Research Article

Pricing Strategy and Simulation of Forest Rights Exchange Centers Based on the Two-Sided Market Theory

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1. Introduction

Since 2003, the Central Committee of the Communist Party of China (CPC) and the State Council have been paying much attention to reforming the collective forest rights system. Based on the principle of “clear property rights and equal distribution to households,” the forest rights reform has been gradually implemented throughout the country with initial successes [1]. In 2018, the CPC released the first Central Committee document, proposing further reforms for collective forest rights and property rights for water conservancy facilities. By the end of 2018, China’s authorized forestland area was 2.7 billion, accounting for 98.97% of the country’s total forestland area. More than 100 million farmers have benefited from forest rights certifications, which indicates that the milestones of “clarifying property rights” and “confirming rights and issuing certificates” have generally been achieved.

However, even after clarifying the property rights for residents of forest areas, the major barrier that remains is further optimizing forest allocation through market mechanisms so as to ensure that the benefits of forestry operations and forest farmers remain [2]. In response, China has implemented additional forest rights reform measures, and the circulation of forest rights has become more prevalent. In this context, forest rights exchange centers have emerged as one of the main methods for trading forest property in the market. As of 2018, China has established more than 1,900 forest rights exchange centers at and above the county level, thereby promoting the flow and reorganization of forest resource property rights.

1.1. Related Research and Motivation. At present, the transaction records for forest rights show a trend of weak marketization [3]. At the end of 2017, forest rights
transactions in China amounted to only 188 million hectares, accounting for about 10.46% of the total forestland area. Moreover, based on a survey of 575 farmers in Fujian, Zhejiang, and Jiangxi provinces, the percentage of transactions was only 8.35% of the surveyed farmers. Some reports have explained this result from both supply and demand angles [4–6]. For instance, Lu et al. [6] concluded that forest rights transactions are largely driven by farmers, including behavioral attitudes, subjective norms, and perceived behavior. Nevertheless, there have been few studies on how to solve the problem of weak marketization. Some scholars have concluded that more attention needs to be paid to the construction of the forest rights exchange market [7, 8]. Empirical evidence indicates the positive effects of circulation through forest rights exchange centers on the price of forest rights [9]. However, the lack of a pricing mechanism in forest rights transaction limits the involvement of farmers and decreases the efficiency of the market. Thus, formulating an effective pricing strategy is an urgent problem facing the center.

In fact, a typical two-sided market structure is defined as two different user groups whose utility comes from transactions through a forest rights exchange center [10]. To establish a pricing strategy for a forest rights exchange center, it is necessary to consider the characteristics of the two-sided market. Among them, a “nonneutral price structure” and “cross-network externalities” are the distinctive features in the market [11, 12]. Early studies of pricing strategies for two-sided markets focused on the nonneutral price structure. The platform can apply different pricing structures according to the degree to which two-sided users are sensitive to membership fees and transaction fees in a two-sided market [13]. For instance, platforms often choose to price users at zero or even to subsidize them, but this does not imply price discrimination. The pricing strategy favors the internalization of the network externality of two-sided users, thus weakening competition [14]. Moreover, some scholars have considered such cross-network externality in a two-sided market that consists of participants on a two-sided platform. They have concluded that the pricing strategy of a platform is affected by the cross-network externality. When the price level remains unchanged, the benefits of users on one side of the platform depend on the size of users on the other side [15].

In addition to the pricing structure and network externalities, the literature has expanded the scope of research through the development of a pricing model in consideration of the user quality, attribution issues, price information, service level, and other factors [16–20]. For instance, Chu and Manchanda [16] examined the effects of user quality on the pricing strategy of a platform. Bellemainne and Peitz [19] studied the price information problem under both monopoly and duopoly conditions. Furthermore, in order to solve a maximization problem of the electricity market’s profit, Irtija et al. [21] considered contract-theoretic demand response management in representative utility functions. They focused on the optimal satisfaction of the prosumers under the conditions of complete and incomplete information, which provided a new idea for the present study. In this work, we focused on the pricing mechanism of a forest rights exchange center to maximize profit in the two-sided market.

Additionally, some reports have applied the two-sided market transaction principle to the pricing strategies of different platforms, including rural homestead transfer, e-commerce platforms, carbon emission trading platforms, carpooling service platforms, and media platforms [22–26]. Li and Zhang [23] studied the strategy of e-commerce platforms, accounting for the reference price effect. Kim [26] developed a pricing model of monopolistic media platforms by analyzing matching technology, the prosumer strategy, and advertising technology. In addition to the above-mentioned strategies, the pricing strategy of the two-sided market provides a new experience to improve the efficiency of market circulation, which has been verified in the property rights exchange markets of other related resources. However, this transaction principle has been rarely applied to the forest rights exchange market, and there has been a scarcity of in-depth research on the pricing strategies of forest rights exchange centers.

To address this gap in the literature, the objective of this study was to develop a pricing mechanism for a forest rights exchange center in the transfer of collective forest rights based on the two-sided market theory. What, then, is the optimal pricing strategy under maximizing profit and social welfare? We focused on the optimal pricing strategy of a two-sided platform considering the impacts of service level, intragroup externality, and cross-network externality. Our findings have managerial implications and urge the center to adopt diversified pricing models.

1.2. Contributions and Outline. The main contributions of this study are as follows: (1) this study contributes to expanding the development of the two-sided market theory by constructing a new pricing model delineating the interactions of all players, including the forest rights exchange center, demanders, and suppliers. We provide a reference for a forest rights exchange center that has not yet established a forest rights transaction pricing system. (2) In order to clarify the factors that affect the pricing of the forest rights exchange center for two-sided users, a pricing model is built under the premise of maximizing profits and social welfare. We demonstrate how three important factors (service level, intragroup externality, and cross-network externality) impact the maximization of profits and social welfare. (3) In order to be compatible with reality, the rationality of the theoretical pricing model is verified using numerical simulations with a dataset of forestry experts in three provinces of China.

The remainder of this paper is structured as follows: in Section 2, we present an analysis of the pricing mechanism of the forest rights exchange center; in Section 3, we develop a pricing model based on two-sided market theory and analyze the price structure of the center; Section 4 details the numerical simulation; and Section 5 provides conclusions and policy recommendations.
2. Analysis of Pricing Mechanism of the Forest Rights Exchange Center

In China, forest rights transaction involves the exchange of property rights for trees and forest resources. A forest rights transaction is mainly based on the negotiation price between farmers in a unilateral market. In reality, however, many farmers should pay higher transaction costs owing to asymmetric information. Thus, in order to revitalize forest resource assets, it is necessary for an information service platform to improve the possibility of both parties to realize transactions. With the emergence of forest rights exchange centers, it is possible to resolve some difficulties such as asymmetric information. The basic function of a forest rights exchange center is to act as intermediary in forest rights transactions, which reduces asymmetric information among farmers and facilitates the sharing of transfer information in the market.

Forest rights trading activities have typical public welfare functions in China. Much of the existing forest rights exchange centers are led by local forestry administrative departments and are governed according to monopoly style leadership. This means that, for farmers, the transaction is completed through the exchange center. At the same time, the government coordinates and manages forest resource asset appraisals and forest loan services, as well as the mediation of forest rights disputes, accounting, and other service institutions. Therefore, the achievement of the maximization of social welfare is the forest rights exchange center’s main objective. The “supplier–forest rights trading center–demand” model is a typical two-sided market structure. First, there is a strong network externality among the participants. A negative intragroup network externality is evident among the same kind of users in a two-sided market. Moreover, the number of users on one side has a positive effect on the participants on the other side with the existence of cross-network externality. Second, the service needs of two-sided users are complementary. The purpose of the demanders is to find suitable forest land and forest resources to achieve large-scale forestry management benefits, and the premise is that the exchange center has a large number of forestland and forest resources suppliers. Correspondingly, the purpose of the suppliers is to find rights buyers and sell at the optimal price in order to maximize their income. Meanwhile, the exchange center has a large number of economic actors that shape the demand and realize transactions at a reasonable price. Furthermore, the pricing strategy of the exchange center directly affects the participation level of both sides. When the total price level of the exchange center is unchanged, the center can encourage more users to enter the market through an asymmetric price structure. The existing platforms generally offer subsidies or free pricing to attract more suppliers, while the demanders charge a fee. Therefore, a forest rights exchange center that is managed by the government can use different price strategies to ensure that both sides of the transaction receive what they need and thereby realize the maximum of social welfare.

3. Methodology

3.1. Pricing Model Assumptions. The pricing model of the existing two-sided market is generally composed of a membership fee, a transaction fee, or both [11]. However, most forest rights exchange centers in China have adopted a transaction fee. In this study, the pricing strategy of government-operated forest rights exchange center is analyzed as follows:

(1) The theoretical models of profit maximization and social welfare maximization in the forest rights exchange market are established

(2) The model is used to derive the transaction price of the two parties and the optimal pricing of the platform

(3) The factors leading to profit and social welfare maximization for a forest rights exchange center are analyzed

Hypothesis 1. The supply and demand of the forest rights exchange market are rational economic actors who can freely choose whether to transfer and trade through the forest rights exchange center. The number of actors on the supply and demand of the market is ns and nb, respectively.

Hypothesis 2. There is network externality between the two parties (suppliers and demanders) in the exchange market. The effect of cross-network externality from the suppliers to the demanders and the effect of cross-network externality from the demanders to the suppliers are α and β, α > 0 and β > 0, respectively; the effect of competition between suppliers is γ, γ > 0; and the degree of competition between demanders is θ, θ > 0.

Hypothesis 3. The services provided by the forest rights exchange center are the same for both parties, i.e., V. The fees charged by the center are determined according to the proportion of the transaction price of both parties, i.e., P1 and P2, respectively.

The utility of the transaction between the suppliers and the demanders through the center is U1 and U2, respectively, and its utility function is as follows:

\[ U1 = V + \beta nb - \gamma ns - P1, \]  \[ U2 = V + \alpha ns - \theta nb - P2. \]

It is assumed that the revenue of the center is π, as the facilities, trading places, and labor services that the center provides to both parties are sunk costs. To simplify the calculation, the exchange centers’ marginal cost of service is zero, that is, the values of f1 and f2 are zero. Also, the profit function is shown as follows:

\[ \pi = (P1 - f1)n_s + (P2 - f2)n_b = P1n_s + P2n_b. \]

This study assumes that the utility function of the transaction between the supply and demand across the center can be expressed as the number of transactions. The suppliers and the demanders aim to maximize their own benefits, while the social welfare function is as follows:
\[ \omega = \pi + CS_1 + CS_2. \]  

(4)

The remaining functions of the supply and demand are \( CS_i = \varphi (ui) \), \( i = s, b \), according to the envelope theorem.

3.2. Derivation of the Pricing Model. In the two-sided market, the pricing strategy of the forest rights exchange center directly affects the trading scale, profit level, and social welfare of the platform. Therefore, this study constructs a pricing model that enables the forest rights exchange center to maximize profits and social welfare. As the unit costs \( f_1 \) and \( f_2 \) provided by the center for two-sided users are zero, the utility function formulas (1) and (2) of the supply and demand are substituted into the profit function (3) of the center. The profit function can be obtained as follows:

\[ \pi = (V + \beta n_b - \gamma n_d - U_1)n_d + (V + \alpha n_s - \theta n_b - U_2)n_b. \]  

(5)

To maximize the profit, the profit function of the forest rights exchange center must be derivative of the first-order function. In this case, the derivative functions of the supply and demand are outlined below:

\[ \frac{\partial \pi}{\partial u_1} = [V + \beta \varphi (u_2) - \gamma \varphi (u_1) - U_1]\varphi (u_1) + \varphi (u_1)[-\gamma \varphi (u_1) - 1] + \alpha \varphi (u_1)\varphi (u_2), \]

(6)

\[ \frac{\partial \pi}{\partial u_2} = [V + \alpha \varphi (u_1) - \theta \varphi (u_2) - U_2]\varphi (u_2) + \varphi (u_2)[-\theta \varphi (u_2) - 1] + \beta \varphi (u_1)\varphi (u_2). \]

(7)

The functions of formulas (6) and (7) are zero. Assuming that the center can maximize profits, its equilibrium pricing for supply and demand is as follows:

\[ P_1 = \gamma n_s - \alpha n_b, \]

\[ P_2 = \theta n_b - \beta n_s. \]

(8)

Assuming that the forest rights exchange center can also maximize social welfare, we derive the social welfare function and obtain the following derivation formula:

\[ \frac{\partial \omega}{\partial u_1} = [V + \beta \varphi (u_2) - \gamma \varphi (u_1) - U_1]\varphi (u_1) + \varphi (u_1)[-\gamma \varphi (u_1) - 1] + \alpha \varphi (u_1)\varphi (u_2) + \varphi (u_1), \]

(9)

\[ \frac{\partial \omega}{\partial u_2} = [V + \alpha \varphi (u_1) - \theta \varphi (u_2) - U_2]\varphi (u_2) + \varphi (u_2)[-\theta \varphi (u_2) - 1] + \beta \varphi (u_1)\varphi (u_2) + \varphi (u_2). \]

(10)

The functions of formulas (9) and (10) are zero. With the maximization of social welfare, the equilibrium pricing for the supply and demand is outlined below:

3.3. Analysis of the Research Results. To intuitively analyze the pricing strategy mechanisms of the forest rights exchange center in the collective forest rights transfer in the two-sided market, this study presents a table of the price structure that maximizes profits, as well as social welfare (Table 2). We have found some results as follows.

(i) The service pricing of the forest rights exchange center depends on the size of the intragroup network externality and the cross-network externality. The service pricing of the center is negatively related to the cross-network externality, but is positively correlated with the degree of competition between the suppliers and the demanders.

(ii) Aiming to maximize its profit, the price structure of the forest rights exchange center is \( 1/\eta_1 = P_1 - \gamma ns + \beta nb/P_1 \) and \( 1/\eta_2 = P_2 - \theta nb + \beta ns/P_2 \) (note: the symbol definitions are the same as those in Table 1). When the platform of demand price elasticity was large, both sides of the cross-network externality were greater than the set of the network externality. In order to maximize profits, the center should reduce costs or subsidies that aim to reduce the related welfare loss.
**4. Numerical Simulation**

From the analysis conducted above, we can infer the pricing strategy of a forest rights exchange center in a two-sided market. Next, we examine whether these derivations hold in practice. In conjunction with the field research, we establish a range of values of the various model parameters and conduct a numerical simulation to verify the rationality of the theoretical pricing strategy.

<table>
<thead>
<tr>
<th>Charging mode</th>
<th>Profit maximization</th>
<th>Social welfare maximization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two-sided payment of transaction fee</td>
<td>$P_1 = y_n - a_n + \varphi(u_1)/\varphi(u_1)$</td>
<td>$P_1 = y_n - a_n$</td>
</tr>
<tr>
<td></td>
<td>$P_2 = \theta n_b - \beta n_s + \varphi(u_2)/\varphi(u_2)$</td>
<td>$P_2 = \theta n_b - \beta n_s$</td>
</tr>
</tbody>
</table>

The symbol definitions in Table 2 are the same as those in Table 1.

When the cross-network externality is ignored, the center sought to maximize its profits by increasing the fee ratio of the party with the larger intragroup network externality and by increasing its transaction costs. This ensures that the market transaction is balanced.

(iii) By combining the service pricing formulas (11) and (12) and the utility formulas (1) and (2) of both parties, the utility functions of both parties are obtained:

$$U_1 = V + (\alpha + \beta)nb - 2\gamma n_s,$$
$$U_2 = V + (\alpha + \beta)ns - 2\theta nb.$$  

For maximizing social welfare, there is a positive relationship between the utility of the suppliers, the service level of the center, the cross-network externality, and the size of the demand. The utility of the supply is negatively correlated with the intragroup network externality and the size of the supply. By improving the service level of the center and adjusting the transaction scale of the supply, the competition within the suppliers can be reduced and the suppliers’ position in the transaction is improved. The utility of the demand is positively correlated with the service level of the center, the cross-network externality, and the scale of the supply. Conversely, the utility of the demand is negatively correlated with the intragroup network externality and the scale of the demand. Therefore, improving the service level of the center and adjusting the scale of internal competition of the demand can help maximize the utility of the transaction, thus maximizing the welfare of the demand.

(iv) The forest rights exchange center adjusts the scale of the supply and demand based on the forest rights transaction price. The transaction scale can be dynamically adjusted by adjusting the pricing ratio of transaction costs. The price of forest rights transactions is directly affected by the strength of network externality.

4.1 Parameter Setting. From 2017 to 2019, the research team has carried out field surveys at forest rights exchange centers in Fujian, Jiangxi, and Zhejiang provinces of China. The results show that the interval between the externality of the supplier and the externality of the demander was consistent. The parameters were defined as follows: $\alpha, \beta \in [0.4, 0.8]$, $\gamma \in [0, 1]$, and $\theta \in [0, 1]$. The annual average number of transactions in the center during this period was 43.

4.2 Analysis of Simulation Results. In order to maximize the profit of the forest rights exchange center, it is assumed that the values of $\alpha$ vary from 0.4 to 0.8 (step size: 0.01) and that the values of $\gamma$ vary from 0.4 to 1 (step size: 0.01). As shown in Figure 1, the service pricing of the forest rights exchange center for the suppliers is correlated with the intragroup and cross-network externality of both parties. The greater the externality of the suppliers compared to the demanders, the lower the service price of the forest rights exchange center for the suppliers. When the cross-network externality of both parties is much greater than the intragroup network externality, the center reduces the fee or subsidy for the service pricing of supplies. This reduces the welfare loss of both parties. The more intense the competition between suppliers, the higher the service price of the center.

In this work, it is assumed that the values of $\theta$ vary from 0.2 to 1 (step size: 0.01) and that the values of $\beta$ vary from 0.4 to 0.8 (step size: 0.01). The forest rights exchange center has a certain influence on the service pricing of the demanders, as well as on the intragroup externality and cross-network externality of both parties. When the cross-network externality is ignored, the center maximizes profits by increasing the fee ratio of the party with greater intragroup network externality. This ensures that the market transaction is in a balanced state. Demanders are inversely related to the cross-network externality of the suppliers and the pricing of the center, as shown in Figure 2.

In order to maximize social welfare, the service pricing of the forest rights exchange center for suppliers is positively related to the intragroup network externality between suppliers. The greater the externality of the suppliers compared to the demanders, the lower the service price of the center for suppliers, as shown in Figure 3.

In addition, as the cross-network externality becomes stronger, the service price of the demanders becomes lower. At this time, there is fierce competition between the demanders for limited forest land and resources. Therefore, the price of the services offered to the demanders by the forest rights exchange center increases, as shown in Figure 4.

4.3 Discussions. Using survey data from the forest rights exchange center in China’s Fujian province, we found that the costs of the forest rights exchange center included...
facilities, trading places, and labor services. Furthermore, the revenue of the center mainly depended on government subsidies and commissions. Therefore, two solutions should be put into place to guarantee the implementation cost of the proposed pricing model in reality, which are given as follows.

At present, the center can adopt progressive commission methods to make profits owing to the limits of government subsidies. For instance, if the transaction amount is less than or equal to 100,000 CNY, the charging standard is 1% of the transaction amount; when the transaction amount is between 100,000 and 1 million CNY, the charging standard is 0.8% of the transaction amount; when the transaction amount is between 1 million and 10 million CNY, the charging standard is 0.5% of the transaction amount; and when the transaction amount is more than 10 million CNY, the charging standard is 0.3% of the transaction amount, but the minimum amount of each transaction is not less than 600 CNY.

However, subsidizing suppliers is more effective in improving the active market rather than subsidizing demanders owing to a higher cross-network externality for

![Figure 1: The relationship of the parameters and $P_1$ for a maximum profit of the forest rights exchange center (note: the symbol definitions in Figure 1 are the same as those in Table 1).](image1)

![Figure 2: The relationship between parameters and $P_2$ for a maximum profit of the forest rights exchange center (note: the symbol definitions in Figure 2 are the same as those in Table 1).](image2)
suppliers. Forest rights exchange centers should aggressively provide more of the free services of dispute mediation and mortgage financing for suppliers. Moreover, charging demanders are the major means to maintain operations for the center. In the situation when the participating number of suppliers has exceeded a certain scale, the center can make profits by charging both suppliers and demanders. According to the research results, the transactions were relatively active in the center of Jiangle County in the Fujian province during the period of 2009–2018 and there were 75 sales per year. Therefore, we consider that when the scales of transactions are at or above 75 sales per year, the county-level center can increase profits by charging both suppliers and demanders. In addition, trading alliances should be established between suppliers to reduce transaction costs.

5. Conclusion and Policy Recommendations

Although previous studies have analyzed the significance of the forest rights exchange market, there is considerable room to develop appropriate pricing mechanism for the
forest rights transactions in China. In order to solve collective forest rights transactions, this study evaluated the pricing strategy of forest rights exchange centers. Based on the two-sided market theory, the pricing model of a forest rights exchange center was constructed and the price structure that maximizes profits and social welfare was derived. In addition, the rationality of the theoretical derivation was verified by numerical simulation. The major conclusions and policy recommendations can be summarized as follows:

(1) The pricing model analysis of a forest rights exchange center demonstrated how three factors (service level, intragroup externality, and cross-network externality) affect the maximizing profits and social welfare. We have found that a high service level and cross-network externalities could facilitate maximizing the utility of the forest rights transaction, while intragroup externality played the opposite role. Previous studies have shown similar results [22, 24]. First, cross-network externality was proven to facilitate maximizing the utility of the transaction. According to the different externalities of the cross-network between the two parties, a forest rights exchange center can introduce price preference and subsidy mechanisms to maximize the benefits of the supply and demand. Second, given the negative correlation between the intragroup externality and the utility of the supply and demand, the government should encourage the establishment of trading alliances among village communities to effectively reduce the transaction costs of suppliers by reducing the number of suppliers and competition among them. In addition, the utilities of the supply and demand were directly associated with a higher service level. In order to maximize the utility of the forest rights transaction, several service measures should be made to improve the service level of the center, such as forest rights transfer transaction information, asset evaluation, mortgage financing, and dispute mediation.

(2) It is important to establish and perfect the two-sided market for forest rights transactions with the current policy conditions. The results indicate that a forest rights exchange center can adjust the scale of the supply and demand based on the forest rights transaction price. Forest rights exchange centers should formulate differentiated pricing strategies and standardize administrative procedures in the forest rights exchange market. For instance, in order to maximize social welfare, a government-led forest rights exchange center should dynamically adjust the transaction scale by regulating the price ratio of transaction costs.

To the best of our knowledge, this study was the first to develop a pricing strategy for a forest rights exchange center using two-sided market theory so far. However, there are some limitations to the study. Owing to the absence of objective data, we used a subjective evaluation to analyze the values of network externality by using dataset forestry experts in three provinces of China. Further study is required to take interconnection factors into account in the pricing strategy of the forest rights exchange centers.

Data Availability
The data generated and analyzed in this manuscript are available from the corresponding author on reasonable request.

Disclosure
Junjie Lin is the first author in this study. Yuanzhu Wei is the corresponding author in this study.

Conflicts of Interest
The authors declare that there are no conflicts of interest regarding the publication of this paper.

Authors’ Contributions
All authors have read and approved the final manuscript.

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