The Price Model of Aquatic Products Based on Predictive Control Theory

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Abstract This paper discusses a disequilibrium cobweb model of price of aquatic products, and applies predictive control theory, so that the system operates stably, and the deviation between supply and demand of aquatic products smoothly tracks the pre-given target. It defines the supply and demand change model, and researches the impact of parameter selection in this model on dynamic state and robustness of the system. I conduct simulation by Matlab software, to get the response curve of this model. The results show that in the early period of commodities coming into the market, affected by lack of market information and many other factors, the price fluctuates greatly in a short time. The market will gradually achieve balance between supply and demand over time, and the price fluctuations in the neighbouring two periods are broadly consistent. The increase in model parameter can decrease overshoot, to promote the stability of system, but the slower the dynamic response, the longer the deviation between supply and demand to accurately track a given target. Therefore, by selecting different parameters, the decision - makers can establish different models of supply and demand changes to meet the actual needs, and ensure stable development of market. Simulation results verify the excellent performance of this algorithm.

Key words Aquatic products price, Supply, Demand, Predictive control, Robust control, China

The price of aquatic products is the specific embodiment of relationship between supply and demand of aquatic products. Conducting reasonable prediction on it, can not only maximize the benefits for enterprises, but also provide scientific basis for the government to work out corresponding policies, to promote continuous and healthy development of aquaculture. Scientific and accurate prediction of price of aquatic products often involves the use of cross-disciplinary theories and empirical knowledge of experts. Batten A. P. takes the lead to use the inverse demand system to research the formation of price of fish and other aquatic products[1]. Pascoe s. *et al* use the inverse demand system or the inverse demand model, to research the formation and variation of price of aquatic products in the European Union, Southeast Asia and other countries and districts[2-3]. Paseoe s. and Mardle S. *et al.* use the inverse supply and bio-economic model to research the reaction of supply of aquatic products in Europe to the price and other factors[4]. Domestic scholar Zhang Xiaoshuan, based on the theory of time sequence combination, predicts the purchase price of aquatic products, and proves the periodic fluctuation existing in the price of aquatic products in China using harmonic analysis method[5]. Yuan Yongming, taking the first-order linear dynamic model as example, advances the basic design idea based on prediction system of price of aquatic products using Internet[6]. Yuan Hongchun puts forward the prediction method of price of aquatic products on the basis of case-based reasoning (CBR)[7].

Since Adam Smith advanced the famous point of view of " invisible hand" in 1776, the problems of non-equilibrium analysis of economic system have become one of hot spots of researches conducted by many scholars[8]. The non-equilibrium market model assumes that the market is imperfect, and the volume of transaction achieved in the trading of supply and demand is not balanced volume of transaction, but the smallest one in demand and supply. When the demand and supply in market is not in balance, the producers will predict the price and arrange the supply of commodities. After a period of price regulation, the supply and demand of market will gradually tend to be balanced. At present, there are few articles analysing the economic market model from the perspective of control theory, and these articles are limited to the use of optimal control methods[9-11]. Optimal control requires the model constructed to be precise, but in the process of operation, the market economy will be affected by many unpredictable factors, thus it is unlikely to get an accurate model. Therefore, the optimal control regulatory strategy obtained based on accurate model has significant limitations, and looking for a control method of the economic system which has low requirements on model is particularly important.

The Predictive Control Theory is a new type of control theory developed gradually in complex industrial environment[12]. It adopts multi-step prediction, rolling optimization and other parts, having no high requirement on accuracy of the model established. Since this theory uses measurement information to repeatedly optimize itself in the process of optimization, which can ceaselessly take into account the impact of uncertainties and promptly correct the flaws, so this can better adapt to the actual process than one optimization of model, and the system has stronger robustness in the case of mismatch of model or interference of uncertainty.

In this paper, I use the advantage of predictive control, and establish the disequilibrium cobweb model of price of aquatic products to analyse and research fluctuation in price of

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aquatic products. This paper defines the supply and demand change model of aquatic products, and researches the impact of selection of parameter in this model on dynamic state of system and robustness. The decision-makers can work out different supply and demand change models according to this, to meet the actual needs, and ensure stable development of market. When acquiring fluctuations in the optimum expected price, this paper does not adopt one overall constant optimized objective, but rolling optimization strategy, so as to timely correct the uncertainty caused by mismatch of model, interference and so on, and thereby improve the control effect of the system. Because the predictive control algorithm always builds the optimization process on the basis of acquisition of the latest information in the actual process and the information is rich, even if the model is not accurate, it can accurately predict fluctuations in price, so the regulation is more effective. The simulation results show excellent performance of the algorithm.

1 Description of the price model of aquatic products

1.1 Establishment of model Since aquatic products are incessantly affected by macro-economy, market supply and demand relationships, distribution and trade, commodity types and other factors, the price of aquatic products is a dynamic process, and the market price, supply capacity and demand capacity of aquatic products will change over the time, showing the law of alternating changes, rise or fall, increase or decrease, therefore, the following model of price of aquatic products is established containing external interference:

$$D_k = \alpha_1 G_k + \beta_1 p_k \quad \beta_1 < 0 \tag{1}$$

$$S_k = \alpha_2 M_k + \beta_2 p_k^* \quad \beta_2 > 0 \tag{2}$$

$$p_k^* = p_{k-1} + \gamma(p_{k-1} - p_{k-2}) \tag{3}$$

$$Q_k = \min(D_k, S_k) \quad k = 0, 1, 2, \cdots, N \tag{4}$$

where D_k is effective demand capacity of aquatic products in period k; S_k is effective supply capacity of aquatic products in period k; p_k is the price of aquatic products in period k; p_k^* is the expected price of aquatic products in period k; Q_k is the trading volume is aquatic products in period k; α_1, α_2, β_1, β_2, γ are the coefficients of variables; G_k is the external force influencing demand, such as climate, season, currency circulation, and disposable income; M_k is the external force influencing supply, such as interest rates of loans, profits, technical level and economic policy.

As to the above model, assuming that when the fluctuations of external interference change little before and after different periods, it will satisfy the following expression:

$$G_{k+1} - G_k \approx G_{k+2} - G_{k+1}$$

$$M_{k+1} - M_k \approx M_{k+2} - M_{k+1}$$

Equation (3) signifies the equation of price adjustment, which indicates the market economic characteristics that when supply falls short of demand in market, the price will rise, and when supply exceeds demand in market, the price will decline. Expression (4) signifies "short-side rule."

1.2 The state-space form of the price model of aquatic products The basic objective of we regulating price in economic system is as follows: on the one hand, to minimize the deviation between total supply and total demand; on the other hand, to make the fluctuations of price in the neighbouring two periods roughly consistent, that is, when $k \to \infty$, $\Delta p_{k-1} - \Delta p_k \to 0$. Let $\Delta p_k = p_{k+1} - p_k$, $x_1(k) = D_{k-1} - S_{k-1}$, $x_2(k) = \Delta p_{k-1}$, $x_3(k) = \Delta p_{k-2}$, $\mu(k) = \Delta p_k$, $\Delta G_k = G_{k+1} - G_k$, $\Delta M_k = M_{k+1} - M_k$.

Then the model of price of aquatic products can be transformed into the following form:

$$x(k+1) = Ax(k) + B\mu(k) + Dw(k) \tag{5}$$

$$y(k) = x_1(k) = Cx(k) \tag{6}$$

where, $A = \begin{bmatrix} 1 & -\beta_2(1+\gamma) & \beta_2\gamma \\ 0 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$, $B = \begin{bmatrix} \beta_1 \\ 10 \end{bmatrix}$, $C = [1, 0, 0]$; $D = \begin{bmatrix} \alpha_1 & -\alpha_2 \\ 0 & 0 \\ 0 & 0 \end{bmatrix}$; $x(k) = [x_1(k)\ x_2(k)\ x_3(k)]^T$, $w(k) = [\Delta G_k\ \Delta M_k]^T$.

2 The analysis and control of the price model of aquatic products

2.1 The analysis of the price model of aquatic products From expression (5), (6), we can obtain the prediction output equation of the deviation between supply and demand of the system in period j after k periods by recursion as follows:

$$y(k+j) = CA^j x(k) + C[A^{j-1}B, \cdots, B][\mu(k), \cdots, \mu(k+j-1)]^T + W \quad (j \in [1, p]) \tag{7}$$

Write expression (7) as vector form:

$$Y = Y_m + GU + W \tag{8}$$

where, $Y = [y(k+1), y(k+2), \cdots, y(k+p)]^T$, $Y_m = K_m x(k)$,

$$K_m = \begin{bmatrix} CA \\ CA^2 \\ \vdots \\ CA^P \end{bmatrix}, \quad U = [\mu(k), \mu(k+1), \cdots, \mu(k+p-1)]^T;$$

$$G = \begin{bmatrix} CB & & & \\ CAB & CB & & \\ \vdots & & \ddots & \\ CA^{P-1}B & \cdots & CAB & CB \end{bmatrix};$$

$$W = \begin{bmatrix} CDw & & & \\ CADw & CDw & & \\ \vdots & & \ddots & \\ CA^{P-1}Dw & \cdots & CADw & CDw \end{bmatrix}.$$

In order to promote the smooth and stable development of market economy, we hope that the price fluctuations in the neighbouring two periods are not big, so as to maintain the supply and demand balance of commodities, but the laws of market economy also tell us that the relationship between supply and demand of commodities can not be completely in equilibrium in a short time, that is, there is always a certain amount of difference between supply and demand, so we allow the oscillation of Y (deviation between supply and demand) around a constant. According to this law, we take the objective function as follows:

$$J = (Y - Y^*)^T (Y - Y^*) + \lambda U^T U \tag{9}$$

where is the supply and demand change model, which is worked out by the decision-makers according to the laws of development of market economy, and can be defined as follows:

$$Y^* = [y_r(k+1), y_r(k+2), \cdots, y_r(k+p)] \quad (10)$$

where $y_r(k+j) = \alpha y(k+j-1) + (1-\alpha)y_s \quad (j=1, \cdots, p)$.

From expression (10), we get that $Y_r = K_r x(k) + S_r y_s$, where $K_r = [\alpha, \alpha^2, \cdots, \alpha^P]^T C$, $S_r = [1-\alpha, 1-\alpha^2, \cdots, 1-\alpha^P]^T \quad (0 \leqslant \alpha < 1)$.

y_s is the given tracking objective, namely the allowable difference between supply and demand formulated by the decision – makers in accordance with reality.

Here, in order to avoid ups and downs of supply and demand in market, we have adopted softened measures in the objective function, so as to make Y start from the current reality $y(k)$, along the supply and demand change model Y^*, to smoothly transit to the given target. y_s From expression (10), we can find that α is an important design parameter in the supply and demand change model, which plays a critical role in dynamic state and robustness of whole economic system. If the decision-makers the deviation between supply and demand is required to rapidly track the given target in a short time, we can take a smaller value of α when designing the supply and demand change model, but such doing may lead to instability of entire market; likewise, if the decision-makers emphasize the stability of market, then the deviation between supply and demand is required to smoothly track the given target y_s, and we can a bigger value of α, but such doing will relatively elongate the tracking time, therefore, in reality, we can adjust the size of to meet different needs.

2.2 The optimum expected price Minimize the objective function (9), and obtain the optimal control law as follows:

$$U = (G^T G + \lambda I)^{-1} G^T (Y^* - Y_m - W) \quad (11)$$

In terms of the rolling optimization strategy in predictive control[13], here, we do not adopt a constant global optimization goal, but a rolling limited time-domain optimization strategy, to timely correct the uncertainty arising from market change. It means that the optimization process is not an off-line process, but an on-line process of repeated optimization, calculation, and rolling implementation, so that the uncertainty caused by mismatch of model, interference and other factors is timely made up for, thereby promoting control effectiveness of system. According to the strategy, we select the first line of expression (10), and let $g = (1, 0, \cdots, 0)(G^T G + \lambda I)^{-1} G^T$, then we get the fluctuation in the optimum expected price in year k is as follows:

$$\mu(k) = g(Y^* - Y_m - W). \quad (12)$$

As can be seen from the above analysis, the predictive control always establishes the optimization process on the basis of the latest information obtained in the actual process, and the amount of information is adequate. It can accurately predict the fluctuations in price, and regulation is more effective.

3 Simulation research

The system parameter of price model of aquatic products is as follows: $\beta_1 = -0.6$, $\beta_2 = 0.4$, $\alpha_1 = 0.11$, $\alpha_2 = 0.116$, $\gamma = 0.1$. But being that this economic system is affected by a variety of unpredictable market factors in practice, and the system identification, linearization and other parts carried out in the process of model building ignore uncertainty of model, it leads to deviation between the parameter of model and the parameter of actual object. Assuming that the parameters of model are as follows: $\beta_1 = -0.599$, $\beta_2 = 0.401$, $\alpha_1 = 0.1101$, $\alpha_2 = 0.116$, $\gamma = 0.1$. Then the corresponding coefficient matrixes of state-space equation (5) and (6) are as follows:

$$A = \begin{bmatrix} 1 & -0.4415 & 0.0401 \\ 0 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}; \quad B = \begin{bmatrix} -0.5590 \\ 1 \\ 0 \end{bmatrix},$$

$$C = [1 \quad 0 \quad 0]; \quad D = \begin{bmatrix} 0.1101 & -0.1160 \\ 0 & 0 \\ 0 & 0 \end{bmatrix}$$

I use Matlab software to conduct simulation, to get the response curve of this model. Fig. 1 is the tracking curve of the deviation between supply and demand in predictive control model, from which we can find that using the conclusion drawn in this paper, can help achieve the goal that the deviation between supply and demand can stably track the given target and maintain the stability of market. Fig. 2 is the fluctuation curve of prices in the neighbouring two periods in predictive control model. The simulation indicates that in the previous period of commodities coming into the market, affected by insufficient knowing about the market information and many other factors, the price in a short time has great fluctuation, and over the time, the market gradually achieves balance between supply and demand, and the fluctuations of price in the neighbouring two periods are basically consistent.

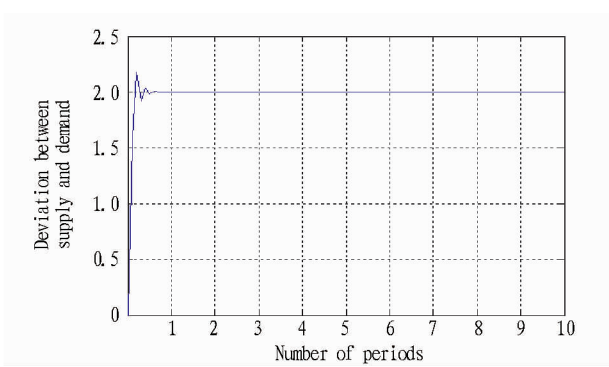


Fig. 1 The tracking curve of the deviation between supply and demand in predictive control model

As α is an important design parameter in the supply and demand change model, the below simulation researches the impact of α on price of aquatic products. Fig. 3a and Fig. 3b are the deviation between supply and demand and the fluctuation curve of prices in the neighbouring two periods when $\alpha = 0.01$ and $\alpha = 0.9$, respectively.

From Fig. 3a and Fig. 3b, we can find that increase in α can reduce overshoot, and promote system stability, but the slower the dynamic response, the longer the time for the devi-

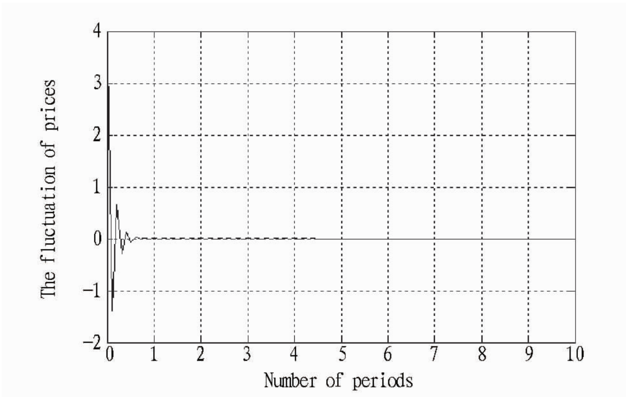
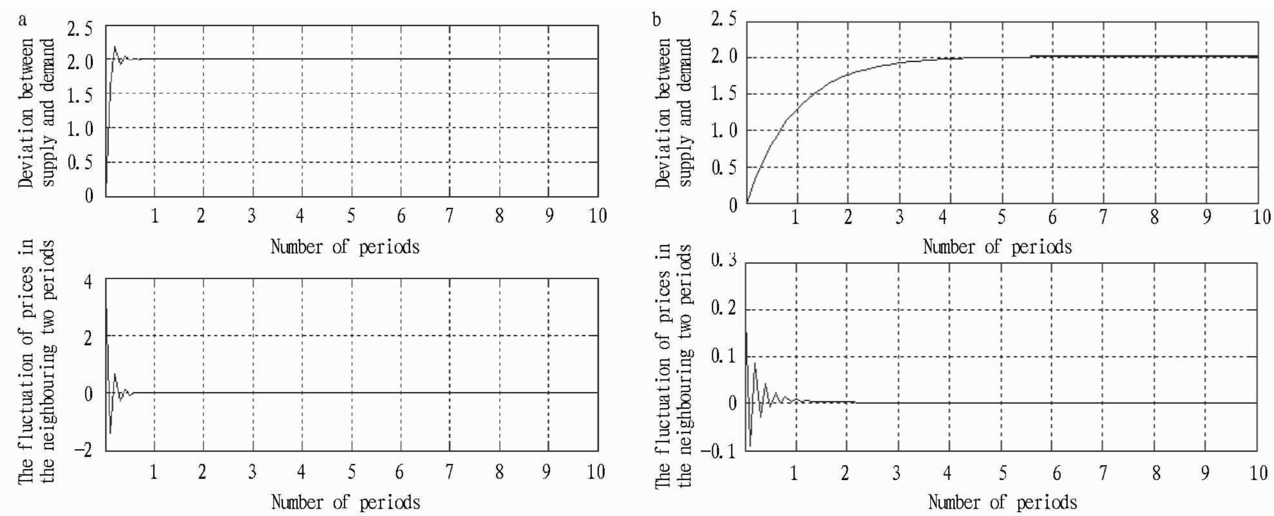


Fig. 2 The fluctuation curve of prices in the neighbouring two periods in predictive control model

ation between supply and demand to accurately track the given target (the time when $\alpha = 0.9$ is 8 times the time when $\alpha = 0.01$), therefore, the decision-makers can work out different models of the supply and demand change to meet the actual needs through selecting different parameters , and ensure stable development of the market.

4 Conclusions

Through analysis and simulation verification, the price model of aquatic products established based on predictive control theory can incorporate new market information into the model in the case of mismatch of model or interference in the market. It adopts rolling optimization strategy, constantly establishes the optimization process based on the latest information obtained from the actual process, and ceaselessly adjusts



Note: a. $\alpha = 0.01$, b. $\alpha = 0.9$.

Fig. 3 The deviation between supply and demand and the fluctuation curve of prices in the neighbouring two periods

the forecast model to accurately predict the price of aquatic products, so that the fluctuations in the price of aquatic products in the neighbouring two periods are broadly consistent, and the deviation between supply and demand can accurately track the given target, to ensure stable development of market. In the prediction system of price of aquatic products, I select different softened factors to work out different prediction models, and provide a variety of forecast reference scenarios, so as to achieve practicality and universality of system application. This theory can help the government and the decision-makers choose different parameters α and work out different models of the supply and demand change according to the actual need in the case of " market failure". It can effectively regulate whole market of aquatic products, correctly use two means of finance and money, avoid great fluctuations in price of aquatic products, and achieve balance between supply and demand, so as to enhance stable and rapid growth of whole market.

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completed by hand, so the institutional operation cost is very high. Therefore, it is required to strengthen infrastructure construction of tobacco information system and establish three-level (city, county and village) information network system. In other words, we should establish an integrated information network system through Internet, Local Area Network and wireless communication technology. This integrated information network system should be able to visually and vividly reflect frontline information of tobacco production in real time, such as topography, landform, traffic, towns and villages, distribution of tobacco fields, soil types, condition of water and fertility, growth and development, climatic condition, diseases and insect pests, *etc*. In addition, we should also formulate applicable standards and codes for development and application of digital tobacco agriculture, to realize information resource sharing, and intercommunication and interconnection of information, put an end to low level repeated construction and waste of resources, and reduce institutional operation cost.

3.6 Reinforce guidance of safe production It is proposed to provide guidance in prevention of chlorosis, injury from pesticides or mechanical operation, falling in the course of packing or discharging tobacco, as well as in dust prevention. Tobacco chlorosis is a kind of nicotine poisoning accident resulted from contact with wet tobacco leaves. Since nicotine is soluble in water, it may penetrate to surfaces of tobacco leaves through rainfall, dew and sweat. If absorbed by human body, it will go into blood, leading to dizziness, nausea or vomiting, which will be shown generally several hours after exposure. Therefore, it is required to guide tobacco farmers to wear clothes with long sleeves, wear gloves, or raincoat to reduce exposure of skin. Once in contact with fresh tobacco leaves, timely wash hands with hot soapy water, so as to prevent chlorosis as much as possible. Besides, improper use of pesticides or incorrect operation may also be harmful to human body. In this situation, we should enhance training and warning for tobacco farmers, to make them safely store and correctly use pesticides. Besides, pesticides should be kept away from children, animals and foods. Furthermore, personal protection equipment must be used when applying pesticides. In the course of tobacco production, mechanical operation may generate splashes and cause accident of personal injury. Therefore, it is required to provide training and authorization for tobacco farmers who carry out mechanical operation. There shall be safe seat and protective clothes. Besides, it is proposed not to stand behind the vehicle or too close, and it is strictly prohibited for teenagers or old, weak, sick and disabled persons to carry out the operation. Baking rooms are basically five to six meters high, so it is required to prevent falling when accidental falling during packing or discharging tobacco, and strictly carry out safe procedure, ensure equipment safety, and relevant persons should wear safety belt and safety net. Finally, in the course of classification and tobacco bundling, it is required to wear mouth mask and keep well ventilation of operation fields, to prevent farmers from absorbing excessive dust.

4 Conclusions

In the environment of information asymmetry, local government and tobacco companies should take effective measures, guarantee sustainable development of tobacco zones, and actively promote transformation of traditional tobacco production to modern tobacco agriculture, to promote healthy and orderly development of tobacco agriculture in Guangxi and even in the whole country.

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