Mechanism for Trading Shoreline Usage Rights Based on an Improved Bilateral Call Auction Model

Jianhua Xiao[1,a], Kaijun Hu[1,b*]

jianhuaxiao1@126.com[a], 965945007@qq.com[b]
Corresponding author. Email:965945007@qq.com[*]

School of Economics and Management, Wuyi University,Jiangmen, China[1]

Abstract. In response to the current supply-demand imbalance of shoreline resources, the market-oriented approach of shoreline resource trading can effectively improve the utilization and allocation efficiency of shoreline resources, promote the overall development of regional marine economy, and ultimately achieve the integration of marine economy. Starting from auction theory, this article explores the mechanism of shoreline resource auction prices, and uses an improved bilateral call auction model considering the cost and transaction volume of shoreline transactions, combined with numerical examples to illustrate the practical application of the model. The results indicate that the improved bilateral call auction model's trading mechanism and price determination rules are reasonable and effective, and have certain practical guiding significance for shoreline resource trading.

Keywords:shoreline usage rights, improved bilateral auction model, trading mechanism

1 Introduction

The coastline has unique geographical, morphological, and dynamic characteristics, and is the junction between the land and the ocean. It has important ecological functions and resource values [1]. The ocean is the most important logistics carrier for human beings from ancient times to the present. The logistics dominated by internal water navigation to the era of great navigation, and then to the era of the global ocean economy nowadays, the economic centers of coastal countries gradually shift to coastal areas. 80% of the global population lives in coastal areas, and more than half of the population lives within 100 km of the coastline [2]. The coastal zone has become the most active and concentrated area of the human economy. The high-intensity development and utilization of coastline and near-shore waters have also led to dramatic changes in the coastline with natural resources shrinking and the ecological functions of the coastline damaged to some extent.

The 13th Five-Year Plan for National Economic and Social Development of the People's Republic of China adopted at the fourth session of the 12th National People's Congress in 2016 stated that it is necessary to "build a scientific and reasonable pattern of natural shorelines", "carry out political actions for the Blue Bay", and "strengthen the protection and restoration of the coastal zone, the natural shoreline retention rate of not less than 35%". 2017 State Oceanic Administration issued the "Coastline Protection and Utilization Management Measures" proposing to strictly protect the natural shoreline and rectify and repair damaged shorelines. Shore-

ICBBEM 2023, May 19-21, Hangzhou, People's Republic of China

DOI 10.4108/eai.19-5-2023.2334247

lines with natural coastal morphological characteristics and ecological functions after rectification and repair require management and control to build a scientific and reasonable development. To sum up, strengthening shoreline protection and utilization management has become a key issue that needs to be solved in the context of a strong ocean country.

To implement the natural shoreline retention rate control system, Guangdong, Zhejiang, and other coastal provinces proposed a coastline occupancy balance mechanism [3,4]. Among them, Guangdong Province proposed the shoreline indicators to occupy the complementary way. In 2015, the State Oceanic Administration issued the "State Oceanic Administration Marine Ecological Civilization Construction Implementation Plan" to point out the need to highlight the market-oriented allocation, refine management, and use marine resources. In Guangdong Province, for example, the natural shoreline retention rate is 35.15%, which meets the minimum national requirements. However, in the 14 coastal cities, the retention rate of natural shorelines varies greatly. In the seven coastal municipalities of the "Pearl River Delta", the core area of the Guangdong-Hong Kong-Macao Bay Area, the natural shoreline retention rate is 32%, which is 3% below the national minimum requirement. The unit shoreline output of the seven coastal cities in the PRD also varies greatly with Guangzhou City's average gross marine product per unit of shoreline from 2011 to 2019 being 1.655 billion yuan and Jiangmen City's lowest being only 198 million yuan. Thus, it is necessary to establish a shoreline trading mechanism, promote the efficient allocation of shoreline resources in the region, and strengthen the management of shoreline utilization. Then, "cities with high shoreline utilization efficiency can have more shoreline utilization indicators, and cities with high natural shoreline retention rate can receive appropriate ecological compensation", as stated by the "Beneficiary Pays Principle" (BPP) and the "Protector Gets Principle" (PGP) [5].

At present, scholars focus on shoreline extraction, shoreline change, and shoreline ecological environment [1,6−8]. However, research on shoreline trading mechanisms still lacks. Therefore, we propose a shoreline trading mechanism based on an improved bilateral auction model based on scholars' research results related to water and sewage rights trading.

2 Improved Bilateral Call Auction Model

From the perspective of resource allocation efficiency, the introduction of market bidding into shoreline usage rights can provide signals for tradable usage rights indicators in the market. At the same time, it reduces transaction costs and improves transaction efficiency. Secondly, as a higher valuation of bidders is more likely to win the rights, the allocation efficiency of shoreline usage rights can improve. Finally, competitive bidding implies equal opportunities to avoid the emergence of market monopoly.

From a macroeconomic perspective, market bidding reflects the principles of fairness, impartiality, and openness. At the same time, market bidding makes the transaction price of the rights more reasonable, which is conducive to increasing the willingness of government departments to take the initiative to manage the natural shoreline actively and effectively. Therefore, it is important to introduce the auction bidding method in the process of forming the price of the rights.

In the shoreline rights transaction, both buyers and sellers are a majority, i.e. "multiple parties to multiple parties". The transaction mechanism is controlled by the seller, and this bilateral auction model is active. According to the characteristics, it is necessary to introduce a bilateral auction model for shoreline rights trading [9−11]. This is a bilateral auction model.

2.1 Determination of auction price

According to auction theory, lots are divided into private and public value auctions according to their value characteristics [12]. The value of a lot in a private auction depends entirely on the ranking of the value of the bidders, while the value information in a public auction is based on official valuations.

As an auction item with high value, poor substitutability, and rigid supply, value changes according to circumstances. The value increases with opportunity cost according to the local development willingness, development capacity, and investment intensity. The value of shoreline usage rights is not a single fixed value but an associated value [13]. Its value consists of two parts: the private value determined by the preferences of each bidder based on private information on the efficiency of local shoreline use, shoreline development options, available capital, and economic benefits, and the public value depending on the value of the ecosystem services of the shoreline [14]. The expected market value is determined by factors such as the cost of shoreline management, market supply, and demand conditions. Thus, when evaluating the value of the shoreline access index, bidders need to consider the value of the shoreline access for their use and the expected market value.

To accurately reflect the index value of the valuation of the shoreline usage rights, we introduce valuation parameters ρ_p $(0 \leq \rho_p \leq 1)$. When $\rho_p = 0$, the type of bidder's value for the shoreline usage rights index is the common value type. That is, the expected future value is determined only based on market information. When $\rho_p = 1$, the bidder's valuation is a private type. The private value is determined based on the shoreline use efficiency, development plan, capital strength, and others. When $0 \leq \rho_p \leq 1$, the bidder's valuation is comprehensive considering the public information of the market and private information.

The following assumptions are made in developing the shoreline access rights indicator valuation model.

(1) Bidders are risk neutral and each bidder i through his or her offer b_i maximizes the expected profit.

(2) c_i indicates that the bidder i's valuation of the shoreline indicator for the bid is based on private information.

(3) u indicates the bidder's valuation of the shoreline indicator to be auctioned based on public market information.

(4) v_i indicates that the bidder i's valuation of the shoreline index is based on private information and public market information, which takes the value space of $[\rho_p c_i + (1-\rho_p)u\,, \rho_p c_h + (1-\rho_p)u]$ and c_l, c_h represents the minimum and maximum estimates of all bidders, respectively.

(5) The bidder pays the same as the offer, and the payment is a function of the offer.

(6) There is symmetry between bidders.

(7) Non-cooperative assumptions of bidders.

Based on the above assumptions, the bidder's valuation function for the value of the shoreline usage rights indicator can be obtained as

$$\mathrm{v}_i = \rho_p \times c_{\mathrm{i}} + (1-\rho_p) \times u \tag{1}$$

2.2 Basic assumptions and model construction

In a transaction of shoreline access indicators, buyers and sellers are risk-neutral rational economic agents, and the transaction is conducted under incomplete information conditions. Suppose that during the period t, the trading market has $m\ (i = 1,2,3,\cdots,m)$, there are bidders $n(j = 1,2,3,\cdots,n)$, two sellers, B for the buyer, and S for the seller. The price and volume of the first trader are b_i, x_i . The price and volume of the first trader of the seller are s_j， and y_j . The buyer's expected return on the shoreline access index is valued at v_i. The seller's input for restoring and maintaining the shoreline through certain ecological functions and the opportunity cost of abandoning the development of the shoreline is valued asd_j. Therefore, the buyer's gain is $W_i(v_i) = x_i \times (v_i - b_i)$ and the seller's gain is $U_j(d_j) = y_j \times (s_j - d_j)$. For trading shoreline indicators, the buyer and the seller are multiple participants, and the transaction organizer has to consider the principle of fairness while seeking to maximize the welfare of all parties. That is, they do not favor the interests of other party. In summary, the auction problem is transformed into an optimization problem that solves the following objective function.

$$\max \sum_{i=1}^{m} \sum_{j=1}^{n} \left\{ E\left[W_i\left(v_i\right)\right] + E\left[U_j\left(d_j\right)\right] \right\} \tag{2}$$

$$\max \sum_{i=1}^{m} E\left[W_i\left(v_i\right)\right] \tag{3}$$

$$\max \sum_{j=1}^{n} E\left[U_j\left(d_j\right)\right] \tag{4}$$

The constraints are as follows.

$$Q_T = \min \left\{ \sum_{i=1}^{M} x_i, \sum_{j=1}^{N} y_j \right\} \tag{5}$$

$$W_i\left(v_i\right) = x_i \times \left(v_i - b_i\right) \geq 0 \tag{6}$$

$$U_j\left(d_j\right) = y_j \times \left(s_j - d_j\right) \geq 0 \tag{7}$$

whereQ_T represents the volume of shoreline access indicators traded in the market during the trading period, and the M， N denotes the number of buyers and sellers who successfully entered the trading bid, respectively.

2.3 Trading Mechanism of Bilateral Call Auctions

Set of transactions.

Both buyers and sellers make quotations within a specified period before the transaction, determine the volume and price of the transaction, and arrange the buyers' quotations in order from highest to lowest and the sellers' quotations in order from lowest to highest according to the "high-low matching" principle to form a set of quotations.

$$B=\{b_1,b_2,...,b_M,...,b_m\};S=\{s_1,s_2,...,s_N,...,s_n\} \tag{8}$$

Among them $b_1 \geq b_2 \geq \cdots \geq b_M \geq \cdots \geq b_m$, $s_1 \leq s_2 \leq \cdots \leq s_N \leq \cdots \leq s_n$.

Assume that $s_N \leq b_M < s_{N+1}$, $b_{M+1} < s_N \leq b_M$, then the top M buyers and the top N sellers of the buyer's offer in the sort enter the transaction set. At this point, the transaction sets are $B^*=\{b_1,b_2,\cdots,b_M\}$; $S^*=\{s_1,s_2,\cdots,s_N\}$. The supply and demand between the two parties in the transaction set are not always equal, so even if they enter the transaction set, the buyers and sellers may not be able to reach a deal.

Transaction matching mechanism.

After determining the transaction set, the buyer selects the transaction objects in order of the higher and lower quotations, i.e., the buyer with higher quotations has a higher priority. Within the specified time, the buyer selects the most suitable seller for the transaction based on their demand, the seller's offer and supply, and the transaction cost of both parties.

After a transaction ends, the buyer of the next priority level trades. If there is still a surplus after a seller's transaction in the previous round, the transaction continues. The trading process is cyclical according to the above principles until the supply or demand of shoreline usage rights indicators is 0 when the transaction is terminated.

Market equilibrium trading price.

To increase the enthusiasm of both sides of the transaction, promote the real quotations of buyers and sellers, and realize the fairness of the procedure, the average value of the quotations of both sides is selected as the final transaction price.

$$\mathrm{P}_h=\frac{b_h+s_h}{2} \tag{9}$$

where h represents the first h transaction, and b_h, s_h is the first h buyer's and seller's quotes in a transaction. For the case of a buyer dealing with multiple sellers, the seller's offer is the average of all seller's offers.

3 Simulation of Algorithms

According to Yan [15] and other scholars, the average value of natural shoreline resources in Dalian is 2990.19 RMB/km-yr, and this value is taken as the seller's reservation price of the shoreline usage rights. Based on the above information, the offers of buyers and sellers are simulated using Matlab in combination with the formulas in the previous paper.

Assume that eight participants, four buyers and four sellers are in the shoreline usage rights trading market at a certain point in time, and both parties make offers. The quotations and transaction volume of both parties are shown in Table 1.

Table 1. Buyer and seller quotes and transaction volume

Buyer	Quotation b_i/[million yuan/(km-yr)]	Trading volume x_i/km	Sellers	Quotation s_j/[million yuan/(km-yr)]	Trading volume y_i/km
b_1	320	20	s_1	310	15
b_2	380	25	s_2	300	20
b_3	350	35	s_3	375	30
b_4	400	20	s_4	350	25

According to the rules of the trading mechanism, the quotations of buyers and sellers are ranked in the order of "high to low" and "low to high", and the sets of buyers and sellers entering the trading set are determined as $B^* = \{b_4, b_2, b_3\}$; $S^* = \{s_2, s_1, s_4\}$.

The transaction costs per unit of shoreline access rights index for buyers and sellers entering the trading are shown in Table 2.

Table 2. Unit transaction costs for each buyer and each seller

Buyer	Sellers		
	s_2	s_1	s_4
b_4	5	3	4
b_2	3	6	5
b_3	4	3	3

Unit: RMB/(km-yr)

According to the deal-matching mechanism, the buyer b_4 first selects the counterpart of the transaction. Based on the quotes of the 3 sellers in the transaction set and the corresponding transaction costs, the buyer b_4 selects s_2. The cost of trading each kilometer of coastline usage rights index is 3.0 + 5 = 3.05 million yuan/km-yr, and the cost of trading is s_1, s_4 The cost required to trade each kilometer of the coastline usage rights index is 3.13 million and 3.54 million yuan/km-yr. The seller s_2 of the transaction meets the buyer b_4 's demand. Therefore,

the b_4 chooses to enter into a transaction with s_2 to carry out the transaction. According to the market equilibrium transaction price formula, the transaction price per unit of shoreline usage rights index in this round is $P_1 = (400 + 305)/2 = 352.5$ million yuan/(km-yr).

Similarly, based on each remaining seller's offer, transaction costs, and the number of transactions, the buyer b_2 determines the number of transactions with s_1 trading 15 km and with s_4. At this point, the seller's offer is the average price of all sellers involved in the transaction, i.e. $(316 \times 15 + 355 \times 10)/25 = 331.6$ million yuan/km-yr. The final transaction price is $P_2 = (380 + 331.6)/2 = 355.8$. The final transaction price is 10,000 yuan/km-yr. Buyer b_3 and seller s_4 trade the remaining 10 km at a final transaction price of $P_3 = (350 + 355)/2 = 352.5$ million yuan/km-yr.

In the above three transactions, although the buyer with the highest offer enters the market first, its final transaction price does not have an advantage over the other two buyers. For buyers who enter the transaction last (b3) and the first buyer (b4), the last buyer has the same price as the first buyer. This shows that the strategy of truthful offer maximizes the utility gain, and the trading mechanism and the rules of price determination are reasonable and feasible.

4 Conclusion

The trading of shoreline usage rights index is an important means to realize the optimal allocation of regional shoreline resources, which is significant to promote the overall development of regional marine economy and realize the integrated pattern of marine economy. Based on the summary of shoreline-related research and auction theory, a value assessment model is established for shoreline resources based on the characteristics of shoreline resources. A simple arithmetic example is examined through an improved bilateral call auction model with reasonable and feasible results. The model provides a reference for the subsequent establishment of a shoreline resources trading market.

Acknowledgment: This research was supported by the Humanities and Social Sciences Research Planning Fund of the Ministry of Education (Research on dynamic pricing and trading mechanism of coastline resources in Guangdong-Hong Kong-Macao Greater Bay Area under the background of marine ecological civilization construction, Project No. 21YJA630097)

Guangdong Philosophy and Social Science Planning Project (Research on the trading mechanism of coastline resources in Guangdong - Hong Kong - Macao Greater Bay Area from the perspective of marine ecological civilization construction, Project No. GD20XGL14)

References

[1] T.Wu,X.Y,Hou.(2016) Review of research on coastline changes. Acta Ecologica Sinica,36:1170-1182. https://doi.org/10.5846/stxb201406181270.

[2] Primavera,J.H.(2006) Overcoming the impacts of aquaculture on the coastal zone. Ocean & Coastal Management,49:531-545. https://doi.org/10.1016/j.ocecoaman.2006.06.018.

[3] Zhou,J.Zhang,Y.F.Qu,L.J,Wang,Y.S.(2020) Discussion of coastline requisition-compensation balance system. Marine Environmental Science,39:230-235. https://doi.org/10.13634/j.cnki.mes.2020.02.010.

[4] Cai,X.J.Bai,L.Yang,X.(2022) Thoughts on the practice of coastline "Requisition-Compensation Balance". Natural Resources Information,8-12.https://gtzq.cbpt.cnki.net/WKG/WebPublication/paperDigest.aspx?paperID=466ab272-4a89-4beb-873a-2c8b9d6340a3

[5] Qin,Y.H.Kang,M.Y.(2007) A Review of Ecological Compensation and Its Improvement Measures. Journal of Natural Resources,22:557-567. https://doi.org/10.3321/j.issn:1000-3037.2007.04.007.

[6] Zhang,X.H.Wu,L.L,Huang,H.M.(2021) Achievements, problems and countermeasures of coastline renovation and restoration in guangdong province. Transactions of Oceanology and Limnology,43:140-146. https://doi.org/10.13984/j.cnki.cn37-1141.2021.04.020.

[7] Liu,L.Wang,H.J.Yue,Q.(2020) Current situation and management countermeasures of coastline protection and utilization in China. Marine Environmental Science,39:723-731. https://doi.org/10.13634/j.cnki.mes.2020.05.010.

[8] Wang,H.J.Yuan,G.J.Liu,L.Lin,N.(2021) Study on the classification and delineation of coastline. Marine Environmental Science,40:430-434. https://doi.org/10.13634/j.cnki.mes.2021.03.014

[9] Li,C.J.Wang,X.J.Fan,W.T.Zheng,X.R.(2006)Double auction Bayesian model and design of mechanism in water rights market. Resources and Environment in the Yangtze Basin,15:465-469. http://yangtzebasin.whlib.ac.cn/CN/Y2006/V15/I4/465.

[10] Chen,W.Y.Cao,S.L.(2010) Application of improved bilateral bidding auction model in water rights trading. China Rural Water Conservancy and Hydropower, 123-125. http://www.irrigate.com.cn/CN/Y2010/V0/I3/123.

[11] Tian,G.L.Liu,J.N.Wei,B.(2020)Pricing of Water Pollution Rights under Improved Bilateral Auction Model and Simulation in Taihu Lake. Ecological Economy,36:172-177. http://www.shengtaijj.cn/index.php?m=content&c=index&a=show&catid=122&id=4362.

[12] Klemperer,P.(1998) Auctions with almost common values: The `Wallet Game' and its applications. European Economic Review,42:757-769. https://doi.org/10.1016/s0014-2921(97)00123-2.

[13] Zhao,R. (2013)Study on Urban Land Granting Mode in China Based on Auction Theory. Xi'an University of Architecture and Technology. https://kns.cnki.net/kcms/detail/detail.aspx?dbname=CDFD2015&filename=1014011005.nh&dbcode=CDFD.

[14] Hu,P.Yang,L.J. (2019)Preliminary Study on the Evaluation Method of Coastline Ecological Value. Price:Theory & Practice,133-136. https://doi.org/10.19851/j.cnki.cn11-1010/f.2019.10.03.

[15] Yan,J.S.Wang,P.Hao,Y.N,Zhang,P.Zhao,B.Huang,J.(2022)Natural Shoreline Resource Accounting Based on Natural Resource Value Theory:A Case Study of Dalian City,Liaoning Province. Areal Research and Development,41:156-160. https://doi.org/10.3969/j.issn.1003-2363.2022.03.027.