patients on demand and the influence coefficient of price on demand. When the influence coefficient of price on demand is greater than that of government subsidy to patients on demand, biosimilars enterprises will set a lower price, which will bring about greater sales. In order to stimulate the enthusiasm of biosimilars enterprises, the government subsidy policy will be tilted to biosimilars enterprises. When the influence coefficient of price on demand is less than that of government subsidy to patients on demand, biosimilars enterprises will set a higher price. Due to the larger influence coefficient of government subsidy to patients on demand, the sales volume will still increase, and the income of biosimilars enterprises will increase.

**Corollary 4:** No matter what subsidy strategies the government makes, consumer surplus always increases with the increase of unit subsidy.

*Proof:* By calculating the first derivative of \( a \) according to equation (8), we obtain:

\[
\frac{d\text{dc}s}{da} = \frac{\theta(\pi+ta)+a(\pi+\pi t+ta)\pi(1-t)+ta}{4\pi} > 0 \tag{18}
\]

From the perspective of consumer groups, the larger the amount of unit subsidy given by the government, the larger the overall consumer surplus.

**Corollary 5:** No matter what subsidy strategies the government makes, the total social welfare increases with the increase of unit subsidy.

*Proof:* By calculating the first derivative of \( a \) according to equation (9), we obtain:

\[
\frac{d\text{dSW}}{da} = \frac{\pi(\pi-2\alpha)(\theta-a\pi+2a\alpha)}{4(\pi 3\alpha)(\pi - \alpha)} \tag{19}
\]

Discussion by cases:

(a) When \( \alpha < \pi < 2\alpha, \pi - 2\alpha < 0, \theta - a\pi + 2a\alpha > 0 \) and \( \frac{d\text{dSW}}{da} > 0 \);

(b) When \( 2\alpha < \pi < 3\alpha \) and \( 0 < a < \frac{\theta}{\pi - 2\alpha}, \frac{d\text{dSW}}{da} > 0 \) when \( 2\alpha < \pi < 3\alpha, 0 < a < \frac{\theta}{\pi} \) and \( a > \frac{\theta}{\pi - 2\alpha} \), while \( \frac{\theta}{\pi} < \frac{\theta}{\pi - 2\alpha}, \frac{d\text{dSW}}{da} > 0 \);

(c) When \( \pi < \alpha, \frac{d\text{dSW}}{da} > 0 \);

(d) When \( \pi > 3\alpha, \frac{d\text{dSW}}{da} > 0 \).

As long as the government adopts a subsidy strategies, the total social welfare will always increase.

**IV. STATISTICAL ANALYSIS**

In order to research the trends of consumer surplus, social welfare and the income of biosimilars, Matlab software is used as a tool of numerical analysis. The relationship between the income of biosimilars enterprises, consumer surplus, social welfare and the amount of unit subsidy, under different subsidy strategies of the government which are analyzed.
through numerical simulation. And the influence trend among variables can be seen more intuitively, for the purpose of verifying the correctness of the game conclusion. So different parameter values are set for the model, which facilitating the calculation. The three subsidy strategies are recorded as follows: Case 1: $\pi > 3\alpha$, subsidy to enterprises; Case 2: $\pi < \alpha$, subsidy to patients; Case 3: $\alpha < \pi < 3\alpha$, the government subsidizes both at the same time. Assume that the parameters satisfy the following relationships: Case 1: $\theta = 200; \pi = 0.4; \alpha = 0.1; t = 0$; Case 2: $\theta = 200; \pi = 0.1; \alpha = 0.4; t = 1$; Case 3: $\theta = 200; \pi = 0.1; \alpha = 0.05$. Figures 1, 2 and 3 show that under three different government subsidy strategies, the income of biosimilars enterprises, consumer surplus and social welfare are positively correlated with the amount of unit subsidy.

V. CONCLUSION

On the basis of the bounded rationality of both sides of the game, the competition behavior of enterprises will be affected by government subsidies. This paper constructs the game models of the government, biosimilars enterprises and patients, which considering different subsidy strategies. The main conclusions of this paper are as follows:

1. Under three different subsidy strategies, the income of biosimilars enterprises, consumer surplus and social welfare always increase with the increase of unit subsidy, no matter the subsidy is given to biosimilars enterprises, patients or both.

2. When patients receive subsidies, they do not always get benefits. When the influence coefficient of price on demand is less than that of government subsidy to patients on demand, although patients get subsidies, their actual spending is higher than that of subsidy to biosimilars enterprises.

3. Under the three different subsidy strategies of the government, the demand for drugs increase with the increase of government subsidies. The two main factors that the government considers when choosing the subsidy strategies are: the price coefficient and the influence of the subsidy on demand. When the influence coefficient of price on demand is greater than that of government subsidy to patients on demand, the government will subsidize biosimilars enterprises. on the contrary, the government will subsidize patients. When the ratio of the influence coefficient of price on demand to that of government subsidy to patients on demand is $\alpha < \pi < 3\alpha$, the government will subsidize both at the same time.

According to the conclusions of this paper, the following suggestions are proposed:

The government subsidy strategies of biosimilars should be reasonably adjusted, and a variety of subsidies should be used to stimulate the enthusiasm of biosimilars enterprises. China is in the initial stage of biosimilars R&D, the industry is not mature enough, and the risk of technological research and development is relatively high. Therefore, there is an urgent need for financial support. For example, tax reduction and exemption should be implemented for biosimilars enterprises, financial support should be given to the research on key technologies of biosimilars. Which the income of biosimilars enterprises should be increased. And social welfare will be maximized.

It is worth noting that this paper does not consider the deadweight loss of biosimilars enterprises, decision-making of retailers, transport costs, market impact and other issues, which will be the next focus of research.

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