An Empirical Analysis of Factors Influencing China's Automobile Exports: A Simulation Experiment Approach

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Abstract. With economic integration and trade liberalization gradually becoming the new normal of world trade, the competition in the international automotive market is becoming increasingly fierce. How can Chinese automotive enterprises continue to develop in the international market, and in what aspects have they affected the export of automobiles? This article is based on the thinking of simulating the operation of automobile enterprises in the international economic simulation experiment of the Digital Economy Laboratory. By applying economic principles and using time series models to analyze various factors and predictions that affect China's automobile exports, it is concluded that steel production, industrial producer factory price index, labor force have a positive impact on China's automobile exports, and tariffs have a negative impact on China's automobile exports. Finally, several suggestions were put forward for Chinese automobile enterprises to enhance their international competitiveness, helping to maintain a sustained high growth trend in China's automobile product exports and promoting the stable operation of the automobile industry.

Keywords: Automobile exports; Simulation experiments; Economic decision-making; Regression analysis; influence factor

1 Introduction

China's role in the global economy and trade has significantly increased with the advancement of world economic integration. Notably, China has emerged as one of the largest automobile exporters, with exports reaching 3.111 million units in 2022. In the field of new energy vehicles, China's development has been remarkable. BYD, for instance, has successfully entered the US market and achieved considerable sales. Chinese companies have also made significant progress in new energy vehicle components, such as drive motor technology, motor control, and power batteries. Moreover, the integration and evolution of technologies in intelligent connectivity and autonomous driving are rapidly advancing, making Chinese automobiles highly anticipated in the era of new energy vehicles[12].

The "2021-2035 Plan for the New Energy Vehicle Industry," issued by the General Office of the State Council in November 2021, aims to promote reform, development,

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and innovation in the Chinese economy through win-win cooperation and open integration. The plan emphasizes the importance of expanding openness to the outside world, increasing international cooperation, and actively participating in global competition[3]. In line with this, the Ministry of Commerce, along with relevant departments, supports the establishment of overseas marketing and after-sales service networks for new energy vehicles, brand promotion, and export enhancement using channels such as the China Europe train.This article focuses on the impact of various factors on China's automobile product exports, employing economic principles and econometric models through simulation experiments and analysis[4]. The findings provide valuable suggestions for Chinese automobile enterprises to improve product quality, facilitate product structure transformation and upgrading, and effectively meet the challenges of global trade. The practical significance of these suggestions is substantial[5].

2 Reflection and summary based on simulation experiments

2.1 Analysis of Factors Influencing Export Quantity in Virtual Simulation Experiments

2.1.1 The impact of labor input on production capacity

(1) The impact of the labor force on production capacity can be analyzed using simulation experiments. Assuming sufficient steel inventory, the simulation demonstrates that increasing the labor force from 0 to 420 people on a production line results in a maximum output of 1520 cars. Beyond this point, adding more people does not increase production capacity and may even lead to resource waste. Hence, the relationship between labor input and production capacity follows an inverted U-shaped pattern, with an initial increase followed by a decrease. Experimental simulations provide valuable insights into understanding this relationship.

(2) The impact of labor hours on production capacity can also be examined through experimental simulations. When the number of workers is insufficient, overtime pay can be used to increase production capacity. Increasing working hours, represented by different levels of overtime pay (10%, 20%, 30%, 40%), leads to an increase in production capacity. For instance, with 420 workers, an additional 10% overtime pay results in a production of 1590 cars, an increase of 70 cars. Similarly, additional 20%, 30%, and 40% overtime pay lead to productions of 1670, 1750, and 1820 cars respectively, with corresponding production increases of 150, 230, and 300 cars. Therefore, it can be concluded that an increase in labor hours positively affects production capacity, but the incremental benefit of production capacity follows an initial increase and then decrease pattern.

2.1.2 The impact of price and brand effect on order volume

In the simulation experiment, price is identified as the primary factor influencing the quantity of orders, with a lower price resulting in a higher order quantity. However, companies must consider their profits and avoid excessively lowering prices to secure orders. Additionally, it is crucial for companies to assess their production capacity to avoid situations where the order volume exceeds their ability to deliver, leading to penalties. Another significant determinant of order quantity is the brand effect, which is calculated based on advertising expenses and sales revenue. Enterprises strive to achieve more orders by offering competitive manufacturer' s quotations and building a strong brand effect. For instance, in the second year, Car 1 had a market quotation of 125,000 yuan per vehicle, significantly lower than other car companies, and consequently received the largest order volume, surpassing the 500-vehicle order volume of other companies. In the fourth year, China Automobile 1 invested 10 million yuan in advertising fees. However, as its quotation was similar to other companies, the order volume only increased by 100 units. This showcases the significant impact of price on the order volume of automobiles.

2.1.3T he impact of tariffs on cross-border trade

In international trade, import and export taxes play vital roles. Export taxes increase fiscal revenue, regulate the export of raw materials, and ensure domestic supply. Import taxes generate revenue, raise costs and prices of imported goods, protect domestic businesses.However, in simulations, zero tariffs are commonly set to facilitate cross-country trade, preventing high prices for imports. For instance, if Chinese Automobile 1 can't meet demand, American Steel 1 can offer excess materials at reasonable prices with zero tariffs. Imposing a 20% import tax hinders trade and disrupts transactions.Overall, zero tariffs in simulations foster smooth cross-border trade, while import taxes impede trade and hinder transactions.

2.1.4 The impact of differences in resource endowments on trade

In the simulation experiment, American Automobile 1 strategically procured high-end steel at a lower price from China Steel 1, capitalizing on the differences in international resource endowment. This highlights how international trade significantly impacts domestic markets. China's competitively priced high-end steel becomes an attractive alternative for American automakers, potentially displacing higher-priced domestic options. Similarly, if a U.S. manufacturer focuses on producing low-end cars, labor cost differentials may limit the likelihood of sourcing from China with its lower labor costs. These observations illustrate the significant influence of resource endowments on trade dynamics.

2.2 Economic Reflection and Summary

The market share and competitiveness of automotive companies in international trade are influenced by several economic principles. Firstly, the law of diminishing marginal returns explains how increasing inputs initially leads to output growth but eventually reaches a point of diminishing returns. Labor becomes the determining factor for output changes in the short term when fixed assets remain constant. However, due to diminishing marginal returns, output eventually decreases.

Secondly, as the economy and society develop, automobiles transition from luxury goods to household necessities. According to the economic relationship between price and demand, increased taxes may raise prices and potentially lower demand for automobiles. However, factors like social comparison and vanity can also influence increased demand.

Thirdly, tariffs, regardless of whether imposed on consumers or enterprises, increase costs for both supply and demand sides, leading to reduced supply or demand. From a macro perspective, tariffs can serve as a double-edged sword. Appropriate tariffs can enhance fiscal revenue and protect industries, but high tariffs may provoke trade disputes between countries.

3 Empirical Analysis

In order to further understand the impact of factors related to the number of car exports in the operation of simulation experiments on China's car export situation in reality[6], this article intends to establish a multiple regression model for validation. The model is as follows[7,8,9].

3.1 Variable selection and data sources

3.1.1 Variable selection

The selection of variables affects the accuracy of research on China's automobile exports. Based on the qualitative analysis of various influencing factors in China's automobile exports, it can be concluded that steel production, tariffs, industrial producer price index, and labor force will have an impact on automobile exports. The specific indicators are explained as follows[10,11,12,13].

The dependent variable: China's automobile export volume (Y), representing the export capacity and influence of China's automobile industry.

Explanatory variables:

(1) Use X1t to represent China's steel production.

(2) Use X2t to represent the ex factory price index of factory producers, reflecting the trend and magnitude of changes in the ex factory price of industrial enterprise products when they are first sold.

(3) Using X3t to represent China's tariffs, if a country imposes high tariffs on cars imported from other countries, it will suppress the exports of cars from other countries, but it is a trade barrier that protects the domestic automotive industry. Therefore, tariffs belong to negative indicators.

(4) Use X4t to represent the labor force population in the Chinese market.

3.1.2 Data source

Data on China's automobile exports, tariffs, steel production, industrial producer price index, and labor force are all sourced from the National Bureau of Statistics of China. A total of 25 sample sizes were selected from 1998 to 2022[14].

Table 1. Variable Description and Data Source[14]

variable	Variable name	Meaning and Explanation	data sources
Dependent variable	Y	Automobile export amount	China National Bureau of Statistics
Explanatory variable	X1	China's steel production	China National Bureau of Statistics
	X2	Factory Producer Factory Price Index	China National Bureau of Statistics
	X3	Tariffs in China	China National Bureau of Statistics
	X4	Labor force in China	China National Bureau of Statistics

Data source: China National Bureau of Statistics (1998-2022)

3.2 Model construction

This article establishes a time series data model based on China's automobile export volume, selects 25 samples from 1998 to 2022, and uses Eviews 8 version to establish a quantitative model for quantifiable factors, constructing a regression model:

$$Yt = C + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 \quad (1)$$

Among them, Yt represents the amount of China's automobile exports in year t; X1t represents China's steel production in year t; X2t represents the factory producer price index; X3t represents China's tariff in year t; X4t represents the number of labor forces in China in year t; β1, β2, β3, β4 is the coefficient before the variable.

3.3 Empirical testing and model revision

Since the established model is a time series model, in order to test whether the data has stationarity, an ADF test is performed first. The inspection results are as follows:

Table 2. Unit Root Test Results of Time Series Data

variable	Inspection method	Stationarity
Y	ADF test (first order)	stable
X1	ADF test (first order)	stable
X2	ADF inspection	stable
X3	ADF test (first order)	stable
X4	ADF test (second-order)	Unstable

According to Table 2, we conducted ADF tests on Y, X1, X2, X3, and X4 time series data. The ADF test results for Y, X1, and X3 had p-values greater than 0.1 (0.989, 0.914, 0.587), indicating that the null hypothesis cannot be rejected, and these sequences are deemed unstable. We performed first-order differencing on the sequences and conducted ADF tests again. After differencing, the ADF test results for Y, X1, X2, and X3 showed p-values of 0.000, indicating rejection of the null hypothesis with a confidence level exceeding 99%. These sequences are now considered stable.

For the factory price (X2) of industrial producers, the ADF test yielded a t-statistic of -4.155 and a p-value of 0.001. The critical values for the 1%, 5%, and 10% significance levels were -3.964, -3.085, and -2.682, respectively. With a p-value of 0.001 < 0.01, we reject the null hypothesis with over 99% confidence, concluding that the sequence is stable.

However, the ADF test for the X4 time series data (number of workers) indicated p-values of 0.127, 0.132, and 0.469 for the original equation, first-order difference, and second-order difference, respectively, all exceeding 0.1. The null hypothesis cannot be rejected, and the sequence remains unstable. Thus, based on the requirements of the time series model, X4 was removed from the original model.

Based on the test results, take the logarithm of the left and right sides of the original equation and revise it as follows:

$$Yt = C + \beta 1X1 + \beta 2X2 + \beta 3X3 \tag{2}$$

3.4 Regression analysis

This article conducts OLS regression analysis on model (2) through SPSS, and the results are shown in Table 3.

Table 3. OLS Regression Analysis Results (n=25)

	Regression coefficient Coef	Standard error Std. Err	T	P	95% CI
constant	-33.681	six point nine five seven	-4.842	0.000**	-47.316~-20.047
Industrial Producer Factory Price Index	three point nine nine two	one point five one six	two point six three four	0.016*	1.022~6.963
Steel production (10000 tons)	two point five seven zero	zero point two eight four	nine point zero four nine	0.000**	2.014~3.127
Tariff (100 million yuan)	-0.634	zero point three eight zero	-1.668	zero point one one zero	-1.378~0.111
R 2	zero point nine seven eight				
Adjust R 2	zero point nine seven five				
F	F (3,21)=318.347, p=0.000				
D-W value	one point three four two				

Dependent variable: Automobile export amount (million US dollars)
* p<0.05 ** p<0.01

Based on the table provided, the model's R-squared value is 0.978, indicating that the factory price index of industrial producers (last year=100), steel production (10000 tons), and tariffs (100 million yuan) collectively account for 97.85% of the variation in automobile export amounts (million US dollars). A detailed analysis reveals that the regression coefficient for the factory price index is 3.992, with a significant level of 0.05 (t=2.634, p=0.016<0.05), suggesting that the factory price index has a significant positive impact on the added value of automobile exports. The regression coefficient for steel production is 2.570, with a significant level of 0.01 (t=9.049, p=0.000<0.01), indicating that steel production has a significant positive impact on automobile export amounts. However, the regression coefficient for tariffs is -0.634, and it is not statistically significant (t=-1.668, p=0.110>0.05, and p>0.1), suggesting that tariffs do not have a significant impact on automobile exports and can be excluded from the model. Therefore, the final regression model can be represented as follows:

$$\mathrm{Ln(Yt)} = -33.681 + 2.570 \times \mathrm{Ln(X1)} + 3.992 \times \mathrm{Ln(X2)} \tag{3}$$

3.5 Summary and shortcomings

The main factors affecting China's automobile exports are steel production and the industrial producer factory price index. These factors can be explained through the principles of input-output and supply and demand in economics. Steel, as a crucial raw material for automobile manufacturing, plays a significant role in determining the output of products. China has a sufficient steel production capacity, which supports the development of industrial manufacturing, including the automotive industry. This is why steel production has a positive impact on automobile exports.

China's automotive industry is undergoing transformation and upgrading, with advancements in new energy vehicle technology driving its international market entry. Advanced technology and competitive prices are key factors influencing demand in the industry.

The analysis results show that the impact of tariffs on the increase in automobile export value (in millions of US dollars) is not significant and has been excluded from the model. However, this does not imply that there is no impact. To further explore the reasons, additional univariate regression analysis was conducted. The results showed a significant negative impact of tariffs on the added value of automobile exports. This may be due to correlations among various factors in the original model or the model's limited ability to dig deeper into the relationships between factors and automobile exports.

Overall, the optimized regression model considering the aforementioned factors can provide valuable insights into China's automobile exports.

Additionally, the stability of the labor force data during the ADF test was found to be inconsistent, thus it was excluded as an explanatory variable in the multiple regression model. This decision was based on the understanding that the labor force indicator does not necessarily exhibit a linear relationship with export value, as recognized in the field of economics. Specifically, the labor force indicator is subject to the law of diminishing returns to scale with respect to output value. Consequently, while there may exist a direct proportionality between the number of labor force and export value within a certain range, an inverse relationship may manifest beyond that particular threshold.

4 Countermeasures and suggestions

4.1 Improving product quality and promoting product structure transformation and upgrading

Improving product quality enhances product competitiveness, allowing enterprises to gain a more advantageous position in market competition and increase their market share and economic benefits. Promoting the upgrade of product structure introduces new materials, processes, and technologies, thereby increasing product value and market share, and ultimately achieving sustainable development for enterprises. Strengthening market research and product design helps to better understand market demand, consumer preferences, and needs, resulting in the design of more competitive and innovative products that cater to diverse consumer needs. This in turn improves the market share and reputation of enterprises.

4.2 Promote the development of the steel industry and ensure high-quality raw materials

The development of a high-quality steel industry is crucial to ensuring that China's industrial manufacturing sector delivers superior product services to consumers from the very beginning. The steel industry, as a key foundational sector of the national economy, plays a vital role in constructing a modern and robust country and is instrumental in achieving environmentally friendly and low-carbon development. Against the backdrop of the COVID-19 pandemic and the global industrial chain restructuring, China's relatively comprehensive steel industry chain and strong technological autonomy have received further recognition. Through ongoing transformation, upgrading, and supply-side structural reforms, the steel industry has seen steady improvements in both quality and efficiency, resulting in a stable operating trajectory. This, in turn, provides high-quality raw materials essential for the advancement of China's automotive industry and other industrial manufacturing fields.

4.3 Seize Important Historical Opportunities and Make Good Use of Free Trade Zone Rules

On November 15, 2020, China signed the Regional Comprehensive Economic Partnership Agreement (RCEP), a formal agreement with 10 ASEAN countries and 15 countries including Japan, South Korea, Australia, and New Zealand. RCEP is currently the largest free trade agreement in the world. China, being the world's largest automotive market, has implemented tax reduction arrangements with the contracting countries under RCEP to facilitate international economic exchanges. However, it is important to note that certain automotive imports have not been included in the tax reduction products or have relatively low tax reduction rates. Therefore, actively participating in the adjustment of import and export tax policies, fully understanding the rules of origin, optimizing the industrial chain, reducing enterprise management costs, and expanding the Chinese automotive market have become crucial objectives.

5 Conclusion

Research on China's export of automobiles provides insights into the global economic situation and the development of the automotive industry amidst globalization. Despite challenges such as talent shortages and logistics instability, advancements in technology and the global economy present vast opportunities for the export of automobiles. Companies are increasingly recognizing the potential and investing resources accordingly. Future prospects for the export automobile industry continue to evolve, necessitating a focus on development trends and proactive measures to optimize the industry's environment. This would promote its rapid growth and enable it to play a crucial role in global economic development. New energy vehicles pose both challenges and opportunities, revolutionizing the automotive market. China should embrace this trend, foster friendly international relations, and establish a free trade zone based on consultation, joint construction, and sharing to stimulate economic progress.

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