A pricing model for water rights trading between agricultural and industrial water users in China

Wenge Zhang, Haochun Mao, Huijuan Yin and Xinwei Guo

ABSTRACT

This paper presents a pricing model developed for the Chinese water rights trading market. The model focuses on the transfer of water rights from irrigators to industrial users in areas with limited water resources. Water rights trading is an efficient means of allocating water resources, and the price plays an important role in this market. At present, China lacks formal mechanisms for water rights pricing. Therefore, an integrated pricing model is built for situations when agricultural users implement water conservation measures and sell water rights to meet industrial water demand. The model accounts for project construction costs, operation and maintenance costs, renewal and reconstruction expenses, irrigation frequency compensation, and the economic cost of ecological damage. The marginal value of water rights to the industrial water user is also quantified on the basis of the production function accounting for water inputs. The pricing model is applied to an example of water rights trading between irrigators and industrial users in an agricultural area on the Yellow River near Ordos in Inner Mongolia.

Key words | pricing, water conservation, water resources, water rights trading, water shortage

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INTRODUCTION

Population growth, urbanization, and economic development result in increasing demand for water resources. In northern China, as in other arid, semi-arid, and water-scarce regions of the world, limited water resources can become a major impediment to growth. The establishment of tradable water rights has been proved to be a cost-effective means of managing limited water resources and water shortages in many countries over the past few decades (Debaere *et al.* 2014; Bitran *et al.* 2014; Moore 2015; Jia *et al.* 2016; Dou & Wang 2017), and many water rights trading schemes have been established worldwide (Grafton *et al.* 2012; Kahil *et al.* 2015). In South Australia, for example, water rights trading has been used successfully to resolve water shortage problems (McKane & Franssen 2013). In some developing countries with water scarcity problems, such as South Africa and Tunisia, water rights trading has resulted in significant water conservation (Speelman *et al.* 2011). In the Inner Mongolian city of Ordos (a test case in the present study), water rights made available by agricultural water conservation measures are traded with industrial users to address water shortage problems (Yuan *et al.* 2007).

Most current studies of water rights trading have focused on efficiency and the benefits of water rights trading (Abdelaziz & Frank 2010; Wildman & Forde 2012; Erfani *et al.* 2015; Lukasiewicz & Dare 2016). For example, Bekchanov *et al.* (2015) analyzed the difference between inter-catchment and intra-catchment water rights trading, based on the integrated hydro-economic river basin management model. Sun *et al.* (2017) constructed the interval optimization model considering the terrestrial ecological impacts for water rights transfer. Wang *et al.* (2017) analyzed the relationship

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between agricultural water rights trading and virtual water export compensation.

In water rights trading schemes, the set price for water rights is the main mechanism, which is used to control water usage and market participation (Li & Wang 2005). However, there has been relatively little research into the best mechanisms for water rights pricing. Bjornlund & Rossini (2005) verified the role of price in the water rights trading market. Wang & Tu (2006) constructed a hydrology-based 'reflux' model that introduced the concept of a shadow price to determine the trade price based on an auction model. Wang *et al.* (2012) later developed a dynamic conversion price model for water rights based on game theory and principles of market economics, taking bargaining as a transaction intermediary. Payne & Smith (2013) established the econometric model used in the per-unit price paid for water rights in New Mexico's Middle Rio Grande Basin.

At present, there exists no formal price setting mechanism for water rights in the Chinese trading market. Therefore, a pricing model that takes into account seller costs and value to the buyer is developed to enable the transfer of China's agricultural water rights to industrial water rights. The method for calculating the total cost of water rights is derived from the cost of implementing agricultural water conservation measures. Ultimately, these models and methods are used to estimate pricing for the transfer of water rights from agricultural to industrial users in an irrigated area in Ordos, Inner Mongolia.

WATER RIGHTS PRICING MODEL

Assumptions

The pricing model for the transfer of water rights from agricultural to industrial users in the Chinese trading environment is based on the following assumptions:

(1) Agricultural water users can obtain tradable water rights by implementing water conservation projects, such as lining canals to prevent infiltration loss and evaporation control measures, and those water rights can be traded to industrial water users via a water rights transaction.
(2) The right to use and trade the water resource must be established.
(3) The State must permit (i.e., recognize the legitimacy of) the water rights transaction.
(4) The agents responsible for pricing water rights are the Ministry of Water Resources and the water administration department of a river basin.
(5) Water rights transactions are subject to approval by the water administration department.
(6) The water rights fund has time value, and the rate of return is subject to a risk-free interest rate.
(7) A traded water right does not involve backflow, pollution, and other water resource problems.

TOTAL COST OF RELEASING AGRICULTURAL WATER RIGHTS

The total cost (C) of agricultural water rights made available by the implementation of water conservation measures can be determined by summation of the following:

(1) Construction cost of the water conservation project (C_j).
(2) Operation and maintenance costs (C_y).
(3) Renewal and reconstruction expenses (C_g).
(4) Irrigation frequency compensation (C_f).
(5) Economic compensation for ecological damage (C_s).

The total cost of water rights is then calculated by:

$$C = C_j + C_y + C_g + C_f + C_s \quad (1)$$

The details of each term are discussed below.

Construction costs

The construction costs of a water conservation project include, for example, expenses incurred in the renewal and reconstruction of an anti-seepage canal lining, ancillary buildings, end-of-canal water conservation systems, water-monitoring facilities and devices, canal slope renovation, road repair, canal greening, temporary construction costs, basic reserve costs, and experimental and research expenses. The level of detail for cost reporting is prescribed by the relevant regulations and investment budget (estimation) standards, all of which vary according to the scale of the reconstruction project.

Operation and maintenance costs

The operation and maintenance costs for a water conservation project refer to the recurrent costs incurred during the normal operation of engineering facilities, including: fuel and electricity; maintenance costs such as regular overhauls, renewal, and routine annual repairs; project management costs such as staff salaries, administrative expenses, daily monitoring, and scientific research and experimental expenses; and other recurrent expenditures. A preliminary estimate of annual operation and maintenance costs can be generally calculated as a percentage, typically 2–3%, of the total investment.

Renewal and reconstruction costs

The renewal and reconstruction costs associated with a water conservation project refer to the costs incurred when the service life of the project is shorter than the water rights transaction period. Renewal and reconstruction expenses can be calculated according to the service life (N_s) of the main water conservation component, the water rights transaction period (N_z), the project construction cost, and other indicators. If $N_s \geq N_z$ (i.e., the service life is longer than the transaction period), renewal and reconstruction expenses are deemed not to occur. If $N_s < N_z$ (i.e., the service life is shorter than the transaction period), all or part of any renewal and reconstruction expenses should be included in the water rights cost calculation.

Irrigation frequency compensation

Agricultural water users are compensated for the loss of revenue due to the compulsory transfer of water rights to industrial water users in dry years. The integrated regulation of water levels in the Yellow River guarantees that industrial users will receive a minimum of 95% of their water demand, to be maintained in dry years by transfer of water rights from agricultural water users. This may mean that, to ensure that the water demand of normal industrial production can be met in particularly dry years, some farmland may not be effectively irrigated. This may result in decreased crop production, and the provision of economic compensation for affected irrigators. We can see the meaning of irrigation frequency compensation from Figure 1.

According to the Code for the Design of Irrigation and Drainage Engineering (GB50288-99), industrial and agricultural water use guarantees are 95–97% and 50–75%, respectively, in cropping areas subject to water supply limitations. Different frequency levels will result in variations in water resource allocation. The multi-year average agricultural water demand that must be compulsorily transferred to industry ($\bar{W}$) based on the differential frequency can be calculated as follows:

$$\bar{W} = \frac{\sum (P_i - P_{i-1}) \times (W_{P_i} + W_{P_i-1})}{2} \tag{2}$$

where $\bar{W}$ is the multi-year average agriculture water consumption transferred to industry, m^3; $(P_i - P_{i-1})$ is the difference in frequency(%); W_{Pi} is the losses of agricultural water demand due to transfer to industrial users when frequency is P_i, m^3; $W_{P_{i-1}}$ is the losses of agricultural water demand due to transfer to industrial users when frequency is P_{i-1}, m^3.

The area of farmland not receiving adequate irrigation can be calculated based on $\bar{W}$ and the irrigation quota after implementation of agricultural water conservation projects (M_j). The annual irrigation frequency compensation per unit area can then be calculated from the difference between the income per unit area of irrigated farmland to that of non-irrigated farmland (B_c), and the results used to calculate the total irrigation frequency compensation (C_f):

$$C_f = \frac{N_z \times B_c \times \bar{W}}{M_j} \tag{3}$$

where C_f is the total irrigation frequency compensation, RMB; B_c is the difference between the income per unit area of irrigated farmland to that of non-irrigated farmland, RMB/ha; N_z is the water rights transaction period, a;

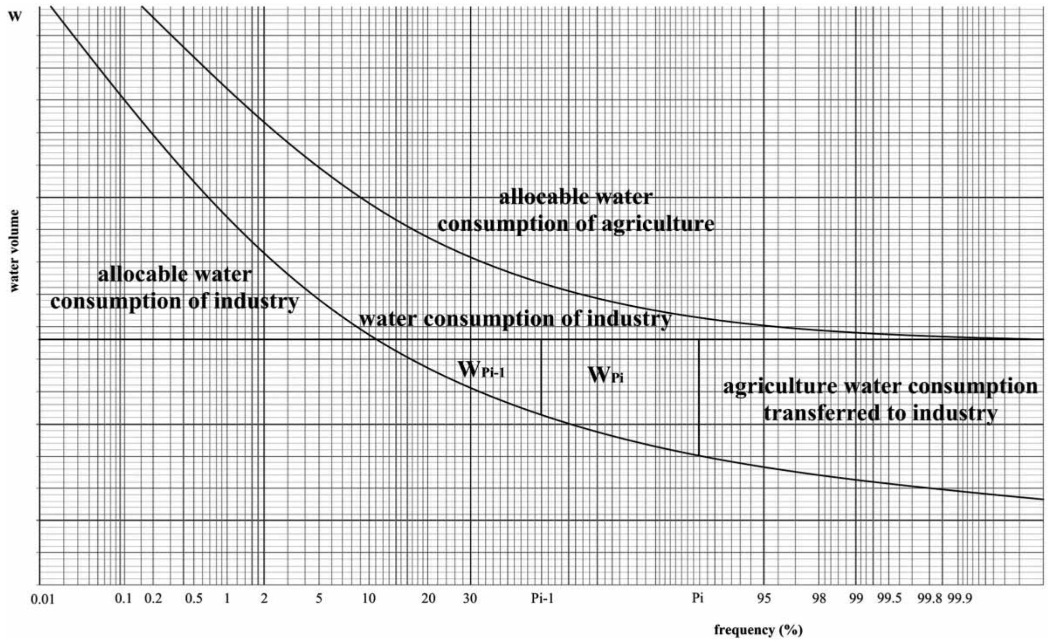

Figure 1 | Schematic diagram of irrigation frequency compensation.

and M_j is the irrigation quota after implementation of agricultural water conservation projects, m^3/ha.

Economic compensation for ecological damage

Economic compensation for ecological damage refers to the repair or compensation costs associated with damage to the environment or other interests.

There are no unified standards or calculation methods for assessing the economic loss associated with ecological damage in the Chinese water rights market. To estimate such costs, the construction cost of a water conservation project (C_j) can be multiplied by an ecological compensation coefficient (b) for the water rights transaction period, as given by:

$$C_s = bC_j \tag{4}$$

where C_s is the economic and ecological compensation fees during the water rights trading period, RMB; b is the ecological compensation coefficient, which is recommended to take 2% to 3% of the project operation fee; C_j is the construction cost of a water conservation project, RMB.

The recommended value of the compensation coefficient b is 2–3%.

Unit cost of water rights

The unit cost of water rights (P_C) is calculated by:

$$P_C = \frac{C}{N_z \times W_n} \tag{5}$$

where P_C is the unit cost of water rights, RMB/m^3·a; c is the total water rights transaction costs, RMB; N_z is the water rights trading period, a; and W_n is the annual volume of water traded, m^3.

INDUSTRIAL VALUE OF WATER RIGHTS TRANSFER

Production function

The production function (e.g., the Cobb–Douglas function; Cheng & Xiang 2014) is commonly used in the field of quantitative economics to analyze the variation in production output (e.g., yield) with change in production inputs (e.g., labor). Typical input factors include capital and labor, but the production function can also be customized for specific purposes by combining these inputs with production factors such as energy, raw materials, land, and water resources. Production factors may not be entirely mutually exclusive of capital and labor inputs (e.g., an increase in energy may be offset by a decrease in labor), but it is generally considered that the magnitude of such trade-offs are small and can be neglected (Shen *et al.* 2000). Here, the effect of increased water consumption (W) on industrial output (X) is modeled simply as a production factor in combination with capital (K) and labor (L), as given by:

$$X = AK^{\alpha}L^{\beta}W^{\gamma} \tag{6}$$

where X is the industrial output, RMB; A is a constant representing technological progress factors and production scale; K is the fixed assets investment, RMB; L is the labor, person; W is the water consumption, m^3; α, β and γ are production elasticity factors for the respective variables.

Logarithmic transformation of this formula yields the following expression:

$$\text{In}\,X = \text{In}\,A + \alpha\,\text{In}\,K + \beta\,\text{In}\,L + \gamma\,\text{In}\,W \tag{7}$$

which can be transformed as:

$$\text{In}\,X = a\,\text{In}\,K + b\,\text{In}\,L + c\,\text{In}\,W + d \tag{8}$$

where a, b, and c represent the output elasticity of capital, labor, and water, respectively, and d represents a constant obtained from data from the national economic statistical yearbook. Equation (8) is a double logarithmic relationship with a linear proportionality between industrial output and capital, labor, and water inputs.

Marginal value of water rights transfer

The marginal benefits of water rights transfer to industrial users can be obtained from the derivative of Equation (8), as given by:

$$\frac{\Delta X}{X} = \frac{a\Delta K}{K} + \frac{b\Delta L}{L} + \frac{c\Delta W}{W} \tag{9}$$

The marginal benefits of water to industrial users V_W can then be expressed as:

$$V_W = \frac{\partial X}{\partial W} = \frac{\partial\,\text{In}\,X}{\partial\,\text{In}\,W} \times \frac{X}{W} = c\frac{X}{W} \tag{10}$$

where V_w is the marginal benefits of water, RMB/m^3·a; X/W is the reciprocal of the ratio of industrial water consumption to production output. The marginal benefits of water to industrial users is therefore equal to the product of the output elasticity of water and the reciprocal of industrial water consumption per unit output.

TRANSACTION PRICE OF WATER RIGHTS

Based on the derivations above, the pricing of water rights should be based primarily on the cost incurred by agricultural water users in releasing water rights, and the marginal value of water to industrial users assuming reasonable benefit coefficients.

The price of a water right (P_z) sold by an agricultural user as a result of implementing water conservation measures can be expressed as:

$$P_z = P_C + K \cdot V_W \tag{11}$$

where P_z is the price of a water right, RMB/m^3·a; P_c is the water rights transaction cost price, RMB/m^3·a; K is a factor, typically on the order of 0.1, determined after consideration of the reasonable benefit of the water rights transfer; and V_w is the marginal benefit of water to the industrial sector, RMB/m^3·a.

In reality, water rights pricing is more complex than suggested by Equation (11) due to the effect of the differential bargaining power of the parties. Therefore, the actual transaction price is difficult to predict accurately, and must be given as a range. The price of water rights derived in this paper can be used as an upper limit for the actual transaction price to reflect the opportunity cost. The price calculated using only the cost to the agricultural water can be used as a lower limit to reflect the minimum compensation value. The actual transaction price of a water right (P) therefore satisfies the condition:

$$P \in [P_C, P_Z]. \tag{12}$$

APPLICATION TO WATER RIGHTS TRADING IN ORDOS, INNER MONGOLIA

Scenario

The irrigation zone adjacent to the Yellow River in Ordos, Inner Mongolia, encompasses 13 townships of

Hangjinqi and Dalad Banner (106°42′–110°27′ E, 37°35′–40°47′ N). The total irrigated area is 62,870.00 ha, comprising 21,330.00 ha of gravity irrigation in Hangjinqi, and 41,530.00 ha of lift irrigation in Dalad Banner. The irrigated area is located north of Ordos on an alluvial plain of the Yellow River between the Ordos platform on the south bank of the Yellow River and the northern edge of the Hobq Desert, which is a long and narrow east–west plain belt. The gravity irrigation area is located upstream of the lift irrigation area. The irrigation zone extends for about 398.00 km along the Yellow River, and is 5.00–40.00 km wide. A flood control dike bounds the northern bank of the Yellow River adjacent to the Hobq Desert.

The water conservation projects undertaken in the Ordos irrigation zone include sprinkler irrigation, canal irrigation, border transformation, drip irrigation, and planting structure optimization and adjustment. The implementation of these water conservation measures has made up to 132.15 Mm^3 per year available for transfer. The water rights transfer period is 25 years, and the assumed year of the water rights transaction is 2014.

COST OF WATER RIGHTS

Construction costs

The estimated total construction cost of water conservation projects in the Ordos irrigation zone is RMB 1,120.94 million.

Operation and maintenance costs

Based on the Code for Economic Evaluation of Water Conservancy Construction Projects (SL72-94), the cost of management, repair, and maintenance of the water conservation projects (payable to the irrigation area water management authority and provided to the water rights owner) is equivalent to 2% of the construction cost. The total operation and maintenance cost of the water conservation projects in the Ordos irrigation zone is therefore RMB 560.47 million.

Renewal and reconstruction costs

The lift irrigation project includes a floating pontoon lift pump, which has a shorter service life than the water rights transaction period (25 years). The project investment is RMB 29.81 million, and this value is taken as the renewal cost.

Irrigation frequency compensation

Calculated water consumption under different irrigation guarantee rates is shown in Table 1.

Industrial water consumption is maintained by transferring the multi-year average industrial water consumption (9.09 Mm^3) from agricultural water users to industrial water users (with payment), resulting in irrigation shortages. According to the design of the irrigation system, the gross irrigation quota for the irrigated farmland is 5,949.00 m^3/ha. The area of arable land that cannot be irrigated is 1,526.70 ha. The compensation fee is then calculated from the difference between income per unit area of irrigated farmland to that of non-irrigated farmland (average RMB 4,500.00/ha based on household survey), multiplied by the area of farmland affected and the period of the water rights transaction; i.e.:

$$\text{Irrigation frequency compensation} = 1{,}526.70 \times 4{,}500.00 \times 25 = \text{RMB } 171.75 \text{ million.}$$

Economic compensation for ecological damage

The annual economic compensation for ecological damage can be calculated assuming a value equivalent to 2% of the construction cost of the water conservation projects during the water rights transaction period: RMB 560.47 million.

Cost price of water rights

The total cost of water rights is given by:

$$C = 1{,}120.94 + 560.47 + 29.81 + 171.75 + 560.47 = \text{RMB } 2{,}443.44 \text{ million.}$$

The cost price per m^3 of water transferred per year (P_C) of the water rights transaction is then given by:

$$P_C = 2{,}443.44/(132{,}149{,}400.00 \times 25) = \text{RMB } 0.74/(m^3{\cdot}a).$$

Table 1 | Calculated water consumption under different irrigation guarantee rates

		Guarantee rate (%)/Water consumption (Mm^3)			
Allocation		**50%**	**75%**	**95%**	**97%**
Yellow River total		5,240,000.00	4,510,000.00	3,620,000.00	3,420,000.00
Irrigation		49,000.00	42,175.00	33,850.00	31,980.00
Allocable water consumption	Agricultural	35,785.06	30,800.71	24,720.90	23,355.23
	Industrial	13,214.94	11,374.29	9,129.10	8,624.77
Actual allocated water consumption	Agricultural	35,785.06	28,960.06	20,635.06	18,765.06
	Industrial	13,214.94	13,214.94	13,214.94	13,214.94
Agricultural water consumption transferred to industry		0	1,840.65	4,085.84	4,590.17

The calculated water consumption under different irrigation guarantee rates between agriculture and industry is 9.09 Mm^3.

MARGINAL VALUE OF WATER RIGHTS TRANSFER

According to the statistical data submitted by the Bureau of Statistics for Ordos in 2014, the total value of industrial output was RMB 155,230.00 million, employment was 1.67 million, and total assets were RMB 226,330.00 million (comprising current assets of RMB 121,830.00 million and net fixed assets of RMB 104,500.00 million). The output and water consumption data are listed in Table 2.

DISCUSSION

Based on the above analysis, the cost price of water rights transferred from agricultural water users to industrial water users in Ordos is RMB 0.74/(m^3·a), and the average marginal value of industrial water consumption is RMB 3.56/m^3. According to Equation (11), with K set to 0.1, the price of water rights P_z is RMB 1.10/(m^3·a). The actual transaction price of water rights is therefore in the range of RMB 0.74–1.10/(m^3·a).

According to the price model in this paper, the actual transaction price of water rights should therefore be in the range of RMB 0.74–1.10/(m^3·a). But in China, water rights trading between agricultural and industrial water users just appear, and it is an exploratory job. In China, the agents responsible for pricing water rights are the Ministry of Water Resources and the water administration department of a river basin. In order to improve the motivation of sellers in water rights transactions and promote water rights transactions, the final cost only includes construction costs, operation and maintenance costs, and renewal and reconstruction costs. Accordingly, the final price is RMB 0.52/(m^3·a).

In the present calculation of the price of water rights, a value of 0.1 has been used for the reasonable beneficial coefficient K. In order to ensure equity in water rights transactions, it may be prudent to consider the economic conditions throughout the region in which the water rights buyer is located. If the buyer is located in a developed economy, while the seller is located in a developing economy, the price of water rights may be appropriately raised by the seller, and vice versa. Moreover, differences in water scarcity between the buyer and seller regions can affect the marginal value and utility of water resources; in the case where water is less scarce in the seller region, the price of water rights may be appropriately reduced, and vice versa. The reasonable beneficial coefficient K for water rights transactions can thus be determined according to the relative scarcity of water resources and degree of economic development in the seller and buyer regions.

CONCLUSIONS

This paper presented an integrated pricing method for water rights trading from agricultural users to meet industrial water demand in China. The pricing method accounts for the construction costs of water conservation projects undertaken by irrigators to release water rights for trading, the operational and maintenance costs of the projects, renewal

Table 2 | Industrial economic and water consumption indicators for Ordos (2014)

Industry	Total industrial output (RMB million)	Annual average no. of employees (person)	Total assets (RMB million)	Industrial water consumption (Mm^3)
Coal mining and processing	110,566.00	40,704	180,714.00	1,622.16
Oil and natural gas extraction	600.00	97	673.00	0.80
Ferrous metal mineral mining and processing	20,269.00	2,890	39,514.00	1,121.48
Non-ferrous metal mineral mining and processing industry	1,981.00	343	2,152.00	12.10
Non-metal mineral mining and processing industry	30,652.00	3,443	20,216.00	153.49
Other mining and processing industries	902.00	241	262.00	5.50
Food processing	769,534.00	29,546	475,493.00	1,519.68
Food manufacturing	332,691.00	41,628	522,128.00	2,365.26
Beverage manufacturing	439,364.00	25,650	514,830.00	8,382.10
Tobacco processing	63,140.00	1,008	61,528.00	52.40
Textiles	554,184.00	106,537	922,267.00	13,014.87
Clothing and other fiber products manufacturing	465,756.00	117,912	489,113.00	375.71
Leather, fur, feather and other products manufacturing	77,479.00	17,343	163,159.00	211.51
Timber processing and bamboo, cane, palm fiber and straw products manufacturing	34,420.00	7,317	55,488.00	129.91
Furniture manufacturing	91,821.00	19,625	105,958.00	208.40
Paper making and paper products	135,080.00	17,189	159,467.00	8,760.89
Printing industry and coal medium recording copying	272,739.00	49,666	430,540.00	1,188.22
Cultural and educational, sporting goods manufacturing	85,104.00	29,843	136,250.00	197.49
Petroleum processing and coking	1,275,499.00	41,752	1,157,386.00	73,064.55
Chemical raw materials and chemical products manufacturing	997,723.00	82,174	1,126,983.00	83,866.54
Pharmaceutical manufacturing	252,502.00	28,299	437,074.00	3,255.11
Chemical fiber manufacturing	30,881.00	7,975	83,538.00	2,271.95
Rubber products manufacturing	134,053.00	20,520	172,529.00	1,902.72
Plastic products manufacturing	262,460.00	37,276	447,568.00	1,438.89
Non-metallic mineral products manufacturing	683,136.00	123,614	1,079,936.00	10,280.15
Ferrous metal smelting and rolling processing	2,002,467.00	137,009	2,977,942.00	177,860.64
Non-ferrous metal smelting and rolling processing	86,106.00	12,786	108,466.00	938.04
Metal products manufacturing	396,729.00	68,524	520,844.00	849.83
Ordinary machinery manufacturing	519,230.00	101,563	1,120,137.00	2,135.15
Special equipment manufacturing	395,856.00	66,541	699,918.00	1,641.29
Transportation equipment manufacturing	1,594,298.00	146,509	1,712,803.00	4,046.18
Weapon and ammunition manufacturing	81,788.00	14,836	151,568.00	946.21
Electrical machinery and equipment manufacturing	429,017.00	79,504	869,627.00	1,373.58
Electronic and communication equipment manufacturing	1,906,185.00	86,577	2,226,328.00	1,893.72
Instrumentation and cultural office machinery manufacturing	307,678.00	38,240	481,337.00	541.38
Other manufacturing	138,896.00	29,774	191,538.00	256.51
Electricity, steam, hot water production and supply	167,334.00	17,080	2,091,791.00	13,370.48
Gas production and supply	29,300.00	8,271	292,641.00	111.80
Tap water production and supply	45,431.00	6,537	403,461.00	706.34
Total	15,222,851.00	1,666,343	22,633,167.00	422,180.12

and reconstruction expenses, irrigation frequency compensation, and economic compensation for ecological damage. The pricing model thus considers a comprehensive range of factors and offers a strong platform for effective water rights trading.

The pricing model accounts not only for the cost of water rights to the seller but also the marginal value of water rights to the buyer. This is a necessary consideration to improve the motivation of both sellers and buyers to participate in water rights trading. It is also of important theoretical significance for improving water rights pricing theory.

The pricing model gives the price of water rights as a range from the fundamental cost to the adjusted marginal value to the buyer. It accounts for many direct and indirect costs as well as the bargaining power of the parties, which will have important practical significance.

It should be noted that the pricing model does not include the actual price of water extracted and used by the industrial water user. After completion of a water rights trade, water usage charges will be applied according to the prevailing water price and water usage, which may influence the economics of water rights trading.

The pricing of water rights involves many factors. Although the present model cannot account for all possibilities, it is critical to consider a wide range of factors to ensure the effective implementation of water rights trading. Future research will examine the range of appropriate settings for the reasonable benefit coefficient K. As shown in this study, with increasing knowledge of water resource value and the factors affecting water rights trading, pricing theories and water rights transactions methods can be improved to increase the efficiency and effectiveness of water rights trading to support economic development in areas with limited water availability.

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