

Research Article

Complexity and Application of Tobacco Manufacturer Pricing Game considering Market Segments

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This paper considers price as a strategy using two methods of market segmentation through game theory based on the collected data of several typical cities in Shandong province. Three oligarchs are discussed to analyze the complexity of the market in tobacco system. The effect of different factors on the equilibrium price of Nash equilibrium is discussed. What is more, the variation of parameters drives the system to change to uncertain status, even to bifurcation or chaos. We also discuss the model under normal circumstances, when the three parties jointly take chaos control measures, and its impact on the system. Finally, we clarify chaos control of economic significance. The results indicate that only reasonable pricing strategy is a critical point to achieve maximized profit and maintain orderly operation at the same time, which is a constructive suggestion for tobacco companies' operational strategy.

1. Introduction

Based on the AHP method and using 20 factors, the results of Zhang et al. [1] showed that 29.82% of the total area was highly suitable for tobacco production and 17.74% was unsuitable. To solve the problem where the regular IAHP model cannot describe the probability with an interval number, Xiao et al. [2] carried out the probabilistic distribution of the weights calculation in IAHP. By the study of fuzzy judgment matrices, Zhou and Wei [3] discussed a new method for deriving posterior weight with an application into a real example. In order to determine attribute weights in multiple-attribute decision-making, Cui et al. [4] analyzed the limitations of the present approaches to determining weights of attributes. Based on grey incidence, Xu and Lv [5] proposed a method for group decision-making. According to fuzzy comprehensive judgment applied to many provinces in practice, Zhong et al. [6] used grey correlation analysis for the comprehensive evaluation. Al-Bayati and Hussein [7] applied the evaluation process to obtain the valuable feedback as its major conclusions for further study. With imprecise data, Kao [8] used DMUs under the framework of DEA. In order to develop the

status of tobacco industry, Li [9] discussed a few measures for developing modern tobacco agriculture. From a new perspective, Li et al. [10] gave two methods and gave an analysis to solve the problems that the structure of BP neural network will become complex when samples' data is not preprocessed. By using the grey correlation analysis of the BP neural network, Tang [11] gave a method for improving the network's forecasting accuracy.

With the rise of chaos theory, many scholars are interested in building model with the use of complex system method. Ma and Wang [12] established a closed-loop supply chain and found that the system will become more complicated when the retailers exacerbate competition. Considering that players have different adjustment mechanisms and expectations, Ma and Guo [13] investigated a dynamic duopoly Cournot game model and studied the influence of adjustment factors on the system. Based on a new supply chain model with supplier and two retailers, J. Ma and X. Ma [14] found that the bullwhip effect is impacted by different factors.

Market segmentation is the procedure which divides into different consumer groups according to certain rule; under this rule the standard variable segments are chosen. After

selecting the standard variable, consumers are assigned to different groups with certain method. Thus market segmentation approach is the main research method to solve these two issues, which is named segmentation criteria to determine the choice of distribution methods.

For the breakdown of standard variables, it may be single or plural. When there are more variables, the number of market segments will increase exponentially. For example, if there are three values for each variable and the total number of variable is three, then there will be $3^3 = 27$ separations of the market. And when the number of variables is four, there will be $3^4 = 81$ separations of the market. Therefore, the number of variables determines the choice of market segmentation. Considering the demand of the actual needs and the degree of difficulty of the two studies, we have to make suitable decision of variable's quantity.

When it comes to market segmentation, there are many ways, such as conjoint analysis, mixed regression model, factor analysis, fuzzy cluster analysis, AHP, and decision tree algorithm.

Tobacco companies in the competitive market adjust their product price to maximize operation profits. Economic significance of chaos control is to minimize the impact of its price and the price of its own competitors in sales. Thus, the tobacco industry needs to improve sales channels, increasing sales service quality and establishing a good brand image. And then gradually the tobacco industry wins the market through quality and service and also wins more consumers.

Consider the situation where three tobacco companies sell their three tobacco products. These three tobacco companies can be seen as a three-oligarch tobacco market. The three tobacco companies' Nash equilibrium price and the change rate of the price have the influence on the equilibrium state.

In practice, more often with real-time changes in the market, the three parties adjust their prices according to the size of the margin of prices. So we need to model the Nash equilibrium of the three parties' game. Find the Nash equilibrium price for tobacco companies and analyze the complexity of price just like impact on the price of the game and the impact on profits of the game and time series game prices.

Finally, through the research, the reasonable pricing strategy is obtained, which is to maintain the image of the enterprise and the profit balance.

2. Market Segmentation Based on Conjoint Analysis

To study simplicity, select a standard variable: product benefits. Market segmentation methods include conjoint and mixed regression model.

Conjoint analysis is a statistical method, which is important for product attribution in the minds of consumers as well as the level of product attributes. For tobacco products, they have different properties, such as aroma, taste, smoke, aftertaste intensity, tar, tobacco, and cigarette paper. Different products have different combinations of attribution and attributing levels; for example, the proportion of white sand tar in Hongtashan, Zhonghua, and other brands of cigarettes

TABLE 1: Hongtashan product attributes.

Hongtashan	
Attribute	Description
Raw material	Yuxi
Additive	Appropriate
Taste	Supple
Aroma	Plump
Gas	Soft
Aftertaste	Clean

is higher than the property tar in Zhongnanhai, Pride, and other low-tar brands of cigarettes. Hongtashan product attribute levels and combinations can be expressed as shown in Table 1.

Different cigarette brands have different combinations of attributes and attribute levels. For different consumers, their preferences for product attributes are different too. The same sense of property has different satisfaction level and the core of this difference is the consumer demand preference differences. Therefore, when segmenting the product, we must focus on the importance of product attributes and attribute levels to improve people's unit utility.

In general, when using the joint analysis of the product segment, it is divided into two steps. First, the experience of the importance of product attributes and attribute levels brings the utility of the preliminary estimation and then using cluster analysis methods depending on the importance of product attributes and attribute levels brings the utility, which will be assigned to different consumers market. It is easy to think that the first step in the estimation process and the ability to recognize the limitations of the amount of data may result in unreliable model parameters and the second step is based on the analyzing result of the first step. So the first step in the estimation process will affect the final result. In this paper, a mixed regression model is proposed to improve the estimating process of the first step.

To study the market segmentation mixed regression model, it was firstly introduced by DeSarbo joint analysis and others. In the conjoint analysis, the respondents need to rate the product of a group. DeSarbo scoring data assume that each respondent residual obeys multivariate normal distribution and the variance-covariance matrix estimation. In the evaluation of the relevance of different product respondents, the efficiency of the model decreases with the increase of the estimated parameters, if you assume that the residuals are scoring one dollar data independently distributed, although there will be some decrease in the estimated accuracy. However, you can make the model much more efficient, so the change is worth trying. At this time, although the independent distribution of the residual will sacrifice the accuracy, the model's efficiency will be improved, which is worth trying.

Complete contour method is a more traditional conjoint analysis, in addition to a hybrid approach, self-described method, and that based on the selected method. Compared with the other three methods, complete contour method is

simple with normal accuracy, which is widely used. Complete contour method comprises the following steps:

- Determine the product attributes and each attribute specific level.
- Prepare an investigation to determine the product mix.
- Make a preference based on the likelihood of respondents to rate the degree of purchase for each product combination.
- Use the least-squares method to estimate the effectiveness of the model coefficients.

The basic model is as follows:

$$U(G) = \sum_{i=1}^n \sum_{j=1}^{l_i} \alpha_{ij} D_{ij}. \quad (1)$$

This is a utility model expressing the sum of the utility of representing a portfolio G . Product attributes are denoted by i , $i = 1, 2, \dots, n$. The horizontal property is denoted by j , as l_i is the number of horizontal values of the property i . α_{ij} represents utility value attribute, which means the utility of product attributes i get from level j . D_{ij} is a dummy variable; when product attribute i has selected level j , its value is 1; otherwise, it is 0.

I_i indicates the importance of each attribute i . The value for this property at all levels brings a little utility, namely, the difference between the maximum and minimum values, expressed as

$$I_i = \max(\alpha_{ij}) - \min(\alpha_{ij}). \quad (2)$$

I_i represents utility full-pitch; attribute weight W_i can represent the whole of its utility from the proportion of the sum of all the properties of the effectiveness of the whole distance; namely,

$$W_i = \frac{I_i}{\sum_{i=1}^n l_i}. \quad (3)$$

We need to have horizontal joint analysis of n attributes and l_i data for each property value. Readily available, the level values to be studied are $\sum_{i=1}^n l_i$. For l_i level values of each property, we need to get a reference, so for the property there is a need to estimate $l_i - 1$ coefficients. Therefore, there are $C = \sum_{i=1}^n l_i - n$ estimated model coefficients. Assume that each respondent evaluates the needs of M combinations. Data collected from each respondent are M . For each respondent, the linear regression equation can be expressed as

$$S_{pM} = \beta_{0M} + \beta_{1M}X_{1pM} + \beta_{2M}X_{2pM} + \beta_{3M}X_{3pM} + \dots + \beta_{CM}X_{CpM} + \delta_{pM}. \quad (4)$$

Model S_{pM} represents respondent p scoring the M case of a portfolio. X_{1pM} to X_{CpM} represents a combination of different levels. Corresponding β_{1M} to β_{CM} are utility

coefficients under that level. β_{0M} represents intercept model, as δ_{pM} are the residuals.

In its estimating coefficients, we use random coefficient model, which overcomes unstable shortcomings in the estimation of OLS regression model caused by fewer coefficients.

In order to express a clear and simple scoring model, it can also be represented as a matrix form: $S_p = \theta_p X_p + \delta_p$.

From the previous formula, $\theta_p = [\beta_{0M} \ \beta_{1M} \ \beta_{2M} \ \beta_{CM}]$; $X_p = [\beta_{0pM} \ \beta_{1pM} \ \beta_{2pM} \ \beta_{CpM}]^{-1}$.

The residual vector is δ_p ; covariance matrix is σ_p^2 .

Therefore, we can use θ_p , X_p , and σ_p^2 to represent the density function of p respondent's scoring, referred to as $f(S_p | \theta_k, X_p, \sigma_p^2)$.

As mentioned above, for simplicity, in the estimation of the model, we assume that δ_p followed single normal distribution rather than a multivariate normal distribution. The reasons are already mentioned above. Under this assumption, the density function is expressed as the product of p normal distribution possibilities. Assuming that the whole market is subdivided into K markets, the proportion of each market is w_k , where $\sum_{k=1}^K w_k = 1$. For one market k , we give the model coefficient θ_k and its variances σ_k^2 ; the respondents density function can be expressed as

$$g(S_p | X_p, \varphi) = \sum_{k=1}^K \pi_k f(S_p | \theta_k, X_p, \sigma_k^2). \quad (5)$$

From (5), $\varphi = (w_1 \dots w_K, \theta_1 \dots \theta_K, \sigma_1^2 \dots \sigma_K^2)$. In this case, coefficients θ_p and σ_p^2 at the individual level of the density function model have been replaced by model coefficients θ_k and σ_k^2 at the segment level, so that the replacement model is a mixed regression model. With the estimated coefficient φ , the probability p individual that belongs to the q market can be calculated based on Bayes' formula, which is as follows:

$$P(q | X_p, S_p, \varphi) = \frac{\pi_q f(S_p | \theta_q, X_p, \sigma_q^2)}{\sum_{k=1}^K \pi_k f(S_p | \theta_k, X_p, \sigma_k^2)}. \quad (6)$$

Using this method, you can assign each respondent to a segment of the market. The principle is to assign the highest probability of the respondents to its home market. Here we will only divide the respondents to a market rather than assigning them to multiple markets.

Each respondent has M data points; thus the total amount of data is $P \times M$. Based on statistical results, in the case of the model parameter estimation, we use the likelihood function:

$$L = \prod_{p=1}^P \ln [g(S_p | X_p, \varphi)] \\ = \prod_{p=1}^P \sum_{k=1}^K \pi_k f(S_p | \theta_k, X_p, \sigma_k^2). \quad (7)$$

TABLE 2: Consumption data of 26 regions in Shandong province.

	Clothing	Household equipment and services	Healthcare	Transportation and communication	Education, culture, and entertainment	Living	Miscellaneous goods and services
Jinan	924.81	536.37	793.09	1448.33	1181.16	985.72	310.2
Qingdao	1041.7	656.94	804.75	988.28	1435.28	951.56	286.07
Zibo	900.05	536.36	783.44	1048.06	1108.46	1013.74	261.81
Zaozhuang	863.73	440.16	323.91	590.55	945.03	458.01	163.9
Dongying	1509.12	625.28	770.32	1095.2	1842.6	751.32	410.97
Yantai	1458.49	272.42	933.11	882.52	999.45	790.02	338
Weifang	1016.72	538.1	590.06	917.65	947.75	972.66	212.75
Jining	820.83	826.42	417.45	619.61	791.7	616.06	162.04
Tyan	798.03	443.74	538.66	623.12	1348.09	727.06	248.7
Weihai	1369.93	609.62	682.48	1080.86	1261.65	1018.55	542.62
Rizhao	982.9	571.58	454.98	1195.46	825.89	579.91	277.91
Laiwu	863.38	713.7	467.06	978.89	1009.62	714.66	183.19
Linyi	980.49	511.48	378.77	1176.03	1070.76	854.93	240.47
Dezhou	889.33	380.85	436.79	887.1	1160.2	594.6	224.04
Binzhou	778.1	430.06	392.1	946.61	1272.55	672.48	191.03
Heze	804.84	336.32	367.33	516.18	633.27	436.34	183.51
Wendeng	742.33	314.85	377.92	952.96	446.54	769.48	200.35
Zhucheng	819.68	333.71	302.22	945.79	785.61	479.52	134.95
Qingzhou	776.72	333.94	627.8	865.29	806.67	786.54	237.13
Weishan	929.52	694.9	351.51	598.42	1274.28	410.42	299.99
Linqing	539.62	337.68	372.83	433.12	479.88	639.22	149.62
Feixian	629.31	402.05	199.15	450.1	757.74	371.59	61.07
Lijin	795.41	327.8	611.97	760.38	1439.42	640.55	224.19
Wucheng	615.4	426.88	385.36	382.57	747.51	524.08	94.81
Donga	516.72	255.33	594.04	358.94	539.33	468.61	125.64
Juye	603.64	405.99	349.08	625.14	622.33	393.37	196.59

Multiplicative model is a simple form by taking the logarithm on both sides of the equation.

$$\begin{aligned} \ln L &= \sum_{p=1}^P \ln [g(S_p | X_p, \varphi)] \\ &= \sum_{p=1}^P \ln \left[\sum_{k=1}^K \pi_k f(S_p | \theta_k, X_p, \sigma_k^2) \right]. \end{aligned} \quad (8)$$

The value for market segments is always determined by the Bayesian Information Criterion and the Akaike information criterion. The calculation method for Bayesian Information Criterion is

$$C_1 = -2 \ln L + (\ln P) \times R. \quad (9)$$

Akaike information criterion is calculated as follows:

$$C_2 = -2 \ln L + 2R, \quad (10)$$

where R represents the number of estimated model coefficients needed, when C_1 and C_2 achieve the minimum; corresponding mode value is the number of market segments.

3. Consumption Region Division with Factor Analysis

Table 2 shows people's income information and nonfood expenditure statistics in different regions of Shandong province.

In order to study the consumption level of different regions in Shandong Province, we analyze the consumption data of 26 cities or regions in Shandong Province in 2005.

Part of the original data is shown in Table 2.

Firstly make principal component analysis of the data. Original indices and their corresponding attributes are as follows:

X_1 : clothing

X_2 : household equipment and services

X_3 : healthcare

X_4 : transport and communications

X_5 : education and cultural and recreational services

X_6 : living

X_7 : miscellaneous goods and services

TABLE 3: Total variance explained.

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	% of variance	Cumulative%	Total	% of variance	Cumulative%	Total	% of variance	Cumulative%
1	4.206	60.085	60.085	4.206	60.085	60.085	2.518	35.971	35.971
2	.984	14.055	74.140	.984	14.055	74.140	2.200	31.429	67.400
3	.681	9.724	83.864	.681	9.724	83.864	1.152	16.463	83.864
4	.446	6.376	90.240						
5	.375	5.359	95.599						
6	.176	2.517	98.115						
7	.132	1.885	100.000						

Extraction method: principal component analysis.

Using SPSS data analysis software for analysis, prior to principal component analysis, due to the different units of data, direct dimension transformation may have a negative impact on the analysis results. And data obtained is shown in Table 3.

Not difficult to see from the table, the cumulative contribution rate of the first component is 60.085%, while the contribution of the first three components was 83.864%. It can be seen that the first three factors explain more than 70% of the variance. The three principal components extracted are set to Y_1 , Y_2 , and Y_3 .

Easy to see for the first principal component, Y_1 , X_1 , X_5 , and X_7 have more contribution; for the second principal component, Y_2 , X_4 , and X_6 have more contribution; for the third main component, X_2 has the highest contribution rate.

According to the ingredient matrix after rotation, we can conclude that the expression of the three main components is as follows:

$$\begin{aligned}
 Y_1 &= 0.827X_1 + 0.208X_2 + 0.614X_3 + 0.274X_4 \\
 &\quad + 0.810X_5 + 0.273X_6 + 0.780X_7 \\
 Y_2 &= 0.361X_1 + 0.137X_2 + 0.622X_3 + 0.796X_4 \\
 &\quad + 0.131X_5 + 0.903X_6 + 0.446X_7 \\
 Y_3 &= 0.156X_1 + 0.929X_2 - 0.218X_3 + 0.282X_4 \\
 &\quad + 0.332X_5 + 0.089X_6 + 0.140X_7.
 \end{aligned} \tag{11}$$

The main ingredient formula has been set with the variables for each region obtaining the value of the main component into each region, Y_1 , Y_2 , and Y_3 . The value of the main component into each region is shown in Table 4.

We use the variance contribution rate as weight, and the score model can be expressed as

$$S = 0.60085Y_1 + 0.14055Y_2 + 0.09724Y_3. \tag{12}$$

Data analysis software SPSS statistical functions and so forth can be used to calculate the level of consumption in different regions and contribute to market segmentation.

The sales strategy of the product is closely related to the local consumption level. It is necessary to have a proper change strategy in areas where consumption levels are low. What is more, companies need to seriously consider issues.

TABLE 4: The value of the main component into each region.

	Y1	Y2	Y3
Jinan	3227.98	3236.698	1401.396
Qingdao	3408.522	2928.147	1477.314
Zibo	3002.92	2897.338	1258.334
Zaozhuang	2184.902	1654.14	1017.032
Dongying	4169.335	3084.489	1693.371
Yantai	3366.445	2841.781	975.5045
Weifang	2765.644	2635.576	1219.652
Jining	2212.662	1894.687	1319.879
Tyan	2738.167	2123.986	1142.111
Weihai	3698.176	3189.965	1521.553
Sunshine	2582.717	2423.515	1286.979
Laiwu	2573.238	2338.466	1396.388
Linyi	2760.328	2615.265	1342.437
Texas	2602.786	2139.871	1116.959
Binzhou	2596.418	2196.353	1211.457
Heze	1877.739	1534.8	778.2524
Wendeng	1900.588	2147.431	839.4313
Zhucheng	2064.511	1878.562	961.1083
Qingzhou	2387.455	2327.088	909.5647
Weishan	2671.25	1797.075	1384.279
Linqing	1544.009	1524.539	675.9059
Feixian	1612.519	1226.46	848.3813
Lijin	2825.749	2184.929	1075.911
Wucheng	1761.671	1438.315	824.54
Donga	1606.313	1426.568	527.8837
Juye	1734.097	1512.691	840.6687

Not difficult to see from the above analysis, different levels of consumption require different sales focus. For example, the consumption level is arranged in the top three in Dongying, Weihai, and Qingdao. For Dongying City, consumption levels are somewhat used to dress the cultural and recreational projects; for Qingdao, the consumer inclines more to education. Tobacco products should belong to miscellaneous goods and services, so for tobacco companies, when considering the level of consumption of the country and developing marketing strategies, they should not only consider the total level of consumption of the country but also take into

consideration the level of consumption for miscellaneous goods.

Product marketing not only needs to consider the local spending power, but also needs to consider the following factors.

(a) *Socioeconomic Factors*. As a result of the rapid economic development, people's living standards continue to improve. The consumption level in the region with low consumption levels has high room for improvement. It is necessary to take into account the future business opportunities in the development of sales strategy. Companies should stand high and see far ahead with sufficient strategic vision for the job.

(b) *Product Quality*. Should we provide low quality goods in areas with low consumption levels? The answer of course is no. Low-quality products can indeed reduce costs and drive down selling prices. In fact, consumers find that getting poor quality products can cause irreversible damage to the image of the business.

(c) *Consumption Habits*. The level of consumption is based on the characteristics of the study area to examine consumer groups and product positioning, but the issue of personal spending habits cannot be ignored. It is difficult for us to meet all the individual needs of consumers, but we cannot view consumers as a static group with specific consumer preferences. With the improvement of living standards, consumers must have higher requirements for the products; for example, the health risks of tobacco products may become increasingly valued. Tobacco companies must respect the habits of consumers in marketing.

The level of consumption in the country to some extent can help make the right business regional marketing strategy with not too hasty making the business decision, which should refine consumer groups, pay attention to product quality, and have a broader strategic vision.

4. Tobacco Manufacturer Pricing Considering Market Segments

Three tobacco companies sell three tobacco products. These three tobacco companies can be seen as representing tobacco market with three oligarchs. The competition of three tobacco companies makes the market price eventually enter the Nash equilibrium.

4.1. *Tobacco Nash Equilibrium Price*. Composition market demand function is

$$\begin{aligned} q_1 &= a_1 - b_1 p_1 + c_1 p_2 + d_1 p_3, \\ q_2 &= a_2 - b_2 p_2 + c_2 p_3 + d_2 p_1, \\ q_3 &= a_3 - b_3 p_3 + c_3 p_1 + d_3 p_2. \end{aligned} \quad (13)$$

All model coefficients are greater than zero. In addition to the fact that the demand for a fixed price is not affected, along with tobacco company's own price increasing, demand decreases with the increase in the price of other brands;

otherwise the demand increases. In addition, the impact of own price changes on demand is greater than the impact of competing prices changes. That is, $b_1 > c_1$ and $b_1 > d_1$. Assume that the sum of all costs for per tobacco product is w ; then three tobacco companies' profit function can be expressed as

$$\begin{aligned} \pi_1 &= (a_1 - b_1 p_1 + c_1 p_2 + d_1 p_3)(p_1 - w), \\ \pi_2 &= (a_2 - b_2 p_2 + c_2 p_3 + d_2 p_1)(p_2 - w), \\ \pi_3 &= (a_3 - b_3 p_3 + c_3 p_1 + d_3 p_2)(p_3 - w). \end{aligned} \quad (14)$$

According to Nash equilibrium, after the three parties in the game, the price reached a steady state, so that the three parties are reluctant to change the price again. So the state corresponding to the price for the marginal profit is zero state. This state may be a function of the price of the derivative profits obtained. The equations to calculate the equilibrium price are therefore

$$\begin{aligned} a_1 - 2b_1 p_1 + c_1 p_2 + d_1 p_3 + b_1 w &= 0, \\ a_2 + d_2 p_1 - 2b_2 p_2 + c_2 p_3 + b_2 w &= 0, \\ a_3 + c_3 p_1 + d_3 p_2 - 2b_3 p_3 + b_3 w &= 0. \end{aligned} \quad (15)$$

Solutions of equations can obtain tripartite equilibrium price.

In addition, in order to make the best price existing, the need to make profit function of the second derivative is less than zero; namely,

$$\begin{aligned} \frac{\partial^2 \pi_1}{\partial p_1^2} &= -2b_1 < 0, \\ \frac{\partial^2 \pi_2}{\partial p_2^2} &= -2b_2 < 0, \\ \frac{\partial^2 \pi_3}{\partial p_3^2} &= -2b_3 < 0. \end{aligned} \quad (16)$$

For example, we give a set of values for the model simulation. According to the analysis above, the definition, and scope of parameters, make $a_1 = 200$, $a_2 = 280$, $a_3 = 200$, $b_1 = 70$, $b_2 = 90$, $b_3 = 60$, $c_1 = 20$, $c_2 = 10$, $c_3 = 40$, $d_1 = 20$, $d_2 = 10$, $d_3 = 40$, and $w = 30$. Numerical simulation is applied to three different tobacco companies. It can be seen that the system has the following characteristics: sales are mainly affected by their own prices and are less affected by the price of competitors. We have studied the specific trends in the following text.

With the use of simulation software for data analysis, we can draw three Nash equilibrium prices: $p_1 = 23.67$, $p_2 = 19.6$, and $p_3 = 31.09$; their profits are $\pi_1 = 2804.82$, $\pi_2 = 9738.56$, and $\pi_3 = 71.286$. So we give Table 5 to compare the three tobacco companies.

It can be seen that the parameters of their own caused a greater impact and the parameters of the competitors caused a smaller impact. Although the price is low, profits are highest, because the price increase brought about by the increase in sales will increase the balance of profits.

TABLE 5: The comparison of the three tobacco companies.

Number	Brand image	Affected by own price	Affected by substitute	Equilibrium price	Equilibrium profit
1	Middle	Middle	Middle	Middle	Middle
2	Good	High	Low	Low	High
3	Middle	Low	High	High	Low

4.2. Complexity of Price Game of Three Oligarchic Tobacco Companies. In practice, more often with real-time changes in the market, the three parties adjust their prices according to the size of the margins of prices. When the profit margin is greater than zero, the price increase is conducive to gaining more income, and when the profit margin is less than zero, we need to lower prices in order to obtain greater profits. Therefore, the price adjustment model can be written as

$$p_i(t+1) = p_i(t) + g_i \times p_i(t) \times \frac{\partial \pi_i(t)}{\partial p_i(t)}, \quad (17)$$

where g_i represents the speed of price adjustment of player i ($i = 1, 2, 3$); then the tripartite price adjustment model is

$$\begin{aligned}
 p_1(t+1) &= p_1(t) \\
 &+ g_1 p_1(t) (a_1 - 2b_1 p_1 + c_1 p_2 + d_1 p_3 + b_1 w), \\
 p_2(t+1) &= p_2(t) \\
 &+ g_2 p_2(t) (a_2 + d_2 p_1 - 2b_2 p_2 + c_2 p_3 + b_2 w), \\
 p_3(t+1) &= p_3(t) \\
 &+ g_3 p_3(t) (a_3 + c_3 p_1 + d_3 p_2 - 2b_3 p_3 + b_3 w).
 \end{aligned} \quad (18)$$

We can first obtain the above model Jacobin matrix in order to get a stable domain model:

$$J = \begin{vmatrix} j_1, c_1 p_1 g_1, d_1 g_1 p_1 \\ d_2 p_2 g_2, j_5, c_2 g_2 p_2 \\ c_3 g_3 p_3, d_3 g_3 p_3, j_9 \end{vmatrix}. \quad (19)$$

From (19),

$$\begin{aligned}
 j_1 &= 1 - 2b_1 g_1 p_1 \\
 &+ g_1 (a_1 - b_1 p_1 + c_1 p_2 + d_1 p_3 - b_1 (p_1 - w)), \\
 j_5 &= 1 - 2b_2 g_2 p_2 \\
 &+ g_2 (a_2 - d_2 p_1 - b_2 p_2 + c_2 p_3 - b_2 (p_2 - w)), \\
 j_9 &= 1 - 2b_3 g_3 p_3 \\
 &+ g_3 (a_3 - c_3 p_1 + d_3 p_2 - b_3 p_3 - b_3 (p_3 - w)).
 \end{aligned} \quad (20)$$

The characteristic equation of (19) is

$$|\lambda E - J| = A_0 + A_1 \lambda + A_2 \lambda^2 + A_3 \lambda^3 = F(\lambda) = 0, \quad (21)$$

where

$$\begin{aligned}
 A_0 &= j_1 j_6 j_8 + j_2 j_4 j_9 + j_3 j_5 j_7 - j_1 j_5 j_9 - j_3 j_4 j_8 \\
 &- j_2 j_6 j_7, \\
 A_1 &= j_1 j_5 + j_1 j_9 + j_5 j_9 - j_3 j_7 - j_2 j_4 - j_6 j_8, \\
 A_2 &= -j_1 - j_5 - j_9, \\
 A_3 &= 1.
 \end{aligned} \quad (22)$$

The Routh-Hurwitz stability criterion proposes that a system whose characteristic roots are both in the unit circle is asymptotically stable, and this equals to satisfying the following conditions:

$$\begin{aligned}
 F(1) &= A_0 + A_1 + A_2 + A_3 > 0, \\
 F(-1) &= A_0 - A_1 + A_2 - A_3 < 0, \\
 A_0^2 - A_3 &< 0, \\
 (A_3 - A_0^2)^2 - (A_1 - A_2 A_0)^2 &> 0.
 \end{aligned} \quad (23)$$

Large-scale price adjustment will cause great harm to the system, so that the price balance is no longer stable, endangering the stability of the entire system.

In the three vendors' characteristics prescribed value, make

$$\begin{aligned}
 a_1 &= 3.6, \\
 a_2 &= 4.2, \\
 a_3 &= 3.6, \\
 b_1 &= 3.2, \\
 b_2 &= 4.2, \\
 b_3 &= 2.6, \\
 c_1 &= 0.4, \\
 c_2 &= 0.2, \\
 c_3 &= 0.6, \\
 d_1 &= 0.5, \\
 d_2 &= 0.3, \\
 d_3 &= 0.7, \\
 w &= 0.15.
 \end{aligned} \quad (24)$$

Examine the impact of price adjustment factor on the system.

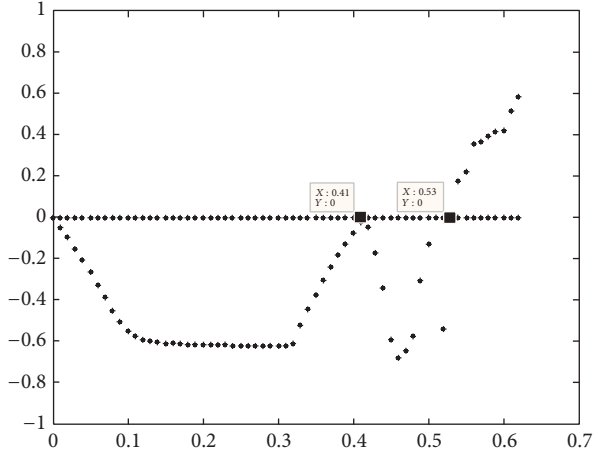


FIGURE 1: The index change map.

(i) *Impact on the Price of the Game.* We fixed the adjustment speed of tobacco companies 2 and 3 as 0.1 and studied the impact of the change of the adjustment speed of company 1 on the system.

The size of the index indicates the average convergence or divergence of the system phase space orbit. The index is calculated as

$$\lambda = \lim_{n \rightarrow \infty} \frac{1}{n} \sum_{n=0}^{n-1} \ln \left| \frac{df(x_n, u)}{dx} \right|. \quad (25)$$

The maximum exponent means the mean of the difference after multiple iterations when difference between the initial values is very small. Iterative equation is as follows:

$$|x_n - y_n| \approx \left| \prod_{n=0}^{n-1} \frac{df(x_n, u)}{dx} \right|_{x_n} |x_0 - y_0|. \quad (26)$$

Knowing the index and the number of iterations n , we can know the difference between the original minor differences through n iterations. Index may be positive or negative, when the index is positive, it indicates that the difference is a proliferation of state in this direction; when the index is negative, it indicates that the difference within the shrinkage is in that direction. If the system phase space trajectory is away from the equilibrium point, the system is out of stability. Whenever there is a positive index, the system will present chaotic state. Thus, to determine whether there is a system chaotic state, you need to check whether there is a positive index. According to the model and numerical simulation of this article, we can obtain the index change map paper systematically. See Figure 1.

Not difficult to see from the figure, when $g_1 < 0.4$, the maximum is always less than zero, so the system is stable. When $g_1 = 0.41$, the maximum for the first time is zero, because there are no indexes greater than zero, so that the maximum of system does not enter a chaotic state but enters the fold bifurcation state. When $g_1 > 0.53$, the maximum number begins to appear positive; then the system enters a chaotic state.

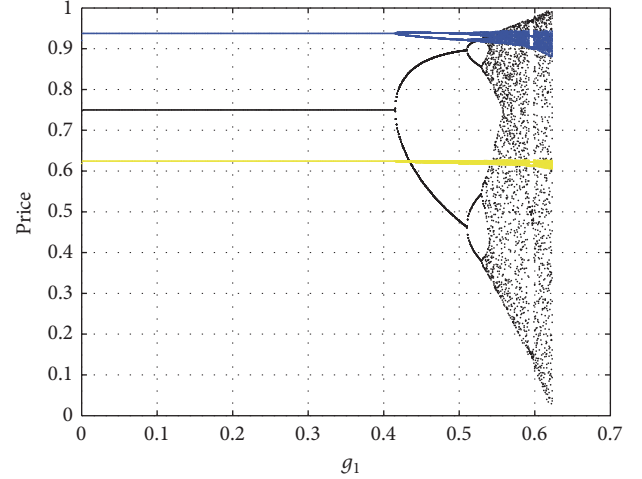


FIGURE 2: The impact of price adjustment speed of evolution of retailer's equilibrium price.

With the increase of retail price adjustment factor 1, the parties of the dynamic evolution of the equilibrium price are shown in Figure 2.

Under a normal price adjustment system, game player keeps stable in the game after a certain period into a steady state. In this condition, the profit side of the game has reached the maximum, which cannot change unilaterally by the price to obtain greater profits. So that is a Nash equilibrium. But if either one of price adjustment coefficients is too large, it will break the steady state, so that the chaotic system enters a state of disorder. As is shown in Figure 2, when the price adjustment factor is greater than 0.41 g_1 , the system began to enter doubling bifurcation state; when g_1 is greater than 0.53, the system enters a chaotic state. In this state, the market competition is chaotic disorder and vicious competition.

(ii) *The Impact on Profits of the Game.* For the company, the price changes directly affect the acquisition of profits. Therefore, the price of the chaotic state of the game will inevitably lead to chaos game profits. We fixed the adjustment speed of tobacco companies 2 and 3 as 0.1 and analyzed the changes in adjustment speed of tobacco company 1. Please see Figure 3.

Through two bifurcation diagrams seen in Figure 3, regardless of the nature of the tobacco industry, the impact of the price adjustment factor on the equilibrium price is similar to the acceleration of price adjustment's speed. Tobacco company's prices gradually appear to be chaotic. The rapid rate of price adjustments by either party will lead to significant tripartite profits to chaos. This stability of the market is very negative.

(iii) *Time Series Game Prices.* Game price time series reflects the increase in the game with the times and the changes in the equilibrium price. At steady state, the price of the game is always in a stable state, as shown in Figure 4.

When the system is in a chaotic state, the price increases with the emergence of the game cycle volatility, as shown in Figure 5.

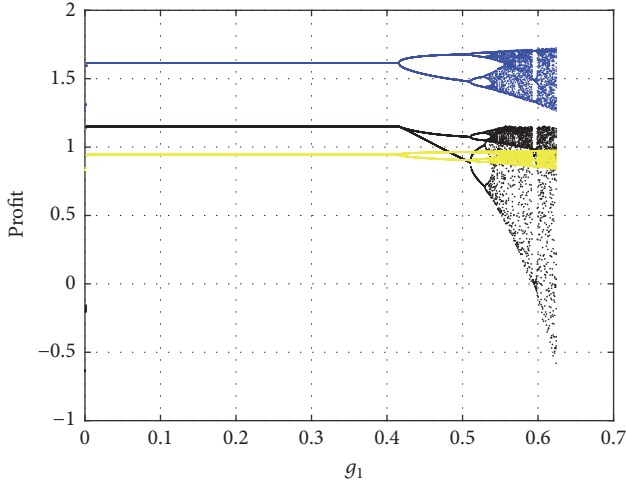


FIGURE 3: The impact of price adjustment speed of evolution of a retailer's balance profit.

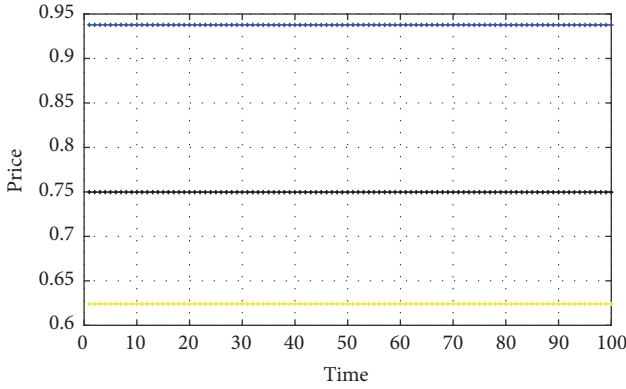


FIGURE 4: The price varies with the steady-state period of the game.

Chaos is a so violent price fluctuations phenomenon, which has certain impact on the stability of the market.

When one of tobacco's price adjustments is too fast, the equilibrium prices go into chaos and the nonlinear feedback control is introduced as follows:

$$u(k, p_n) = k \prod_{i=1}^m (p_n - p_i). \quad (27)$$

After introducing the chaotic control coefficient, the power system of the tobacco company game is shown as follows:

$$\begin{aligned} p_1(t+1) &= p_1(t) \\ &+ g_1 p_1(t) (a_1 - 2b_1 p_1 + c_1 p_2 + d_1 p_3 + b_1 w) \\ &+ k_1 (p_1(t) - p_1(t+1)), \end{aligned}$$

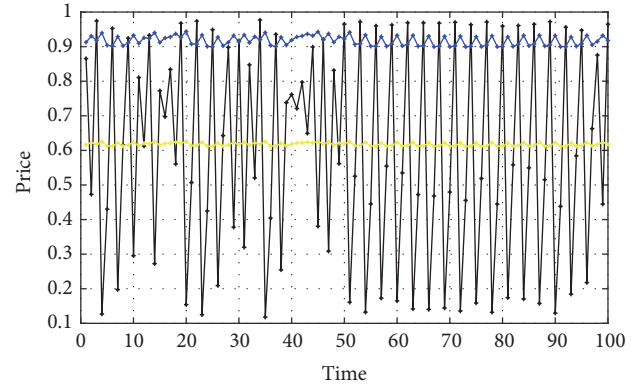


FIGURE 5: The price varies with the chaotic state of the game cycle.

$$\begin{aligned} p_2(t+1) &= p_2(t) \\ &+ g_2 p_2(t) (a_2 + d_2 p_1 - 2b_2 p_2 + c_2 p_3 + b_2 w), \\ p_3(t+1) &= p_3(t) \\ &+ g_3 p_3(t) (a_3 + c_3 p_1 + d_3 p_2 - 2b_3 p_3 + b_3 w). \end{aligned} \quad (28)$$

According to (28), we can get

$$\begin{aligned} p_1(t+1) &= p_1(t) + \left(\frac{g_1}{(1+k_1)} \right) p_1(t) \\ &\cdot (a_1 - 2b_1 p_1 + c_1 p_2 + d_1 p_3 + b_1 w) \\ &+ k_1 (p_1(t) - p_1(t+1)), \\ p_2(t+1) &= p_2(t) + g_2 p_2(t) \\ &\cdot (a_2 + d_2 p_1 - 2b_2 p_2 + c_2 p_3 + b_2 w) \\ &+ k_2 (p_2(t) - p_2(t+1)), \\ p_3(t+1) &= p_3(t) + g_3 p_3(t) \\ &\cdot (a_3 + c_3 p_1 + d_3 p_2 - 2b_3 p_3 + b_3 w) \\ &+ k_3 (p_3(t) - p_3(t+1)). \end{aligned} \quad (29)$$

The impact of coefficient changes on the stability of the system under such conditions is shown in Figure 6.

It can be seen that the system is stable when the value is close to 0.47, which means that the tobacco companies can make more rapid price adjustments.

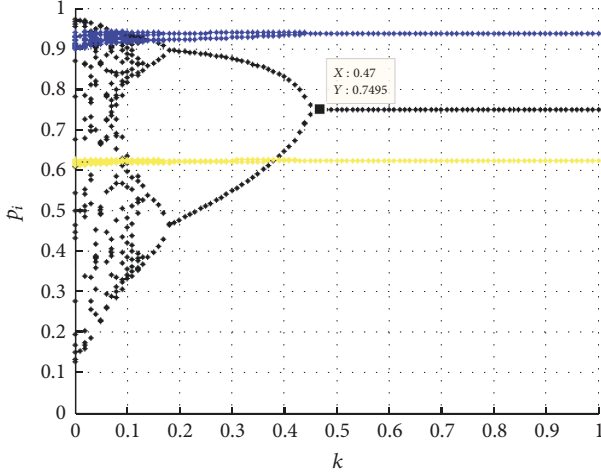


FIGURE 6: Chaos unilateral control factor on system stability.

If all the tobacco companies on the market work together to stabilize the market, chaos control factor of the system becomes

$$\begin{aligned}
 p_1(t+1) &= p_1(t) \\
 &+ g_1 p_1(t) (a_1 - 2b_1 p_1 + c_1 p_2 + d_1 p_3 + b_1 w) \\
 &+ k_1 (p_1(t) - p_1(t+1)), \\
 p_2(t+1) &= p_2(t) \\
 &+ g_2 p_2(t) (a_2 + d_2 p_1 - 2b_2 p_2 + c_2 p_3 + b_2 w) \\
 &+ k_2 (p_2(t) - p_2(t+1)), \\
 p_3(t+1) &= p_3(t) \\
 &+ g_3 p_3(t) (a_3 + c_3 p_1 + d_3 p_2 - 2b_3 p_3 + b_3 w) \\
 &+ k_3 (p_3(t) - p_3(t+1)).
 \end{aligned} \tag{30}$$

According to (30), we can get

$$\begin{aligned}
 p_1(t+1) &= p_1(t) + \left(\frac{g_1}{(1+k_1)} \right) p_1(t) \\
 &\cdot (a_1 - 2b_1 p_1 + c_1 p_2 + d_1 p_3 + b_1 w) \\
 &+ k_1 (p_1(t) - p_1(t+1)), \\
 p_2(t+1) &= p_2(t) + \left(\frac{g_2}{(1+k_2)} \right) p_2(t) \\
 &\cdot (a_2 + d_2 p_1 - 2b_2 p_2 + c_2 p_3 + b_2 w) \\
 &+ k_2 (p_2(t) - p_2(t+1)),
 \end{aligned}$$

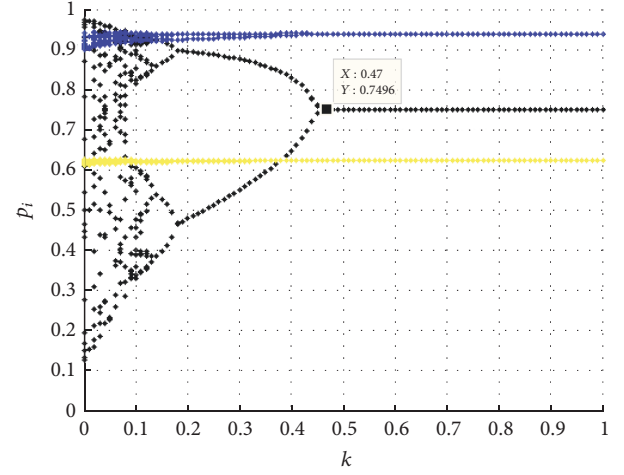


FIGURE 7: Chaos tripartite control factor on system stability.

$$\begin{aligned}
 p_3(t+1) &= p_3(t) + \left(\frac{g_3}{(1+k_3)} \right) p_3(t) \\
 &\cdot (a_3 + c_3 p_1 + d_3 p_2 - 2b_3 p_3 + b_3 w) \\
 &+ k_3 (p_3(t) - p_3(t+1)).
 \end{aligned} \tag{31}$$

In order to facilitate analysis and comparison, chaos control factor drives to all tobacco companies. Observing chaotic control factor on system stability at this time, see Figure 7.

Under normal circumstances, when the three parties jointly take chaos control measures, the system will be easier to control to enter a stable state. In the diagram, the key point is to make the system's stable k value smaller. In this case, it seems that the three parties take effect to unilateral chaos control when there is not much difference among them. This is mainly due to the price adjustment factor 1 retailers sensitively affected by too high corresponding unilateral system. And the chaotic state of preselected g_1 coefficient is relatively large.

Chaos control of economic significance actually reduced by adding k value for each of original price determination coefficients b , c , and so on. So its economic significance is actually to minimize the impact on the sales price.

Tobacco companies in the competitive market adjust product price to maximize profits. But the price adjustment speed should not be too fast; otherwise, it will cause the chaotic phenomena in tobacco companies' equilibrium price, which further causes the chaos phenomenon in profits and huge price fluctuations. Therefore, it is necessary to introduce a method of chaos control. Economic significance of chaos control is to minimize the impact of its price and that of competitors in sales. Thus, the tobacco industry needs to improve sales channels and service quality and establish a good brand image. That helps to gradually win the market through quality and service and finally win more consumers.

5. Conclusion

This paper describes two methods of market segmentation. When considering segmentation, the equilibrium price can be determined based on game theory. By using the theory of complexity, we build a three-oligarch competitive model in tobacco market. Lastly, it discusses the stability of the equilibrium price. By numerical simulation, we calculate the stable region with the change of adjustment speed. We also observe the phenomenon of bifurcation and chaos under different values of parameters. In the practice of management, the decision-maker should avoid the price entering into bifurcation and chaos. The reasonable pricing strategy, which is to maintain the image of the enterprise, obtains the profit balance at last. A constructive suggestion is put forward for the development of the tobacco companies.

Conflicts of Interest

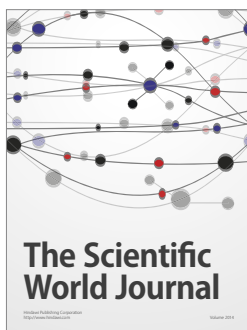
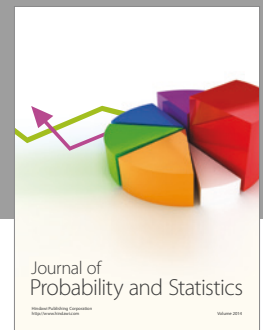
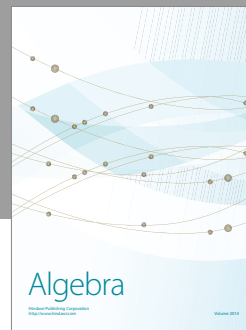
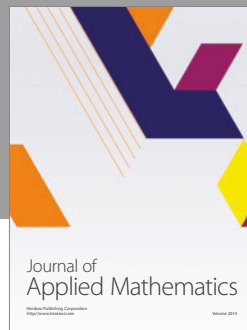
The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

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