Research on the Dynamic Evolution of Export Product Quality of Chinese Industrial Enterprises: Based on the Dual Dimensions of Quantitative Change and Qualitative Change

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Abstract. Most of the existing studies on the dynamic evolution of Chinese export product quality have been analyzed from an empirical perspective, lacking theoretical investigation of its intrinsic evolution rules. Therefore, this paper defines the connotation of export product quality improvement (quantitative change of export product quality) and export product quality upgrading (qualitative change of export product quality), analysis the connection and difference between them, and constructs the corresponding evaluation indexes by referring to the rules of quantitative change and qualitative change in materialistic dialectics. Based on the data of Chinese industrial exporters from 2000 to 2013, the dynamic evolution of export product quality was measured statistically. The results of the research are as follows: (1) the overall export product quality of Chinese industrial enterprises showed a fluctuating upward trend. Among them, the export product quality of foreign-invested enterprises, large enterprises, and enterprises in the eastern region is higher. (2) From the dimension of quantitative change, the export product quality of Chinese industrial enterprises improved in 2001, 2003-2005, 2007, and 2011-2012, and there are some differences in the improvement of export product quality among enterprises of different ownership, scale, and regions. (3) From the dimension of qualitative change, the number of enterprises that achieve export product quality upgrading is increasing, and the mean and level of export product quality upgrading are improving. Among them, the export product quality upgrading of state-owned enterprises, large enterprises, and enterprises in the western region is higher.

Key Words: Export Product Quality, Export Product Quality Improvement, Export Product Quality Upgrading, Dynamic Evolution, Quantitative Change, Qualitative Change

1. Introduction

Since the reform and opening up, China has vigorously promoted the development of an export-oriented economy, and its economy has continued to grow rapidly and the scale of exports has continued to expand. China's imports and exports reached USD6.05 trillion in 2021, crossing two major steps of USD5 trillion and USD6 trillion in the year [The data is from import and export statistics for the year 2021 released by the General Administration of Customs of the People's Republic of China]., However, behind the great achievements, there are also hidden worries. In recent years, with the trade war between the US and China, and the global spread of Covid-19, the global political and economic situation has become more severe, compounded by the downward pressure on the domestic economy, China urgently needs to shift its core competitive advantage from "low price" to "high quality". The "Guidance Opinions of the CPC Central Committee and State Council on Launching Quality Improvement Actions" released in September 2017 pointed out that "improving supply quality is the main direction of structural reform on the supply side, and improving the quality of products and services across the board is the central task of the supply system upgrading." So how has the Chinese industrial enterprises' export product quality evolved? What inner rules do they follow? Based on the perspective of enterprise heterogeneity, does the dynamic evolution of export product quality differences between different groups of enterprises? These questions have rarely been discussed and answered by scholars, and they are the core of this paper's concern. This paper helps to understand the trends of Chinese industrial enterprises' export product quality at the micro level, and provides micro evidence for China's "Great Power of Quality" strategy.

2. Literature Review

There are three main branches of literature related to this paper, one is related to the connotation of product quality,
the second one is related to the measurement of export product quality, and the third one is related to the dynamic evolution of export product quality of China.

2.1 The connotation of product quality
In the existing research literature, the connotation of product quality is not uniform, but in general, it can be divided into two types: the definition of conformity quality and the definition of applicability quality. First, the definition of conformity quality is based on the degree of "conformity" to a particular standard. Crosby (1979)[1] states that quality is "conformity to requirements" and cannot simply be defined as "good, excellent". Because "good, excellent" is subjective or vague. ISO 8402:1986 Quality- Terminology defines quality as the sum of characteristics and features that reflect the ability of a product or service to meet a specified or potential need. ISO 9000:2000 Quality Management Systems - Fundamentals and Terminology defines quality as the degree to which a set of inherent characteristics meets a requirement. When quality requirements can be solidified by production standards, conformity quality becomes the new "basic quality" of a product(Liu, 2018)[2]. Second, the definition of suitability quality is based on the degree to meet the consumer needs. Lancaster (1966)[3] states that the quality of a product is the consumer's choice preference. Thus, product quality is the attractiveness of a product to consumers, and a product that consumers perceive as more valuable or have a stronger practical need for or are willing to pay more for has better quality (Aiginger, 2001; Kuhn and McAusland, 2008; Hallak and Schott, 2011)[4-6].

2.2 The measurement of export product quality
Currently, the unit value method, the quality-adjusted price index method, the demand information extrapolation method (KSW method), and the supply-demand information method measure quality according to the definition of suitability quality; the product characteristics method and product quality certification (ISO 9000) measure quality according to the definition of conformity quality. First, the theoretical logic of the unit value method is that the higher the unit value of a product, the higher the export product quality. Manova and Zhang (2012)[7], and Li and Wang(2013)[8] use unit value as a proxy variable for quality. However, since the unit value method ignores the influence of other factors on price, Hallak and Schott(2011)[6] propose the quality-adjusted price index method, which decomposes the product price into two parts: quality and quality-adjusted price, and then uses the quality-adjusted price index to measure the quality. Khandelwal(2010)[9], and Khandelwal et al. (2013)[10] propose a demand information extrapolation method (KSW method) from a demand perspective, arguing that if the prices of two products are equal, the variety with greater export market demand has higher export product quality. Feenstra and Romalis (2014)[11] further consider both supply and demand factors and provides an alternative analytical framework for measuring export product quality. Second, the product characteristic method designs indicator variables based on the specific characteristics of a product. Goldberg and Verboven(2001)[12] use engine power, car displacement, etc. as indicators of car quality; Crozet et al.(2012)[13] use the ratings of different brands in the Champagne Handbook as a proxy variable for champagne product quality. Verhoogen (2008)[14] uses ISO 9000 quality certification as a proxy variable for product quality.

2.3 Study on the current situation of the dynamic evolution of Chinese export product quality
The current empirical research on China's export product quality has presented different dynamic evolutionary trends, including the following three types of findings. First, Chinese export product quality is on the rise. Yin (2011)[15] used the unit value method to measure the macro-level export product quality and found that China's export product quality showed an accelerated upgrading trend since its accession to the WTO. Yu and Zhang (2017)[16] constructed an expression for export quality at the firm-product level based on the supply-demand information method and found that Chinese export product quality continued to rise from 2001 to 2006, but there were differences in the growth rate, showing an upward and then a slowdown trend. Second, Chinese export product quality is on a declining trend. Shi (2013)[17] measured the export product quality of local firms from 2000 to 2006 by using the inverse demand function regression method and found that the export product quality showed a decreasing trend with a growth rate of -2.58%. Li et al. (2014)[18] using the unit value method to measure Chinese export product quality from 2000-2006 found that the export product quality has a decreasing trend. Third, Chinese export product quality shows a fluctuating trend. Huang et al. (2015)[19] empirically found that the export product quality showed a rising trend (before the 2008 financial crisis) and then a declining trend. Xu and Wang (2016)[20] found that Chinese export product quality generally showed an upward trend from 2000 to 2011, but showed two "U" shaped changes (2000-2007 and 2007-2011). The above-related studies provide useful insights and basic references to further explore the connotation, measurement methods, and dynamic evolution of export product quality, but there are still some problems to be explored: (1)measuring the export product quality based on the definition of suitability quality uses indicators such as export quantity, export value, and income of export destination countries, which are vulnerable to economic fluctuations, resulting in more unstable export quality. In contrast, measuring the export product quality based on the definition of conformity quality needs the specific quality characteristics of the product, but in reality, due to the different characteristics of products, it is difficult to determine the quality characteristics indicators at the enterprise level. Therefore, it is necessary to comprehensively consider the conformity quality and suitability quality when measuring product quality. (2)the existing studies analyze the trend of Chinese export product quality from an empirical perspective, but lack theoretical analysis of its intrinsic dynamic evolution
rules, ignoring the quantitative-qualitative change rules of the dynamic evolution of export product quality. (3) the existing studies do not involve the theoretical exploration of the connotation, connection, and difference between export product quality improvement (quantitative change) and export product quality upgrading (qualitative change), and lack the construction of the corresponding evaluation index system.

Based on this, this paper intends to make marginal contributions from three aspects: (1) based on the dialectical materialist rules of quantitative change and qualitative change, this paper pointed out that the dynamic evolution of export product quality is both quantitative change (called export product quality improvement in this paper) and qualitative change (called export product quality upgrading in this paper). This paper defines the connotation of export product quality improvement and export product quality upgrading, constructs the evaluation indexes of export product quality improvement and export product quality upgrading, divides the three levels of export product quality upgrading, and discusses the difference and connection between export product quality improvement and export product quality upgrading, and studies the materialistic dialectics explains that quantitative and qualitative changes are the two basic states of development and change of things. The development and change of anything cannot be without quantitative change or qualitative change, but rather the unity of quantitative and qualitative change. This is also true for the development and change of export product quality. However, existing studies have failed to reveal the dynamic evolution of product quality from quantitative to qualitative changes in the process of development, and indiscriminately use product quality improvement or product quality upgrading to indicate the positive dynamic evolution of product quality, which is confusing in terms of connotation and a major research gap. This study concludes that product quality improvement and product quality upgrading reflect quantitative and qualitative changes in product quality respectively and that there are differences in their connotations, as analyzed below.

3.1.1 Quantitative dimension: export product quality improvement

Export product quality improvement refers to the improvement of an enterprise's export product quality over time compared to the previous period, focusing on the change in quantity. In this study, export product quality improvement has the following meaning: let $\text{quality}_{it}$ denote the export product quality evaluation index of enterprise $i$ in year $t$. If the export product quality in period $t$ is higher than the export product quality in period $t-1$, the export product quality is improved; otherwise, the export product quality is not improved.

3.1.2 Qualitative change dimension: export product quality upgrading

Export product quality upgrading refers to the upgrading of an enterprise's export product quality from a lower to a higher grade over time, focusing on a qualitative leap. In this study, export product quality upgrading means the following: within a certain time and space range, an enterprise's export product quality reaches or exceeds a specific standard (such as national quality certification or international quality certification, etc.), or obtains a certain recognized quality reputation or honor (such as obtaining a national well-known trademark, famous brand product, or quality award, or obtaining an international well-known trademark, famous brand product, or quality award, etc.), then the export product quality is upgraded, otherwise, the export product quality is not upgraded.

3.1.3 The relationship between export product quality improvement and export product quality upgrading

Export product quality improvement and export product quality upgrading are both related and different. Export product quality improvement is a process of gradual and quantitative change; while export product quality upgrading is a process of abrupt and qualitative change. Only when the gradual change accumulates to a certain degree can it produce a sudden change. Therefore, export product quality improvement is the basis and necessary preparation for export product quality upgrading, and export product quality upgrading is the inevitable result of export product quality improvement. Export product quality upgrading is bound to have export product quality improvement, while export product quality improvement does not necessarily have export product quality upgrading. Combined with the reality of China's import and export trade, export product quality improvement is not equivalent to export product quality upgrading for two main reasons: first, the magnitude of export product quality improvement is limited, and the accumulation of quantity is insufficient to achieve a higher grade of
quality. For example, in 2018, China’s ZTE Corporation was imposed by the United States for up to four months of chip sanctions, and ZTE officially resumed operations only after paying a deposit of $400 million because Chinese enterprises cannot independently produce high-end chips, and can only rely entirely on imports. Chinese enterprises have also been increasing the R&D to improve the chip products quality, but due to the lack of high-end core technology and high-precision talent, Chinese chips have not yet taken a place in the international high-end chip field, can only say that the quality of export products has been improved to a certain extent, but has not yet achieved the leap from low-quality grade to high-quality grade. Secondly, although the quality of export products has been improved to the international leading level, due to the lack of brand effect, it is still in the middle and low end of the international product quality grade. Chinese enterprises are hamstrung by foreign monopolies in the field of high-end chips, which indeed reflects the distance from the world’s frontier. So whether Chinese products achieve the same level of technology as foreign products, it can be considered that the two are in the same quality grade. The answer is still no. China is the “world factory”, through years of high-quality intermediate goods imports, processing trade equipment imports, and advanced management experience learning, many enterprises have reached the international leading level of product technology, and export product quality has indeed been improved. However, it is difficult to avoid the dilemma that many Chinese enterprises produce the same batch of products with the same production line, some of which are branded with the well-known trademarks of foreign entrusted enterprises and become world-famous brand products, which are favored by domestic and foreign consumers, while another part is printed with the private brand of Chinese enterprises, but few customers to consume. The export price and export sales revenue of Chinese private brand products may be significantly lower than those of foreign brand-name products. Therefore, due to the lack of trademark reputation and brand awareness, Chinese export products have not achieved a leap across the quality level. Figure 1 depicts the dynamic evolution of export product quality is a cyclical process of “quantitative change - qualitative change - new quantitative change - new qualitative change”. The specific analysis is as follows: with the enhancement of enterprise's R&D and innovation ability, the export product quality gradually improves and accumulates quantitative changes; then the export product is recognized and favored by consumers, and obtains quality awards, well-known trademarks (famous brand products), quality certification and other quality honors. In the initial stage, enterprises usually obtain lower-level quality reputation or honor, such as provincial quality awards, well-known trademarks (brand-name products), and quality certification, while in the subsequent stage, they obtain higher-level quality reputation or honor, such as national and international quality awards, well-known trademarks (brand-name products), and quality certification, that is, the export product quality is upgraded. After the completion of the first round of “quantitative - qualitative change”, enterprises will start a new round of “quantitative - quality” process on a higher level of export product quality.

3.2 Evaluation system of dynamic evolution of export product quality

3.2.1 Quantitative dimension measurement indicators of export product quality improvement

This paper first measures the firm-level export product quality values using the mainstream Khandelwal et al. (2013)[10] demand information inference method (KSW method), with the following theoretical derivation process: given a product whose quality and price are exogenously given to consumers, the product is considered to be of higher quality if consumers agree with its value and are willing to allocate more income expenditure. The quality of the product is considered to be higher. Using $c, m, i, t, \omega$ to denote the exporting country, importing country, exporting firm, year and product on the HS6 code, $c, m \in 1, \ldots, K$, $i \in 1, \ldots, N$, the number of consumers owned by importing country $m$ is $\Omega_m$, and the set of products that these consumers can purchase is $\Omega_m \subset \Omega$, can vary between countries. Based on the CES utility function, assume that the utility function of representative consumers in importing country $m$ is as in equation (1).

$$
U_m = \left[ \int_{\omega \in \Omega_m} \left( \lambda_{im}(\omega) q_{im}(\omega) \right)^{\frac{1}{\sigma-1}} d\omega \right]^\frac{\sigma}{\sigma-1}
$$

In equation (1), denotes the product type; $\omega \Omega_m$ denotes the cluster of all product types available to consumers in importing country $m$ (including domestic production and imports); $\lambda_{im}(\omega)$ denotes the quality of HS6 code products $\omega$ exported by firm $i$ to country $m$ in year $t$; $q_{im}(\omega)$ denotes the quantity of HS6 code products $\omega$ exported by firm $i$ to country $m$ in year $t$; and $\sigma$ denotes the elasticity of substitution between different types of products, assuming $\sigma > 1$. Combined with the budget constraint, the Lagrangian function is applied to Eq. (1) to solve for consumer utility.
maximization and obtain the demand function with respect to the product type $\Theta$ as shown in equation (2).

$$q_{imt}(\omega) = \left[ p_{imt}(\omega) \right]^\gamma \left[ \lambda_{imt}(\omega) \right]^{-1} Y_{mt}^{\sigma - 1} \rho_{imt}^{\rho - 1}$$ (2)

In equation (2), $p_{imt}(\omega)$ denotes the price of HS6 code product $\Theta$ exported by firm $i$ to country $m$ in year $t$; $P_{mt}$ denotes the total price index of importing country $m$ in year $t$.

Fora monopolistically competitive market, fluctuations in product prices of individual firms usually do not cause changes in the total price index, so the total price index $P_{mt}$ is assumed to be constant, while the consumer spending in the importing country $Y_{mt}$ (i.e., the income level of the importing country) is assumed to be constant. The specific measurement of product quality requires the use of customs product-level data information, containing four dimensions of firm-year-destination-product information, and taking logarithms of both sides of equation (2) to obtain equation (3).

$$\ln q_{imt}(\omega) = \ln Y_{mt} + (\sigma - 1) \ln P_{mt} - \sigma \ln p_{imt}(\omega) + (\sigma - 1) \ln \lambda_{imt}(\omega)$$ (3)

In equation (3), $Y_{mt}$, $(\sigma - 1) \ln P_{mt}$ is the quantity that varies with importing country and time, and drawing on Fan et al. (2015)[21], it is treated as an importing country-time dummy variable, i.e., it is expressed as a year-country fixed effect model $\Phi_{mt}$, while a product fixed effect is added to the regression model $\Phi_{\omega m}$, which is collapsed to give equation (4).

$$\ln q_{imt}(\omega) = \sigma \ln p_{imt}(\omega) = \Phi_{mt} + \Phi_{\omega m} + \epsilon_{imt}(\omega)$$ (4)

In equation (4) $\epsilon_{imt}(\omega) = (\sigma - 1) \ln \lambda_{imt}(\omega)$ is the residual term from which the mass $\lambda_{imt}(\omega)$ of HS6 code product $\Theta$ exported by firm $i$ to country $m$ in year $t$ can be deduced as shown in equation (5).

$$\lambda_{imt}(\omega) = \ln \lambda_{imt}(\omega) = \frac{\epsilon_{imt}(\omega)}{(\sigma - 1)}$$ (5)

Further, referring to Shi and Shao (2014)[22], the export product quality indicators at the product level of equation (5) are normalized to obtain equation (6).

$$quality_{imt}(\omega) = \frac{quality_{imt}(\omega) - \min quality_{imt}(\omega)}{\max quality_{imt}(\omega) - \min quality_{imt}(\omega)}$$ (6)

In equation (6), $\max quality_{imt}(\omega)$ and $\min quality_{imt}(\omega)$ represent the maximum and minimum quality values of HS6 code product $\Theta$ at the level of all years, all enterprises and all export destinations, respectively, and $quality_{imt}(\omega) - \min quality_{imt}(\omega)$ represents the quality step length of HS6 code product. $quality_{imt}(\omega)$ It is a standardized export product quality indicator at the HS6 product level, which ranges from $[0,1]$ and does not have measurement units and can be summed to different levels for analysis.

The summation equation for export product quality at the firm level is shown in equation (7).

$$quality_{it} = \sum \frac{value_{imt}(\omega)}{\sum value_{imt}} \times quality_{imt}(\omega)$$ (7)

In equation (7), $quality_{it}$ denotes the export product quality level of firm $i$ in year $t$, $\sum value_{imt}$ represents the sum of samples at this level, $value_{imt}$ denotes the sum of HS6 product values exported by firm $i$ to country $m$ in year $t$, and $\sum value_{imt}$ denotes the sum of product values exported by firm $i$ to all countries in year $t$.

After measuring the export product quality at the firm level, this study then uses the magnitude of the difference between the current period’s export product quality level and the previous period’s export product quality level to measure whether the export product quality has improved. The formula for measuring export product quality improvement is shown in equation (8).

$$QI_{it} = \Delta quality_{it} = quality_{it} - quality_{it-1}$$ (8)

In equation (8), if $QI_{it} = \Delta quality_{it} > 0$, the export product quality is improved; if $QI_{it} = \Delta quality_{it} \leq 0$, the export product quality is not improved.

3.2.2 Quality change dimension: the evaluation system of export product quality upgrading

When constructing an evaluation system for export product quality upgrading, the criteria for classifying the quality grade should be clarified first. Crozet et al. (2012) [13] use the ratings of different brands of champagne in the Champagne Handbook to measure the quality of champagne, and this method better reflects the quality ladder. But unfortunately, the study was only conducted for Champagne companies and could not be replicated across products and industries. Then, how to select the quality grade evaluation index at the enterprise level? Ideas can be provided in the "Guidance of the Central Committee of the Communist Party of China State Council on the Development of Quality Improvement Action" released in September 2017, which states, "improve the national quality incentive policy, continue to carry out the national quality award selection and recognition, …… to cultivate and grow national enterprises and well-known brands, strengthen the cultivation and protection of Chinese old brands, geographical indications and other brands, and enhance the visibility and reputation of Chinese brands. …… improve the third-party quality evaluation system and carry out high-end quality certification." Therefore, this paper takes quality awards, well-known trademarks (famous brand products), and quality certification as evaluation indicators of export product quality upgrading, and assigns values to
provincial, national, and international quality awards, and well-known trademarks (famous brand products). First, the quality awards can be divided into domestic quality awards and international quality awards. In terms of domestic quality awards, the more authoritative ones are the provincial government quality awards and the national quality awards. In terms of international quality awards, the more representative ones are the world's three major quality awards (Edward Deming Prize, 1951; Malcolm Baldrige National Quality Award, 1987; European Quality Award, 1991). Most of the selection criteria of quality awards are based on the Guidelines for the Evaluation of Performance Excellence (GB/T 19580) and the Implementation of the Guidelines for the Evaluation of Performance Excellence (GB/Z 19579), which measure the quality of enterprises comprehensively from leadership, strategy, customers and markets, resources, process management, measurement and analysis improvement, results, etc., and then give material and spiritual awards to the enterprises with excellence quality. Therefore, quality awards can be used to measure the export product quality upgrading, and provincial government quality awards, national quality awards, and international quality awards can also reflect the different levels of export product quality upgrading.

Second, well-known trademarks can be divided into provincial well-known trademarks, Chinese well-known trademarks, and world well-known trademarks. Well-known trademarks is a trademark that enjoys a high reputation in society and the product quality is trusted and recognized by the public. Therefore, the acquisition of well-known trademarks is a reflection of export product quality upgrading, and provincial well-known trademarks, Chinese well-known trademarks, and world well-known trademarks can also reflect different levels of export product quality upgrading. Famous brand products can be divided into provincial well-known trademarks, Chinese well-known trademarks, and world well-known trademarks. The quality of famous brand products is advanced in the world, with a high degree of user satisfaction. The famous brand product mark is the quality mark. Therefore, enterprises getting the famous brand product mark is also a reflection of export product quality upgrading, and provincial well-known trademarks, Chinese well-known trademarks, and world well-known trademarks can also reflect different levels of export product quality upgrading.

Third, quality certification can be divided into Chinese product quality certification and international quality certification. Chinese product quality certification is divided into compulsory certification and voluntary certification. Compulsory certification mainly refers to the CCC certification. Voluntary certification is for high-quality enterprises to distinguish themselves from low-quality enterprises. Voluntary certification reflects the enterprise's "quality confidence" in their products. International quality certification mainly refers to the ISO 9000 certification. After obtaining the ISO 9000 certification, enterprises can not only improve their quality reputation and enhance their management level but also cross the trade barriers set by some countries. The enterprise obtains the domestic or international quality certification can be regarded as a quality signal to consumers. Therefore, enterprises obtaining quality certification is a reflection of export product quality upgrading, and Chinese product quality certification, and international quality certification can also reflect the different levels of export product quality upgrading.

So, this paper uses quality awards, well-known trademarks, famous brand products, and quality certification as evaluation indicators of export product quality upgrading, as shown in Table 1.

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<th>Variables</th>
<th>Symbols</th>
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<td>Export product quality upgrading</td>
<td>$QU$</td>
<td>Obtained the provincial well-known trademarks (provincial famous brand products) $QU=1$, the provincial government quality awards $QU=2$; the Chinese well-known trademarks (Chinese famous brand products) $QU=3$, the Chinese product quality certification $QU=4$, the Chinese world famous brand products $QU=5$, the national quality awards $QU=6$; the world famous trademark (world famous brand product) $QU=7$, the international quality certification (ISO 9000) $QU=8$, the world's three major quality awards $QU=9$. If an enterprise receives more than one quality honor at the same time, the one with the largest value is taken.</td>
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<td>Low-level export product quality upgrading</td>
<td>$LQU$</td>
<td>Obtained the provincial well-known trademarks (provincial famous brand products) or get the provincial government quality awards $LQU$ take 1, otherwise take 0.</td>
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<tr>
<td>Mid-level export product quality upgrading</td>
<td>$MQU$</td>
<td>Obtained Chinese well-known trademarks (Chinese famous brand products, Chinese world famous brand products) or Chinese product quality certification or national quality awards $MQU$ take 1, otherwise take 0.</td>
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<tr>
<td>High-level export product quality upgrading</td>
<td>$HQU$</td>
<td>Obtained the world well-known trademarks (world famous brand products) or international quality certification or the world's three major quality awards (Edward Deming Prize, 1951; Malcolm Baldrige National Quality Award, 1987; European Quality Award, 1991) $HQU$ take 1, otherwise take 0.</td>
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4. A statistical measurement of the dynamic evolution of export product quality

To comprehensively examine the dynamic evolution of Chinese industrial enterprises' export product quality, this paper measures and analyzes export product quality, export product quality improvement (quantitative dimension), and export product quality upgrading (qualitative dimension) respectively.

4.1 Data sources

The research object of this paper is export enterprises, and the data are obtained from three major databases, the 2000-2013 Chinese Import and Export Customs Database collected by the Chinese Customs Office, the Chinese Industrial Enterprises Database collected by the Chinese National Bureau of Statistics, and the Chinese Export Product Quality Upgrading Database collected by the author.

For the treatment of the Chinese import and export customs database, this paper refers to the treatment of Fan and Guo(2015)[23], and Yu and Zhang(2017)[16]: the first step removes observations with missing information, including observations with missing enterprise names, countries of origin and destination, HS product codes, etc.; the second step eliminates observations with trade amounts less than USD50 and transaction quantities less than 1; the third step, the observations of trade intermediaries are removed; the fourth step, the eight-digit Harmonized System of trade products from 2000-2013 are converted into six-digit Harmonized System, and then the six-digit Harmonized System of different versions of each year are uniformly converted to Harmonized System version of 1996; finally, the export enterprise data from 2000-2013 are retained.

For the treatment of the Chinese industrial enterprises database, this paper refers to the treatment of Brandt et al. (2017)[24], and Yang(2015)[25]: the first step eliminates observations with zero, negative or missing enterprise names, gross industrial output value, sales, capital stock, total assets, fixed assets, and employees, etc.; the second step eliminates observations with the number of employees less than or equal to eight; the third step eliminate observations with the survival age of enterprises less than 10; the fourth step eliminate observations with total assets less than fixed assets, total assets less than current assets, total assets less than net fixed assets, industrial value added greater than industrial sales value, etc.; finally, retain observations of manufacturing industries with industry codes 13-43.

To merge and match the Chinese import and export customs database and the Chinese industrial enterprise database, this paper refers to Yu et al. (2012) [26] and Fan and Guo(2015)[23]: the first step, enterprises with the same name and year are merged; the second step, enterprises with the same postal code and the same last seven digits of the telephone number are merged again. According to the names of export enterprises from 2000-2013 obtained by the above merging and matching, the assignment of export product quality upgrading is carried out. Among them, the quality awards information obtained from the official website of the enterprise, the data platform of the provincial government, and the public documents of awards and recognition published by the provincial government and relevant competent departments in previous years; the well-known trademarks and famous brand products information obtained from the official website of the enterprise, the provincial market supervision administration, the provincial intellectual property office and the website of the well-known trademark; the quality certification information obtained from the official website of the enterprise, the national public service platform of certification and accreditation information, and the website of China Quality Certification Center. The Chinese export product quality upgrading database collected in this paper is a useful supplement to the existing micro database of Chinese industrial enterprises. Through the above treatment, we finally obtained 417072 observations for 124332 exporters from 2000-2013.

4.2 A statistical measurement of the export product quality of Chinese industrial enterprises

This paper refers to Fan and Guo (2015) [23], assuming the elasticity of substitution $\sigma = 5$, and then provides an overall and grouped statistical measure and analysis of the export product quality.

4.2.1 The overall measurement of export product quality

Figure 2 reflects that the overall export product quality of Chinese industrial enterprises has shown a fluctuating upward trend, from 0.525 in 2000 to 0.546 in 2013. The overall export product quality showed a slow growth during 2000-2002; during 2003-2007, the export product quality showed a rapid growth; during 2008-2010, the subprime crisis caused a continuous decline in the export product quality; during 2011-2013, the export product quality regained an upward trend as the world economy gradually recovered.

Figure 2 The overall trend of export product quality from 2000 to 2013
4.2.2 Group measurement of export product quality

4.2.2.1 A statistical measurement of export product quality with different ownership

The export product quality is measured by different ownership enterprises, and the results are shown in columns (1)-(3) in Table 2: the export product quality of foreign-invested, state-owned, and private enterprises all show a fluctuating upward trend during the period 2000-2013. Among them, the export product quality of foreign-invested enterprises is higher, followed by state-owned enterprises and private enterprises. Foreign-invested enterprises usually have more advanced production technology, richer management experience, more abundant capital, and stronger R&D ability, and have obvious advantages in export product quality. In terms of the growth rate, the growth rate of export product quality of state-owned enterprises is higher, followed by foreign-invested enterprises and private enterprises.

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</table>

4.2.2.2 A statistical measurement of export product quality with different scale

The export product quality is measured by different enterprise scale.[According to the criteria for classifying large, medium, small, and micro enterprises released by the National Bureau of Statistics in 2017, they can be classified based on the number of employees (X) or business income (Y), and this study uses the number of employees to classify: X ≥ 1000 is a large enterprise; 1000 > X ≥ 300 is a medium enterprise; 300 > X ≥ 20 is a small enterprise; and X < 20 is a micro-enterprise.] and the results are shown in columns (4)-(7) in Table 2: the export product quality of large, medium, small, and micro enterprises all show a fluctuating upward trend during the period 2000-2013. Among them, the export product quality of large enterprises is higher, followed by medium, small and micro enterprises. In China, large enterprises are usually the industry leaders, employing more skilled labor, having more capital, and making efforts to R&D, therefore, the export product quality of large enterprises is significantly higher than those of small, medium, and micro enterprises. In terms of the growth rate, the large enterprises are higher, micro-enterprises are second, and small enterprises and medium enterprises are relatively low.

4.2.2.3 A statistical measurement of export product quality with different region

According to the division of eastern, central, and western regions by Sheng and Niu (2009) [27], the export product quality is measured by enterprises in different regions, and the results are shown in columns (8)-(10) in Table 2: the export product quality of enterprises in eastern, central and western regions show a fluctuating upward trend during 2000-2013. Among them, the export product quality in the eastern region is higher, followed by the central region, and western region. The regional development of the export product quality is uneven. Due to the earlier opening up of the eastern region, and the advantages of coastal location and production resources, the enterprises in the eastern region have undertaken more foreign orders and absorbed more advanced technology and management experience from abroad, and the export product quality is higher than those of the central and western regions. However, with the implementation of national strategies such as the development of the west and the rise of central, the export product quality in the central and western regions is also gradually improved. In terms of the growth rate, the western region is higher, the eastern enterprises increase second, and the central region enterprises relatively low.

4.3 A statistical measurement of the export product quality improving of Chinese industrial enterprises

4.3.1 The overall measurement of export product quality improvement

According to the above connotation, if $Q_i(t) > 0$, the export product quality in period $t$ is higher than in period $t-1$, it is called export product quality improvement; if $Q_i(t) \leq 0$, the export product quality has not been improved. Next, this paper will use the bar chart to portray the status of export product quality improvement.

Figure 3 portrays the export product quality improvement from 2001 to 2013. The positive bar chart in 2001 indicates that the export product quality improved in 2001, but the positive bar chart is short, which also reflects that the improvement of export product quality was low in the
initial stage; after China joined the WTO at the end of 2001, the tariff barriers for exporters to enter the international market were significantly lowered, and the total amount of China's exports increased during this period, but a large number of low-quality enterprises also newly flooded into the export market, therefore, from the bar chart, the export product quality in 2002 did not improve and was smaller negative. In 2003-2007 (except year 2006), with the continuous improvement of international experience, management ability, and technical, the positive bars of 2005 are the highest, and the positive bars of 2003 and 2007 are higher, implying that the export product quality has been significantly improved in these years. The negative bar for 2006 indicates that the export product quality did not improve in that year, probably due to the time lag effect of the CNY exchange rate reform implemented in July 2005. The appreciation of the CNY brought about an increase in export prices and a short-lived decrease in the international competitiveness of export products, which may have affected foreign consumers' demand and thus may have reduced both the export product quality and the export product quality improvement measured by the KSW method. From 2011 to 2012, the export product quality improvement maintain positive, while the bar chart of 2013 shows a small negative value, indicating that the export product quality did not improve in that year. In summary, although the international economic and trade situation is changing, the export product quality improvement of Chinese industrial enterprises is positive in most years and negative in only a few years, reflecting that the export product quality has achieved a positive quantitative change in most years.

![Figure 3 Export product quality improvement from 2001 to 2013](image)

### 4.3.2 Group measurement of export product quality improvement

#### 4.3.2.1 A statistical measurement of export product quality improvement with different ownership

Figure 4 portrays the export product quality improvement of different ownership enterprises from 2001 to 2013. From the bar chart, the export product quality improvement of foreign-invested enterprises was negative in 2006, 2008, and 2013, indicating that no export product quality improvement was achieved in these years, while export product quality improvement was achieved in the rest of the years. The positive bar for state-owned enterprises is highest in 2011, and higher in 2003-2005 and 2007, implying that the export product quality improvement in these years has been significantly improved, but it is more negative in the period 2008-2010, which also implies that the export product quality of state-owned enterprises is more susceptible to the impact of external economic. The export product quality improvement of private enterprises is positive in most years, which steadily improved during 2003-2005, and then shows strong volatility, negative in 2006, 2008-2010, and 2012, indicating that the export product quality improvement has not been achieved in these years.

![Figure 4 Export product quality improvement of enterprises with different ownership from 2001 to 2013](image)

#### 4.3.2.2 A statistical measurement of export product quality improvement with different scale

Figure 5 portrays the export product quality improvement of different scale enterprises from 2001 to 2013. Among them, the export product quality improvement of large enterprises is mostly positive before the global financial tsunami broke out in 2008 and is rapidly increasing in 2001-2005, 2007, and 2011, while it is negative in 2008-2010 and 2012. Export product quality improvement for medium enterprises is positive in most years, with longer positive bars in 2003-2005, 2007, and 2012, implying that more substantial export product quality improvement was achieved in these years. Export product quality improvement for small enterprises is positive in most years, with longer positive bars in 2003, 2005, 2007, and 2011, implying that small firms achieved significant export product quality improvement in these years. The export product quality improvement of micro-enterprises was negative only in 2004 and 2008-2009 and positive in the rest of the years, which also showed a more stable product quality improvement trend.
4.3.2.3 A statistical measurement of export product quality improvement with different region

Figure 6 depicts the export product quality improvement of different regions’ enterprises from 2001 to 2013. From the bar chart, the export product quality improvement of enterprises in the eastern, central, and western regions shows the same rising and falling trend in most years, including negative performance in 2006 and 2008-2009, and positive performance in most other years, indicating that enterprises in the eastern, central and western regions have achieved product quality improvement in most years. The positive bars of enterprises in the eastern region are longer in 2003, 2005, 2007, and 2011, and the positive bars of enterprises in the central and western regions are longer in 2003-2004, 2007, and 2010, implying that the export product quality has been significantly improved in these years.

4.4 A statistical measurement of the export product quality upgrading of Chinese industrial enterprises

4.4.1 The overall measurement of export product quality upgrading

Figure 7 depicts the export product quality upgrading of Chinese industrial enterprises from 2000 to 2013. Among them, the annual average of export product quality upgrading increased from 0.2319 in 2000 to 4.2231 in 2013. The number of enterprises achieving low-level export product quality upgrading increased from 33 in 2000 to 1421 in 2013, and the number of enterprises achieving high-level export product quality upgrading increased from 412 in 2000 to 21,606 in 2013. On the whole, the number of Chinese industrial enterprises that have achieved product quality upgrading is increasing, and the mean and level of product quality upgrading are increasing.

4.4.2 Group measurement of export product quality upgrading

4.4.2.1 A statistical measurement of export product quality upgrading with different ownership

The export product quality upgrading is measured by different ownership enterprises, and the results are shown in columns (1)-(3) in Table 3: the export product quality upgrading of foreign-invested, state-owned, and private enterprises all shows an increasing trend during 2000-2013. Among them, the export product quality upgrading of state-owned enterprises is higher, followed by private and foreign-invested enterprises. In the initial 2000s, the differences in export product quality upgrading among different ownership enterprises were not obvious, but after 2001, the state-owned enterprises began to accelerate, which reflects the cultivation of state-owned enterprises for quality awards, well-known trademarks, famous brand products, and quality certification. State-owned enterprises actively use advanced standards and methods of quality management and also to a certain extent played a “leading” role, driving other types of enterprises to enhance quality management. In terms of the growth rate, the growth rate of export product quality upgrading of state-owned enterprises is higher. The trend of export product quality upgrading of private and foreign-invested enterprises was close before 2011, and the export product quality upgrading of private enterprises was slightly higher than that of foreign enterprises in most years, but after 2011, the growth rate of private enterprises was significantly faster and higher than that of foreign-invested enterprises.
The export product quality upgrading of enterprises in the eastern, central, and western regions all show an increasing trend during 2000-2013. Among them, the export product quality upgrading of enterprises in the eastern region is higher, followed by the eastern and central regions. The export product quality upgrading of enterprises in the eastern region is lower than that in the western region, probably because the eastern region is more open to the outside world and has a larger number of enterprises than the western region, plus a lot of them are engaged in OEM production and do not own well-known trademarks, famous brand products, government quality awards, and quality certification, thus lowering the annual average of export product quality upgrading of enterprises in the eastern region. In terms of the growth rate, the central region is higher, followed by the eastern and western regions.

5. Main Conclusions and Policy Recommendations

This paper analyzes the "quantitative-qualitative change" rule of the dynamic evolution of export product quality and conducts statistical analysis of the export product quality, export product quality improvement (quantitative change), and export product quality upgrading (qualitative change) of Chinese industrial enterprises, based on 41702 observations of 124332 export enterprises from 2000 to 2013. The main conclusions of this paper are as follows: (1) The export product quality of Chinese industrial enterprises shows an overall fluctuating upward trend. The export product quality of foreign-invested enterprises is higher than that of state-owned enterprises and private enterprises; the export product quality of large enterprises is higher than that of medium, small and micro enterprises; the export product quality of enterprises in the eastern region is higher than that of those enterprises in the central and western regions. (2) From the dimension of quantitative change, the export product quality of Chinese industrial enterprises improved in 2001, 2003-2005, 2007, and 2011-2012, but not in the rest of the years. And there are some differences in export product quality improvement among enterprises of different ownership, different scale, and different regions.

4.4.2.2 A statistical measurement of export product quality upgrading with different scale

The export product quality upgrading is measured by different scale enterprises, and the results are shown in columns (4)-(7) in Table 3: the export product quality upgrading of large enterprises, medium enterprises, small enterprises, and micro enterprises all show an increasing trend during 2000-2013. Among them, the export product quality upgrading of large enterprises is higher, followed by medium enterprises, small enterprises, and micro enterprises. In terms of the growth rate, the initial export product quality upgrading of micro-enterprises is lower, thus leading to a higher growth rate, while the initial export product quality upgrading of large enterprises is higher, thus leading to a lower growth rate.

4.4.2.3 A statistical measurement of export product quality upgrading with different regions

The export product quality upgrading is measured by enterprises in different regions, and the results are shown in columns (8)-(10) in Table 3: the export product quality upgrading of enterprises in the eastern, central, and western regions all show an increasing trend during 2000-2013. Among them, the export product quality upgrading of enterprises in the western region is higher, followed by the eastern, and central regions. The export product quality upgrading of enterprises in the eastern region is lower than that in the western region, probably because the eastern region is more open to the outside world and has a larger number of enterprises than the western region, plus a lot of them are engaged in OEM production and do not own well-known trademarks, famous brand products, government quality awards, and quality certification, thus lowering the annual average of export product quality upgrading of enterprises in the eastern region. In terms of the growth rate, the central region is higher, followed by the eastern and western regions.

Table 3 The measurement of export product quality upgrading of enterprises with different ownership, different scale, and different region

<table>
<thead>
<tr>
<th>Year</th>
<th>Different ownership</th>
<th>Different scale</th>
<th>Different region</th>
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<tr>
<td></td>
<td>For</td>
<td>St</td>
<td>Pri</td>
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<tr>
<td>2000</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
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<tr>
<td>2003</td>
<td>0.7</td>
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<td>0.7</td>
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<tr>
<td>2006</td>
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<td>1.1</td>
</tr>
<tr>
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<tr>
<td>2012</td>
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<td>2015</td>
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<td>3.2</td>
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<td>2024</td>
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<td>3.8</td>
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<tr>
<td>Growth rate (%)</td>
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upgrading of large enterprises is higher than that of medium, small and micro enterprises; the export product upgrading of enterprises in western regions is higher than those of enterprises in eastern and central regions.

The policy recommendations of this paper are as follows: First, export enterprises should enhance technology innovation and production process improvement to satisfy the consumer and stimulate consumption potential. Enterprises can increase R&D investment through issuing corporate bonds, listing financing, and obtaining government subsidies to improve innovation efficiency and transformation of innovation results. Second, export enterprises should tell a good brand story through advertising, marketing, promotion, social welfare, etc, to obtain well-known trademarks and famous brand products. Export enterprises should actively participate in the official and authoritative quality awards selection activities, improving their production and operation during the evaluation process, and the incentive funds will further help the winning enterprises to improve quality. Enterprises should obtain the ISO 9000 certification to improve the whole process quality control. Third, the government and the community should mobilize and protect the enthusiasm of enterprises for quality innovation and quality improvement.

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