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*Research Article*

# Credit Rating Model of Family Farms and Ranches Based on Dynamic Dichotomous DEA

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The key to the sustainable development of family farms and ranches is to solve the problem of financing difficulty, and the construction of the credit rating system of family farms and ranches is the basis of solving the financing difficulty. Therefore, the construction of the credit rating system of family farms and ranches is not only a theoretical problem but also has strong practical significance. On the basis of dichotomous method and improved DEA technology, this paper sets up a credit rating model based on dynamic cycle dichotomous DEA method with the goal of maximizing the efficiency value of credit scoring of family farm and ranch and the constraint of increasing default loss rate. The first feature of this paper is that it constructs a direct mapping from the credit index system to the credit score through the three-stage DEA model, which avoids the disadvantages of the classical linear weighting formula that relies heavily on the measurement results of different weights, and obtains more accurate and stable credit score results of family farms and pastures. Second, the three-stage DEA efficiency value is used as the credit score value of the family farm and pasture, and whether it is located in the optimal preset interval is taken as the basis for efficiency dichotomy. The DEA credit score of the family farm and pasture is calculated by dynamic cycle, and the samples belonging to each level of the family farm and pasture are calculated successively according to the order of the credit grade from high to low. Finally, the result of reasonable credit rating of family farm and ranch with high default loss rate and low credit score was obtained. The pyramid test results of matching credit rating and default loss rate show that this research method is effective and has a good pyramid shape.

## 1. Introduction

According to statistics, by 2020, the national family farm directory system has reported more than 3 million, and the number of demonstration family farms at or above the county level has reached 117,000, including 265,818 family farms in Inner Mongolia and 4,400 demonstration family farms at or above the county level [1]. The key to the sustainable development of family farms is to solve the problem of financing difficulties, and the construction of credit rating system of family farms is the basis of solving this problem. Therefore, the construction of credit rating of family farms is not only a theoretical problem but also of great practical significance. However, judging from the current research situation, the research on family farms mainly stays on its own macrolevel qualitative description and analysis, lacking the corresponding quantitative analysis, which leads to the unreasonable credit rating standard of family farms and the lack of an effective credit rating system. Because of this, commercial banks and financial institutions lack judgment on the credit status of family farms and ranches, which leads to their inability to provide financial support, and thus family farms and ranches fall into financing difficulties. Therefore, credit rating of family farms and ranches is a research work of great practical significance.

Different classifications of existing credit rating methods are as follows:;

*1.1. Credit Rating Model Based on Family Farm and Pasture.* Ning used the cloud model to quantify qualitative indicators, established BP neural network model, and improved the existing evaluation system of family farm [2]. Ni and Zhang, by observing the characteristics of different business entities, divided them into three different types of business entities: family business, cooperative business, and enterprise business. Based on the principles of comprehensiveness, systematicness, and comprehensiveness, they constructed different credit evaluation index systems for the divided business entities [3]. Lin described and analyzed in detail the reasons for the financing difficulties of the new-type of agricultural business entities through the investigation of many new-type agricultural business entities in Yancheng City, Jiangsu Province. At the same time, according to the investigation results, it was considered that multiparty efforts were needed to solve the financing difficulties [4]. Huang and Qin established a new family farm credit rating model by combining the mathematical model to assign the weight of the family farm credit rating and adopting the linear weighted average and comprehensive fuzzy evaluation method [5]. Li and Zhang constructed the credit index screening model of family farm and ranch by using the depth weighted fuzzy Bayes method [6].

*1.2. Credit Rating Model Based on Credit Score.* Industrial and Commercial Bank of China uses two sets of different evaluation index systems for credit scoring of different enterprises according to their own conditions and classifies them into ten credit grades, such as AA, AA−, A+, A, A−, BBB+, BBB-, BB, and B [7]. China Construction Bank graded the enterprises according to the 100% credit score and divided them into the following five grades. The grading standards are as follows: (90, 100) is AAA grade, (80, 90) is AA grade, (70, 80) is grade A, (60, 70) is grade B, and (60,0) is grade C [8].

*1.3. Credit Rating Model Based on Customer Number Distribution.* Zhi and Yang introduced the idea of normal distribution into the classification of credit grades and proposed that the number of people in each credit grade should also approximately obey the normal distribution. According to this idea, 200 customers were divided into 9 different credit grades [9]. Chi et al. found that the distribution of customers showed bell-shaped distribution characteristics, so the customer's credit score was divided into nine credit grades, such as AAA and AA, which avoided the unreasonable situation that the samples were excessively concentrated in certain grades [10].

*1.4. Credit Rating Model Based on Loss Given Default.* Zhou established a credit rating model by means of the information gain method, which made it possible to overcome the disadvantage of existing research that the weighting does not reflect the ability of indicators to identify the default [11]. Shi and Wang used ELECTRE III method to evaluate the credit rating of new-type merchants' microfinance based on the entropy weight method [12]. Chi et al. classified the credit rating with the goal that the higher the credit rating, the lower the loss rate and built a rating system that could identify the default risk [13].

There are two problems in the existing credit rating models: Firstly, the basis of credit rating is credit score, while most of the credit scores in the existing research depend on the precalculation of credit index weights. The problem is that different index weight calculation models will cause different credit scores with great differences due to different model mechanisms and mathematical foundations, so how to calculate accurate and stable credit scores that are not affected by index weights is the first difficult problem to be solved. Secondly, the existing research lacks the quantitative analysis of the research on family farms, which leads to the fact that the credit rating of family farms mostly adopts the personal or enterprise credit rating method. How to find the sample customer groups corresponding to the corresponding grades in the existing data environment and establish a credit rating model that accords with the characteristics of family farms is an extremely important problem faced by the existing research.

In view of the existing problems of credit rating, this paper constructs a credit rating model of family farms based on the dichotomy DEA (data envelopment analysis) method of dynamic cyclic adjustment and makes an empirical analysis with the data from the investigation data of family farms in Inner Mongolia, the credit database of a commercial bank, and the urban statistical yearbook and puts forward a new credit rating method of family farms that is suitable for multi-input and multioutput variables and solves the optimal critical point of adjacent rating. In this paper, the DEA model is introduced, the credit indicators affecting family farms are used as model inputs to calculate the relative efficiency of family farms, the efficiency value of family farms is used as credit score to divide the credit rating, and the final credit rating result is obtained. The following progress has been made: first, loss given default is included in the credit rating model of family farms and pastures, and loss given default constraint is set to meet the reality that the higher the credit rating, the lower the loss given default; second, by presetting the credit rating and interval, taking whether it is in the optimal preset interval as the basis of efficiency dichotomy and using DEA credit score adjusted by dynamic cycle, it is ensured that the inherent cycle division can always get the relatively optimal credit rating [14–17].

The main reasons for choosing the dichotomous DEA model with dynamic cyclic adjustment in this paper are as follows: Firstly, the existing research has proved that the three-stage DEA model has strong objectivity, does not depend on the determination of artificial subjective weight, can eliminate the influence of external environment and other interference factors after data revision, and has good evaluation ability in the evaluation field. Secondly, when the credit evaluation of family farms is carried out by the DEA model, it overcomes the problem that the default information of family farms cannot be effectively evaluated because there is no need to know the default status of family farms in advance. Thirdly, the efficiency value of household farm credit score calculated by DEA is divided into two parts by preset optimal critical interval, loss given default constraint is set to meet the reality that high-grade loss given default is low, and the sample space is continuously reduced by two parts by using the fixed optimal critical interval, so that each grade has the best efficiency compared with the next grade and the relative optimal grade is determined.

## 2. Materials and Methods

### *2.1. The Difficulty of the Problem*

Difficulty 1: How to get rid of the inconsistency of credit scores caused by different weight measurement methods?

Difficulty 2: What method is used to find the sample customer base corresponding to the corresponding level?

*2.2. Ideas to Break through the Difficulties.* Solution to the first difficulty: The DEA model of nonparametric frontier efficiency analysis is used to map the input and output data of all family farms to geometric space. At the same time, SFA is used to eliminate the influence of environmental factors, and a direct mapping from credit index system to credit score is constructed. The credit score efficiency value of family farms is calculated by the idea of relative comparison. The idea of solving the first difficulty is shown in Figure 1.

Solution to the second difficulty: By setting the fixed optimal critical interval, the efficiency value of household farm credit score calculated by DEA is divided into two parts, and the loss given default constraint is set to meet the reality that the high-grade loss given default is low. Taking whether it is at the optimal frontier as the basis of efficiency dichotomy, the DEA efficiency credit score is dynamically and circularly adjusted, and the sample space is continuously reduced by dichotomy by using the fixed optimal efficiency interval. The idea of solving the second difficulty is shown in Figure 2.

*2.3. The Construction Principle of Credit Rating Model.* The principle of building the credit rating model of family farm based on dichotomy DEA under dynamic cycle is shown in Figure 3.

*2.4. English Thumbnail Table.* The proper nouns involved in this paper are shown in Table 1.

## 3. Constructing a Two-Stage Nonparametric Bayesian Discriminant Model

### *3.1. One-Stage Screening Method between Default and Nondefault*

*3.1.1. Step 1: Original DEA Model.* Let $\theta$ be the effective value of family farm sample; $s^+$ and $s^-$ are relaxation variables, $s^+$ and $s^-$ are the introduced slack and residual variables, respectively; $\varepsilon$ is a non-Archimedes infinitesimal (A number that is less than any positive number and greater than zero); $x_j$ is the input vector; $y_j$ is the output vector; $\lambda$ represents the coefficient of a linear combination of sample elements; and $v_i$ is a measure of the ith input.

$$
\begin{cases}
\min\left[\theta-\varepsilon\left(\sum_{j=1}^{m}s^{-}+\sum_{j=1}^{m}s^{+}\right)\right]=v_d(\varepsilon),\\
\text{s.t.}\ \sum_{j=1}^{n}\lambda_j x_j+s^{+}=\theta x_0,\\
\sum_{j=1}^{n}\lambda_j y_j-s^{-}=y_0,\\
\sum_{i=1}^{n}\lambda_i=1,\lambda_i\geq 0, s^{+}\geq 0, s^{-}\geq 0.
\end{cases}
\tag{1}
$$

Meaning of model (1): Determine whether the sample of family farm is located at the optimal frontier. When $\theta = 1$ and $s^+$ and $s^-$ are 0, the sample unit is located at the optimal frontier and DEA is effective, which indicates that the sample efficiency of family farm is the best. The economic significance of this model in the credit rating of the family farm and pasture is to calculate the economic efficiency of the family farm and pasture, which is used as the credit score of the rating system and is the basis for dividing the credit rating.

Let TE be the comprehensive technical efficiency of family farm and pasture; SE be the scale efficiency of family farm; and PTE be the pure technical efficiency of family farm.

$$
\text{TE}=\text{SE}\times\text{PTE}. \tag{2}
$$

Meaning of formula (2): Technical efficiency (TE), pure technical efficiency (PTE), and scale efficiency (SE) of each family farm can be distinguished by $BC^2$ (A DEA model assuming variable returns to scale) model. Based on TE comprehensive technical efficiency, this paper solves the credit score of family farm.

*3.1.2. Step 2: Stochastic Frontier Analysis*

*(1) The Establishment of Regression Equation.* SFA (stochastic frontier analysis) regression equation is built to remove the influence of random interference and external environmental factors on the credit score of family farms. The SFA regression equation is as follows.

Let $s_{ij}$ represent the relaxation variable of the $I$-th input of the $J$-th family farm sample; $Z_j$ represent observable macroscopic environmental variables, and $\beta_j$ represent environmental variable parameters. $f(z_j;\beta)$ indicates the influence of environmental variables on redundant $s_{ij}$, and $v_{ij}+u_{ij}$ is the mixed error. Assuming $v_{ij}\sim N(0, \delta_{vi}^2)$, $v_{ik}$ is random interference; $u_{ik}$ is management inefficiency, assuming that $u_{ik}$ obeys truncated normal distribution, $u_{ik}\sim N(u_i, \delta_{vi}^2)$; and $v_{ij}$ and $u_{ij}$ are independent of each other. Gamma is the proportion of technical inefficiency variance to total variance.

$$
\begin{cases}
S_{ij}=f\left(Z_j;\beta^j\right)+v_{ij}+u_{ij},\\
\gamma=\dfrac{\sigma_{\text{ui}}^2}{\sigma_{\text{ui}}^2+\sigma_{\text{vi}}^2}.
\end{cases}
\tag{3}
$$

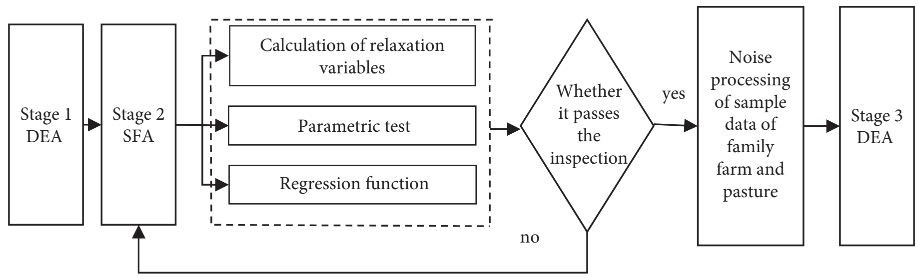


Figure 1: Ideas for solving difficulty 1.

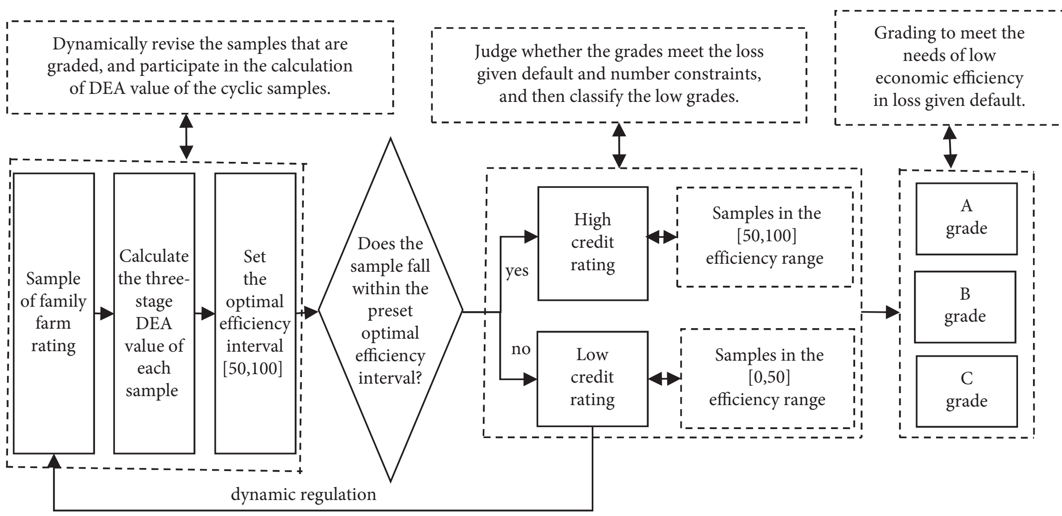


Figure 2: Ideas for solving difficulty 2.

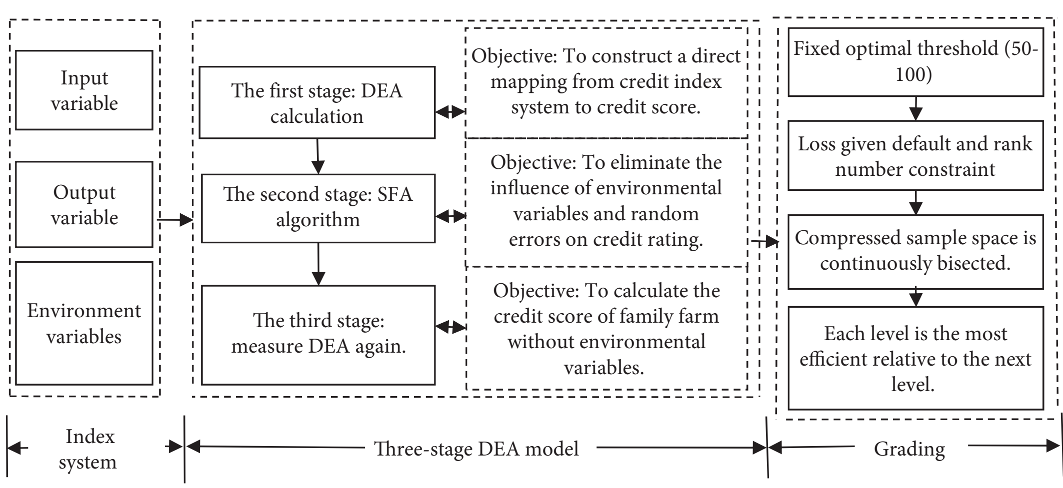


Figure 3: Technical route of credit rating model.

Table 1: Professional term.

| English abbreviations | DEA | TE | PTE | SE | SFA | $BC^2$ |
|---|---|---|---|---|---|---|
| English full name | Data envelopment analysis | Technical efficiency | Pure technical efficiency | Scale efficiency | Stochastic frontier analysis | BCC |

Meaning of formula (3): Formula (3) represents the solution process of model relaxation variables. When the value of $\gamma$ approaches 0 or 1, it shows that the influence of random error or management factors is dominant, respectively.

*(2) Adjust the Sample Unit Data.* The sample input of family farm is further adjusted according to the regression result of the SFA model, and it is adjusted based on the principle that all sample units are placed in the same environment while considering the interference of random factors.

$x_{ij}^A$ represents the adjusted sample input of family farm and pasture; $x_{ij}$ represents the original input of the first stage; $z_j$ is an environmental variable that affects the credit evaluation of family farms; $\beta$ is an environmental variable parameter; and $v_{ij}$ is the random error obtained by the first input of the $J$-th small family farm credit research status sample.

$$x_{ij}^A = x_{ij} + \left[\max_j \left\{z_j\widehat{\beta}^j\right\} - z_j\widehat{\beta}^j\right] + \left[\max_j \left\{\widehat{v}_{ij}\right\} - \widehat{v}_{ij}\right]. \quad (4)$$

Meaning of formula (4): Formula (4) represents the adjusted input quantity formula, which means that all samples of family farms have eliminated the influence of macroenvironmental factors and random errors on the credit rating of family farms.

*3.1.3. Step 3: The Adjusted DEA Model.* DEA analysis is carried out on the adjusted input and output variables of family farm, and the adjusted input value and original output value of family farm obtained by SFA regression are brought into DEA model again, and then the credit scoring efficiency value of family farm after eliminating the influence of macroenvironmental factors and statistical noise is obtained.

*3.2. The Construction Principle of Credit Rating Model.* Based on dichotomy, the family farm is graded. By setting the optimal critical point, the credit score of the family farm calculated by DEA is divided into two parts, and the loss given default constraint is set to meet the reality that the given high-grade loss default is low. By using the fixed optimal critical point, the sample space is continuously reduced by dichotomy, and the relative efficiency of the high-grade is always the best, so as to ensure that the grading is closer to the real level.

*3.2.1. Step 1: DEA Model to Calculate Credit Score.* According to the three-stage DEA model, the efficiency of family farms and pastures is analyzed, and the credit scores of all farms and pastures are obtained, and the grades are divided according to them.

*3.2.2. Step 2: Dichotomy Classification under Dynamic Cycle.* Based on dichotomy, the family farm is graded. By setting the optimal efficiency interval (50–100), the credit score of the family farm calculated by DEA is divided into two parts. The samples in the optimal efficiency interval are classified as A credit grade, and the samples in the nonefficiency interval are classified as low grades and dynamically adjusted and calculated by DEA credit score. According to the newly calculated DEA value, it is judged whether the samples fall into the optimal efficiency interval or not. If the samples fall into the optimal efficiency interval, the grades are classified as B credit grade; otherwise, the samples are classified as C credit grade.

*3.2.3. Step 3: Loss Given Default Constraint Conditions.* Let us say that $\mathrm{LG}D_g$ represents the $g$ family farm credit rating loss given default, hg represents the total number of all family farms in the $g$ family farm credit rating, $L_{ig}$ represents the unpaid principal and interest receivable of the $i$ family farm in the $g$ family farm credit rating, and $R_{ig}$ represents the principal and interest receivable of the $i$ family farm in the $g$ family farm credit rating.

$$\mathrm{LG}D_g = \frac{\sum_{i=1}^{hg} L_{ig}}{\sum_{i=1}^{hg} R_{ig}}. \quad (5)$$

Meaning of formula (5): In this paper, with the goal of maximizing the credit score efficiency of family farms and pastures, the loss given default constraint is set at the same time. By calculating the loss given default of all grades through formula (5), it is judged whether the given high-grade loss default is lower than the given next-grade loss default, so that the credit grade is closer to the reality.

*3.3. Comparative Analysis.* In the past, the research on credit rating was based on the credit score at the earliest, and later scholars classified credit rating from the perspective of customer sample distribution and loss given default, which formed the research process of credit rating research. The main differences between this model and previous research are shown in Table 2.

## 4. Empirical Analysis

*4.1. Comparative Analysis.* This paper selects 836 survey data of family farms in Inner Mongolia and extracts 8 indicators, including 3 input indicators, 3 output indicators, and 2 environmental variable indicators, including 207 default family farms and 629 nondefault family farms. When evaluating the credit of farm by DEA, different decision-making units represent different family farms, the selected input and output indicators are all indicators representing the financial ability and nonfinancial ability of farm, and the selection of environmental variables is the macro-environmental factors affecting the credit status of family farms. Usually, the indicators that are positively correlated with the credit score of family farms are output indicators, and the indicators that are negatively correlated with the credit score of family farms are input indicators. The index comes from literature [19–22], and the sample data of family farms are shown in Table 3.

Table 2: Differences between this model and existing research.

| (1) Representative literature | (2) Division basis | (3) Implementation method | (4) The idea of grading | (5) Classification characteristics |
|---|---|---|---|---|
| Measures of China construction bank for small business customer evaluation [8] | Credit score | Linear programming | Divide corresponding intervals of credit score | It can be ensured that samples with high credit scores correspond to high grades, thus dividing credit grades |
| The credit evaluation of small businesses in leasing business services [17] | Sample size | Adjust equally | Divide into enterprise samples equally, and then make dynamic adjustment | It can ensure that enterprise samples are evenly distributed at different levels, but the dynamic adjustment process is somewhat complicated |
| Inclusive finance, bank credit, and merchant microfinance based on the perspective of risk level matching [18] | Loss given default | Fuzzy clustering | Taking loss given default as the dividing standard | The loss given default from low grade to high grade is gradually reduced |
| This text | Economic efficiency | Dichotomy of fixed optimal critical interval | Take the maximum efficiency value of farm and pasture samples as the target | Under the condition of ensuring that the higher the credit rating, the lower the loss given default, the efficiency of high rating is the best compared with low rating |

Table 3: Differences between this model and existing research.

| (1) Serial number | (2) Variable type | (3) Index name | (4) Index type | (5) Sample 1 | . . . | (840) Sample 836 |
|---|---|---|---|---|---|---|
| 1 | Input variable | Expenditure-income ratio | Negative direction | 0.544 | ... | 0.805 |
| 2 | | Number of families/workforce | Negative direction | 1.000 | | 1.000 |
| 3 | | Loan amount | Negative direction | 1.000 | | 1.000 |
| 4 | Output variable | Annual net income | Forward direction | 0.409 | ... | 0.303 |
| 5 | | Do you gain credibility? | Forward direction | 0.250 | | 0.250 |
| 6 | | Value of fixed assets | Forward direction | 0.210 | | 0.107 |
| 7 | Environment variables | Regional GDP growth rate | Forward direction | 0.460 | ... | 0.591 |
| 8 | | Engel coefficient | Negative direction | 0.628 | | 0.413 |

*Note.* *Engel coefficient (total food expenditure as a proportion of total personal consumption expenditure).

### 4.2. Calculation of Credit Score Based on Three-Stage DEA Model

*4.2.1. Step 1: The First Stage: DEA.* In the first stage, the data are substituted into the BC2 model to calculate the credit score efficiency values (TE, SE, and PTE) of all family farm samples. The specific calculation results are shown in the second to fourth columns of Table 4.

*4.2.2. Step 2: The Second Stage: Stochastic Frontier Analysis (SFA) Regression.* In the second stage, the influence of environmental factors (regional GDP growth rate and Engel coefficient) on the slack variables of input indicators was investigated. Because the stochastic frontier is only suitable for single output analysis (only one input variable is adjusted at a time), there are three input variables in this paper, so it is adjusted three times. With the environmental variables (regional GDP growth rate and Engel coefficient) in the first column of Table 5 as independent variables and the relaxation variables of household farm input indicators in the first row of Table 5 as dependent variables, SFA regression is established for each input indicator selected in this paper. For example, the coefficients of the regression function established by the relaxation variables of input indicators (expenditure-income ratio) and environmental variables are shown in the second column of Table 5, and the $t$ test results are shown in the third column of Table 5. The regression coefficient of environmental variables in the regression function established by analyzing the input indicators passed the $T$ test, which showed that the regression parameters had practical significance and the external economic environment interacted with the family farm. At the same time, the unilateral likelihood ratio (LR) greater than the critical value meant that SFA regression could be carried out, so the elimination of environmental variables in the SFA regression model had a good influence on the efficiency value of the family farm. The SFA regression test results are shown in Table 5.

*4.2.3. Step 3: The Third Stage: DEA.* In the third stage, the input variables are adjusted by using the SFA regression results of the second stage, and the adjusted variables are substituted into the model to calculate the adjusted efficiency value. At this time, the obtained value is the efficiency value of household farm credit score excluding environmental factors and random errors. The specific calculation results are shown in columns 5 to 7 of Table 4 [23–27].

Table 4: Efficiency test results of family farm in different stages.

| (1) Serial number | The first stage DEA efficiency value | | | The third stage DEA efficiency value | | | (8) Credit score | (9) Membership level |
|---|---|---|---|---|---|---|---|---|
| | (2) TE | (3) PTE | (4) SE | (5) TE | (6) PTE | (7) SE | | |
| 1 | 0.397 | 0.414 | 0.957 | 0.398 | 0.415 | 0.96 | 39.8 | B |
| 2 | 0.422 | 0.500 | 0.843 | 0.451 | 0.500 | 0.902 | 45.1 | B |
| 3 | 0.232 | 0.264 | 0.880 | 0.239 | 0.264 | 0.906 | 23.9 | B |
| ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 430 | 0.232 | 0.271 | 0.854 | 0.252 | 0.272 | 0.928 | 23.2 | B |
| 431 | 0.24 | 0.263 | 0.913 | 0.24 | 0.263 | 0.913 | 24 | B |
| 432 | 0.251 | 0.285 | 0.881 | 0.28 | 0.285 | 0.983 | 25.1 | B |
| ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 834 | 0.865 | 1.000 | 0.865 | 0.871 | 1.000 | 0.871 | 87.1 | A |
| 835 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 100 | A |
| 836 | 0.671 | 0.715 | 0.938 | 0.671 | 0.715 | 0.938 | 67.1 | A |

Table 5: SFA regression test.

| (1) Variables | (2) Expenditure-income ratio | (3) $T$ Test | (4) Number of families/ labor force | (5) $T$ Test | (6) Loan amount | (7) $T$ Test |
|---|---|---|---|---|---|---|
| Constant term | $-0.909E-01^*$ | $-0.909E-01$ | $-0.271E-01^*$ | $-0.307E+01$ | $-0.362E-01^*$ | $-0.362E-01$ |
| Industry prosperity index | $0.657E-02^*$ | $0.657E-02$ | $0.447E-01^*$ | $0.628E+01$ | $0.147E-01^*$ | $0.147E-01$ |
| Engel coefficient | $0.552E-01^*$ | $0.552E-01$ | $-0.264E-01^*$ | $-0.321E+01$ | $-0.192E-01^*$ | $-0.192E-01$ |
| Σ2 | $0.00E+00^*$ | $0.00E+01$ | $0.176E-01^*$ | $0.896E-01$ | $0.00E+00^*$ | $0.00E+00$ |
| $\gamma$ | $0.95E+00^*$ | $0.95E+00$ | $0.999E+00^*$ | $0.946E+03$ | $0.95E-01^*$ | $0.95E-01$ |
| LR | $0.00E+00^*$ | — | $0.00E+00^*$ | — | $0.00E+00^*$ | — |

*Note.* *means passing the significance test of 0.01.

*4.3. Dichotomy DEA Credit Rating under Dynamic Cycle.* According to the three-stage DEA model, the credit score of family farms is calculated. By dichotomy, the farms with the credit score efficiency of 50–100 are classified into Grade A and the remaining farms are classified into Grade B. At the same time, the three-stage DEA model is used again to calculate the credit score of the family farms with the credit score efficiency of 50–100, and the remaining family farms are classified into Grade B and Grade C, and the loss given default of each grade is calculated. The results are shown in Table 6.

*4.4. Comparative Analysis Results*

*4.4.1. Comparative Analysis.* The credit rating model based on credit score and the credit rating model based on customer number distribution are used as the comparison objects of DEA-dichotomy credit rating model with dynamic cyclic adjustment. The credit rating results are shown in the second to fourth rows of Table 7.

*(1) Step 1.* Credit rating based on credit score: For the comparative analysis of the credit rating results made in this paper, the sample customers of family farms are divided into three credit ratings: A, B, and C. The classification criteria are as follows: the credit score of family farm is Grade A at (80, 100), Grade B at (60, 80), and Grade C at (0, 60). The credit rating results are shown in the second row of Table 7.

*(2) Step 2.* Credit rating based on customer number distribution: In order to compare and analyze the results of credit rating made in this paper, the sample customers of family farms are divided into three credit ratings: A, B, and C on average. The number of samples is dynamically adjusted to meet the loss given default decreasing constraint, and the credit rating results are shown in the third row of Table 7.

*(3) Step 3.* Pyramid diagram of credit rating and loss rate. In order to more clearly show the correspondence between the credit rating and its rating loss given default and to show the differences of different credit rating classification methods, the pyramid matching the credit rating and loss given default with the rating as the ordinate and the rating loss given default as the abscissa are drawn. From the top of the pyramid to the bottom of the pyramid represents the highest to lowest credit rating, and the size of credit rating default loss rate corresponds to the area of pyramid vertebral segment, as shown in Figure 4.

*4.4.2. Comparative Analysis Conclusion.* By comparing with the credit rating model based on credit score and the credit rating model based on customer number distribution, it is found that first the credit rating model based on credit score does not consider the given sample loss default and ignores the default status of the sample; second, the credit rating model based on customer distribution takes into account the

Table 6: Credit rating classification results.

| (1) Credit rating | (2) Number | (3) The efficiency value of the first dichotomy credit score | (4) The efficiency value of the second dichotomy credit score | (5) Loss given default (LGD) (%) |
|---|---|---|---|---|
| A | 300 | 50–100 | — | 3.13 |
| B | 189 | 0–50 | 50–100 | 8.36 |
| C | 347 | — | 0–50 | 16.4 |

Table 7: Comparative analysis results.

| (1) Division basis | (2) A | (3) B | (4) C | (5) Loss given default is increasing |
|---|---|---|---|---|
| Credit score | 362 | 446 | 28 | No |
| Customer distribution | 122 | 672 | 40 | Be |
| Economic efficiency | 300 | 189 | 347 | Be |

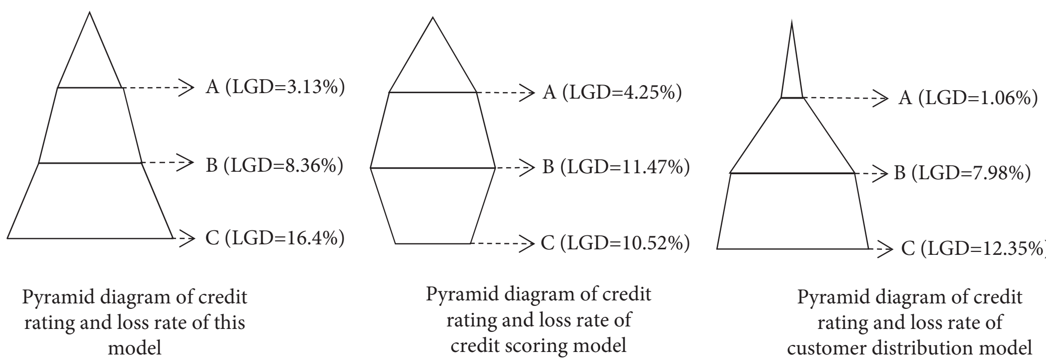


Figure 4: Contrast effect of pyramid diagram.

loss given default constraint between the grades, but the dynamic adjustment process is too cumbersome; thirdly, the pyramid diagram between the credit ratings of different classification methods and the loss given default is constructed and compared. The results show that the credit ratings of this research method are effective and have better pyramid shape than those of other methods.

## 5. Conclusion

(1) Through the three-stage DEA model, a direct mapping from the credit index system to the credit score is constructed, and the credit score efficiency value of family farms is calculated by the idea of relative comparison, which avoids the disadvantage that the classical linear weighting formula relies heavily on the weight calculation results and obtains more accurate and stable credit score results of family farms.

(2) By using the three-stage DEA efficiency value as the credit score of family farms, taking whether it is in the optimal preset interval as the basis of efficiency dichotomy, the DEA credit score of family farms is calculated by cyclic correction, and the samples belonging to each grade of family farms are measured from high to low in order of credit rating, and finally a reasonable credit rating division result of family farms with high credit rating and low credit rating in loss given default is obtained.

(3) By constructing the pyramid between credit rating and loss given default, the results show that this research method is effective and has better pyramid shape than other methods.

(4) This paper identifies and evaluates the credit risk by constructing the credit rating model of family farms, accurately identifies the credit risk of family farms, provides more accurate lending standards for commercial banks and financial institutions, effectively alleviates the financing difficulties of family farms, and promotes the sustainable development of family farms.

## Data Availability

This paper makes an empirical analysis of the sample data of family farms and ranches through DEA.P software. The sample data of this paper come from the actual survey data of family farms and ranches in Inner Mongolia, China.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

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