

Received August 11, 2021, accepted September 13, 2021, date of publication September 24, 2021, date of current version October 12, 2021.

Digital Object Identifier 10.1109/ACCESS.2021.3115358

A Model for Pricing the Construction Land Quota and Efficient Land Allocation by Using Improved Sequential Auction and Price Discount

JINGYU LIU¹, WEIDONG MENG², YUYU LI¹, AND BO HUANG²

¹School of Economics and Management, Chongqing Normal University, Chongqing 400047, China

²School of Economics and Business Administration, Chongqing University, Chongqing 400044, China

Corresponding authors: Bo Huang (huangbo@cqu.edu.cn) and Weidong Meng (mengweidong@cqu.edu.cn)

This work was supported by the National Natural Science Foundation of China under Grant 71573025.

ABSTRACT In this study, a two-stage sequential auction of complements is conceptualized by considering the rule of price discount. In addition, a reasonable pricing mechanism is designed for the land quota. This framework is based on the complementary characteristics of the construction land quota and the construction land in practice. The results indicate that the rule of price discount enhances the bidding price of the construction land quota and construction land. In other words, the greater the limit of price discount, the greater is the increase in the bidding price offered by bidders. Furthermore, the bidding price of the quota declines with an increase in the number of bidders and increases with an increase in the penalty amount for delayed construction. Accordingly, local governments should implement the rule of price discount and improve the qualification audit of bidders, in addition to appropriately raising the penalty amount for delayed construction, to raise the quota price and encourage farmers to reclaim their idle homesteads. This approach would ease conflicts between construction land demands and farmland protection, as well as promote rapid urbanisation and development of the national economy in China.

INDEX TERMS Sequential auction of complements, construction land quota, the rule of price discount, second-price sealed-bid auction.

I. INTRODUCTION

The central government allocates ‘land quota’ in a step-wise manner and free of charge to control local land use behaviour. This approach is in accordance with the prevention and control of the loss of cultivated land resources [1], [2]. However, the amount of construction land required has sharply increased with rapid industrialisation and urbanisation, thereby leading to the scarcity of the land quota [3]. Furthermore, the economic development has promoted the rural population to migrate to urban areas, which has resulted in numerous idle rural homesteads, thereby causing a serious waste of land resources [4], [5]. Consequently, large portions of construction land remain unused and wasted, which is emerging as one of the greatest obstacles to the sustainable development of China.

The associate editor coordinating the review of this manuscript and approving it for publication was Ahmed A. Zaki Diab¹.

Local governments in China, including those of Chengdu and Chongqing, have attempted to acquire construction land quotas with innovative land management tools to tackle the large disparity between fewer land quota and the high demand for construction land for rapid economic development [6]. Under this policy, farmers with idle homesteads can reclaim their homesteads into qualified cultivated land and acquire a certain number of quotas. Thereafter, local governments sell these quotas to demanders [7]. In practice, construction land quota and construction land are interdependent, and developers require quota and land for construction. The complementarity between the land and the quota should be considered when pricing land quota. However, the price is mainly based on the government’s guideline price, which overlooks the complementarity between the quota and the land. Furthermore, in the current mechanism of production and trading of quota, the government’s guideline price does not precisely reflect the intrinsic value of quota.

Cao *et al.* [8] and Zhang and Wang [9] stated that the intrinsic value of the quota is reflected through the investment projects that developers can undertake in advance. The authors further mentioned that the value of quota is the added time value in construction land use. In other words, considering that the construction land quota mainly enables the early implementation of projects on construction land, its intrinsic value is the value addition to the developers who can commence their projects earlier after acquiring the construction land. Indeed, this value reflects the complementarity between quota and land. However, the current pricing mechanism of quota (adopted by Chongqing, Chengdu, and Guangzhou) fails to reflect the additional value, resulting in low prices for quota and reluctance of a large number of farmers to reclaim their unused residential land [10].

Notably, some differences exist in the trading systems of Chengdu and Chongqing with regard to the practice of construction land quota. In line with the Interim Measures for the Administration of Chongqing's Rural Land Transactions and the Measures for the Administration of Dipiao in Chongqing, purchasing of quota serves two main purposes. First, developers retain the right to use the same amount of urban land. Second, the bidders who successfully obtain the land use quota and land can acquire a price discount [11], [12]. By contrast, Chengdu highlights that quota only serves to increase the same amount of urban land. Notably, the transactions of construction land quota generate extra profits to developers as well as extra taxes and other social benefits to local governments. Accordingly, if the local government transfers additional benefits to farmers by offering a price discount to developers, the questions that arise are whether the land compensation standard for land-lost farmers be raised and a large number of farmers be encouraged to actively reclaim their idle homesteads. Therefore, designing an effective pricing mechanism for construction land quota is essential to reflect the actual market value. Meanwhile, exploring whether the rule of price discount encourages farmers to reclaim their idle homesteads and ease conflicts between construction land demands and farmland protection is crucial.

The present study has various key contributions. First, the study proposes that the construction land quota and construction land should be complementarily and simultaneously investigated. Furthermore, this study considers that the market value of the construction land quota is reflected in the time taken for the implementation of construction projects to an advance value, that is, the value of private information of developers. Therefore, the sequential auction of complementary goods is an effective approach to price the quota. Second, in line with the main characteristics of the transactions of construction land quota, developers who do not win the quota in the auction of land quota would lower the valuation of the urban land. The study recommends improving the classic sequential auction of complementary goods and applying it to price the quota. Third, according to the current rule of land quota trading, the study explores whether the rule of price discount can guarantee the land-lost farmers' income, improve

farmers' enthusiasm for land reclamation, and promote the trading system for the construction land quota, as well as promote industrialisation and urbanisation.

Studies on the transaction mechanism for the construction land quota have mainly focused on the general introduction of the transaction mechanism, including its significance, production process, and basic characteristics. Wang *et al.* [13] noted that the trading mechanism of land use quota effectively released rural idle land resources, reduced the risk of cultivated land loss, and provided a model for other pilot studies in the future. Chen *et al.* [14] believed that Dipiao, a type of development rights transfer in Chongqing, considerably enhanced the efficiency of urban and rural land use and avoided the waste of scarce resources. Meanwhile, the distribution system of income protected the land rights and interests of land-lost farmers in remote rural areas. Wang *et al.* [15] determined that the Transfer of Development Rights Programme in Chongqing ensured food security and stimulated economic growth. Certainly, this programme could effectively solve the dilemma in the urbanization process. Only a few studies have reported on the quota pricing mechanism for construction land. Moreover, all of these studies highlighted the defects of the quota pricing mechanism for construction land and provided qualitative policy suggestions. However, these studies could not design a targeted and feasible pricing mechanism. For instance, Feng *et al.* [16] demonstrated that the current pricing of construction land quota is based on the cost-oriented pricing method and that the price does not reflect the market value of land quota. Ma *et al.* [17] discovered that the quota price was formed as the market and administrative pricing mechanisms. Zhang [18] opined that the quota price should be independent of the production cost and reflect the regional characteristics. Hao and Du [19] believed that the core of land quota trading is the transaction of land development rights. Meng and Xiong [20] emphasised that the local government should gradually reduce the control of the quota price and introduce the market mechanism to effectively reflect the intrinsic value of the quota. Sun *et al.* [21] suggested that the secondary market for land use quota trading should be opened by clarifying the functional positioning of the market and improving the regulation and supervision mechanism of the market.

The quota value in the market is kept as private information by developers, and auctioning is one of the most effective means to reveal the private value of developers. In addition, construction land and quota are interdependent complementary goods. Therefore, considering the construction land quota and construction land transaction as two-stage complementary goods, a sequential auction can precisely reveal the essential attributes of the construction land quota. Scholars have extensively focused on the sequential auction of complementary goods. Leufkens and Peeters [22] observed that a second-price sealed-bid sequential auction generated a higher price than a first-price sealed-bid sequential auction. Boudreau and Shunda [23] examined a novel sequential auction and indicated a distinct pattern of initial overbidding

followed by underbidding. Kong [24] performed a structural analysis of sequential auctions with synergy and affiliation across auctions. Furthermore, the author proposed a flexible yet tractable sequential auction model under the private value paradigm and established its nonparametric identification, which represented an intuitive and general method for disentangling synergy from affiliation. Li and Shonkwiler [25] examined the price trend in a sequential online live cattle auction. The authors found that the buyer’s maximum valuation on the subsequent object declined as the buyer won more objects, which offers a plausible explanation for the declining price anomaly in sequential auctions. De Silva *et al.* [26] indicated that winners in the previous stage were more likely to participate in subsequent auctions and that their average bid was lower. Branco [27] discovered the equilibrium in pure strategies. The author indicated that under equilibrium, the expected price declined from the first to the second auction. Certainly, scholars have intensely discussed the sequential auction of complements in theory and have applied the model to fields such as live cattle. However, none of the studies have applied the theory of sequential auction of complements to the transaction of construction land quota.

II. METHODOLOGY

A. PROBLEM AND VARIABLES

1) PROBLEM

A local government sells a piece of project land. However, the quota allocated by the central government in a particular year is completely utilised. The local government thus relies on land-lost farmers to reclaim unused rural homesteads to increase the number of quota [28], [29]. Considering the complementary characteristics of land quota and the urban land, the government organizes a second-price sealed-bid sequential auction to auction the land quota and construction land. The first stage of the sequential auction is the auction of the construction land quota, whereas the second stage is the auction of the construction land. Under the second-price sealed-bid rule, bidders with the highest price bids for the construction land quota or the construction land and pays according to the second highest price. China’s land transfer market stipulates that developers should simultaneously acquire urban land and land quota to utilise the plot for development. Accordingly, developers should successively participate in the construction land quota auction as well as the construction land auction to successfully bid for both these items.

Furthermore, developers with a potential demand for the construction land quota or the construction land may participate in the aforementioned two stages [30]. Notably, if winners in the second stage fail to win the land quota in the first stage, the acquired land cannot be immediately used for development. Thus, the winner should participate in another round of construction land quota auction and obtain the construction land quota to ensure development. During this period, the construction land remains idle and

cannot be utilised for development. Furthermore, failure of the developers to begin the development within the time limit specified by the government may amount to a penalty for delayed construction, which represents a certain proportion of the land transaction price [31]. After the two-stage auction, the farmers who provide construction land quota may be compensated for the loss of land at 85% of the price of the quota.

In addition, two rules of price discount exist in the land quota trading practice [32], [33]. First, a part of the transaction price of the quota can be deducted from the land quotation. Second, no price discount is provided. However, whether the rule of price discount can release idle land in rural areas and enhance the efficiency of land resource allocation remains questionable. This study explores whether the rule of price discount can demonstrate the intrinsic value of the quota and guarantee the legal rights and interests of farmers.

Thus, this manuscript adopts the sequential auction of complement to design the pricing method of construction land quota. Figure 1 illustrates the relationships among the government, developers, and farmers.

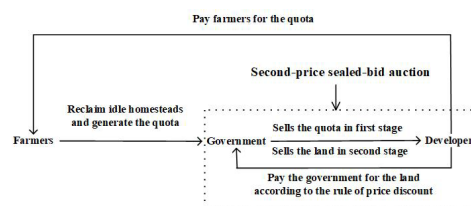


FIGURE 1. Relationships among the government, developers, and farmers.

2) VARIABLES

A risk-neutral local government organises second-price sealed-bid sequential auction to sell a construction land quota and a piece of construction land. Furthermore, $n(n \geq 2)$ risk-neutral bidders hold neither the construction land quota nor the construction land to participate in the two-stage auction. The winner in the quota auction is denoted as w , and the loser is denoted as l . The bidders’ valuation of the land quota is denoted as $V_{1i}, i = 1, 2, \dots, n$, and the valuation of the land is denoted as $V_{2i}, i = 1, 2, \dots, n$, with both V_{1i} and V_{2i} following a uniform distribution [22]. Considering that the value of the construction land quota is considerably lower than the actual value of the construction land, the bidders’ valuation of the construction land is assumed to follow a uniform distribution $[0,1]$. The valuation of the construction land quota follows a uniform distribution $[0, a]$, where $a(0 < a \ll 1)$ is a constant [34]. The distribution of the bidder type and number is common knowledge. However, information on the type of each bidder is confidential, which remains unavailable to the government or other bidders until the auction begins. The valuation and offer process of auction are as follows: (i) bidders value the construction land quota, (ii) bidders propose offers for the construction land quota, (iii) bidders value the construction land, and (iv) bidders

propose offers for the construction land. This valuation and offer process represent a situation, wherein, for instance, a government contract for the supply of public services is auctioned annually. In any given auction, bidders are unaware about the details of next year’s contract, although the contract is considered identical a priori (random equivalence).

The classical sequential auction considers that winning the first auction increases the valuation to R times. This complementarity applies only to the valuation of the second good V_{2i} . Winning the first auction increases the valuation of the second auction from V_{2i} to RV_{2i} without any effect on the valuation of the first auction V_{1i} . However, in practice, bidders with the construction land quota may immediately develop the construction land after they acquire the land, whereas those without the construction land quota would be required to wait until the next round auction of the quota to obtain the permission. Throughout this period, a delay in construction would amount to a certain fee to bidders. In other words, compared with winners in the first stage, losers would lose profits. Therefore, if losers in the first stage win the construction land, they would suffer additional cost loss and reduce the construction land quotation. By contrast, the winners’ valuation of the urban land remains unchanged. Therefore, the losers’ valuation of the land would be reduced compared with the original valuation, from V_{2i} to V_{2i}/R ($R > 1$) [35]. Here, R is a parameter of land value depreciation. When the penalty amount for delayed construction is high, the additional cost loss of losers in the quota transaction of the construction land is high and the value added of the construction land is low, implying a greater R .

In the land quota auction, the bidding price of bidder i is b_{1i} , $i = 1, 2, \dots, n$. E_{1i} , $i = 1, 2, \dots, n$ is the ex-ante expected surplus of bidder i or the difference between the expected value of quota for bidder i and the expected price the bidder pays. In the land auction, if the bidding price of bidder i is b_{2i} , then, the winners’ ex-ante expected surplus in the land auction is E_{2i}^w , $i = 1, 2, \dots, n$, and the losers’ ex-ante expected surplus in the construction land auction is E_{2i}^l , $i = 1, 2, \dots, n$. The difference in the ex-ante expected surplus between winners and losers is Δ , which represents the added surplus and is expressed as $\Delta = E_{2i}^w - E_{2i}^l$, $i = 1, 2, \dots, n$. Accordingly, winners in the first stage can avoid the fine for delayed construction, which implies that they can obtain extra profits.

In addition, the local government stipulates that the bidders who successfully acquire the quota and the land can obtain a fixed discount, which implies that a part of the quota price can be deducted from the price of the land, denoted as $p \in (0, 1)$. China’s land transfer market stipulates that developers should simultaneously acquire construction land quota and construction land to utilise the land for development. Therefore, developers should successively participate in the quota auction and the urban land auction to successfully bid both the items. Consequently, the local government makes an ex-ante commitment before the auction begins (i.e. the auction of quota and land), according to which if the bidders

win the first (quota auction) and second (land auction) stages, they will receive a discount of $p \in (0, 1)$. The bidders are bound to be willing to increase the land quota or the construction land according to the fixed discount to increase the probability of obtaining the two items. Without loss of generality, this study assumes that the bidders will pay extra px_i , $i = 1, 2, \dots, n$ for obtaining the quota and $(1 - x_i)p$, $i = 1, 2, \dots, n$ for obtaining the land. In this expression, x_i denotes the extent to which a bidder is willing to raise the quota price according to the fixed price discount.

B. BIDDERS’ CONSTRUCTION LAND QUOTA AND QUOTATION

1) THE BIDDERS’ QUOTA AND LAND PRICE WITHOUT THE RULE OF PRICE DISCOUNT

For solving the sequential game, backward induction is used to identify the equilibrium bidding strategy of bidders. Thus, the construction land bidding stage is given the top priority, followed by the construction land quota bidding stage.

In the construction land bidding stage, the bidders with quota are required to conduct land auction through sealed-bid auction alongside the bidders without quota. In the land auction, the quota holders do not enjoy any priority rights. In other words, the bidders who hold quota start bidding on an equal footing with those who lack quota. Thus, the price offered for the construction land depends only on the bidder’s valuation of the construction land rather than the price of the construction land quota.

In the construction land quota auction stage, bidders can generate additional value for the quota by winning the construction land quota, thereby avoiding the loss of idle land fee while holding the construction land without the quota. Thus, the bidder’s construction land quota offer includes the bidder’s valuation of the construction land quota and the additional value generated through the construction land quota. Thus, our propositions are as follows:

Proposition 1: In the auction of land use quota and the construction land, the bidders’ equilibrium bidding price in the two stages, respectively, are:

$$b_{1i}(V_{1i}) = V_{1i} + \Delta, \tag{1}$$

$$\begin{cases} b_{2i}^w(V_{2i}) = V_{2i} & i = 1, 2, \dots, n \\ b_{2j}^l(V_{2j}) = V_{2j}/R & j = 1, 2, \dots, n, j \neq i \end{cases} \tag{2}$$

where $\Delta = (R - 1)[(R - 1)n + 2]/(2R^2n)$.

Proof: If losers, who are affected by the characteristics of quota trading, succeed in obtaining the construction land in the first stage, they would still be required to wait for another round of auction of the quota to successfully obtain the quota before acquiring permission to develop the acquired land. During this period, a delay in construction would amount to a certain fee. In other words, compared with winners in the first stage, losers would lose profits. Therefore, if losers in the first stage win the construction land, they would suffer additional cost loss and reduce the land price. By contrast, the winner’s valuation of the urban land remains unchanged. Therefore,

the losers' valuation of the land would be reduced compared with the original valuation, from V_{2i} to V_{2i}/R ($R > 1$) [35]. Thus, according to Leufkens *et al.* [35], in the land auction, the price of bidders in the second stage is as follows:

$$\begin{cases} b_{2i}^w(V_{2i}) = V_{2i} & i = 1, 2, \dots, n \\ b_{2j}^l(V_{2j}) = V_{2j}/R & j = 1, 2, \dots, n, j \neq i \end{cases}$$

When bidder i , $i = 1, 2, \dots, n$, wins the quota, the maximum land price of other $n - 1$ bidders, expect for bidder i , can be recorded as z , and the ex-ante expected surplus of the bidders i in the second stage is

$$\begin{aligned} E_{2i}^w &= \iint_{V_{2i} > z/R} (V_{2i} - z/R)(n - 1)z^{n-2} dV_{2i} dz \\ &= \int_0^{\frac{1}{R}} dV_{2i} \int_0^{RV_{2i}} (V_{2i} - z/R)(n - 1)z^{n-2} dz \\ &\quad + \int_{\frac{1}{R}}^1 dV_{2i} \int_0^1 (V_{2i} - z/R)(n - 1)z^{n-2} dz \\ &= 1/[R^2 n(n + 1)] + [(R - 1)(Rn - n + 2)]/(2R^2 n) \quad (3) \end{aligned}$$

where $i = 1, 2, \dots, n$.

If bidder i , $i = 1, 2, \dots, n$, fails in the first stage and bidder k , $k = 1, 2, \dots, n, k \neq i$, wins in the first stage, let the bidding price of bidder k in the second stage be z_1 . Furthermore, the maximum value in the second stage of other $n - 2$ bidders, except i and k , in the first stage is denoted as z_2 . Thus, the ex-ante expected surplus of bidder i in the second stage can be acquired as follows:

$$\begin{aligned} E_{2i}^l &= \iiint (V_{2i}/R - \max\{z_1, z_2/R\})(n - 2)z_1^{n-3} dV_{2i} dz_1 dz_2 \\ &= \int_0^1 dV_{2i} \int_0^{\frac{V_{2i}}{R}} (V_{2i}/R - z_1) dz_1 \int_0^{Rz_1} (n - 2)z_2^{n-3} dz_2 \\ &\quad + \int_0^1 dV_{2i} \\ &\quad \times \int_0^{V_{2i}} (n - 2)z_2^{n-3} dz_2 \int_0^{\frac{z_2}{R}} (V_{2i}/R - z_2/R) dz_1 \\ &= 1/[R^2 n(n + 1)] \quad (4) \end{aligned}$$

where $\Delta = [(R - 1)((R - 1)n + 2)]/[2R^2 n]$.

The aforementioned expression indicates that if bidder i , $i = 1, 2, \dots, n$, wins the construction land quota, it can obtain an extra profit of Δ , that is, the quota brings an extra value of Δ to the bidder i . Consequently, the total value or the bidding price of bidder i is the sum of the original value of the construction land quota and extra value, $b_{1i}(V_{1i}) = V_{1i} + \Delta$. Q.E.D.

Overall, in Proposition 1, the following points may be observed: in the bidding stage of the construction land quota, the bidding price of the construction land quota is related to the number of bidders n and the parameter of land value depreciation R . In the construction land auction, the equilibrium bidding price of losers in the first stage is related to the parameter of land value depreciation R .

2) THE BIDDERS' QUOTA AND LAND PRICE WITH THE RULE OF PRICE DISCOUNT

Proposition 2: In the auction of land quota and the urban land, the bidding price of bidders in the two stages, respectively, are:

$$\begin{cases} b_{1i}^o(V_{1i}, p) = V_{1i} + \Delta^o + px_i & (5) \\ \begin{cases} b_{2i}^w(V_{2i}, p) = V_{2i} + (1 - x_i)p & i = 1, 2, \dots, n \\ b_{2j}^l(V_{2j}, p) = V_{2j}/R + (1 - x_j)p & j = 1, 2, \dots, n, j \neq i \end{cases} \end{cases} \quad (6)$$

where $\Delta^o = (R - 1)[(R - 1)n + 2]/(2R^2 n)$.

Proof: As proved by Proposition 1, the loser's valuation of the construction land in the first stage would be reduced compared to the original valuation, from V_{2i} to V_{2i}/R ($R > 1$) [35]. Meanwhile, because of the rule of price discount, the bidders who successively obtain the two items will inevitably receive a fixed discount. To increase the probability of obtaining the two items, bidders are bound to be willing to increase the land quota or the construction land according to the fixed discount. Without loss of generality, this study assumes that bidders will pay extra px_i , for obtaining the quota and $(1 - x_i)p$ for obtaining the land. Thus, according to Leufkens *et al.* [35] and Jeitschko and Wolfstetter [36], in the land auction, the bidding prices of bidders in the second stages are as follows:

$$\begin{cases} b_{2i}^w(V_{2i}, p) = V_{2i} + (1 - x_i)p & i = 1, 2, \dots, n \\ b_{2j}^l(V_{2j}, p) = V_{2j}/R + (1 - x_j)p & j = 1, 2, \dots, n, j \neq i \end{cases}$$

When bidder i , $i = 1, 2, \dots, n$, wins the quota of the construction land, the maximum land price of the other $n - 1$ bidders, expect for bidder i , can be recorded as z_3 , and the ex-ante expected surplus of bidders i in the second stage is expressed as follows:

$$\begin{aligned} E_{2i}(V_{2i}^w, p) &= \iint_{b_{2i}(V_{2i}^w) > b_{2j}(V_{2j}^l)} (V_{2i}^w + (1 - \varepsilon)p - (z_3/R + (1 - \varepsilon)p))(n - 1)z_3^{n-2} dV_{2i}^w dz_3 \\ &= \int_0^{\frac{1}{R}} dV_{2i}^w \int_0^{RV_{2i}^w} (V_{2i}^w - z_3/R)(n - 1)z_3^{n-2} dz_3 \\ &\quad + \int_{\frac{1}{R}}^1 dV_{2i}^w \int_0^1 (V_{2i}^w - z_3/R)(n - 1)z_3^{n-2} dz_3 \\ &= 1/[R^2 n(n + 1)] + [(R - 1)(Rn - n + 2)]/(2R^2 n) \quad (7) \end{aligned}$$

where $i = 1, 2, \dots, n$.

If bidder i , $i = 1, 2, \dots, n$, fails in the quota auction and bidder k , $k = 1, 2, \dots, n, k \neq i$, wins in the quota auction, let the land price of bidder k be z_4 . The maximum value in the land auction of other $n - 2$ bidders, except i and k , in the quota auction is denoted as z_5 . Thus, the ex-ante expected surplus of bidder i in the land auction is

TABLE 1. Definition of the parameters.

Parameters	Description
V_{li}	The bidders' valuation of the land quota, $i = 1, 2, \dots, n$
V_{2i}	The bidders' valuation of the land, $i = 1, 2, \dots, n$
R	The parameter of land value depreciation
n	The number of bidders
b_{li}	The quota price of bidders, $i = 1, 2, \dots, n$
b_{2i}	The land price of bidders, $i = 1, 2, \dots, n$
Δ	The difference in the ex-ante expected surplus between the winner and losers
E_{2i}^w	The ex-ante expected surplus of a winner who acquire the quota in the auction of land, $i = 1, 2, \dots, n$
E_{2i}^l	The ex-ante expected surplus of a loser in the auction of land, $i = 1, 2, \dots, n$
p	The limit of price discount
x_i	The extent to which the bidder is willing to raise the quota price according to the fixed price discount $i = 1, 2, \dots, n$
w	The winner in the quota auction
l	The loser in the quota auction
a	The upper limit of quota's valuation

as follows:

$$\begin{aligned}
 & E_{2i}(V_{2i}^l, p) \\
 &= \iiint \frac{(V_{2i}^l/R + (1 - \varepsilon)p - \max\{z_4 + (1 - \varepsilon)p, z_5/R + (1 - \varepsilon)p\})(n - 2)z_5^{n-3} d_{V_{2i}^l} d_{z_4} d_{z_5}}{+ (1 - \varepsilon)p} \\
 &= \int_0^1 d_{V_{2i}^l} \int_0^{V_{2i}^l} (V_{2i}^l/R - z_5/R)(n - 2)z_5^{n-3} d_{z_5} \int_0^{\frac{z_5}{R}} d_{z_4} \\
 &\quad + \int_0^1 d_{V_{2i}^l} \int_0^{\frac{V_{2i}^l}{R}} (V_{2i}^l/R - z_4) d_{z_4} \int_0^{Rz_4} (n - 2)z_5^{n-3} d_{z_5} \\
 &= 1/(R^2 n(n + 1)) \tag{8}
 \end{aligned}$$

where $\Delta^\rho = (R - 1)[(R - 1)n + 2]/(2R^2 n)$.

The aforementioned expression indicates that bidder i , $i = 1, 2, \dots, n$ can obtain an extra profit of Δ^ρ if he wins the construction land quota. In other words, the quota brings an extra value of Δ^ρ to the bidder i . Consequently, the total value or the bidding price of bidder i is the sum of the original

value of the land quota and the extra value, $b_{li}^\rho(V_{li}, p) = V_{li} + \Delta^\rho + px_i$.

Q.E.D.

From Proposition 2, we find that the bidding price of quota is related to the number of bidders n , the parameter of land value depreciation R , and the limit of price discount p . During land auction, the land price of losers relates to the parameter of land value depreciation R and the limit of price discount p . In addition, the quota price of the winner relates to the limit of price discount p .

By comparing Propositions 1 and 2, we find that $\Delta^\rho = \Delta$. Therefore, the difference in the ex-ante expected surplus between winners and losers during the first stage under two different rules are the same in the auction. This observation implies that the rule of price discount cannot increase the added value of quota.

3) QUOTATION ANALYSIS UNDER TWO DIFFERENT RULES

Proposition 3: Under two different rules, the quota price of bidders decreases with the increase in the number of bidders,

whereas the price increases with the increase in the fee for delayed construction.

Proof: Taking the first derivative of the quota price of bidders with respect to the number of bidders n and the parameter of land value depreciation R , we can acquire $\partial b_{1i}(V_{1i})/\partial n < 0$, $\partial b_{1i}^p(V_{1i}, p)/\partial n < 0$, $\partial b_{1i}(V_{1i})/\partial R > 0$, $\partial b_{1i}^p(V_{1i}, p)/\partial R > 0$, respectively, $i = 1, 2, \dots, n$. Therefore, the quota price of bidders is strictly a decreasing or increasing function of the number of bidders and the parameter of land value depreciation, respectively, implying that in the quota auction, the quota price decreases with the increase in the number of bidders and increases with the increase in the fee for delayed construction.

Q.E.D.

Proposition 3 demonstrates that the quota price of bidders decreases with the increase in the number of bidders. This change occurs because the valuation of the land use quota represents the extra profits of undertaking of these projects. The competition for the construction land intensifies with the increase in the number of bidders in the two-stage auction. If bidders increase the payment for the construction land, the payment for the construction land quota would be reduced, thereby reducing the bidding price for the quota.

Additionally, Proposition 2 helps infer that the quota price of bidders increases with the increase in the parameter of land value depreciation. This change occurs because the government stipulates the construction land quota as a prerequisite for developers to use the construction land. When losers in the first auction obtain the construction land, they have to wait for another round of quota auction. This process may result in an increase in the fee incurred on developers for a delayed construction; higher the fee for delayed construction, higher is the intrinsic value of the quota, i.e. larger R , which implies that bidders are willing to pay a large amount to acquire the quota. Therefore, its price would increase.

Proposition 4: In the quota auction, the bidders' price with the rule of price discount increases with the increase in the limit of price discount.

Proof: Taking the first derivative of the quota price of bidders with respect to the limit of price discount p , we can obtain $\partial b_{1i}(V_{1i})/\partial p > 0$, $\partial b_{1i}^p(V_{1i}, p)/\partial p > 0$, $i = 1, 2, \dots, n$. Therefore, the price is strictly an increasing function of the limit of price discount, suggesting that in the first stage, the price of quota increases with the increase in the limit of price discount.

Q.E.D.

Proposition 4 indicates that in the first stage, the quota price of bidders increases with the increase in the limit of price discount, mainly because the value of the land use quota relies on the land and land projects. The higher the limit of price discount, the higher is the probability to acquire the construction land for winners in the first auction. Accordingly, winners in the first stage will gain extra profits, thereby increasing the quota price of bidders.

Proposition 5: The land quota price under the rule of price discount is higher than the price without rule.

Proof: According to Propositions 1 and 2, we can obtain $\Delta^p = \Delta$, and $b_{1i}^p(V_{1i}, p) - b_{1i}(V_{1i}) = px_i > 0$. Therefore, the quota price of bidders under the rule of price discount is higher than prices without the rule.

Q.E.D.

We infer from Proposition 5 that a high price of the quota exists under the rule of price discount, which implies that the rule of price discount can effectively increase the price of the land use quota. In practice, the government may raise the price of the quota through the rule of price discount. Consequently, the farmers' income can be effectively increased and construction land and the land quota can be efficiently utilised.

III. NUMERICAL ANALYSES

A. OPTIMAL BIDDING PRICE

Through numerical simulation, the study determines the optimal bidding price of the land quota and construction land, as well as explores the related factors that affect the quota and land quotations.

Assume that a local government holds a two-stage sequential auction to sell the quota and urban land. After the announcement of the auction, 10 bidders participate in bidding. According to the variables, the valuation of the construction land follows a uniform distribution [0,1]. Chongqing, located in western China, is one of the first pilot zones for construction land quota, and we conduct a simulation analysis based on realistic quota trading data. According to the relevant data of Chongqing country land exchange, the transaction price of the construction land quota is considerably lower than that of the construction land [10]. Without the loss of generality, we assume that the upper limit of uniform distribution of the construction land quota $a = 0.1$, that is, the valuation of the land use quota, follows a uniform distribution [0, 0.1]. All bidders' estimates of the land use quota and land are randomly generated in [0, 1] and [0, 0.1] according to practices and model assumptions (Table 3).

According to the land administration law of the People's Republic of China, the penalty amount for delayed construction is approximately 10%–20% of the annual land price. Without the loss of generality, the parameter R equals 1.3. According to the previous assumptions of price discount and considering that the two parameters are randomly generated in (0, 1), the parameter p equals 0.3.

B. SENSITIVITY ANALYSIS OF MAIN PARAMETERS

We perform a sensitivity analysis to explore the effects of the parameter of land value depreciation and the limit of price discount on the equilibrium bidding price of the quota, the construction land, and the expected income of farmers.

Figure 2 illustrates the effects of the land value depreciation parameter and the price discount limit on the bidding price of the quota.

Figure 2a illustrates that the quota price increases with the increase in the land value depreciation parameter.

TABLE 2. The extent to which each bidder is willing to increase the price of the quota.

Proportion x_i	Bidders									
	1	2	3	4	5	6	7	8	9	10
	0.8	0.75	0.6	0.6	0.5	0.3	0.7	0.4	0.2	0.45

TABLE 3. Values of the land quota and construction land of bidders.

Valuation	Bidders									
	1	2	3	4	5	6	7	8	9	10
V_{1i}	0.09	0.07	0.06	0.075	0.05	0.03	0.082	0.036	0.01	0.04
V_{2i}	0.8	0.5	0.42	0.31	0.87	0.65	0.12	0.6	0.9	0.81

TABLE 4. Equilibrium bidding price of bidders during both stages under two different rules.

Valuation	Bidders									
	1	2	3	4	5	6	7	8	9	10
$b_{1i}(V_{1i})$	0.134	0.114	0.104	0.119	0.094	0.074	0.126	0.08	0.054	0.084
$b_{2i}(V_{2i})$	0.8	0.385	0.323	0.239	0.669	0.5	0.092	0.462	0.692	0.632
$b_{1i}^p(V_{1i}, p)$	0.374	0.339	0.284	0.299	0.244	0.164	0.336	0.2	0.114	0.219
$b_{2i}^p(V_{2i}, p)$	0.86	0.46	0.443	0.359	0.819	0.71	0.182	0.642	0.932	0.788

Notes. The equilibrium bidding price of bidders are derived from calculations of the formulas in Proposition 1 and Proposition 2, respectively.

The practical reasons for this phenomenon are as follows: The construction land quota is crucial for the development of real estate and other related land investment projects. Holding the construction land and not the quota prohibits developers to immediately undertake the development projects on the land, which amounts to a large penalty for delayed construction. On the one hand, a large penalty reduces the developers' valuation of urban land. On the other hand, it improves the valuation of the land quota. The higher the fee for delayed construction, that is, the greater the land value depreciation parameter, the higher are the fee and value saved by the construction land quota, thereby the quota price will increase.

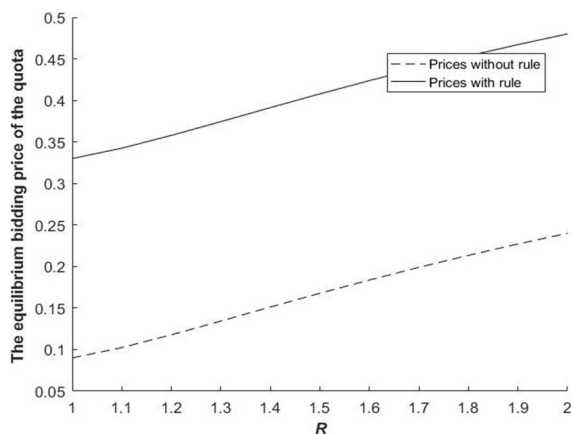
Figure 2b illustrates that the price of the construction land quota would increase with the increase in the price discount

limit. Because the rule of price discount can provide subsidies to the developers who obtain the quota and the land, the developers would inevitably improve their bidding price. Therefore, the price of the construction land quota would increase.

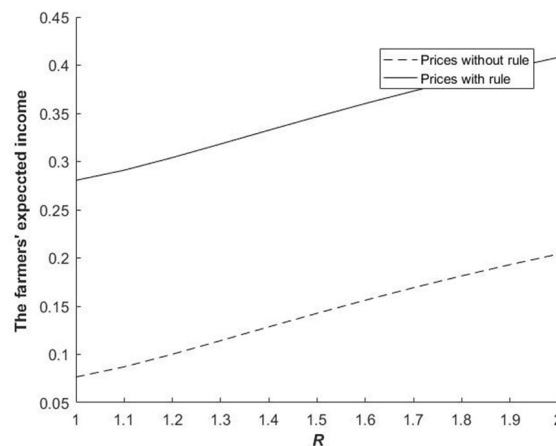
Figures 2a and 2b indicate that the price of the land quota under the rule of price discount is much higher than the price without the rule. Certainly, the rule of price discount enhances the price of land use quota and reveals the intrinsic value of the quota.

Figures 2a and 2b illustrate Propositions 3, 4, and 5.

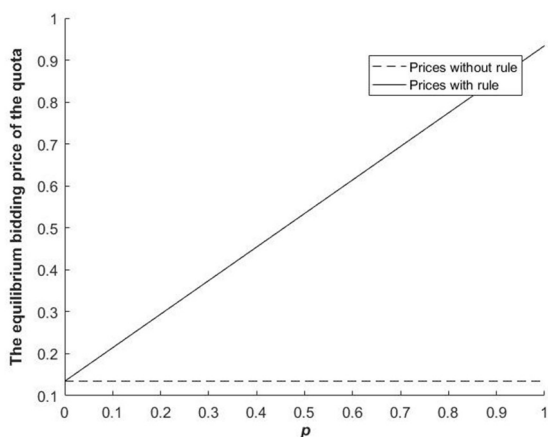
Figures 3c and 3d demonstrate that the land value depreciation parameter and the price discount limit affect farmers' expected income under the rule of price discount. Thus, the greater the land value depreciation parameter and the



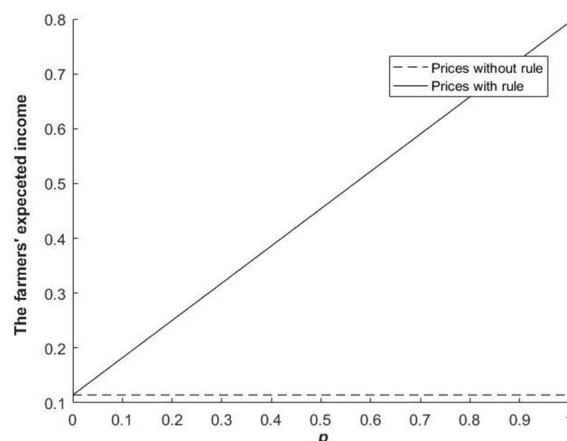
(a)



(c)



(b)



(d)

FIGURE 2. Effects of the main parameters on the price of the quota: (a) Effects of land value depreciation parameter on the bidding price of the quota; (b) Effects of the price discount limit on the bidding price of the quota.

price discount limit, the higher is the income of farmers. Figure 3 illustrates that the farmers' income is higher under the rule of price discount, indicating that the rule of price discount can effectively protect the farmers' expected income.

Figures 4e and 4f depict that the bidding price of the construction land under the rule of price discount is much higher than the price without the rule. The rule of price discount implies that the developers who obtain the quota and the land receive compensation to some extent. In other words, bidders are willing to pay more for the land according to the subsidies to increase the probability of acquiring the quota and the land. Therefore, the bidding price of the construction land under the rule is higher than the price without the rule.

Moreover, the land price of losers decreases with the increase in the land value depreciation parameter. This is because the government prohibits the developers without the quota to immediately undertake development projects on the land, thereby resulting in a high penalty amount for

FIGURE 3. Effects of the main parameters on the farmers' expected income: (c) Effects of the land value depreciation parameter on the farmers' expected income; (d) Effects of the price discount limit on the farmers' expected income.

delayed construction. The higher the fee for delayed construction, that is, the greater the land value depreciation parameter, the higher is the amount to be paid by losers in the second stage. Considering the fee for delayed construction, the losers will lower their bids for the construction land.

IV. DISCUSSION

The present study has three main findings. First, our improved two-stage sequential auction with complementarity is a reasonable and feasible approach to price the quota as the equilibrium bidding price. According to the Outline of the National Overall Land Use Plan (2006–2020), the central government emphasises that local governments can develop and utilise land only if they hold the construction land quota. Certainly, this outline clarifies the characteristics of complementarity between the quota and construction land. Moreover, this complementarity is the source of the intrinsic value of the construction land quota. In practice, the main function of the construction land quota is to enable the early

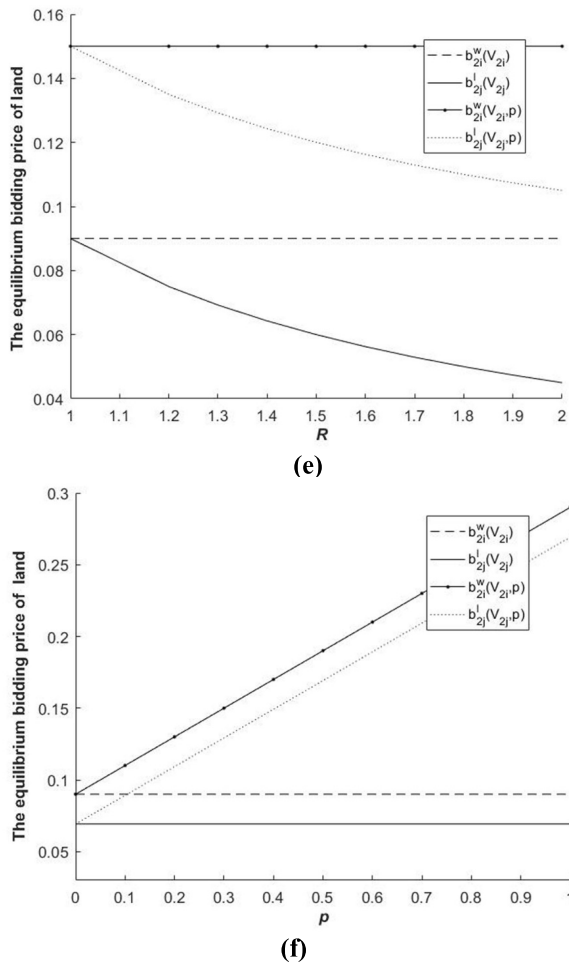


FIGURE 4. Effects of the main parameters on the bidding price of land: (e) Effects of the land value depreciation parameter on the bidding price of land; (f) Effects of the price discount limit on the bidding price of land.

implementation of projects on construction sites. Its intrinsic value is the time gain of developers who can develop their projects immediately after acquiring the construction land. However, in the current construction land quota pricing mechanism, the government still uses the cost plus pricing method to trade the quota. Arguably, the current reclamation cost-based pricing (adopted by Chongqing, Nanjing, and Guangzhou) is unreasonable and fails to motivate farmers [15].

Second, the price of the construction land quota increases with the increase in the land devaluation coefficient. The conclusions reached by Jeitschko and Wolfstetter [36] and Brendstrup [37] indirectly corroborate the conclusions of the present study. In practice, R is positively correlated with the fee for delayed construction by developers. The higher the penalty amount, the higher is the cost savings of the quota, which implies that the intrinsic value and price of the quota increase with R . In addition, the construction land quota offer decreases with an increase in n . This result is indirectly supported by Leufkens *et al.* [35].

The political implication of this finding is that the government should increase the fine for developers who delay construction or lower the number of bidders (i.e. increase developer qualification audits) to increase their bid prices for quota and farmers' incomes.

Finally, the rule of price discount enhances the price of construction land quota and increases farmers' earnings. This finding is highly consistent with those of Xie [38]. In practice, the rule of price discount for quota adopted by Chongqing reflects the functional role of quota, which further expands the intrinsic value of quota. Therefore, developers are willing to pay a large amount. The government should adopt the rule of price discount to increase the price of the land quota and motivate farmers to withdraw from overoccupied and unused residential bases, thereby promoting the intensive and economical use of rural land.

Overall, we used the specific trading rules of Chongqing and other pilot areas as the basis of our investigation to design a reasonable and effective pricing and trading mechanism for the construction land quota and construction land. Thus, our model and conclusions can be applied to constrained land resource allocation and use. Moreover, our model can serve as a reference for the national construction land quota trading mechanism in future.

V. CONCLUSION

Based on the complementarity characteristics of the construction land quota and construction land, this study proposes an improved two-stage sequential auction of complements for pricing the construction land quota by considering the rule of price discount. Through theoretical and numerical analyses, the results reveal that the rule of price discount enhances the bidding price of the land use quota and the construction land. The higher the price discount, the greater is the bidding prices of the quota and land. Meanwhile, the rule of price discount increases the farmers' income, which increases with the increase in the price discount limit. In addition, the bidding price of quota and the expected income of farmers decrease with an increase in the number of bidders and increase with an increase in the penalty amount for delayed construction.

The policy implications can be summarised as follows: The governments should increase the fee for delayed construction and ensure the strict implementation of provisions of the 'land management law', 'urban real estate management law', and other regulations on the construction land that has not been developed for two consecutive years and could be recycled free of charge. On the one hand, this measure would improve the efficiency of land use. On the other hand, the measure would effectively improve the bidding price of the construction land quota, thereby increasing the reclamation income and enthusiasm of farmers. With regard to the trading programme design, the government should implement the rule of price discount and enhance the qualification requirements of bidders. This approach would improve the quota price

and encourage farmers to voluntarily withdraw from their idle homesteads more actively to revitalise the idle rural construction land.

REFERENCES

- [1] W. Zhang, W. Wang, X. Li, and F. Ye, "Economic development and farmland protection: An assessment of rewarded land conversion quotas trading in Zhejiang, China," *Land Use Policy*, vol. 38, pp. 467–476, May 2014.
- [2] H. Wang, R. Tao, L. Wang, and F. Su, "Farmland preservation and land development rights trading in Zhejiang, China," *Habitat Int.*, vol. 34, no. 4, pp. 454–463, Oct. 2010.
- [3] Y. Li, Y. Li, H. Westlund, and Y. Liu, "Urban–rural transformation in relation to cultivated land conversion in China: Implications for optimizing land use and balanced regional development," *Land Use Policy*, vol. 47, pp. 218–224, Sep. 2015.
- [4] Q. Zhao and Z. Zhang, "Does China's 'increasing versus decreasing balance' land-restructuring policy restructure rural life? Evidence from Dongfang Village, Shaanxi Province," *Land Use Policy*, vol. 68, pp. 649–659, Nov. 2017.
- [5] L. Tian, "Land use dynamics driven by rural industrialization and land finance in the peri-urban areas of China: 'The examples of Jiangyin and Shunde,'" *Land Use Policy*, vol. 45, pp. 117–127, May 2015.
- [6] Y. Liu, F. Fang, and Y. Li, "Key issues of land use in China and implications for policy making," *Land Use Policy*, vol. 40, pp. 6–12, Sep. 2014.
- [7] S.-S. Chien, "Local farmland loss and preservation in China—A perspective of quota territorialization," *Land Use Policy*, vol. 49, pp. 65–74, Dec. 2015.
- [8] Y. Cao, X. Zhang, X. Zhang, and H. Li, "The incremental construction land differentiated management framework: The perspective of land quota trading in China," *Land Use Policy*, vol. 96, Jul. 2020, Art. no. 104675.
- [9] P. Zhang and Q. Wang, "The analysis of intrinsic value and pricing model of Dipiao transaction takes Chongqing as an example," *Rural Econ.*, vol. 35, no. 5, pp. 39–45, 2017.
- [10] Y. M. Ye, B. Qi, and L. Yu, "The sluggish development in rural China from the perspective of land management: A comparative analysis between China and the U.K.," *Chin. Rural Econ.*, vol. 34, no. 3, pp. 123–137, 2018.
- [11] L. Fang and C. Tian, "Construction land quotas as a tool for managing urban expansion," *Landscape Urban Planning*, vol. 195, Mar. 2020, Art. no. 103727.
- [12] S. S. Han and W. Q. Lin, "Transforming rural housing land to farmland in Chongqing, China: The land coupon approach and farmers' complaints," *Land Use Policy*, vol. 83, no. 4, pp. 370–378, 2019.
- [13] J. Wang, Y. Li, Q. Wang, and K. C. Cheong, "Urban–rural construction land replacement for more sustainable land use and regional development in China: Policies and practices," *Policies Practices. Land*, vol. 8, no. 11, pp. 171–189, 2018.
- [14] C. Chen, L. Yu, and C. L. Choguill, "'Dipiao', Chinese approach to transfer of land development rights: The experiences of Chongqing," *Land Use Policy*, vol. 99, Dec. 2020, Art. no. 104870.
- [15] B. Wang, F. Li, S. Feng, and T. Shen, "Transfer of development rights, farmland preservation, and economic growth: A case study of Chongqing's land quotas trading program," *Land Use Policy*, vol. 95, Jun. 2020, Art. no. 104611.
- [16] Y. B. Feng, Q. Y. Yang, W. D. Mu, and Y. Liu, "Analysis on the innovation of the land ticket transaction policy and its replications in Chongqing," *Reform Econ. Syst.*, vol. 34, no. 6, pp. 193–196, 2016.
- [17] M. D. Ma, W. Xiaoyan, and M.A. Zhili, "Analysis of pricing mechanism and influence factors of land tickets," *World Sci-Tech R & D*, vol. 36, no. 2, pp. 453–457, 2014.
- [18] Z. Z. Zhang, "An analysis on the Chengdu's 'land ticket' trade price," *Res. Econ. Manag.*, vol. 32, no. 7, pp. 84–90, 2012.
- [19] L. H. Hao and D. Q. Du, "Discussion on formation mechanism of Dipiao price," *Price, Theory Pract.*, vol. 33, no. 7, pp. 42–43, 2011.
- [20] W. D. Meng and H. Xiong, "The issue research on land ticket price and income distribution based on game theory in Chongqing," *Ecol. Econ.*, vol. 31, no. 4, pp. 20–23, 2015.
- [21] F. Sun, C. G. Zheng, D. L. Niu, and Y. Q. Wu, "Thoughts about opening secondary market of land coupon trading," *Acta Agric. Jiangxi*, vol. 25, no. 3, pp. 156–158, 2013.
- [22] K. Leufkens and R. Peeters, "Synergies are a reason to prefer first-price auctions," *Econ. Lett.*, vol. 97, no. 1, pp. 64–69, 2007.
- [23] J. W. Boudreau and N. Shunda, "Sequential auctions with budget constraints: Evidence from fantasy basketball auction drafts," *J. Behav. Exp. Econ.*, vol. 62, pp. 8–22, Jun. 2016.
- [24] Y. Kong, "Sequential auctions with synergy and affiliation across auctions," *J. Political Economy*, vol. 129, no. 1, pp. 148–181, Jan. 2021.
- [25] Y. Li and J. S. Shonkwiler, "Assessing the role of ordering in sequential English auctions—Evidence from the online western video market auction," *Amer. J. Agricult. Econ.*, vol. 103, no. 1, pp. 90–105, Jan. 2021.
- [26] D. G. De Silva, T. D. Jeitschko, and G. Kosmopoulou, "Stochastic synergies in sequential auctions," *Int. J. Ind. Org.*, vol. 23, nos. 3–4, pp. 183–201, Apr. 2005.
- [27] F. Branco, "Sequential auctions with synergies: An example," *Econ. Lett.*, vol. 54, no. 2, pp. 159–163, Feb. 1997.
- [28] R. Liu, "Discussion about improvement of land ticket trade system in overall plans for urban and rural areas," *J. Northwest A&F Univ. Soc. Sci. Ed.*, vol. 16, no. 5, pp. 49–55, 2016.
- [29] Z. L. Wang, Q. Y. Yang, and N. Wang, "A study of the protection of farmers' homestead exit revenue in Chongqing: Basing on comparative revenue," *China Land Sci.*, vol. 30, no. 8, pp. 47–55, 2016.
- [30] L. W. Xie, "Comparison of Chengdu-Chongqing Dipiao trading system and price formation mechanism," *Price, Theory Pract.*, vol. 31, no. 8, pp. 43–44, 2011.
- [31] H. X. Wang, J. L. Shao, and W. J. Zhang, "Vacant land governance in China from the perspective of policy instrument-based on the analysis of 192 policy texts (1992–2015)," *Chin. Public Adm.*, vol. 31, no. 3, pp. 108–112, 2017.
- [32] S. H. Wang, "Study on the transaction of Dipiao in Chongqing," *J. Southwest Univ. Natl. Hum. Soc. Sci.*, vol. 35, no. 2, pp. 134–138, 2013.
- [33] X. Xie, "Micro-mechanism analysis of urban and rural land transfer under indicator control—A case study of Chengdu-Chongqing Dipiao practice," *Chin. Rural Econ.*, vol. 36, no. 12, pp. 17–31, 2012.
- [34] J. Liu, W. Meng, Y. Li, and B. Huang, "An improved sequential auction with complementarity for pricing the construction land quota," *PLoS ONE*, vol. 15, no. 10, Oct. 2020, Art. no. e0241397.
- [35] K. Leufkens, R. Peeters, and D. Vermeulen, "Sequential auctions with synergies: The paradox of positive synergies," *Econ. Lett.*, vol. 109, no. 3, pp. 139–141, Dec. 2010.
- [36] T. D. Jeitschko and E. Wolfstetter, "Scale economies and the dynamics of recurring auctions," *Econ. Inq.*, vol. 40, no. 3, pp. 403–414, 2002.
- [37] B. Brendstrup, "A simple nonparametric test for synergies in multi-object sequential English auctions," *Econ. Lett.*, vol. 93, no. 3, pp. 443–449, Dec. 2006.
- [38] L. W. Xie, "Comparison of Dipiao trading system and price formation mechanism between Chengdu and Chongqing," *Price Theor. Pract.*, vol. 31, no. 11, 43–44, 2011.



JINGYU LIU was born in Chengdu, China, in 1991. He received the B.S. and M.S. degrees from Sichuan Agricultural University, in 2014 and 2017, respectively, and the Ph.D. degree from Chongqing University, in 2020. He is currently a Lecturer with the School of Economics and Management, Chongqing Normal University, China.

He is also mainly engaged in teaching and research in the fields of strategic management and financial engineering. He had mainly worked in the field of strategic management includes regional cooperation strategic research and research on incentive mechanism of research and development alliance.



WEIDONG MENG was born in Chongqing, China, in 1964. He received the B.S., M.S., and Ph.D. degrees from Shanghai Jiao Tong University, China.

He is currently the Vice President with Chongqing University, where he is an Associate Professor and a Doctoral Supervisor with the School of Economics and Business Administration. He is also mainly engaged in teaching and research in the fields of strategic management

and financial engineering. He had mainly worked in the field of strategic management includes regional cooperation strategic research and research on incentive mechanism of research and development alliance. He has published more than 210 academic papers in academic journals and international academic conferences, and four monographs and textbooks.

Prof. Meng was a member of the Teaching Steering Committee for E-commerce major in colleges and universities, Ministry of Education, from 2006 to 2010. He is also the Director of the Center for Chinese Enterprise Reform and Development, Chongqing University; the Deputy Director of the Institute of Securities, Chongqing University; the Director of the National Society of System Dynamics; the Vice President of Chongqing Society of Quantitative Economics; and the Director of Chongqing Society of Technological Economy and Management Modernization. He was the Editorial Board Member of *Reform, Review of Chinese and Foreign Management Accounting Research—Based on Management Accounting Research Topics and Research Methods*, and *Journal of Chongqing University*.



YUYU LI received the Ph.D. degree in management science and engineering.

She was a Visiting Professor with the University of Pittsburgh, in 2017. She is currently an Associate Professor with the School of Economics and Management, Chongqing Normal University, China. She also focuses her research efforts on supply chain management and innovation management. She has published articles in various international journals, such as *Applied Energy*,

International Journal of Environmental Research and Public Health, *Journal of Applied Mathematics*, and others. She had successfully managed various national and local sponsored research projects and grants.



BO HUANG was born in Chongqing, China, in 1972. He received the B.S. degree in applied mechanics and engineering from Zhongshan University, in 1995, and the M.S. and Ph.D. degrees from Chongqing University, in 2006 and 2009, respectively.

He is currently an Associate Professor and a Doctoral Supervisor with the School of Economics and Business Administration, Chongqing University. He is also mainly engaged in strategic management, supply chain management, mechanism design, and other fields.

As the person in charge, he had undertaken various project funds, such as the National Social Science Fund Project and the Humanities and Social Sciences Project, Ministry of Education. He had published more than 50 academic papers in international journals and conferences, such as *International Journal of Environmental Research and Public Health* (SSCI), *Journal of Applied Mathematics* (SCI), *Journal of Management Sciences*, and *Chinese Journal of Management Science*. He has published three monographs and two textbooks. He received one provincial or ministerial award. He also serves as a Reviewer for the *International Journal of Production Research*, *Journal of Management Sciences*, and other journals.

...