Research on the relationship between government policy and enterprise production decision in green background

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Abstract. In the low-carbon background, China must develop green manufacturing actively, and take a new road to industrialization. Government subsidies can promote the promotion of low-energy products, and thus control the total carbon emissions. Aiming at production decision of a kind of manufacturing business, A 0-1 Nonlinear decision model was built with consumer surplus as the optimization objective. This model provided guidance for the government policy decision and the firm production decision. A genetic algorithm was put forward to solve the 0-1 nonlinear decision model. A case study of refrigerator was reported to demonstrate the feasibility and rationality of this approach.

1. Introduction
The rapid development of human society has led to the destruction of the climate and the environment. In particular, the massive emissions of greenhouse gases have exacerbated the further deterioration of the climate. According to the IPCC report, greenhouse gas emissions from human activities are the main cause of global warming and frequent occurrence of extreme weather [1]. As the world's largest manufacturing country, China's greenhouse gas emissions are the second highest in the world. In order to actively respond to and improve this deterioration, the National Development and Reform Commission issued the Interim Measures for the Management of Low-Carbon Products Certification in 2013, strengthening the low-carbon product certification system and encouraging the development and production of low-carbon products. In March 2015, "Made in China 2025" proposed a green development background, China will turn from a manufacturing power to a manufacturing power, actively develop green manufacturing, and take a new road to industrialization, which coincides with the vision of Industry 4.0. Some scholars have also argued that different local government tax policies will directly affect the production decision-making and operation mode of enterprises. In summary, it can be seen that the government's low-carbon subsidy policy can promote the production and promotion of low-energy products, and thus control the total amount of carbon emissions.

In this new situation and new background, more and more consumers have a low-carbon consumption concept. Liu [2] pointed out in the study that consumers' environmental awareness is gradually increasing and they are willing to pay additional fees for green low-carbon products. Fu found through market research that more than half of auto consumers are more inclined to buy more energy-efficient hybrid vehicles [3]. On the other hand, the price of low-carbon products constrains most consumers' final purchase decisions. Xu conducted a survey of the household appliance market and found that low-carbon environmentally friendly products cost hundreds to thousands of dollars more than ordinary products, which eventually led to a large number of low- and middle-income families to abandon the purchase of low-carbon environmentally friendly products.
The research on corporate decision-making behavior in a low-carbon context is divided into two perspectives: One is to study the production decision of enterprises based on the perspective of carbon trading rights [4][5][6]. Another view of low-carbon backgrounds as a government policy study of its impact on corporate decision-making behavior [7][8]. Few studies study corporate product portfolio decision-making in the context of low carbon. At the same time, most of the research literature on corporate decision-making does not consider government subsidy policies. Possibly ignore the different government subsidy policies that will have different guiding effects on corporate decision-making.

This paper will build a decision-making system model for a class of manufacturing enterprises based on the existing theoretical basis. Study the guiding effect of different government subsidy policies on corporate decision-making behaviour. Compared with the production decisions of enterprises under different policies, government subsidy policy has the highest degree of promotion of low-carbon products.

2. Problem Description
This paper studies the optimization of product portfolio decision-making for a class of home appliance companies, and analyzes the impact of different government policies on corporate decision-making behavior. Companies need to build a comprehensive and effective evaluation method for these important indicators in order to Weighing important indicators such as cost, benefit, carbon emissions and government subsidy policies in product portfolio decisions. This paper constructs a 0-1 nonlinear product portfolio decision-making optimization model based on the above-mentioned several types of indicators. This type of decision-making problem is optimized under four different government policies (no policy support, carbon allowance subsidy policy, tax subsidy policy, low-energy product subsidy policy). The details of the problem are shown in Figure 1. It can be seen from Figure 1 that under the constraint of carbon emission, the comprehensive benefit of product portfolio is the optimization goal, the product portfolio of decision-making enterprises, and the difference of enterprise decision-making schemes under the influence of four different government policies are compared.

![Figure 1. problem description diagram.](image)

3. Optimization model
The optimization model is constructed based on the enterprise innovation decision-making mechanism explained above. This section will explain the specific components and constraints of the optimization model.
The optimization goal of this paper is that the product family can meet the needs of different market segments and maximize the profit of the company. The attribute level of the objective function decision product. Assume that the maintenance innovation product in the product family can select a total of \( N \) attributes, denoted as \( a_n, n = 1, 2, \ldots, N \). Each attribute \( a_n \) is divided into \( L_n \) horizontal levels. Then the \( l \) horizontal level of the \( n \) attribute is expressed as \( a_{nl} \). A product can be seen as a combination of the attributes selected for each attribute. Maintaining an innovative product \( N \) type of attribute each selected a grade consisting of a total of \( J = \prod_{n=N}^L \). Assuming that each permutation has a corresponding product configuration scheme, denoted as \( P_j, j = 1, \ldots, J \), the product collection is \( P = \{P_j, j = 1, \ldots, J \} \). Decision variables \( x_j \in \{0, 1\}, j = 0, 1, \ldots, J \). Where \( x_0 = 1 \) represents the production of maintenance innovation products, and \( x_0 = 0 \) opposite. \( x_j = 1, j = 1, \ldots, J \) indicates the production of the \( j \) model, and \( x_j = 0, j = 1, \ldots, J \) opposite. The decision variable \( v_{jnl} \in \{0, 1\}, v_{jnl} = 1 \) indicates that the \( j \) product selects the \( l \) attribute level of the \( n \) attribute. The objective function is as in Equation 1:

\[
\text{Max} F = \sum_{i=1}^{n} \sum_{j=1}^{J} \frac{U_i}{C_j} \cdot P_j \cdot Q_i \cdot x_j
\]

\( U_i \) indicates the perceived utility of the \( i \) \( i = 1, 2, \ldots, I \) segment of the \( j \) \( j = 1, 2, \ldots, J \) product. \( u_{nl} \) and \( \omega_{jn} \) respectively represent the score utility and the corresponding weight coefficient of the \( n \) module of the \( j \) product in the \( i \) market segment. \( \pi_{ij} \) indicates the combined utility of the \( i \) market segment for the \( j \) product. Expressions such as 2:

\[
U_i = \sum_{n=1}^{N} \sum_{l=1}^{L_n} (\omega_{jn} u_{nl} v_{jnl} + \pi_{ij}) + \epsilon_{ij} \forall i, j
\]

\( Q_i \) indicates the size of the market. \( P_i \) indicate that the probability of the \( i \) segment consumer selecting the \( j \) product is as shown in equations 3:

\[
P_i = \exp \left( \frac{\mu U_i}{\sum_{j=1}^{J} \exp(\mu U_j)} \right)
\]

\( C_j \) represent the cost of the \( j \) product as in equations 4:

\[
C_j = \sum_{n=1}^{N} \sum_{l=1}^{L_n} v_{jnl} c_l
\]

\( H_j \) represents the carbon emissions produced by the production of product \( j \), as in Equation 5:

\[
H_j = \sum_{n=1}^{N} \sum_{l=1}^{L_n} v_{jnl} h_l
\]

In addition, in order to ensure the difference between products, give the corresponding constraints on the choice of equations 6:

\[
\sum_{n=1}^{N} \sum_{l=1}^{L_n} |v_{jnl} - v_{jnl}| > 0, \forall j, i \neq j
\]

The enterprise innovation decision-making optimization model is as follows:

\[
\text{Max} F = \sum_{i=1}^{n} \sum_{j=1}^{J} \frac{U_i}{C_j} \cdot P_j \cdot Q_i \cdot x_j
\]
Model solving

The method of model solving is usually based on the complexity of the model, and the complexity depends on the size of the model and the complexity of the constituent functions. Model 7 is a nonlinear combinatorial optimization problem with multiple 0-1 variables, and the constituent function is more complicated. The general random search method unable to prove that the obtained solution is a global optimal solution. Therefore, the genetic algorithm is used to directly solve the model. Compared with traditional search technology, genetic algorithm is better at solving combinatorial optimization problems. It is a relatively mature, efficient, parallel, global search method that automatically acquires and accumulates knowledge about the search space during the search process, and adaptively controls the search process to find the optimal solution.

In order to guarantee the convergence of the algorithm, we construct a fitness function based on the objective function. The specific solution strategy is: randomly initialize the population and verify the feasibility of the population; calculate the fitness value and determine whether the maximum algebra is reached. If it has been reached, the optimal value is recorded and stopped; if not, the sorting, selection, crossover and mutation operators are applied to the population to produce the next generation population. After the above steps are cycled a certain number of times, the termination condition is reached and the optimal solution is obtained.

5. Case study

5.1. Background description

A case study of a well-known domestic refrigerator company proves that the optimization model of this paper is suitable for decision-making optimization problems of companies. Compare the production decision results of the enterprise under the four government influence policies. According to actual research, the government’s carbon emission limit for the company is 1700kg/year. The government’s tax incentives are 7% (products are Tier 1 or Tier 2). The government subsidies for low-energy refrigerators are level 1 energy consumption of 300 yuan/unit, and level 2 energy consumption of 100 yuan/unit. This paper will use a domestic refrigerator enterprise as an application case to optimize its decision-making mechanism, and compare the production decisions of the enterprise under the influence of four different policies, such as non-support policy, carbon quota subsidy policy,
tax subsidy policy and low-energy product subsidy policy. Through the investigation and analysis of actual production, it is known that the refrigerator company can produce the composition, grade and grade cost of the refrigerator (Table 1) and the carbon emissions (Table 2). The refrigerator has the most profit.

Table 1. Refrigerator attribute composition and related information.

| Attributes | Attribute item | Type description | Cost (yuan) |
|------------|----------------|------------------|-------------|
| Box, condenser | \(a_{11}\) | Three doors VCM 205 liters | 980 |
| | \(a_{12}\) | Three doors PPM 223 liters | 1280 |
| | \(a_{13}\) | Three doors PCM 258 liters | 1680 |
| ... | ... | ... | ... |
| Evaporator | \(a_{51}\) | Tube plate | 35 |
| | \(a_{52}\) | Aluminum plate inflation | 55 |
| | \(a_{53}\) | Finned coil | 320 |

Table 2. The carbon emissions of various grades of refrigerators.

| Attributes | Carbon emission | Attributes | Carbon emission |
|------------|-----------------|------------|-----------------|
| \(a_{1}\) | 42              | \(a_{22}\) | 50              |
| \(a_{12}\) | 45              | \(a_{23}\) | 60              |
| \(a_{13}\) | 48              | \(a_{31}\) | 24              |
| \(a_{14}\) | 64              | \(a_{32}\) | 28              |
| \(a_{15}\) | 70              | \(a_{33}\) | 32              |
| \(a_{16}\) | 72              | \(a_{41}\) | 15              |
| \(a_{17}\) | 75              | \(a_{42}\) | 18              |
| \(a_{18}\) | 80              | \(a_{51}\) | 2               |
| \(a_{19}\) | 90              | \(a_{52}\) | 2               |
| \(a_{110}\) | 96             | \(a_{53}\) | 3               |
| \(a_{21}\) | 45              |             |                 |

The energy consumption ratings of all products are given by surveying actual production and referring to energy consumption indicators for household appliances (Table 3).

Table 3. Refrigerator attribute level composition and energy consumption level.

| Product serial number | Attribute level composition | Energy consumption level |
|-----------------------|-----------------------------|-------------------------|
| 1                     | \(a_{11} a_{21} a_{31} a_{41} a_{51}\) | 3                       |
| 2                     | \(a_{11} a_{21} a_{31} a_{41} a_{51}\) | 4                       |
| 3                     | \(a_{11} a_{21} a_{31} a_{41} a_{51}\) | 4                       |
| ...                   | ...                         | ...                     |
| 539                   | \(a_{110} a_{23} a_{33} a_{42} a_{52}\) | 1                       |
| 540                   | \(a_{110} a_{23} a_{33} a_{42} a_{53}\) | 1                       |

5.2. mathematical model

This paper combines the actual situation of the refrigerator company to give specific parameters, and builds a complete case of enterprise innovation decision-making mechanism optimization. Simplify the model appropriately without affecting the nature of the model, assuming that only one product segment is considered, \(i = 1\). Market size takes a fixed value \(Q_i = 1000\). Through market research, the refrigerator company can produce the number of traditional car products. Utility functions \(U_{ij}\) are determined by \(\omega_{jn}, \mu_{int}, \pi_{ij}\). The weight \(\omega_{jn}\) is given according to the actual situation, \(\mu_{int}\) is
calculated by joint analysis, and $\pi_q$ is constructed according to the comprehensive attributes of the product. The joint analysis is applicable to the market research of product design. The joint analysis method is used to estimate the utility value $\mu_{\text{util}}$. The steps are as follows: firstly, the statistical software SPSS is used to perform orthogonal analysis on all the combined products to obtain a representative product collection. Then randomly select 100 consumers, and ask them to sort the various attribute level combination schemes according to their personal preference order. Finally, using SPSS for joint analysis and calculation, the utility value of the consumer to the attribute level is obtained, as shown in Table 4.

Table 4. Refrigerator attribute level utility value.

| Attribute item | $\mu_{\text{util}}$ | Attribute item | $\mu_{\text{util}}$ |
|----------------|--------------------|----------------|--------------------|
| $a_{11}$       | 1.33               | $a_{22}$       | 1.20               |
| $a_{12}$       | 1.97               | $a_{23}$       | 1.56               |
| $a_{13}$       | 2.11               | $a_{31}$       | 0.60               |
| $a_{14}$       | 2.06               | $a_{32}$       | 1.18               |
| $a_{15}$       | 3.12               | $a_{33}$       | 1.45               |
| $a_{16}$       | 3.35               | $a_{41}$       | -0.16              |
| $a_{17}$       | 3.46               | $a_{42}$       | 0.33               |
| $a_{18}$       | 3.27               | $a_{31}$       | -0.08              |
| $a_{19}$       | 3.70               | $a_{32}$       | 0.08               |
| $a_{110}$      | 4.12               | $a_{33}$       | 0.50               |
| $a_{21}$       | 0.26               |                |                    |

5.3. Calculation solution

The optimization model of this paper is nonlinear, non-convex, and has 0-1 variables. The optimal or approximate optimal solution can be obtained by genetic algorithm. Set the initial population size to 100, the mutation probability to 0.005, the crossover probability to 0.6, and the algebra to 200. Get optimization results under four government policies (Tables 5-9).

Table 5. Four government policy objectives optimization results.

| Government policy                      | Optimization Results |
|----------------------------------------|----------------------|
| No support policy                      | $F^*_1 = 16.74$      |
| Increase carbon emissions policy       | $F^*_1 = 16.85$      |
| Low energy product subsidy policy      | $F^*_1 = 17.16$      |
| Tax subsidy policy                     | $F^*_1 = 17.77$      |

Table 6. Enterprise optimization decision results without policy support.

| Enterprise product series | Attribute item |
|---------------------------|----------------|
| Refrigerator #1           | $a_{16}, a_{22}, a_{32}, a_{42}, a_{33}$ |
| Refrigerator #2           | $a_{18}, a_{22}, a_{32}, a_{42}, a_{33}$ |
| Refrigerator #3           | $a_{18}, a_{22}, a_{33}, a_{42}, a_{33}$ |
| ...                       | ...            |
| Refrigerator #9           | $a_{12}, a_{21}, a_{31}, a_{42}, a_{32}$ |
| Refrigerator #10          | $a_{11}, a_{21}, a_{31}, a_{42}, a_{32}$ |
Table 7. Enterprise optimization decision results supported by subsidized carbon allowance policy.

| Enterprise product series | Attribute item   |
|---------------------------|------------------|
| Refrigerator #1           | $a_{16}, a_{22}, a_{32}, a_{42}, a_{53}$ |
| Refrigerator #2           | $a_{18}, a_{22}, a_{32}, a_{42}, a_{53}$ |
| Refrigerator #3           | $a_{18}, a_{22}, a_{32}, a_{42}, a_{53}$ |
| ...                       | ...              |
| Refrigerator #9           | $a_{18}, a_{21}, a_{31}, a_{42}, a_{53}$ |
| Refrigerator #10          | $a_{19}, a_{23}, a_{33}, a_{42}, a_{53}$ |

Table 8. Enterprise optimization decision results supported by low energy consumption subsidy policy.

| Enterprise product series | Attribute item   |
|---------------------------|------------------|
| Refrigerator #1           | $a_{16}, a_{22}, a_{32}, a_{42}, a_{53}$ |
| Refrigerator #2           | $a_{18}, a_{22}, a_{32}, a_{42}, a_{53}$ |
| Refrigerator #3           | $a_{18}, a_{22}, a_{32}, a_{42}, a_{53}$ |
| ...                       | ...              |
| Refrigerator #9           | $a_{17}, a_{23}, a_{33}, a_{42}, a_{53}$ |
| Refrigerator #10          | $a_{19}, a_{23}, a_{33}, a_{42}, a_{53}$ |

Table 9. Enterprise optimization decision results supported by tax subsidy policy.

| Enterprise product series | Attribute item   |
|---------------------------|------------------|
| Refrigerator #1           | $a_{16}, a_{22}, a_{32}, a_{42}, a_{53}$ |
| Refrigerator #2           | $a_{18}, a_{21}, a_{32}, a_{42}, a_{53}$ |
| Refrigerator #3           | $a_{18}, a_{22}, a_{32}, a_{42}, a_{53}$ |
| ...                       | ...              |
| Refrigerator #9           | $a_{17}, a_{23}, a_{33}, a_{42}, a_{53}$ |
| Refrigerator #10          | $a_{19}, a_{23}, a_{33}, a_{42}, a_{53}$ |

5.4. Result analysis

Table 5-9 shows the cost-efficiency ratios of enterprise innovation decision-making schemes and innovation schemes under the influence of different government policies. Under the influence of the four government policies, corporate profits are ranked by tax incentives, low-energy product subsidy policies, subsidized carbon quota policies, and unsupported policies. It can be seen that with the different policies of the government, the optimal decision-making plan of the enterprise is also different. The main reason is that the government formulates different policies according to different environments, goals and political factors, and the company's goal is to maximize profits. Based on the corporate perspective, tax incentives can bring the most profit to the enterprise, followed by the low-energy product subsidy policy. Based on the government's perspective, all three policies can change the enterprise's decision-making plan to produce products with lower energy consumption. The subsidy carbon allowance policy does not need to occupy the government's fiscal expenditure, but the carbon emissions of the production chain are the largest, and the proportion of low-energy products is lower than the other two policies. Tax incentives will take up part of the government's fiscal expenditures. Under this policy, enterprises will invest more resources in the relatively low-end level 2 energy-consuming products, because such products are more cost-effective and can bring higher
profits to enterprises. The low-energy product subsidy policy will encourage enterprises to invest more resources in mid-to-high-end products and produce more high-performance first-class energy-consuming products, but the government fiscal expenditure of this policy is higher than the other two policies. This paper believes that in order to encourage enterprises to produce more energy-saving and environmentally friendly products, the government should give corresponding policy support. It should be considered that low-energy subsidy policies can encourage enterprises to produce products with higher technological content and lower energy consumption under financial constraints.

6. Conclusion

This paper build a decision-making system model for a type of manufacturing enterprise based on the existing theoretical basis, and on this basis, study the guiding effect of different government subsidy policies on corporate decision-making behavior. Through the production decisions of enterprises under different policies, which government subsidy policy has the highest degree of promotion of low-carbon products, it provides a theoretical basis for government policy formulation and enterprise production decision-making. Selecting a domestic refrigerator enterprise case, applying decision-making system and optimization model to obtain innovative decision-making schemes that bring the most profit to the enterprise, verifying the applicability and effectiveness of the model.

The research object of this paper has certain limitations, only for one type of manufacturing enterprise. Subsequent research can consider the impact of the same government policy on production decisions of enterprises in different industries. This paper establishes a relatively complete model, but it can be further improved in the case application, for example, it can increase the constraints of different market segments on the special requirements of the corresponding products.

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