A study on the identification of economic contribution of import and export based on random forest algorithm under Gini index

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Abstract. In the context of economic globalization and the building of a community of human destiny, the integration of the world economy has accelerated, and import and export trade is particularly important in a country's economic development. Many factors influence the import and export economy, and the uncertainty is high and more challenging to predict. In order to carry out a random forest model for the import and export economy, this paper constructs a random forest model. Also, it introduces the Gini index to ze China's total import and export economy. The method starts with the RF model construction based on the factors set. The data for Beijing 1987-2021 was used as a forecast by constructing five impact factors and then introducing the Gini index to measure the importance of the impact factors. The final test was carried out by two indicators, MSE, and R2. The conclusions are as follows: for the divided training and test sets, the MSE calculated by is 0.095 and 0.188 ,and R2 is 0.924 and 0.849, respectively, which shows that the prediction model is more accurate and yields more precise prediction results. The empirical analysis shows that the method can identify the impact indicators of China's total import and export economy more accurately.

Keywords: Random Forest, Gini index, Export-import economy, Confusion matrix, Foreign trade.

1. Introduction

In today's globalized society, international contacts are becoming increasingly close. As an important factor in demonstrating a country's comprehensive strength, the import and export economy have been given great importance at all stages of development. China is the world's largest trading nation, and foreign trade is a significant contributor to China's economic growth. The concept of Made in China is well known globally, and the market for Chinese products abroad is becoming more and more extensive. At the same time, there are many imported products in China, such as mobile phones, computers and cars, that are used every day, making the Chinese people more aware of foreign markets. The import and export market has a significant impact on China's economic development. It is influenced by many complex factors, making it an integral part of China's national economic system and presenting a complex operating mechanism. With China's modernization and increasing openness, the import and export trade is also increasing further. At present, China is opening up to the outside world, and the first reform and opening-up cities such as Shenzhen, for example, have seen an increase in the foreign trade economy, and the resulting import and export economy generated by foreign-owned enterprises in China is increasing as a proportion of China's GDP, further demonstrating the impact of the import and export economy, which is of great importance to China's economic development.

Due to the importance of the import and export economy to national development, many scholars at home and abroad have done much research on the import and export economy in recent years. Chen Juchao [3] used the GMDH network to forecast China's total import and export trade and optimized the model with the PSO algorithm to improve the forecast accuracy. Jing Li et al. [4] used the random forest algorithm to forecast the transformation of local and regional economic growth dynamics. Wenhua [5] used the ADF test to study the relationship between import and export trade

and economic growth in Jilin Province, and put forward relevant policy recommendations based on the experiment results. Tomàš Brabenec [7] used a neural network model to analyze the factors influencing China's trade with the Czech Republic and proposed the basic assumption that the growth of China's foreign trade exports to Czechoslovakia (CR) would gradually weaken compared to that of imports.

Throughout the previous studies, there has been a great deal of experience with the import/export economy, and there are a number of cutting-edge findings to draw on. However, some areas deserve further research. The former studies have focused on the macro level, on the impact of macroeconomic policies on the import/export economy, or the relationship between the import/export economy and national development using certain algorithms, with only a few studies refining the issue. This paper aims to use the Gini index in conjunction with the Random Forest (RF) algorithm to analyze the economic factors influencing China's import and export trade. The paper begins by explaining the import/export trade economy, identifying its influencing factors, and constructing a system of relevant indicators. The RF model and Gini index are then introduced and used to construct a functional model using the data collected. Finally, using Beijing as an example, R2 and MSE methods test the empirical analysis and draw the corresponding conclusions. Through the above research, this paper finds that constructing a random forest model from the perspective of Gini index can better identify the magnitude of the contribution of different influencing factors, which is beneficial to the formulation of macroeconomic policies.

2. Construction of an economic impact indicator system for imports and exports

2.1 Quantification of the economy of import and export trade

The import and export trade arose and developed under certain historical conditions. The two basic conditions for the formation of import and export trade are, firstly, the development of the productive forces of society leading to the emergence of surplus products for exchange and, secondly, the formation of nations. The development of social productivity produces surplus goods for an exchange, and these surplus goods are exchanged between countries, giving rise to international trade in imports and exports.

The specific contents of the business include buying, selling, and trading of import and export commodities; transportation and storage of import and export commodities; inspection of import and export commodities; customs supervision of import and export commodities; freight insurance of import and export commodities; international settlement and bank credit business for settling payments and providing funds for import and export commodities, arbitration work and judicial hearing for resolving disputes in import and export business; import and export business Management and administration of import and export business, etc.

For calculating total trade in the economy after entry and exit, this paper defines Y as the total amount of goods entering and leaving China's borders. Total imports and exports are used to observe the total size in terms of foreign trade. China requires that exports be counted on FOB and imports on a CIF basis.

2.2 Influencing factor indicator system construction

2.2.1 Gross Domestic Product

China's foreign trade dependency is increasing year on year and is much higher than the 14-20% level of developed and developing countries such as the US and Germany. Although some arguments deny this phenomenon, this does not deny the fact that domestic consumer demand is a low contributor to GDP. According to relevant research data, China's foreign trade can only develop further if GDP continues to soar. In order to adapt to compete in international markets, and increase total foreign trade, domestic production must be used as an adequate backup to support it. Therefore, GDP (X1) should be an important factor in measuring the total amount of import and export trade.

2.2.2 Total social investment in fixed assets

The amount of investment in fixed assets (X2) is the workload of construction and acquisition activities of fixed assets expressed in monetary terms. It is a comprehensive indicator reflecting the scale, speed and proportional relationship of investment in fixed assets. Investment in fixed assets in China can cause the restructuring of domestic industries, improve the investment environment, enhance the competitiveness of domestic enterprises, and have a more prominent impact on the import and export trade economy.

2.2.3 Amount of actual foreign investment utilized

This factor encompasses external borrowing and various acts of foreign investment. In terms of the structure of foreign trade, more than 60 percent of the incremental volume of China's imports and exports is achieved by individual foreign-invested enterprises, particularly in the manufacturing sector. The concentration of foreign investment in the manufacturing sector has led to the increasing integration of Chinese manufacturing into the global production and operation system, making it an essential part of world trade. [10] To a certain extent, it shows that China's import and export economy will maintain a high growth rate as long as the trend of foreign investment into China's manufacturing sector continues. However, as that state is subject to the continued investment of foreign capital, it will turn down once the investment is withdrawn for one reason or another. Therefore, the amount of actual foreign investment utilized (X3) is a double-edged sword for investment in China.

2.2.4 Foreign exchange reserves

In recent years, the rapid growth of China's foreign exchange reserves has attracted much attention. China's high foreign exchange reserves are mainly formed by accumulating China's balance of payments surplus, with the current trade surplus being the primary source of foreign exchange reserves. [9] Import and export trade affects China's foreign exchange reserves, and high foreign exchange reserves also impact trade development. Therefore, considering foreign exchange reserves (X4) as an important variable is of great use in the study of import and export trade.

2.2.5 Annual average exchange rate of RMB to USD

The US dollar has a vital role in foreign trade as the world's currency. China has long had a controlled floating exchange rate system between the RMB and the US dollar, which does not allow free foreign exchange transactions. After completing each import and export trade, manufacturers have to calculate the cost of foreign exchange, [8] and compare it with the current foreign exchange rate to determine whether this foreign trade is cost-effective. Although the average annual exchange rate of RMB to USD (X5) is at a relatively stable level, it still has to be taken into account.

2.2.6 Year-end balance of savings of urban and rural residents

The year-end savings balance (X6) of urban and rural residents determines the number of funds that can be used for investment to a certain extent.. It can be considered as a kind of idle funds that will be transformed into reserve funds under certain conditions. To a certain extent, it represents the purchasing power of the domestic market, influencing the values of the above-mentioned types of factors and playing an important role in the process of foreign trade. In summary, the specific indicators are shown in Table 1

Table 1 Indicator system

Indicator name	Indicator code	Meaning	Unit
GDP	X1	National strength	Yuan
Total social fixed asset investment	X2	Competitiveness of domestic enterprises	Yuan
Amount of actual foreign investment utilized	X3	Volume of foreign investment in foreign trade	Yuan
Foreign exchange reserves	X4	Trade Impact Factors	Yuan
Average annual exchange rate of RMB to USD	X5	Trade Impact Factors	Yuan
Year-end balance of urban and rural savings	X6	Domestic market purchasing power	Yuan

3. Random Forest - GINI Index

3.1 Random forests

Random Forest is an integrated algorithm via decision trees proposed by Leo Breiman and Adele Cutler [11], as shown in Figure 1. And the test sample categories are determined by the plurality of the categories output from the individual decision trees. It operates by constructing multiple decision trees at training time and outputting the classes as patterns of classes or average predictions. Stochastic decision forests correct the habit of decision trees to over-fit their training set. By random sampling and adding randomness to the split variables, the independence between trees in a random forest is increased, and the upper bound on the generalization error is reduced. This paper investigates the identification of RF (Random Forest) based on the Gini index in the economic contribution of imports and exports to provide a basis for further development of the integrated algorithm for variable selection.

Each tree is constructed according to the following steps [12].

STEP1. Use P to denote the number of training samples and R to denote the number of features.

STEP2. The number of input features, r, is used to determine the decision outcome of a node in the decision tree; where r should be much smaller than R.

STEP3. Random selection of data, from P training samples, with put-back sampling, repeat random sampling P times to form a sample set (i.e. bootstrap sampling, i.e. allowing duplicate samples among them), and use the unsampled samples for prediction and evaluate their errors.

STEP4. When each node of the decision tree needs to be split, r features are randomly selected. For each selected feature, all possible splitting methods are iterated, and the Gini index is obtained separately. Based on these r features, the best splitting method is calculated. The above steps are repeated to obtain z decision trees, which form a random forest model for the identification of economic contribution of imports and exports based on RF (random forest) with Gini index.

STEP5. Each tree will grow intact without pruning, which is likely to be adopted after building a normal tree-like classifier.

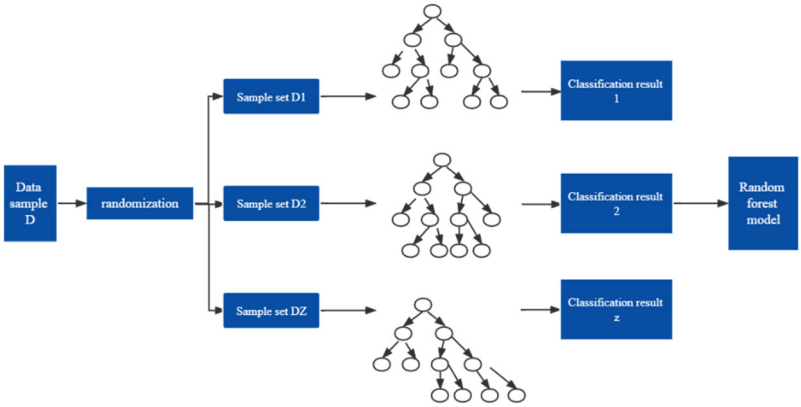

Figure 1 How random forests work

3.2 GINI Index

In the construction of RF, a feature is used as a segmentation attribute of a node because it maximizes the Gini gain at that node. Therefore the importance of the feature is reflected by the segmentation of the node data.

Random forests adapt impurity [13] as the best partitioning measure for classification trees. Impurity is calculated by the Gini index method, one of the most widely used partitioning rules. Suppose the set n contains records of k categories, then the Gini index is.

$$I_G(n) = 1 - \sum_{j=1}^{k} p_j^2 \tag{1}$$

$I_G(n)$ is the Gini index of the node n and p_j is the proportion of samples of the category j in the node n . When $I_G(n)$ is at least 0, i.e. all records at this node belong to the same category, it means that the maximum useful information is obtained at this time; When all records at this node are uniformly distributed for the category field, $I_G(n)$ is the maximum, which means that the minimum useful information is obtained.

The statistic $PORT_i^{Gini}$ is the Gini index-based feature importance in a random forest, and represents the average change in Gini index of the first i feature overall decision tree nodes in the RF. The data on the node n is divided into its left and right children, i.e., assuming that the data on the parent node n is divided into its children n_l and n_r , the change in Gini index before and after n_l and n_r is shown in the equation: The Gini gain maximization principle [14] is to maximize equation (2):

$$PORT_{in}^{Gini} = \Delta I_G = I_G(\mathrm{n}) - p_l * I_G(n_l) - p_r * I_G(n_r) \tag{2}$$

p_l and p_r are the proportions of data from the parent node n to its left and right children n_l and n_r , respectively, in the data of the parent node. ΔI_G is the change in Gini index before and after the branching of the node n .

If the feature x_i appears N as a node in the k decision tree in the random forest model, the importance of the feature in this decision tree is [15].

$$PORT_{ik}^{Gini} = \sum_{n=1}^{N} PORT_{in}^{Gini} \tag{3}$$

Therefore, if there are K trees in the RF model, the importance of the feature variable x_i in the overall RF can be expressed as:

$$PORT_i^{Gini} = \frac{1}{K} \sum_{k=1}^{K} PORT_{ik}^{Gini} \tag{4}$$

Where K is the number of decision trees in the RF, i.e., the number of classifiers.

4. Model test index determination

To ensure model accuracy and confidence in the GINI index, the RF needs to be tested at R2, MSE. This paper measures the model's goodness of fit to the data in terms of R2 and MSE to ensure that the linear regression model is sufficiently accurate. The closer to 1, the better the fit, and the smaller the MSE, the better.

If the square of the difference between the true and predicted values is important, the MSE is the expected value of the sum of the squares of the differences between the estimated and true values of the parameters.

$$MSE = \frac{SSE}{N} = \frac{1}{N}\sum_{i=1}^{N}(y_i - \hat{y}_i)^2 \tag{5}$$

N is the number of samples, the result of the calculation is the sum of squares of the difference between the predicted and true values of the data.

If what the model wants is to find the dependent variable that explains the variation in the target y , then R2 is a more appropriate choice. R2 is provided to evaluate the goodness of fit of the regression model coefficients, called the coefficient of determination. For the unfit and perfect fit, this is a value between 0 and 1. The closer to 1, the better the fit, indicating that the model explains the dependent variable more adequately (the independent and dependent variables are related, and it appears that the independent variable determines the dependent variable), and the smaller it is, indicating that the independent variable has a relatively small effect on the dependent variable. This indicator shows the extent to which the independent variable and the parameters determine the value of the dependent variable.

The R2 expressions are as follows.

$$R^2 = \frac{SSR}{SST} = 1 - \frac{MSE}{VAR} \tag{6}$$

Where: $SST = SSR + SSE$, SST (total sum of squares): the total sum of squares, SSR (regression sum of squares): regression sum of squares, SSE (error sum of squares): residual sum of squares, and VAR: variance, $VAR = \frac{1}{N}\sum_{i=1}^{N}(y_i - \overline{y})^2$

5. Empirical analysis

5.1 Data collection

5.1.1 Overview of the study area

Since implementing the policy of opening up to the outside world, Beijing's economy has grown rapidly along with the rapid expansion of foreign trade. Based on the characteristics of Beijing's headquarters economy, a large amount of China's import demand is purchased through the headquarters of related enterprises in Beijing, a process that drives the scale of regional imports to expand subsequently. In 2022, Beijing's total import and export reached 304.384 billion yuan. As a result of the rapid growth of import and export trade and the increasing openness to the outside world, the share of foreign trade in the gross national product has been rising. Therefore, the practical activities of Beijing's foreign trade and economic growth provide a good case study of the impact of the economic contribution of imports and exports, and have strong theoretical research significance.

Based on the combination of existing studies, this paper selects annual data from 1987 to 2021 to identify the economic contribution of import and export. Among them, 34 periods of customs import (Y1) and customs export (Y2) are selected as explanatory variables to represent the import and export economy; GDP (X1), total social fixed asset investment (X2), the amount of real utilised foreign investment (X3), foreign exchange reserves (X4), the average annual exchange rate of RMB to USD (X5), the year-end balance of urban and rural residents' savings (X6) are selected as the factor explanatory variables. Statistics are obtained from the Beijing Statistical Yearbook.

5.1.2 Data processing

Using the sklearn.cluster tool in Python, the customs import amount (Y1) and customs export amount (Y2) data were discretized, and the values of the continuous attributes were clustered using a clustering algorithm and designated into four groups of data. The clusters obtained from the clustering are processed, merged into one cluster of continuous attribute values, and uniformly labeled. Spatial matching of Y1 and Y2 values and all explanatory variable data was achieved, with a total of 280 matched samples. Using the years 2018-2021 as an example, all influencing factors are shown in the table.

Table 2 2018-2021 Sample Data Presentation

X1	X2	X3	X4	X5	X6	Y1	Y2
33106.00	8062.24	1731089.00	30727.12	661.30	34019.00	3	3
35445.10	7868.75	1421299.00	31079.24	689.48	37309.70	3	3
36102.60	8041.86	1410441.00	32165.22	692.54	42888.80	2	2
40269.60	8435.91	1555716.42	32502.00	645.17	47184.30	3	3

5.2 RF-GINI calculation

5.2.1 Confidence test

This paper constructs a random forest regression model based on matched sample data, with all influencing factors are explanatory variables and customs import and export amounts are dependent variables. By 7:3 training data and test data, the test set's model accuracy (MSE and R2 and MAE) is used to determine how suitable the model is. The confusion matrix is shown in Figure 2. It can be seen from the figure that the MSE is 0.122, 0.033 very low, R2 is high, 0.918, 0.972, and MAE is low, 0.194, 0.106, respectively, indicating a high prediction model accuracy.

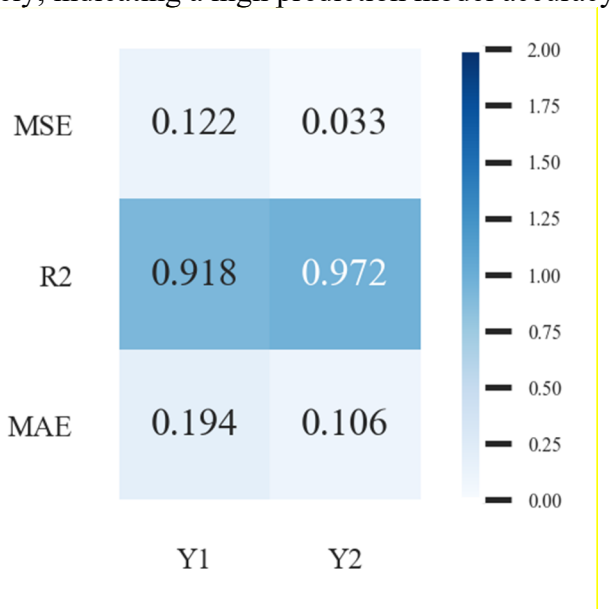

Figure 2 Confusion matrix

5.2.2 GINI importance analysis

In this paper, based on the above accuracy, the importance ranking of the influence factors under the Random Forest method is derived. Figures 1 and 2 show the importance ranking of the variables obtained by the Random Forest Regressor method based on Gini impurity. In Y1, X6 has the largest effect and X1 the smallest; in Y2, X6 has the largest effect and X5 the smallest

In both the import and export economies, the year-end balance of savings of both urban and rural residents is the most influential factor in terms of contribution. The year-end balance of urban and rural residents' savings represents funds available for investment, which under certain conditions will be transformed into reserve funds to enter the trade market, and to some extent, represents the market's purchasing power. Urban and rural residents' savings are closely linked to developing a country's economy. Its movement reflects the good state of the country's economic development, the balance of government finance and payments, the stability of the national currency, and the rise in employment. Therefore, we can consider that the year-end balance of savings of urban and rural residents contributes to the import-export economy. The amount of actual foreign investment utilized ranked second in both the import and export economies in terms of contribution, and the huge economic pull that foreign direct investment used to have on China as a developing country. In terms of the structure of foreign trade, more than 60% of the increase in China's imports and exports was achieved by individual foreign-invested enterprises, particularly in the manufacturing sector.

The average exchange rate of the Renminbi against the US dollar is the third-largest contributor to the import economy, but the last in the export economy. The exchange rate is the relative price of the two currencies, and small changes can have a large impact on the selling price on the export side and the buying cost on the import side. Due to the long-standing trade surplus between China and the US, the average RMB/US dollar exchange rate contributes more to the import economy than the export economy. GDP ranks lowest in the import economy but fourth in the export economy, with an increase in GDP actively or passively contributing to the growth of imports and exports. As a measure of a country's productive capacity, an increase in GDP means increased fiscal revenues, higher corporate profits, higher incomes for people. The government makes use of its financial and special administrative powers to actively create a more suitable, standardized and favorable business environment, and create more business opportunities for enterprises, thus promoting the growth of import and export trade in all aspects.

Foreign exchange reserves are the fifth-largest contributor to the import economy and the third-largest to the export economy. Since China's total exports have been larger than its imports for a long time, the fact that net exports have been positive for a long time means that the country holds a large amount of foreign exchange reserves, which can have a certain impact on or even threaten the stability of other countries' currencies. But holding too many foreign exchange reserves also faces the risk of devaluation of the foreign exchange held, when the devaluation of foreign exchange is equivalent to the plunder of the country's wealth and people's labor, and therefore vulnerable to other countries. The impact of foreign exchange reserves on the import and export economy is also significant. Investment in fixed assets ranks fourth in the import economy and fifth in the export economy. Investment in fixed assets in China can lead to a restructuring of the domestic industry, improve the investment environment, enhance the competitiveness of domestic enterprises, and have a more obvious impact on the import and export economy.

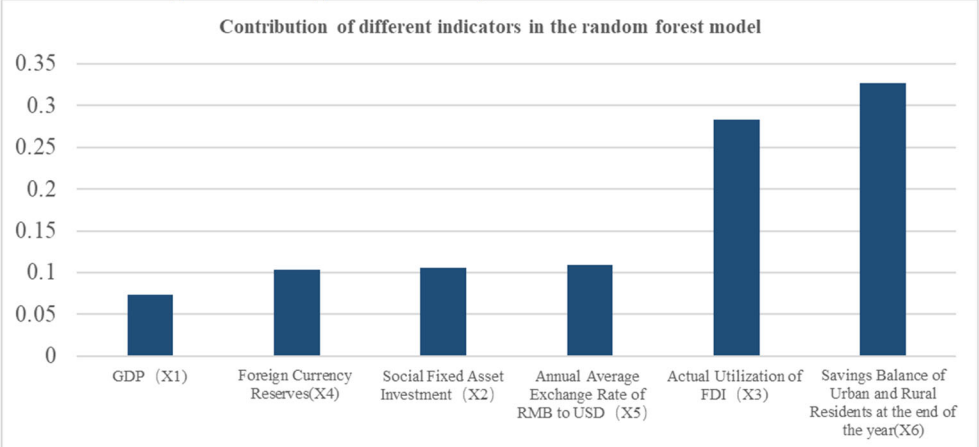

Figure 3 Import economy importance of different characteristics in the random forest model

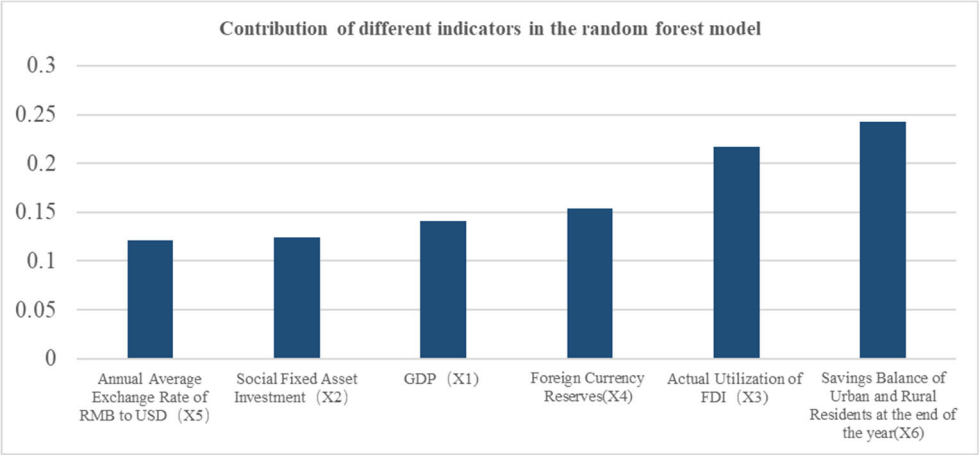

Figure 4 Importance of different characteristics of the export economy in the random forest model

6. Conclusion

This paper uses a combination of the Gini index and the Random Forest (RF) algorithm to identify indicators of the economy's contribution to the study of import and export trade.

Firstly, we explain the import and export trade economy, identify the factors that influence it, and construct a system of relevant indicators. The RF model and the Gini index are used to construct a functional model with the collected data. Finally, using Beijing as an example, MAE, R2 and MSE indicators are used to test the empirical analysis and draw the corresponding conclusions.

(1) For the first time, a refined study of the contribution of the regional import/export trade economy was conducted, using MAE, R2 and MSE for error analysis to demonstrate the soundness of the model. A study to identify the contribution of the regional import and export trade economy by constructing a random forest model to analyze the different degrees of influence of indicators based on Gini impurity.

(2) The analysis shows that the contribution of the year-end balance of urban and rural residents' savings in the import economy is the largest, at 0.327, and the contribution of GDP is the smallest, at 0.073. In the export economy, the contribution of the year-end balance of urban and rural residents' savings is also the largest, at 0.243, while the contribution of the average annual exchange rate of RMB to USD is the smallest, at 0.121.

Based on the main research findings, corresponding countermeasures are proposed for import and export economic development in Beijing.

(1) Promote technological innovation and improve production efficiency

The analysis of the empirical findings shows that the balance of urban and rural residents' savings at the end of the year and the amount of investment in fixed assets positively impact the import and export economy. We can promote technological innovation, improve the production efficiency of enterprises, reduce production costs, enhance international competitiveness, improve the investment environment of enterprises, and increase residents' income.

(2) Promote the reform of foreign trade system and establish safeguard measures

The empirical analysis of this paper shows that both the average exchange rate of RMB to USD and foreign exchange reserves have a large contribution to the import and export economy. It is essential to promote the development of import and export economy by promoting the reform of foreign trade system to increase the average exchange rate of RMB to USD and foreign exchange reserves. First, reform the regulation of foreign trade enterprises to fully use the exchange rate, interest rates, tax rates and other economic levers to regulate foreign trade enterprises greater autonomy. Second, give full play to the role of export credit insurance, guide all kinds of financial institutions to cultivate market players, support foreign trade enterprises to develop the market, and protect the stability of the foreign trade industry chain supply chain smooth.

(3) Promote transformation and upgrading, rational use of foreign investment

From the changes in Beijing's regional GDP and actual utilization of foreign investment to the contribution of the import and export economy, the development of Beijing's economy, the improvement of the business environment, the active attraction and rational utilization of foreign investment, and the guidance of foreign investment, the growth of Beijing's import and export, economic development has important significance. Accelerate the pace of upgrading the industrial structure, promote the transformation of the development model of enterprises, actively promote the development of effective services, and vigorously develop the information technology industry and third-party logistics. Create a good business environment, encourage private enterprises to export, and support the development of small and medium-sized enterprises. At the same time, create a fair and competitive investment environment, and protect the safety of foreign investment funds and the legality of investment.

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