Research on resource allocation of drug safety supervision in Ningxia based on PSO-GM(1,1) and GRA

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ABSTRACT

Drug quality and safety status is an important symbol of a country's economic development level and people's quality of life. In order to explore the resource allocation of drug safety supervision in Ningxia Hui Autonomous Region of China, this study used the particle swarm optimization GM(1,1) model to predict the relevant data of Ningxia Drug Administration in 2023. Grey relational analysis model was used to analyze the input and output of drug safety supervision in Ningxia from 2019 to 2023. The research results show that: in the past five years, Ningxia's drug safety supervision has achieved good output, but there are some problems in the allocation of regulatory resources, such as unfair allocation of drug supervision funds and other market supervision affairs costs, and excessive neglect of cosmetic affairs. Therefore, it is proposed to adjust the structure of general public service fees and increase the proportion of drug supervision funds. Adjust the fund structure of drug supervision and optimize the output of drug safety supervision; Standardize the annual report, and make government information open.

Key words: Particle Swarm Optimization, Grey Prediction Model, Grey Relational Analysis, Drug Safety Regulatory Resource Allocation

1 INTRODUCTION

Drug safety is directly related to people's health and life safety, social stability, long-term national peace and stability, and the construction of a harmonious society [1]. Drug quality and safety status is also an important symbol of a country's economic development level and people's quality of life. The 20th National Congress of the Communist Party of China made a series of major discussions and major arrangements on safeguarding people's health, deepening the reform of the medical and health system, and strengthening drug safety supervision, which pointed out the direction, provided guidance, and injected impetus for drug supervision in the new era.

In the evaluation and analysis of drug regulatory efficiency and resource allocation, Huang F et al. (2020) used data envelopment analysis model and Malmqusit index to evaluate the drug safety regulatory efficiency in Guangdong Province, analyzed the current situation of drug regulation in Guangdong Province, and put forward relevant suggestions [1]. Duan X (2022) et al. also used data envelopment analysis and Malmqusit index to evaluate and analyze the status quo of drug regulation in China [2]. However, neither of the two studies discussed the interaction between each indicator and the regulatory effect. Zhang X (2020) et al. used the analytical network process fuzzy comprehensive evaluation model to conduct a quantitative evaluation of the food safety supervision performance of the Chinese government [3]. Although the correlation among indicators was considered, the main data sources and questionnaires were determined by the Delphi method, which made the model more subjective. The National

Academy of Sciences, the Academy of Engineering and the Medical School of the United States proposed that the dependence of various drug regulatory departments should be strengthened, synergistic effectiveness, and all-round cooperation and communication should be accelerated to promote the development of the pharmaceutical industry.

In order to provide a new perspective for the efficiency evaluation and resource allocation analysis of drug regulation in China, this study took the drug regulation situation of Ningxia Hui Autonomous Region as the research object, combined with official data, used the GM(1,1) model optimized by particle swarm optimization to predict the small sample data of various indicators of drug regulation in Ningxia, and conducted residual and grade ratio tests. Thus, the objectivity and effectiveness of the analysis data are guaranteed [4]. Based on the historical data and the predicted data, the grey correlation analysis model was used to explore the influence of various indicators on the output effect of drug supervision, and the problems existing in the allocation of drug supervision resources in Ningxia were found and relevant suggestions were provided, which could provide references for the analysis of drug supervision resources allocation in other cities in China.

2 RELATED WORK

2.1 Particle Swarm Optimization Algorithm (PSO)

Particle swarm optimization (PSO) is derived from the bionic intelligent algorithm of bird foraging. It is solved through the interaction of information between particle swarm, and has the advantages of high precision and fast convergence. The particle velocity and position update formulas are shown in equation (1) and equation (2).

$$v_n^i = w v_n^{i-1} + c_1 r_1 (p_n^i - s_n^i) + c_2 r_2 (g^i - s_n^i) \tag{1}$$

$$s_n^{d+1} = s_n^d + v_n^d \tag{2}$$

Where v_n^i represents the velocity of the NTH particle at the i iteration; s_n^d represents the position of the NTH particle at the i iteration; r_1 and r_2 are random numbers on [0,1]; c_1 and c_2 are individual learning factors and social learning factors respectively. p_n^i is the optimal solution of the NTH particle at the i iteration; g^i is the optimal solution for all particles by iteration i.

2.2 Grey Prediction Model (GM(1,1))

GM(1,1) is a forecasting model which takes the uncertainty system with small sample and poor information as the research object. It is a forecasting model of time series. GM(1,1)The original data is used as the data column to build the model, as shown in equation (3).

$$x^{(0)}(k) + a z^{(1)}(k) = b,\ k = 1,2,\dots,n \tag{3}$$

Where k is the KTH item of the data column, $x^{(0)}(k)$ is the original data column, a is the development coefficient, b is the gray action, and $z^{(1)}(k)$ is the number of neighboring values generated by the data column under the generation coefficient alpha after the accumulation of the original data, as shown in equation (4).

$$z^{(1)}(k) = \alpha x^{(1)}(k) + (1-\alpha) x^{(1)}(k+1),\ k = 1,2,\dots,n \tag{4}$$

Then the cumulative number series predicted value and final predicted result generated by GM(1,1) model after prediction are shown in equation (5) and equation (6).

$$\hat{x}^{(1)}(k+1) = \left(x^{(0)}(1) - \frac{b}{a}\right)e^{-ak} + \frac{b}{a}, \ k = 1,2,\dots,n \tag{5}$$

$$\hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k), \ k = 1,2,\dots,n \tag{6}$$

It can be seen from the model that the generation coefficient alpha of the formula for calculating neighboring generated numbers will affect the final prediction effect of the model, and $\alpha \in [0,1]$, the specific value of the generation coefficient is difficult to determine. Therefore, particle swarm optimization algorithm is used in this paper to optimize and select the optimal generation coefficient [5].

2.3 Grey relational Analysis (GRA)

Grey relational analysis refers to the method of quantitative description and comparison of the development and change of a system [6-7]. By determining the similarity degree of geometric shapes between reference data columns and several comparison data columns, it determines whether the relationship is close. It reflects the degree of correlation between curves. The variable matrix was constructed from the sub-parent sequence, the matrix was initialized and normalized to obtain the matrix G^q, and the maximum difference ∂ and minimum difference φ were calculated respectively. The maximum difference and minimum difference formulas of the two poles were shown in equations (7) and (8).

$$\partial = \max_l \max_m |G^q{}_{1m} - G^q{}_{lm}| \tag{7}$$

$$\varphi = \min_l \min_m |G^q{}_{1m} - G^q{}_{lm}| \tag{8}$$

Where$l = 2,3,4,\dots;m = 1,2,3,\dots$.Define the Grey relational degree of y_q and βas $\gamma(y_q,\beta_m)$, then the Grey relational coefficient of y_q and β is calculated as follows:

$$\gamma(G^q{}_{1m}, G^q{}_{lm}) = \frac{\varphi + \tau * \partial}{|G^q{}_{1m} - G^q{}_{lm}| + \tau * \partial} \tag{9}$$

Grey relational degree can be calculated by Grey relational coefficient:

$$\gamma(y_q, \beta_m) = \frac{\sum_{m=1}^{\theta} \gamma(G^q{}_{1m}, G^q{}_{lm})}{\theta} \tag{10}$$

3 MODEL ESTABLISHMENT AND SOLUTION

3.1 Index selection

This study analyzed and summarized the input and output of drug safety supervision resources in Ningxia, and studied the allocation fairness and efficiency of drug safety supervision resources in Ningxia based on the GM(1,1) model after particle swarm optimization and the gray prediction model. By referring to the public data of China State Drug Administration and Ningxia Drug Administration, and combining the data of China Health Statistics Yearbook, Ningxia Health Yearbook and China Food and Drug Administration Yearbook [8]. The input index of drug supervision in Ningxia region was determined to be the number of administrative inspections, the number of administrative charges, the cost of drug supervision in Ningxia and the proportion of drug supervision fund input in Ningxia, and the output index of drug supervision was the number of administrative penalties, the number of reapprovals, the rate of administrative licensing and the passing rate of random inspection.

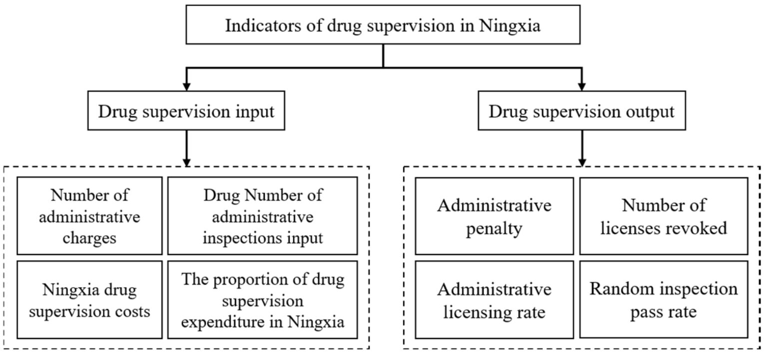

Figure 1: Indicators of drug supervision in Ningxia

3.2 Particle swarm GM(1,1) model

Since the data that can be collected and analyzed is only four years' data, there may be chance in the prediction of the general trend. Therefore, the GM(1,1) model is used to forecast the above small sample indicators, and the data of 2023 is obtained. However, the artificial selection of the generation coefficient of the GM(1,1) model will lead to deviations in the prediction results [9]. The particle swarm optimization algorithm was used to optimize the GM(1,1) model.

Before the GM(1,1) model is constructed, it is necessary to carry out the level ratio test on the original data column, and the expression of the original data column is shown in equation (11).

$$x^{(0)} = (x^{(0)}(1), x^{(0)}(1), \dots, x^{(0)}(n)) \tag{11}$$

Then the calculation formula of grade ratio test is shown in equation (12).

$$\rho(k) = \frac{x^{(0)}(k-1)}{x^{(0)}(k)}, k = 2,3 \dots, n \tag{12}$$

If all the level ratios are within the tolerable coverage interval $(e^{\frac{-2}{n+1}}, e^{\frac{2}{n+1}})$, then the original data column $x^{(0)}$ can construct the GM(1,1) model and make gray prediction. It is necessary to translate the data until all levels of the obtained data column are in $(e^{\frac{-2}{n+1}}, e^{\frac{2}{n+1}})$, and after passing the level ratio test, the original data column $x^{(0)}$ needs to be accumulated to generate a data column $x^{(1)}$. As shown in equation (13).

$$x^{(1)}(k) = \sum_{j=1}^{k} x^{(0)}(j), k = 1,2, \dots, n \tag{13}$$

Then the particle swarm optimization model is built, the number of particles, inertia weight and learning factor are initialized, the number of iterations, the value range of particles and the speed range of particles are set, and the position of particles is initialized. In order to achieve the optimal prediction effect, the average error sum of the prediction results is taken as the evaluation index, then the fitness function F of the model is:

$$F = \sum_{k=2}^{n} [\hat{x}^{(0)}(k) - x^{(0)}(k)]^2 \tag{14}$$

Substitute equation (5) and (6) into equation (14) to get the fitness function formula.

$$F = \sum_{k=2}^{n} [e^{-ak}(1-e)(x^{(0)}(1) - \frac{b}{a}) - x^{(0)}(k)]^2 \tag{15}$$

The smaller the fitness function value is, the better the prediction effect of the model is. The historical optimal solution of each particle is used to update the velocity and position of the particle through equations (1) and (2). When the maximum number of iterations is reached, the iteration is stopped, and the minimum fitness value and the position of the particle at this time g^i are output. Taking g^i as the optimal generation coefficient, construct the adjacent generation number of $x^{(1)}$ under the generation coefficient g^i, as shown in equation (16).

$$z^{(1)}(k) = g^i x^{(1)}(k) + (1 - g^i)x^{(1)}(k+1),\ k = 1,2,\dots,n \tag{16}$$

The GM(1,1) model is constructed with $x^{(0)}$ and $z^{(1)}$, and the GM(1,1) model is obtained by substituting equation (16) into equation (3), as shown in (17).

$$x^{(0)}(k) + a[g^i x^{(1)}(k) + (1 - g^i)x^{(1)}(k+1)] = b,\ k = 1,2,\dots,n \tag{17}$$

Equations can be listed from the above mentioned as shown in equation (18).

$$\begin{cases} x^{(0)}(2) + a[g^i x^{(1)}(1) + (1 - g^i)x^{(1)}(2)] = b \\ x^{(0)}(3) + a[g^i x^{(1)}(2) + (1 - g^i)x^{(1)}(3)] = b \\ \vdots \\ x^{(0)}(n) + a[g^i x^{(1)}(n-1) + (1 - g^i)x^{(1)}(n)] = b \end{cases} \tag{18}$$

According to the equations of equation (18), the correlation coefficient can be extracted:

$$\mu = \begin{bmatrix} a \\ b \end{bmatrix} \tag{19}$$

$$Y = \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{bmatrix} \tag{20}$$

$$B = \begin{bmatrix} -[g^i x^{(1)}(1) + (1 - g^i)x^{(1)}(2)] & 1 \\ -[g^i x^{(1)}(1) + (1 - g^i)x^{(1)}(3)] & 1 \\ \vdots & \vdots \\ -[g^i x^{(1)}(1) + (1 - g^i)x^{(1)}(n)] & 1 \end{bmatrix} \tag{21}$$

Then the GM(1,1) model can be expressed as $Y = B\mu$, and estimates of the development coefficient a and gray action b can be obtained by least square method.

$$\hat{\mu} = \begin{bmatrix} \hat{a} \\ \hat{b} \end{bmatrix} = (B^T B)^{-1} B^T Y \tag{22}$$

After the estimate is obtained, $t = 2,3\dots,n$ are treated as continuous variables, so the corresponding whitening model is shown in equation (23).

$$\frac{dx^{(1)}(t)}{dt} + \hat{a}x^{(1)}(t) = \hat{b} \tag{23}$$

The predicted value of $x^{(1)}$ can be obtained by solving the whitening model, and the relative residual test is carried out on the predicted results obtained by the GM(1,1) model based on particle swarm optimization [10]. If all the values of $|\varepsilon(k)||$ are less than 10%, it indicates that the prediction effect is good.

$$\varepsilon(k) = \frac{\hat{x}^{(0)}(k) - x^{(0)}(k)}{x^{(0)}(k)} * 100\%, k = 1,2,\dots,n \tag{24}$$

3.3 Drug regulatory resource allocation association analysis model

In order to explore the fairness and efficiency of drug safety regulatory resource allocation in Ningxia, the correlation analysis of input and output of drug safety regulatory resources in Ningxia was conducted. Due to the small amount of data and small sample data, the traditional regression analysis is not applicable, so the Grey relational analysis is chosen as the evaluation model for the study.

Taking the output of drug safety supervision as the parent sequence and the input of drug safety supervision as the sub-sequence, the sets of parent sequence and sub-sequence are respectively:

$$Y = (y_1, y_2, \dots, y_q) \tag{25}$$

$$\beta = (\beta_1, \beta_2, \dots, \beta_m) \tag{26}$$

The variable matrix $A^q(q = 1,2,3, \dots)$can be formed from the above subsequently-parent sequences.

$$A^q = \begin{pmatrix} y_{q1} & \beta_{11} & \beta_{21} & \cdots & \beta_{m1} \\ y_{q2} & \beta_{12} & \beta_{22} & \cdots & \beta_{m2} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ y_{q\theta} & \beta_{1\theta} & \beta_{2\theta} & \cdots & \beta_{m\theta} \end{pmatrix} \tag{27}$$

Where $\theta = 1,2,3, \dots$ initializes the matrix A^q to find the mean value of each index, and then divide each element in the index by its mean value to get the matrix G^q. The maximum difference ∂ and minimum difference φ of the two poles were calculated for columns 2-5 of the matrix G^q according to equations (7) and (8), and the Grey relational coefficients of y_q and β were calculated by substituting the Grey relational coefficients into equation (9). The Grey relational degree of each drug safety supervision output to the safety supervision input index could be calculated by substituting the Grey relational coefficients into equation (10).

3.4 Model solving

3.4.1 Prediction model solving

For the trend analysis of data from 2019-2022 only, it is difficult to exclude the interference of specific values caused by special events on the analysis results. In order to ensure the effectiveness of trend analysis of input and output of drug safety regulatory resources by relevant drug regulatory departments in Ningxia, the particle swarm GM(1,1) model is constructed for each input and output index of safety regulatory resources. To predict the corresponding data of each index in 2022, and the prediction results are shown in Table 1 and 2.

Table 1: Predicted results of drug safety supervision input indicators

Year	Administrative inspection	Supervision fees in Ningxia (10,000 yuan)	Proportion of supervision expenditure in Ningxia	Number of administrative charges
2019	164	5822.11	86.57%	49
2020	236	5188.73	85.78%	50
2021	226	5972.00	84.26%	32
2022	265	5997.83	80.72%	20
2023	274	6558.73	78.65%	13
$\varepsilon(k)$	4.51%	3.04%	0.55%	1.28%

Table 2: Predicted results of drug safety regulatory output indicators

Year	Administrative penalties	Number of licenses revoked	Administrative licensing rate	Pass rate of random inspection
2019	46	24	98.06%	97.20%
2020	27	14	96.55%	99.06%
2021	20	0	97.59%	99.17%
2022	23	0	98.99%	99.58%
2023	19	0	99.89%	99.79%
$\varepsilon(k)$	8.89%	3.70%	0.08%	0.07%

The average relative residual test of the prediction results of the relevant indicators in Table 1 and Table 2 is less than 10%, and the model fitting effect is good, and the prediction results are valuable for reference.

3.4.2 Solving association analysis

Combined with the data, it can be seen that there are 4 drug safety supervision input indicators and 4 drug safety supervision output indicators, and the time series is five years from 2019-2023, so the model parameters $q = m = 4$, $\theta = 5$. SPSS is used to solve the correlation degree between each drug safety supervision output indicator and all input indicators [11]. The Grey relational between the number of administrative penalties and the input of drug safety supervision is shown in Table 3. Ningxia has the highest correlation between the input of regulatory funds and the number of administrative penalties, while the correlation between the other indicators and the number of administrative penalties is small.

Table 3: shows the Grey relational degree between administrative penalties and drug safety supervision input

Evaluation Items	Relevance	Ranking
The proportion of drug supervision expenditure in Ningxia	0.718	1
Drug supervision expenses in Ningxia	0.650	2
Number of administrative charges	0.649	3
Number of administrative inspections	0.645	4

As shown in Table 4, the number of administrative charges has the highest correlation with the number of administrative penalties, followed by the regulatory fund input ratio, and the number of administrative inspections has the lowest correlation with the output result of the number of reapprovals.

Table 4: Grey relational degree between license revocation number and drug safety supervision input

Evaluation Items	Relevance	Ranking
Number of administrative charges	0.806	1
The proportion of drug supervision expenditure in Ningxia	0.665	2
Drug supervision expenses in Ningxia	0.640	3
Administrative inspection	0.634	4

As shown in Table 5, the gray correlation degree between the administrative license rate and the input of drug safety supervision is the highest in Ningxia, which is as high as 0.902, followed by the regulatory expenditure, and the correlation degree between the number of administrative charges and the output result of the administrative license rate is the lowest.

Table 5: Grey relational degree between administrative license rate and drug safety supervision input

Evaluation Items	Relevance	Ranking
Number of administrative charges	0.806	1
The proportion of drug supervision expenditure in Ningxia	0.665	2
Drug supervision expenses in Ningxia	0.640	3
Administrative inspection	0.634	4

The gray correlation results of the pass rate of sampling inspection and the input of each drug safety supervision are shown in Table 6. The proportion of drug supervision fund input to the administrative license rate has the highest correlation, and the number of administrative charges has the lowest correlation with the output result of the administrative license rate.

Table 6: shows the Grey relational degree between the qualified rate of sampling inspection and the input of drug safety supervision

Evaluation Items	Relevance	Ranking
Number of administrative charges	0.806	1
The proportion of drug supervision expenditure in Ningxia	0.665	2
Drug supervision expenses in Ningxia	0.640	3
Administrative inspection	0.634	4

In addition, in order to understand the correlation degree of drug regulatory cost subdivision index on output results in detail, the issues of fairness and efficiency of drug regulatory resource allocation in Ningxia were studied, and the gray correlation degree of administrative operation, drug affairs, cosmetic affairs, other market regulatory affairs and drug regulatory output results under drug regulatory cost were calculated.

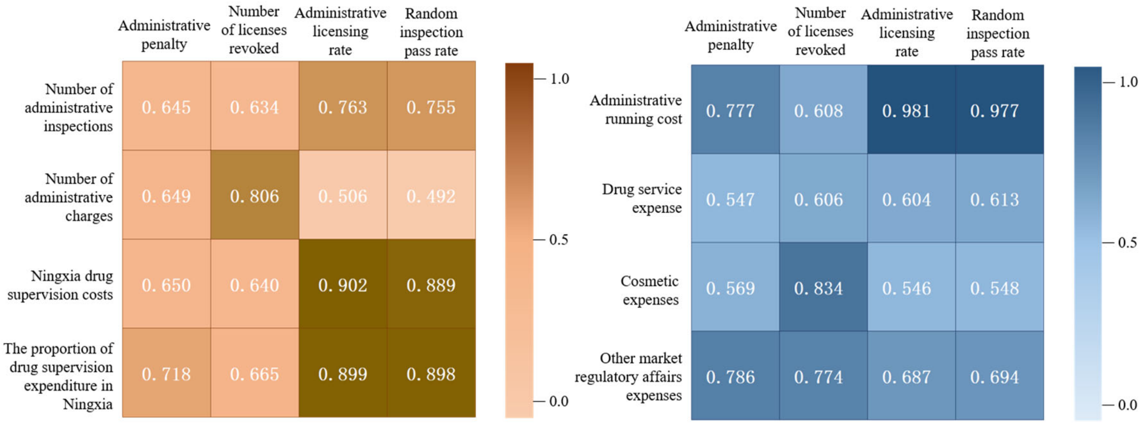

Figure 2: Grey correlation degree of drug supervision cost input index, drug supervision cost subdivision index and drug safety supervision output4 Discussion

4.1 Input and output of drug safety supervision in Ningxia

4.1.1 Input of drug supervision in Ningxia

In this study, the input of drug supervision in Ningxia was divided into drug supervision expenditure, proportion of supervision expenditure, number of administrative inspection and number of administrative charges. As can be seen from Figure 3, the cost of drug supervision in Ningxia has increased year by year since 2020, but the ratio of drug supervision fund input has continued to decline. It can be seen that the general public service cost of Ningxia Drug Regulatory Bureau is increasing significantly, but the expenditure on aspects other than drug supervision, such as unit medical treatment, house purchase subsidies, office expenses, training expenses, etc., also increases significantly, reducing the proportion of drug supervision funds. As an important financial input index, drug supervision funds are bound to have an impact on the output of drug supervision.

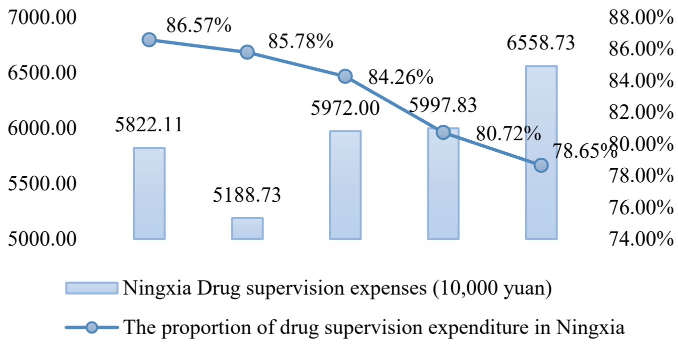

Figure 3: The proportion of drug regulatory expenditure and regulatory expenditure input in Ningxia from 2019 to 2023

The change trend of administrative operating expenses in Ningxia's drug supervision is the same as that of drug supervision expenses. It can be seen that administrative operating expenses increase with the increase of Ningxia's regulatory expenses, and decrease with the decrease.

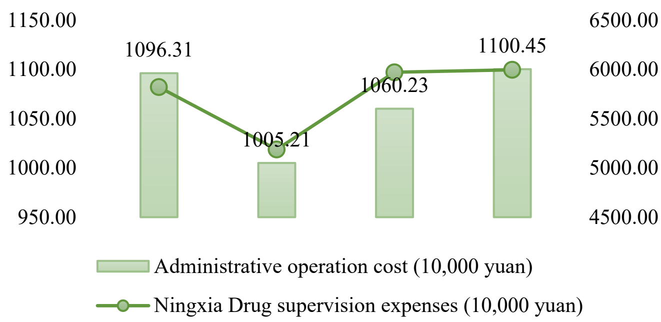

Figure 4: Administrative operating expenses and drug regulatory expenses of Ningxia from 2019 to 2022

However, cosmetics affairs and other market supervision and management affairs showed a similar trend to the proportion of drug supervision funds in Ningxia, showing a continuous decline. However, in contrast, the expenditure of cosmetics affairs decreased at a faster rate.

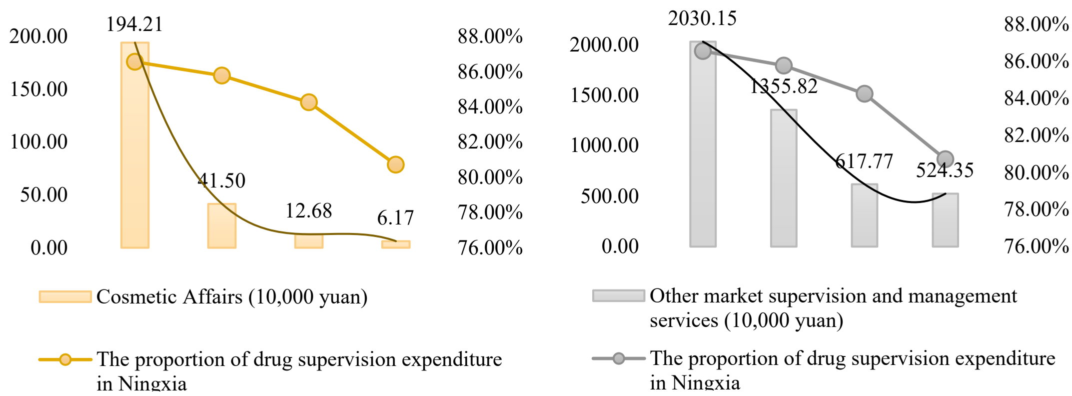

Figure 5: Ratio of drug Regulation, cosmetics affairs, other market regulatory affairs and expenditure expenditure in Ningxia, 2019-2022

On the other hand, the changes of drug affairs are completely different from the ratio of drug regulatory expenditure and regulatory expenditure input. In 2020, when the regulatory expenditure is relatively low, drug affairs have the highest expenditure compared with 2019 and 2021. In 2020, there is a large demand for drug affairs due to the influence of external environment, which is an exceptional value. However, combined with the analysis of other subdivision indicators, it can be seen that as the expenditure on drug affairs increases, the expenditure on other drug supervision correspondingly decreases. From the perspective of the overall regulatory expenditure, this exceptional value is also of research value as a correlation index data.

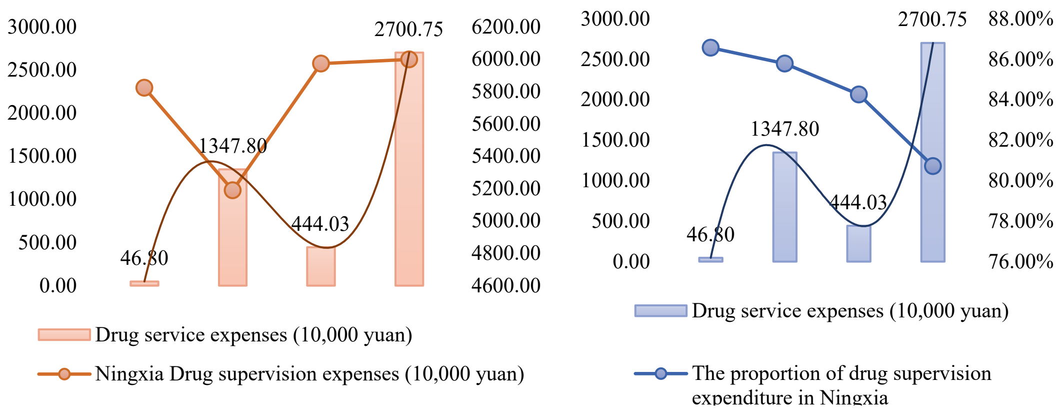

Figure 6: Ratio of drug affairs, regulatory expenditure and funding input for drug regulation in Ningxia from 2019-2022

It can also be seen from the solution results that the number of administrative charges in Ningxia Drug Regulatory Bureau has significantly decreased, but combined with the analysis of the output of drug supervision, it is speculated that the marginal effect of the change of administrative charges on the output of drug supervision has shown diminishing phenomenon, and a small amount of changes will not have a significant impact on the output of drug supervision. On the other hand, the number of administrative inspections showed an upward trend, and the increase in the number of inspections had a positive impact on the output of drug supervision.

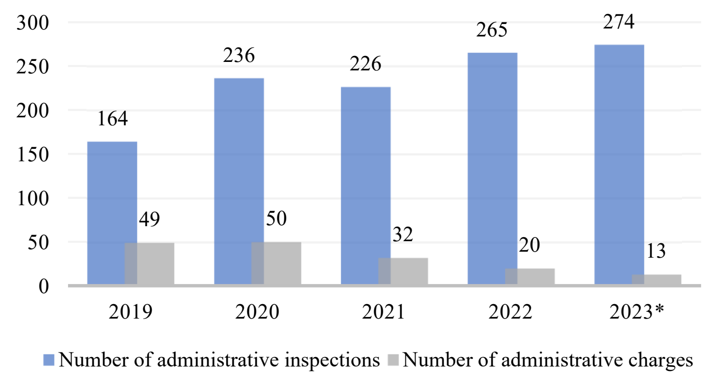

Figure 7: The number of administrative inspections and administrative charges of Ningxia Drug Regulatory Bureau in 2019-2023

4.1.2 Output of drug supervision in Ningxia

In the output of Ningxia drug supervision in this study, the number of administrative penalties and the number of revocation of licenses are both cost-oriented indicators; The qualified rate of sampling inspection and the administrative license rate were the effect-type indicators. Combined with the solution results of the model for the output index, it can be seen that the number of administrative penalty decisions made by Ningxia Drug Regulatory Bureau decreased year by year from 2019 to 2023, and the number of license revocation decisions dropped to 0 in 2021, and continued to be maintained from 2022 to 2023. In terms of drug supervision output, both of them gave positive feedback.

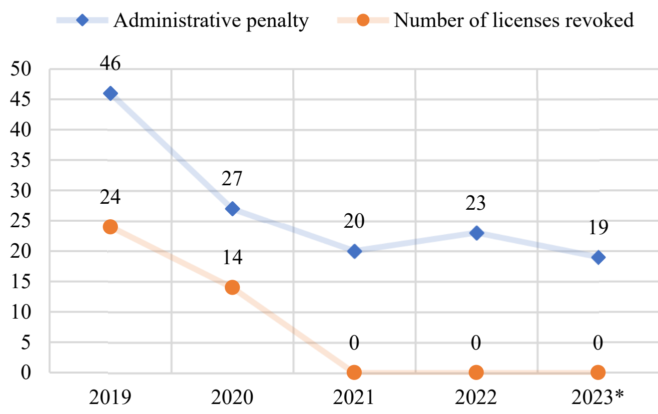

Figure 8: Changes in the number of administrative penalties and license revocations from 2019 to 2023

In addition, if there are no major changes, if the original policy is implemented, the passing rate of random inspection will increase all the way, and it is expected to reach a new high of 99.58% by 2023; Although the administrative license rate will decline in 2019-2020, it will surpass 2019 again after 2022, and it is expected to reach 99.89% in 2023. It can be seen that the policy orientation and resource investment are effective.

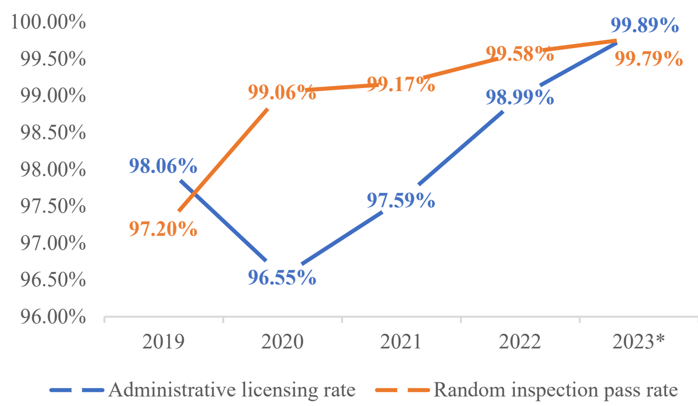

Figure 9: Changes in the passing rate and administrative license rate of sampling inspection from 2019 to 2023

The above four indicators reflecting the output of drug supervision all show the correctness of the Ningxia Regional Drug Supervision Bureau in the general direction of resource input and policy guidance. However, according to the analysis of resource input in drug supervision, there is still room for optimization of the output results.

4.2 Problem Analysis

4.2.1 The allocation of drug supervision funds is unfair

According to the calculation results of the model, the correlation degree of input ratio of drug supervision fund in Ningxia is higher than 0.89 in the two regulatory output results of administrative license rate and random inspection pass rate, and the input ratio of drug supervision fund in Ningxia has a significant impact on the administrative license rate and random inspection pass rate. However, according to the above trend analysis of drug regulatory fund input ratio, Ningxia's drug regulatory fund input ratio continues to decline, which is not conducive to the maintenance and growth of administrative license rate and random inspection pass rate.

4.2.2 Excessive neglect of cosmetic affairs

As shown in Figure 2, in the subdivision index of drug safety supervision funds, the correlation degree between cosmetic affairs expenses and the number of revocations is 0.834, which can greatly affect the number of revocations in the result of safety supervision. However, as can be seen from Figure 5, among the components of drug regulatory funds in Ningxia, the cost of cosmetics affairs shows a trend of substantial decrease. There is a lack of supervision over cosmetics, and the revocation of cosmetics licenses will have an impact on the annual revocation of licenses of Ningxia Drug Regulatory Bureau.

4.2.3 Unfair allocation of regulatory affairs expenses in other markets

Other market supervision fees have a high correlation with the number of administrative penalties and the number of license revocation, but in the actual data of Ningxia Food and Drug Administration, the change trend of their costs has decreased year by year with the ratio of drug supervision input. Therefore, Ningxia Drug Administration should appropriately increase the share of other market supervision costs, such as drug affairs, the correlation of the four safety supervision is not high, and it can be appropriately reduced to fill other market supervision costs.

4.3 Suggestions for optimization

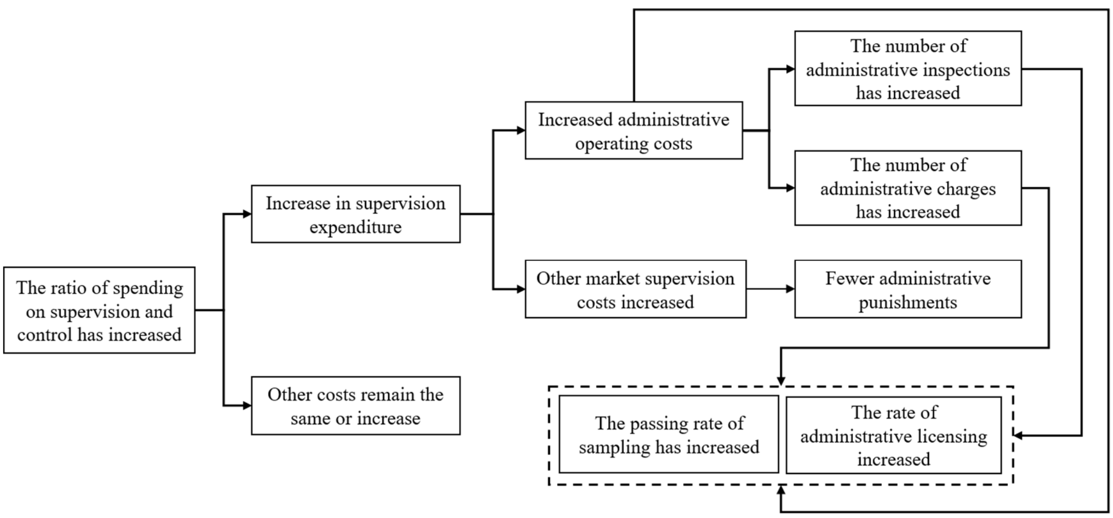

Figure 10: Optimization of drug regulatory fund input ratio

The cost of general public service keeps increasing, and the first three indicators that affect the rate of administrative license and the passing rate of sampling inspection are the input ratio of drug supervision fund of Ningxia, drug supervision fund and the number of administrative inspection. In this case, Ningxia drug supervision Bureau should reduce the share of other expenses within a reasonable range, and increase the proportion of safety supervision fund in the general public service cost. Thus, the drug supervision cost has been improved; The correlation degree of administrative costs in drug supervision funds to the administrative license rate and sample test pass rate is also greater than 0.95, the increase of regulatory costs, administrative operating costs are also increased, the number of administrative inspections, administrative charges are increased, the administrative license rate and sample test pass rate can be improved; At the same time, the cost of other market supervision affairs increased, resulting in a decrease in the number of administrative penalties. Based on the above analysis, relevant optimization suggestions are put forward.

4.3.1 Adjust the general public service fee structure and increase the proportion of drug supervision fund investment

The amount of drug supervision fund input and supervision fund input are more important than the effective output of drug supervision, and there is still a waste of resources in other expenses. Therefore, Ningxia Drug Administration should standardize other expenses through strict reimbursement mechanism and other ways to focus more funds on drug supervision.

4.3.2 Adjust the fund structure of drug supervision and optimize the output of drug safety supervision

Cosmetics affairs have a strong correlation with the number of revocation permits, and basic financial support needs to be guaranteed; The administrative operation cost has a correlation degree greater than 0.95 with the administrative license rate and the passing rate of random inspection, and other market regulatory affairs have a high correlation with the number of administrative penalties and the number of retractions, so it is necessary to maintain or even increase the costs of administrative operation and other market regulatory affairs. On the other hand, such as drug affairs and other affairs that are not highly correlated with each output index can appropriately reduce the investment.

4.3.3 Standardize the annual report and make government information public

In order to facilitate data analysis and adjust the allocation of drug regulatory resources in real time, Ningxia Drug Regulatory Bureau should standardize the annual report. The outline of the report should be standardized and unified as far as possible, and frequent changes should not lead to a large number of incomplete data, which makes it difficult to make long-term analysis and macro-control of drug regulatory situation. At the same time, it should actively publicize government information and take the initiative to sort out the information on the official website, so as to facilitate the operation of the functions of the people's supervision department.

5 CONCLUSION

In this study, particle swarm optimization algorithm was used to optimize the generation coefficient of GM(1,1) model, and the input and output indicators of Ningxia drug supervision in 2023 were predicted by the constructed particle swarm GM(1,1) model. Combining historical data and forecast data, the allocation fairness and efficiency of drug safety supervision resources in Ningxia were studied based on grey correlation analysis. Through research, we can see that there are problems in drug supervision in Ningxia, such as the allocation of drug supervision funds, unfair allocation of other market supervision affairs, and excessive neglect of cosmetic affairs, and put forward optimization suggestions. However, there are still limitations in the selection of input and output indicators of drug regulation in Ningxia. In the subsequent study, more indicators can be analyzed to provide a more comprehensive analysis of drug regulation in Ningxia and a reference for the analysis of drug regulation in other cities in China.

REFERENCES

[1] Di, J., & Zang, Q. (2021). Research on Drug Supervision System Based on Fisco Bcos Blockchain. Frontiers in Business, Economics and Management, 2(3), 109-111.

[2] HUANG, F., & MENG, G. (2020). Evaluation on the Efficiency of Drug Safety Supervision in Guangdong Province Based on Super Efficiency DEA Model and Malmquist Index. China Pharmacy, 2310-2315.

[3] DUAN, X., & WANG, S. (2022). Evaluation of efficiency of drug safety supervision in China based on DEA model and Malmquist index. China Pharmacy, 1814-1819.

[4] Zhang, X., Zhang, J., & Chen, T. (2020). An ANP-fuzzy evaluation model of food quality safety supervision based on China's data. Food Science & Nutrition, 8(7), 3157-3163.

[5] National Academies of Sciences, Engineering, and Medicine. (2020). Regulating medicines in a globalized world: the need for increased reliance among regulators.

[6] Kennedy, J., & Eberhart, R. (1995, November). Particle swarm optimization. In Proceedings of ICNN'95-international conference on neural networks (Vol. 4, pp. 1942-1948). IEEE.

[7] Gad, A. G. (2022). Particle swarm optimization algorithm and its applications: a systematic review. Archives of computational methods in engineering, 29(5), 2531-2561.

[8] Duan, H., & Liu, Y. (2021). Research on a grey prediction model based on energy prices and its applications. Computers & Industrial Engineering, 162, 107729.

[9] Ceylan, Z. (2021). Short-term prediction of COVID-19 spread using grey rolling model optimized by particle swarm optimization. Applied soft computing, 109, 107592.

[10] Peng, X., Tang, X., Chen, Y., & Zhang, J. (2021). Ranking the healthcare resource factors for public satisfaction with health system in China—based on the grey relational analysis models. International Journal of Environmental Research and Public Health, 18(3), 995.

[11] Liu, H., & Liu, Y. (2023). Colleges' performance assessment of university based on grey relational analysis. Journal of Intelligent & Fuzzy Systems, (Preprint), 1-10.