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Research on Data Asset Pricing based on Bargaining Model

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Abstract

Data, is difficult to be priced for its timeliness and non-physical characteristics. This paper innovatively brings the Real Option Method of intangible assets into the discussion to better pricing data assets. The conclusion is that, under the condition of perfect information, a seller can only be the price taker. And, trading platforms play an important role in restraining sellers' high price premium behavior.

Keywords: Data Asset Transaction; Real Asset Option Method; Information Asymmetry; Trading Platform Intervene; Bargaining Pricing Model

1. Introduction

The Fourth Plenary Session of the 19th CPC Central Committee made it clear for the first time that, data can be treated as a factor to participate in the Income Distribution phase, according to its contribution to the social material wealth production. This arrangement aimed to accelerate the construction of the fair factor market system, enhancing three goals of factor market: factors pricing, factors autonomous and orderly flowing, factors efficiently and fairly allocating. In December 2022, *The Opinions of the CPC Central Committee and The State Council on Building a Data Basic System to Better Play the Role of Data Elements* required to establish a data property system, which will set up a thorough property protection; a circulation that integrates both inside and outside the country; a data element income distribution system that reflects efficiency and promotes fairness.

The innovation of this paper lies in the application of real option method to assess data asset prices. The structure of the paper is as followed: the second part is the literature review. The third part shows the complete Bargaining

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process analysis. In the fourth part, using a MATLAB numerical simulation experiment to demonstrate the conclusion. The fifth part summarizes the experiment and gets some inspirations.

2. Literature review

As the traditional market theories mentions, “Price” plays an essential role in market operating, maintaining and regulating. But as mentioned above, there are some limitations on the traditional asset appraisal methods. Data assets do not depend on a certain physical object, and their future value will fluctuate greatly with their timeliness. It results in low efficiency of big data assets pricing, and is not conducive to the transaction of them [1]. Scholars at home and abroad are committed to exploring the related issues. For example, to reach the goal of encouraging the resource utilization, accelerating the process of stepping forward, and realizing comprehensively the market-based circulation, which is also the premise of realizing data capital transaction.

Most scholars' research is about the trading mechanism, legal loopholes, rule algorithms and so on. Chang V et al. [2] proposed a new concept of "Big Data Reduction". Data reduction operations are carried out to achieve purposes such as reducing service utilization costs, enhancing trust between customers and enterprises, protecting privacy and realizing secure data sharing. Dobre C et al. [3] proposed the application of big data in the transportation industry. They pointed out that big data can collect real-time positioning information and observe the actual situation of each transportation route, screen useful information for matching, and finally obtain the best distribution route to improve efficiency.

Following is about the research on data asset valuation. When studying the management system and operation mechanism of data asset valuation and pricing, Lu Min-feng et al. [4] believed that data asset exchanges should be divided into two party, primary market and secondary market. The primary market should be responsible for data asset valuation, while the secondary market be responsible for data asset pricing, but in fact the relationship between valuation and pricing has not been clear. Dai Bing-rong et al. [5] believed that data asset valuation should be completed in the data asset commercialization stage, and data asset pricing should be completed in the asset operation stage. In view of the problems that there is a large amount of fuzzy and uncertain information in the pricing process of data assets, it is impossible to price data assets accurately and unbiased. For this, Zu Guang-zheng [6] improved B-S model with fuzzy mathematics to price big data assets better. Based on the decomposition estimation method of data assets, Zuo Wen-jin [7] believes that when the overall price of data assets is greater than the sum of all parts of assets, the Shapley Value Method should be used to evaluate the assets; If the opposite is the case, the Bankruptcy Distribution Method should be used for pricing. Lin Juan-juan [8] used KNN Machine Learning Classification Algorithm to manipulate consumer utility function, and analyzed that, in the case of heterogeneous consumer utility sensitivity, the comprehensive score and pricing of data assets have differentiated impacts on data platform profits. Some scholars also adopt the Two-person Bargaining Model, that is, the initial asset pricing model is determined by "Alternating Bidding Between Players". Zou Gui-lin et al. [9] believed that the market price of assets can be comprehensively determined by following steps: adopting the Two-stage Revised Cost Method first, then the Analogy Historical Transaction Price Model, the Marketing Trial Method and Counterparty Utility Method and alike methods to confirm the pay.

3. Bargaining analysis

The Present Value Method determines the minimum price of data asset. It shall be the discounted future income of the asset in each of the remaining years:

$$P_L = \sum_{t=1}^{n-1} \frac{A_t}{(1+D)^t} + \frac{A}{(1+D)^n} \tag{1}$$

Besides, $A_t(t=1,2,\cdots)$ means each future income cash flows at the end of t periods; A represents the final income that will be obtained when the asset matures; D is the discount rate at the base point.

The Real Option Method determines the maximum price of the data asset. According to Yang Ya-xi [10], the price of intangible assets, should also include the value of the right of making decisions:

$$P_U = P_L + C \tag{2}$$

Besides, $C = SN(d_1) - Xe^{-rT}N(d_2)$, means the current value of the option. S is the value of the underlying asset. X is the strike price. $N(d_1)$, $N(d_2)$ represents the cumulative probability that the random variable is less than d_1, d_2 in the case of standard normal distribution. r is the risk-free interest rate corresponding to the validity period of the option. σ is the standard deviation of the return of the underlying asset. T is the time from the expiration date of the option. $SN(d_1)$ represents the expected value of an asset. $Xe^{-rT}N(d_2)$ represents the expected cost of the asset. u is the buyers' highest valuation of the data asset. As forementioned, we further subdivide the game into three situations.

- Case 1: If, buyer bids is lower than the lowest price that the seller accepts, $u < P_L$, the transaction fails;
- Case 2: If, buyer bids is within the range, $u \in [P_L, P_U]$. It is suitable for bargaining method;
- Case 3: If, buyer bids is higher than the seller asks, $u > P_L$, the transaction succusses.

3.1. Assumptions and Predeterminate hypothesis

In this part, it can be found that: the intervention of trading platform can reduce the information asymmetry between the buyer and the seller. And, reducing the possibility that seller earns a higher premium.

During the game, both of them can further revise their reserve prices by the prices returned by the opposite at each stage. Here are several needed basic assumptions to be comprehensively illustrated.

- Hypothesis 1: Both the buyer and the seller are rational, who will pursue their maximization revenues;
- Hypothesis 2: The seller takes the lead during the game;
- Hypothesis 3: The value of the data asset remains unchanged during the game.

3.1.1 Perfect information

Under this condition, the buyer and the seller are fully aware of each other. As long as the seller's price is higher than P_L, the buyer will not move. So that, seller has to bear the opportunity cost. Therefore, seller'd better trade at P_L. The final transaction price P_1^* is P_L. The seller can only participate in the market as a price bearer.

3.1.2. Imperfect information, but No Platform participates in the game

In the case of no platform participating in the game, parties have information asymmetry about data assets. The buyer usually is hardly aware of the asset value, while the seller has all the information about it. Therefore, the seller has a certain trading advantage, with the possibility asking a high or low price. Here, we assume that the probability of the seller asks high is $\rho(0 < \rho < 1)$.

Stage 1: The seller asks first and records it as P_2^1. The buyer decides whether to accept it or not.

When the buyer accepts the price, the game is apparently terminated. However, when the buyer does not accept the seller's price, enter Stage 2, and Stage 2 will start at the buyer's bid price P_2^2.

For the seller in Stage 1, his payoff is clearly P_2^1 minus P_L:

$$ES_1 = P_2^1 - P_L \tag{3}$$

For the buyer, when the seller asks for a higher price, P_2^1 (with probability ρ), the buyer's payoff is $u - P_2^1$.Whereas, when the seller asks a low price (usually P_L), his payoff is $u - P_L$.

In summary, the equilibrium payoff of the buyer in the first stage is:

$$EB_1 = \rho(u - P_2^1) + (1-\rho)(u - P_L) \tag{4}$$

Moreover, the buyer will gradually revise his advanced estimation ρ to ρ' during game processing.

Stage 2: The buyer bids P_2^2, and the seller decides whether to accept it or not.

When the seller accepts P_2^2 at this time, the game terminated. If the price is not accepted, Stage 3 will start and the seller offer P_2^3. Moreover, the losses generated in this phase, such as time and patience consumption, are measured by δ_S for seller, and δ_B for buyer. To sum up, the seller's payoff is:

$$ES_2 = \delta_S(P_2^2 - P_L) \tag{5}$$

The equilibrium payoff of the buyer is:

$$EB_2 = \delta_B q(u - P_2^2) \tag{6}$$

Stage 3: The seller asks P_2^3 and the buyer decides whether to accept it or not.

The buyer accepts, the game ends. If not, the process will repeat, the buyer continues to bid, and the bargaining continues. For the seller, if the buyer accepted his asks, then the seller's final payoff at this time were:

$$ES_3 = \delta_S^2(P_2^3 - P_L) \tag{7}$$

For the buyer:

$$EB_3 = \delta_B^2[\rho'(u - P_3) + (1-\rho')(u - P_L)] \tag{8}$$

According to the analysis of infinite order games in the paper of Shaked and Sutton[11]: a subgame starting at any stage is equivalent to the whole game starting at t=1. We simplify it into a game which ends at Stage 3.

To avoid entering the Stage 3, the buyer's bid, must let the seller's payoff in Stage 2 at least be greater than or equal to the Stage 3's to end the game, which means $ES_2 \geq ES_3$. Follow equation is generated from Equation (3), (5):

$$\delta_S(P_2^2 - P_L) \geq \delta_S^2(P_2^3 - P_L) \tag{9}$$

For the seller's aspect, to avoid entering Stage 2, he must make the buyer's Stage 2 payoff is also at least greater than or equal to Stage 1's. From Equation (2) and (4), we know:

$$\rho(u - P_1) + (1-\rho)(u - P_L) \geq \delta_B q(u - P_2^2) \tag{10}$$

According to Shaked and Sutton, whether from the Stage 1 or from Stage 3, the final outcome for the seller is the same as any prices that he asks at any his stages:

$$P_2^1 = P_2^3 = P_2^* \tag{11}$$

Finally, the price of the data asset is solved as follows.

$$P_2^* = P_L + \frac{(\delta_B q - 1)(P_L - u)}{\rho - q\delta_B\delta_S} \tag{12}$$

It can be seen from the above equation. When the prior probability of the buyer bids a high price for the seller is large enough ($\rho - q\delta_B\delta_S > 0$), compared with P_L, obviously, P_2^* is higher. $\frac{(\delta_B q - 1)(P_L - u)}{\rho - q\delta_B\delta_S}$ can be regarded as some kind of information cost. This shows that: in the case of imperfect information and no platform to participate in the game, since the buyer does not fully understand the asset, the seller can ask a higher price then P_L.

3.1.3. Imperfect information, but Platform participates in the game

When there is a platform participating trading, the buyer no longer knows nothing about the asset. Because some similar data assets needed by the buyer will be publicly available through the platform. In addition, the platform will protect the buyer's interests. It helps the buyer to be more patient and confident in the bargaining. However, it is totally contradicted to the seller. In this context, we introduce factors $\theta(0 < \theta < 1)$ to account for this change.

For the buyer, the platform increases his confidence, reduces his loss, and enables he to obtain greater benefits in the game process. This makes the buyer obtain greater benefits in the game process, and the corresponding cost measurement factor is changed to $\frac{\delta_B}{\theta}$; The seller, on the other hand, increases to $\theta\delta_S$. Other than that, the processing steps are exactly the same as 3.1.2.

In a word, take the above instruction into consideration, there is two changes in Equation (9) and (10):

$$\theta\delta_S(P_3^2 - P_L) \geq \theta^2\delta_S^2(P_3^3 - P_L) \tag{13}$$

$$\rho(u-P_3^1)+(1-\rho)(u-P_L)\geq\frac{\delta_B}{\theta}q(u-P_3^2) \tag{14}$$

According to the previous procedure in 3.1.2, we get the result for 3.1.3:

$$P_3^*=P_L+\frac{(\frac{\delta_B}{\theta}q-1)(P_L-u)}{\rho-q\delta_B\delta_S} \tag{15}$$

The conclusion is similar to the forementioned in 3.1.2. But in particular, if $\theta=q\delta_B$, then the equilibrium price under imperfect information is equal to the equilibrium price with perfect information. It can be seen that the effect of the platform in data asset trading also limits the high premium behavior of the seller to a certain extent, making the asset price close to the equilibrium price under perfect information.

3.2. Factor analysis

- Discount factor

In game theory, the discount factor is expressed as $\frac{1}{1+D}$, is a measure of the time cost of discounting future payoffs. The size of the discount factor affects the return of the data asset. The smaller the discount rate, the lower the return. The discount factor is defined to be a decreasing function of time, the longer the trade duration, the smaller the discount factor and the more impatient of the buyer and the seller. Normally: $\delta_S=f(t_S),\delta_B=f(t_B)$

$$\frac{\partial\delta_S}{\partial t_S}<0,\frac{\partial\delta_B}{\partial t_B}<0 \tag{16}$$

The first-order partial derivatives of the equilibrium prices of Equation (12) with respect to and are obtained:

$$\frac{\partial P_2^*}{\partial t_S}=\frac{\partial P_2^*}{\partial\delta_S}\frac{\partial\delta_S}{\partial t_S}=q\delta_B\frac{(\delta_Bq-1)(P_L-u)}{(\rho-q\delta_B\delta_S)^2}\frac{\partial\delta_S}{\partial t_S}<0 \tag{17}$$

$$\frac{\partial P_2^*}{\partial t_B}=\frac{\partial P_2^*}{\partial\delta_B}\frac{\partial\delta_B}{\partial t_B}=q(P_L-u)\frac{(\rho-\delta_S)}{(\rho-q\delta_B\delta_S)^2}\frac{\partial\delta_B}{\partial t_B}>0 \tag{18}$$

It can be seen from Equation (17) that, if, as the buyer's patience decreases, the higher the final transaction price is, the buyer's income decreases. It can be seen from Equation (18) that with the extension of negotiation time, the seller's discount factor becomes smaller and the degree of patience decreases, resulting in the lower the final transaction price and the lower the seller's income. Therefore, in the process of transaction price negotiation, in order to maximize their own interests, both parties hope to reduce the time cost and reach the transaction as early as possible.

- Posterior probability

The posterior probability is the buyer's guess of the seller's strategic behavior based on the previous round of trading quotations, reflecting the "Cooperation preference" of both parties. Since there are transaction costs of negotiation, cooperation is beneficial to both parties, and if the benefits of cooperation are sufficiently large, then the probability that the buyer guesses that the seller accepts the low offer increases as the transaction progresses. Thus, cooperation gains are the key factor affecting the posterior probability. Establish the following functional relationship:

$$q=Q(a,m) \tag{19}$$

a refers to the benefits obtained from the cooperation reached by both parties. m represents other influencing factors. For that, the following is obtained:

$$\frac{\partial q}{\partial a}>0 \tag{20}$$

At the same time, the first-order partial derivative of the equilibrium price pair is obtained:

$$\frac{\partial P}{\partial a}=\frac{\delta_B(\delta_S-\rho)(u-P_L)}{(\rho-q\delta_B\delta_S)^2}\frac{\partial q}{\partial a} \tag{21}$$

According to the result of Equation (21), if $\rho>\delta_S$, then $\frac{\partial P}{\partial a}<0$. That is: if the seller is not patient enough, then he is more likely to accept a lower offer under the induction of cooperation gains, with a lower price.

4. Numerical simulation experiment

In order to illustrate the effectiveness of the model, this paper uses MATLAB 2018b to conduct numerical simulation experiments. Simulated data are generated according to different hypothetical environments, which are substituted into the model to calculate the prices in the case of two imperfect information games, and the factors affecting the equilibrium prices are analyzed.

The sample size is set to be 1000. u is assumed that the buyer's valuation of big data assets follows a uniform distribution, $U(400,1000)$. Where "400" represents the lowest estimated cost of the data asset set by the seller, that is, $P_L = 400$, and this also means the transaction price under the condition of perfect information, and it is named as P_1; "1000" represents the highest bid that the set buyer estimates to bring using this big data asset, $P_U = 1000$. δ_S and δ_B obey the uniform distribution, $\delta_S, \delta_B \sim U(0,1)$.

According to the reality, it is obvious that some conditions are needed to directly discuss the bargaining between the two parties $u \geq P_L$. We then define the price generated under incomplete information and no trading platform as P_2, whose data can be calculated according to the conditions set above and Formula (10), and obtain condition $P_2 \leq u$. At the same time, Moreover, according to Formula (8), $\rho > 1 - q\delta_B + q\delta_S\delta_B$ can be obtained. This also satisfies the previous assumption $\rho > q\delta_S\delta_B$. Similarly, the price obtained 3.1.3 names as P_3. $\rho < \delta_S$ can be obtained according to conclusions (14) and (15).Now, we can compare prices under different scenarios, P_1, P_2, P_3.

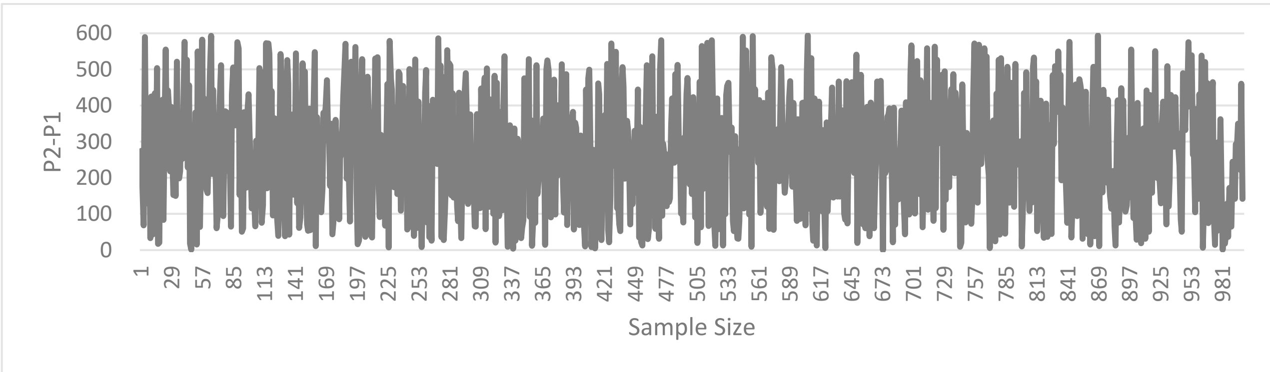

Fig.1. P_2 and P_1 relationship diagram

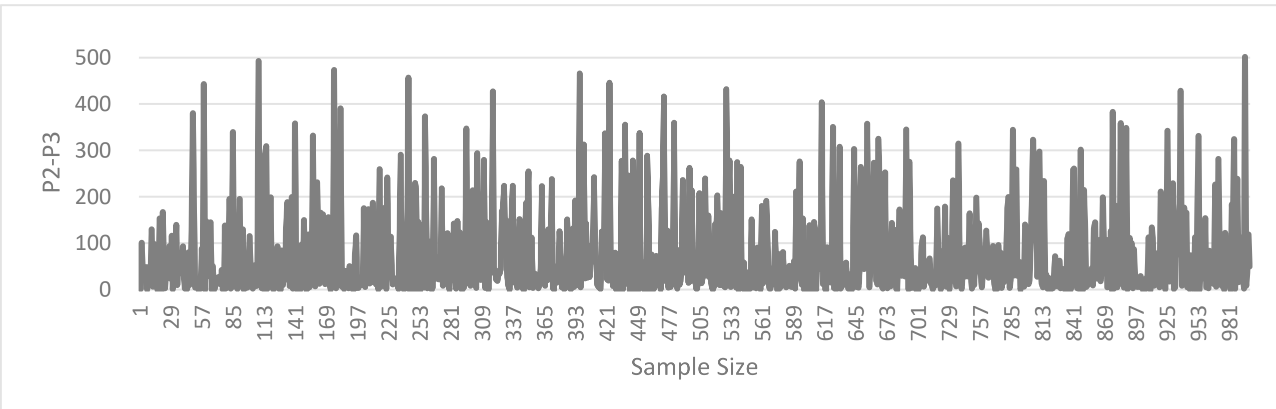

Fig.2. P_2 and P_3 relationship diagram

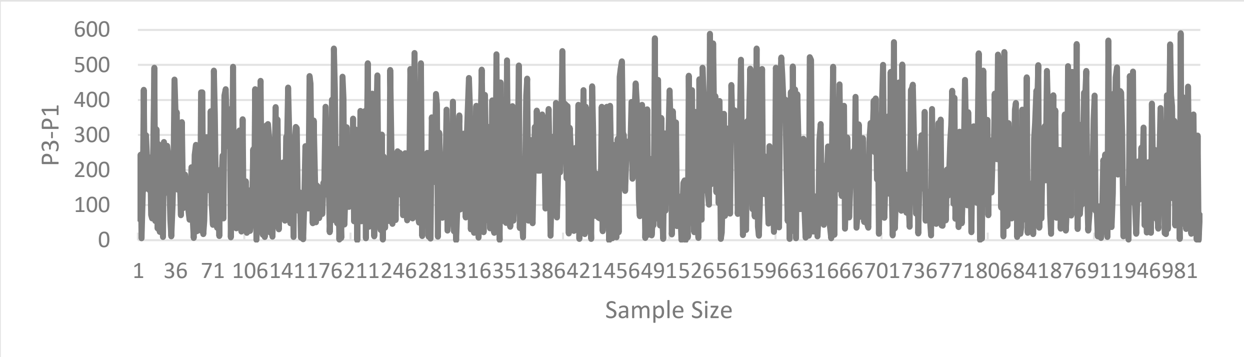

Fig. 3. P_3 and P_1 relationship diagram

First of all, the relationship between P_2 and P_1 in Fig.1. It can be seen that the curve is always above the horizontal line. This shows that the price under perfect information is smaller than the price under imperfect information and no trading platform. Secondly, the relationship between P_3 and P_2 is shown in Fig.2. It shows that the trading platform does play an important role in trading, restraining the seller's premium. In Fig.3, again, the curve is above the horizontal line. It is further verified the price under imperfect information is greater than the price under perfect information.

5. Conclusions

Based on the characteristics of data asset, this paper discusses the bargaining models under the condition of complete information and incomplete information respectively. The rationality of the model is proved by simulation experiments. Moreover, based on the above analysis, the following conclusions are drawn:

First, in data asset pricing, the equilibrium price is related to the degree of information asymmetry, and the greater the degree of information asymmetry is, the more likely the seller is to ask a high price.

Second, the participation of the trading platform reduces the degree of information asymmetry, making the final transaction price closer to the price under complete information.

Third, improving transaction efficiency and reducing transaction costs (including time costs) can improve pricing efficiency. From the result of the experiment, we can θ influence the difference between P_3 and P_2

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