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Identifying the influencing factors on the quality of China's forestry exports

Based on the exports from China to ten developed countries

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Abstract

Purpose – China is not only the biggest importing country of the raw materials of forest products, but also the biggest exporting country of intermediate and final forest products. The paper aims to discuss these issues.
Design/methodology/approach – The authors use the Khandelwal (2010) method and trade data from 2000 to 2014 of bilateral forest products between China and ten main developed countries to evaluate the quality of China's forestry imports and exports. Subsequently, the influencing factors of product quality are analyzed.
Findings – The results show that the current export quality of plywood and fiberboard is decreasing, and the export quality of particleboard and paper products is on the rise. A further study finds that several factors have the positive effects on the quality of forestry exports, including gross domestic product of the importing country, forestry export value of the importing country as well as the number of forestry higher education graduates of the exporting country. Moreover, the study also finds that the status of an Asia-Pacific Economic Cooperation member has a negative effect on the quality of forestry exports, while the distance cost has a negative influence on fiberboard, paper and paperboard.
Practical implications – The study suggests that China needs to strengthen the research and development investment on forest products, and improve the quality of forest products to promote the trade development of forestry exports.
Originality/value – The existing literature has not shown much research regarding the quality of China's forestry exports through econometric analysis. Therefore, the research results provide new perspective about the influencing factors on China's forestry trade activities.

Keywords Export, Quality, Trade, Forest products

Paper type Research paper

Introduction

In recent years, with the rapid development of China's forestry industry, the export trade volume of forest products has continuously improved. By the end of 2015, the export trade volume of China's forest products had reached $140bn, which was the highest in the world.

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However, several problems associated with the rapid quantity growth cannot be ignored: on the one hand, China has become the world's wood processing center. Although the total export of forest products has yearly increased, the added value of exports is low, and the international competitiveness is weak (Guan and Gong, 2015). On the other hand, with the disappearance of China's demographic dividend and the rapid increase of labor cost, the price competitive advantage of forest product trade will be unsustainable (Wu *et al.*, 2016). Therefore, the transition of China's forest product industry from the type of quantity to the type of quality has become the inevitable trend. In this respect, the quality of forestry exports has become an important indicator to measure the level of forest product trade. Therefore, the following questions deserve deep discussion:

- How is the quality of the current China's forest exports[①]?
- What are the characteristics of the quality change?
- What are the factors that could affect such quality?

We intend to answer these questions based on theoretical research and empirical test.

At present, the relationship between product quality and trade has become an important research field that attracts plenty of scholars. In terms of theoretical research, Linder was the first scholar who engaged into the research of product quality and trade. He put forward that the quality of products was highly related to the level of the per capita income of a country. The higher the level of per capita income the citizens have, the higher level of product quality they demand, and vice versa. Therefore, the frequency of bilateral trade between the countries with similar economic development level is relatively high (Linder, 1962). After that, Helpman used north-south difference model to introduce quality differences into the theory of vertical industry trade. He argued that income differences lead to the northern countries producing relatively higher quality and trading with relatively lower quality of products made by the southern countries (Helpman, 1987). In the 1990s, Grossman and Helpman creatively proposed the quality ladder endogenous growth model to further enrich the study of product quality (Grossman and Helpman, 1991). After that, Berry provided the basic idea of measuring and evaluating the quality level through supply and demand equilibrium model. With the continuous development of trade theory, especially the proposal of New-New Trade Theory, the research on the quality theory and methods of export and import products have been continuously flourished (Berry, 1994).

In terms of research theory on export product quality, Melitz pioneered the New-New Trade Theory. He considered that enterprises have heterogeneity and only the enterprises with high production efficiency would export. Moreover, the export enterprises with higher production efficiency have the characteristics of low production costs and strong product competitiveness. In order to maintain a strong competitiveness and expand the scale of export, their product quality is also higher than that of the similar non-export enterprises (Melitz, 2003). Based on the New-New Trade Theory, some studies find that the flow of international trade has showed a vertical specialized system mode. When the rich and poor countries are to export goods within the same product category, the rich countries will sell the goods with high unit value (Schott, 2004; Hummels and Klenow, 2005; Hallak and Schott, 2008). Under the theoretical framework of product unit value, Crozet and Erkel-Rousse pointed out that the product quality was highly correlated with the price elasticity of the product. They used the demand price elasticity function to further study the good and bad degree of export products' quality (Crozet and Erkel-Rousse, 2004). In addition, based on the production theory, Sutton (2007) found that the quality of products was mainly reflected in the production efficiency of enterprises and the production cost of each production line. Therefore, advancing production methods and improving production efficiency can further improve

product quality. Other studies studied the intra-industry trade of China and Southeast Asian countries. The results revealed that the quality of China's exports to the Southeast Asian countries was generally low, while the quality of the exports to the developed countries was relatively high (Azhar *et al.*, 2008). Moreover, based on the segmentation theory of production chain, Wang *et al.* (2015) found that there was an inverted U-shaped relationship between the proportion of international production segmentation and the quality improvement of exports by Chinese enterprises.

As for research methods, the current methods of product quality measurement are mainly based on the new growth theory and the New-New Trade Theory. The quantitative methods related to product quality include product unit value method, export technology complexity index, nested logit model, etc. Additionally, Fisher index, pure price index, quality adjustment price index method and inverse method have also been used (Baldwin and Harrigan, 2011; Eshraghi and Ismail, 2013; Abdouli and Hammami, 2017). Some scholars show that the product quality could be represented by the calculated product unit value. But this method ignores the differences between the products since the unit value is hard to be compared. Hence, the quality gradient was also unable to be detected (Schott, 2004; Baldwin and Harrigan, 2011). Michaely (1986) and Hausmann *et al.* (2007) systematically introduced how to measure product quality in terms of technical complexity. This method used the revealed comparative advantage index of product export to multiply gross domestic product (GDP) per capita of the exporting country. The current widely used method to measure product quality is proposed by Khandelwal (2010). This method uses the product quality and market share to calculate the quality of product under the nested logit model. The core thought is to determine the product price and quality through the market share of the product, which can better reflect the actual quality characteristics of the product (Khandelwal, 2010). Yin and Jun (2016) employed the method of Khandelwal (2010) to study the liberalization of trade and the quality of import intermediate products.

The previous studies have also analyzed the influencing factors of export product quality. Most studies consider that the factors may include: the level of economic development of the importing country; the institution of the exporting country; the industrial structure of the exporting country; the labor quality of the exporting country; the industry fixed investment of the exporting country; the level of industrial development of the exporting country; the opening degree of trade of the importing country, etc. (Chiang and Masson, 1988; Martínez-Zarzoso and Burguet, 2000; Oladi *et al.*, 2008; Faruq, 2011; Eshraghi and Ismail, 2013; Abasian *et al.*, 2017). Moreover, other studies also consider that: the consumer preference on the importing country; bilateral trade costs; the industry export value of the importing country; the distance between bilateral countries; and the participation of the two sides in common economic organization and so on can influence the development of intra-industry trade (Caballero and Krishnamurthy, 2004; Hallak and Schott, 2005; Lee and Kim, 2013; Henn *et al.*, 2014; Fan *et al.*, 2015; Eyvindson *et al.*, 2018).

Therefore, this study takes a more mature method of Khandelwal (2010) to study China's forest exports quality. Our innovation is that we adopt a specific product rather than a particular industry as a whole, and empirically analyze the influencing factors of forest exports quality. In this way, we intend to provide research support for making strategies regarding forest product export for the relevant enterprises or government departments. The remaining parts of the paper are arranged as follows: the second part explains the quality measurement model of the forest exports and the empirical method about how to analyze the influencing factors. The data source and variable selection are explained as well. The third part shows the quality measurement result of the forest exports and the analysis thereof, including the quality situation and characteristics of the forest exports. This part

also analyzes the regression results of the quality of the forest exports. The fourth and fifth parts are the discussion on the quality measurement of forest exports and its influencing factors and to obtain corresponding conclusions.

Research methods and data collection

Product quality measurement method

The product quality measurement method of Khandelwal (2010) is based on the nested logit model about consumer's heterogeneous product selection by Berry (1994). Compared with other methods, this one has the advantages as follows: first, the model advances the simple measurement method of product unit value that was used to be equal to the product quality, and overcomes the defects caused by calculating unit value or price proposed by Schott (2004). Second, the model is able to measure more detailed quality of the product segments, instead of being limited at the industry level. The specific calculation model of Khandelwal (2010) is as follows: we suppose the utility obtained from consuming a product g by a consumer h is:

$$U_{hg} = x_g\beta - \alpha P_g + \mu_g + \varepsilon_{hg}. \tag{1}$$

In the Formula (1), x_g is the observable characteristic of product g; P_g is the price of product g, and μ is the unobservable characteristic of product g. ε_{hg} is the level characteristic of product g for consumer h; β and α are the parameters to be estimated. According to Berry (1994), the market share of product g in this case can be expressed as:

$$M_g = \frac{e^{(x_g\beta - \alpha P_g + \mu_g)}}{\sum_n e^{(x_n\beta - \alpha P_n + \mu_n)}}. \tag{2}$$

Formula (2) is the logit form of the market share of product g, and n is the other products. It is assumed that the product purchased by the consumer except for product g is the base product 0, and the average utility is 0. The market share (also known as the external market share) is:

$$M_0 = \frac{1}{\sum_n e^{(x_n\beta - \alpha P_n + \mu_n)}}. \tag{3}$$

The natural log on the Formulas (2) and (3) is taken, respectively. And the difference between the two is:

$$\ln(M_g) - \ln(M_0) = x_g\beta + \alpha P_g + \mu_g. \tag{4}$$

Adding the nested logit model in Formula (4) yields:

$$\ln(M_{sgt}) - \ln(M_{0t}) = \lambda_{1,sg} + \lambda_{2,t} + \alpha p_{sgt} + \ln(ns_{sgt}) + \lambda_{3,sgt}. \tag{5}$$

In the Formula (5), the subscript s, g and t, respectively, represent the exporting country, exported product and year of export. P_{sgt} is the price of the exported product. ns_{sgt} is the nested market share (i.e. the proportion of the scale of product g imported from s country within t period in the total imports of the domestic product g). $\lambda_{1,sg}$ is the product variety characteristic (entity fixed effect) which is not changing with time; $\lambda_{2,t}$ is the product variety characteristic (time fixed effect) which is only changing with time; $\lambda_{3,sgt}$ is the product variety characteristic (error term) which has unobservable product, but it can produce some certain effects in estimation error. It is important to note that according to the method by

Khandelwal (2010), the external market share (M_{0t}) of product g in the Formula (5) can be calculated through (1 – import penetration ratio), the total market share (M_{sgt}) is:

$$M_{sgt} = \frac{q_{sgt}}{\mathrm{GKT}_t}. \tag{6}$$

In Formula (6), q_{sgt} represents the import quantity of product g from country s in time t. And GKT is the total product value of the same product. The formula is:

$$\mathrm{GKT}_t = \sum_{sg \neq 0} \frac{q_{sgt}}{1 - M_{0t}}. \tag{7}$$

In addition, in order to control the level of product differentiation, the population size or GDP variable of the exporting country should be selected for control (Bin *et al.*, 2013). The details can be found in the following formula:

$$\ln(M_{sgt}) - \ln(M_{0t}) = \lambda_{1,sg} + \lambda_{2,t} + \alpha p_{sgt} + \phi \ln(ns_{sgt}) + \eta \ln(\mathrm{people}_{st}) + \lambda_{3,sgt}. \tag{8}$$

According to the Formula (8), it can be found that with the control on the influences of product differentiation and the product price, the factor influencing the product market share is the product quality (vertical difference factor) only. Regressing (8) yields coefficients α, φ and η, so as to calculate the product quality λ_{sgt}. In addition, in the Formula (8), the difference between $\ln m$ and $\ln(M_{sgt})$ as well as $\ln(M_{0t})$ is the relative market share of product g:

$$\lambda_{sgt} = \hat{\lambda}_{1,sg} + \hat{\lambda}_{2,t} + \hat{\lambda}_{3,sgt}. \tag{9}$$

Further, the normalization of product quality is carried out as:

$$\hat{\lambda}_{sgt} = \frac{\lambda_{sgt} - \min \lambda_{gt}}{\max \lambda_{gt} - \min \lambda_{gt}} \times 100. \tag{10}$$

The quantitative value of the normalized product quality is between 0 and 100, in order to further observe the changes in product quality and introduce the product quality ladder, namely the difference between the maximum and minimum quality values in a product, specifically as follows:

$$Ld = \max \lambda_{gt} - \min \lambda_{gt}. \tag{11}$$

Model specification of the influencing factors of product quality

In the empirical analysis of the influencing factors of forest exports, the quality measurement values of four varieties of forest products (including fiberboard, particleboard, plywood, paper and paperboard) are specifically regarded as the explained variables. According to the existing studies (Martínez-Zarzoso and Burguet, 2000; Caballero and Krishnamurthy, 2004; Hallak and Schott, 2005; Oladi *et al.*, 2008; Faruq, 2011; Eshraghi and Ismail, 2013; Fan *et al.*, 2015), the following explanatory variables are selected: first, per capita GDP of the importing country. The larger the market preference for high-quality product is, the higher the quality threshold is. Second, GDP of the importing country. It can reflect the consumer market scale of the country. The country with greater market scale has large uncertainty about the demand of product quality. There is higher probability that the product access threshold could be correspondingly lowered due to the large market scale, which is not good for the improvement of product quality. The second is that the greater the market scale is, the stronger the product competition is (Mayer *et al.*, 2014). If the country

wants to capture a certain market share, the product quality has to be improved. Third, degree of trade openness of the importing country. The higher the degree of trade openness of the importing country is, the lower the access threshold of market is, which is not conducive to the quality improvement of the exports of the exporting country. Fourth, distance factor. Harrigan *et al.* (2015) considered that only the products with the best advantage can be exported to further afield. This advantage may be from higher product quality or lower price. The transportation cost of wood products is relatively high. Thus, the quality of wood products shall be quite high if the products are exported to farther. Therefore, the farther the distance of bilateral countries is, the higher the quality of China's forestry exports is. Fifth, forestry fixed investment of the exporting country. The forestry fixed investment of the exporting country consists of the supports from forestry science and technology, infrastructure and financial aspects, which would conduce to improve the quality of wood processing products. The higher the amount of the investment is, the greater the effect on quality improvement is. Sixth, number of the higher education graduates in forestry sector of the exporting country. The number of the forestry workers with higher education reflects the labor pool of high-quality practitioners, which can promote the production quality improvement of forest products. Seventh, trade level of forest product of the importing country. This is expressed by the export value of forest products of the importing country. The higher the export value is, the more advanced the country's forest industry is. Thus, the demand for the high quality of forestry imports is relatively higher, which may in turn motivate the quality of forestry exports from China to those countries. Eight, whether Asia-Pacific Economic Cooperation (APEC) member states. In general, as APEC member countries, the strong mutual trade facilitation may cause larger total volume of import and export products compared with non-APEC member countries. However, due to the reduction of the thresholds in the mutual import and export trade and the increase in total volume, the quality of their trade products would also be affected. Based on the definitions of the explained variables and explanatory variables above, the model is set as follows:

$$Q_{it} = \beta_0 + \beta_1 Ipgdp_{it} + \beta_2 Igdp_{it} + \beta_3 Iopen_{it} + \beta_4 \text{Distance}_{it} + \beta_5 Efinvestment_{it} + \beta_6 Efedu_{it} + \beta_7 Ifvalue_{it} + \beta_8 Apec_{it} + \varepsilon_{it}. \quad (12)$$

In Formula (12), Q_{it} represents the export quality of variety i in the four types of forest products in period t. *Ipgdp* is the per capita *gdp* of the importing country. *Igdp* is the *gdp* of the importing country. *Iopen* is the degree of trade openness of the importing country. *Distance* represents the bilateral distance between the exporting country and the importing country. *Efinvestment* is the forestry fixed investment of the exporting country. *Efedu* is the number of forestry with higher education graduates of the exporting country. *Ifvalue* is the export value of forest products of the importing country. And *Apec* represents whether the country is APEC member. In order to improve the robustness of model regression and avoid the problem of heteroscedasticity, we take the logarithms on both sides of the above model (except the virtual variables) to form a new semi-logarithm model (the following formula):

$$\ln(Q_{it}) = \beta_0 + \beta_1 \ln(Ipgdp_{it}) + \beta_2 \ln(Igdp_{it}) + \beta_3 \ln(Iopen_{it}) + \beta_4 \ln(Dis\ \tan\ ce_{it}) + \beta_5 \ln(Efinvestment_{it}) + \beta_6 \ln(Efedu_{it}) + \beta_7 \ln(Ifvalue_{it}) + \beta_8 Apec_{it} + \varepsilon_{it}. \quad (13)$$

Data collection

First, in terms of the quality measurement of forestry exports, the export data of China's forest products for the major developed countries from 2000 to 2014 are mainly selected.

Four typical forest products are targeted as the research objects, including fiberboard, particleboard, plywood, paper and paperboard. In these four varieties of forestry exports, the export volume to the major ten developed countries (Asia: Japan; Europe: Belgium, Britain, Germany, France, Italy, the Netherlands; North America: Canada, the USA; Oceania: Australia) accounts for more than 75 percent of the total export volume from 2000 to 2014. Therefore, our study samples have a certain representativeness. In order to comply with a more refined demand of the nested logit model for product classification, the forestry exports data in this research are acquired from the online forestry statistic database and forest product yearbook of the Food and Agriculture Organization of which the product classification method is HS8 encoding. Since the statistical data of product unit price (*Psgt*) cannot be obtained, this research refers to the method by Khandelwal (2010) and uses the export volume divided by total product export volume. In addition, we select population scale of the exporting country to control the product differentiation and the data are from the World Bank website. In terms of data processing, the samples with missing data and the samples with the trade scale of less than $1,000 are eliminated. The specific variables are shown in Table I.

Moreover, the statistical description and data sources of the explained and explanatory variables are shown in Table II.

Results

Quality measurement results

Regarding the measurement of the quality of China's forestry exports, Formula (8) is adopted as the regression formula for estimation. Since the data of forestry exports are panel data, the relevant test of panel data regression is carried out. Breusch–Pagan test ($p = 0.0000$) shows that the estimation of the fixed effect or random effect is better than that of the mixed effect. Hausman test is continued and the test result is ($\chi^2 = 20.74$, $p = 0.0000$). Therefore, OLS fixed effect is adopted for estimation. Meanwhile, the instrumental variable method (IV) is used for further estimation for precision. The specific regression results are shown in Table III.

The regression results show that the IV regressions are better than those of OLS estimation and the variable coefficient direction has not changed significantly. Hence, the reliability of regression results is verified. According to the results of IV estimation, it can be found that: first, the distance cost does not significantly influence the relative market share of China's forestry exports, which indicates that the distance factor is not an important factor that influences China's forestry exports on occupying the targeted market share. Second, the nested market share of fiberboard, particleboard and plywood is one of the important factors influencing the market share of such product in the importing country. It indicates that the higher the number of the three varieties of forest products exported by China, the greater the nested market share captured, and the greater the relative market share occupied in the importing country. Third, the population factor has significantly a negative impact on the relative market share of plywood and paper and paperboard, which

Table I.
Data description on quality measurement of forest exports

	Mean				SD			
Forest exports (unit)	*lnm*	*lnp*	*lnns*	*lnpeople*	*lnm*	*lnp*	*lnns*	*lnpeople*
Fiberboard (m^3)	−3.706	0.355	−5.120	14.092	2.149	0.122	2.648	0.023
Particleboard (m^3)	−4.782	0.277	−6.899		1.605	0.085	2.579	
Plywood (m^3)	−3.585	0.378	−6.569		1.530	0.097	1.586	
Paper and paper board (m^3)	−3.777	0.851	−10.166		0.943	0.145	3.363	

Note: The price (P) unit is US dollar and the population (people) unit is 1,000 people

Variable type	Variable (abbreviation, unit)	Mean	SD	Data sources
Dependent variables	Quality of fiberboard export ($Q_{\text{Fibre board}}$)	52.066	2.206	Calculated by Khandelwal (2010)
	Quality of particleboard export ($Q_{\text{Particle board}}$)	32.588	1.752	
	Quality of plywood export(Q_{Plywood})	94.497	1.516	
	Quality of paper and paper board export ($Q_{\text{Paper and paperboard}}$)	79.014	0.950	
Independent variables	Per capita GDP of importing countries (*Ipgdp,* dollar)	39,499.700	9,922.843	Worldbank
	GDP of importing countries (*Igdp,* millions dollars)	3,166,058.000	3,844,965.000	Worldbank
	The degree of trade openness of importing countries (*Iopen*, %)	57.103	9.342	International Monetary Fund (IMF)
	Bilateral distance cost of exporting and importing country (*Distance,* dollar)	4,479,986.000	14,900,000.000	Worldbank
	Exporting country's fixed investment in forestry sector (*Efinvestment*, 10,000 of dollars)	523,616.000	1,636,698.000	FAO
	Graduates of Forestry Higher Education in exporting countries (*Efedu,* people)	85,086.400	40,083.460	FAO
	Export value of forest products in importing countries (*Ifvalue,*dollar)	8,937,015.000	8,444,730.000	China free trade agreement service network
	whether or not APEC member states, yes = 1, no = 0 (*Apec*)	0.400	0.492	IMF

Sources: Woldbank (https://data.worldbank.org.cn/), FAO (www.fao.org/home/en/), IMF (www.imf.org/external/index.htm), China free trade agreement service network (http://fta.mofcom.gov.cn/)

Table II. Variable explanation

Estimate method	Variable	Fiberboard *lnm*	Particleboard *lnm*	Plywood *lnm*	Paper and paper board *lnm*
OLS	*lnp*	−0.725 (−0.35)	−0.214 (−0.26)	0.844 (0.55)	−0.475 (−1.19)
	lnns	−0.147* (−1.69)	−0.104** (−2.23)	0.147*** (2.94)	0.0283 (1.53)
	lnpeople	1.420 (0.13)	−0.0678 (−0.02)	−15.25** (−2.42)	−6.105* (−1.92)
	_cons	15.81 (0.10)	−4.482 (−0.09)	212.0** (2.40)	82.94* (1.86)
IV	*lndis*	−0.434 (−0.66)	0.125 (0.37)	0.112 (0.44)	0.226 (1.43)
	lnns	−0.143 (−1.64)	−0.103** (−2.22)	0.147*** (2.89)	0.0309* (1.74)
	lnpeople	3.778 (0.27)	−2.716 (−0.37)	−14.09*** (−2.67)	−13.15*** (−3.82)
	_cons	−52.06 (−0.27)	31.16 (0.31)	194.5*** (2.72)	179.0*** (3.82)
B–P test	chibar2	164.42	283.66	732.98	222.01
	p	0.0000	0.0000	0.0000	0.0000
Hausman test			$\chi^2 = 20.74$, $p = 0.0000$		
n		150	150	150	150

Notes: *t*-statistics in parentheses. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

Table III. Regression results of product quality model for forest exports

indicates that the difference of the quality level of China's forestry exports has a significantly negative relationship with the relative market share of the products.

According to the estimation of the relative market share model for the forestry exports, the estimation results of the IV method with higher estimation precision are selected to measure the quality of the forest exports. The variation coefficients of equations after

regression are used to measure the quality (λ_{sgt}) of the forestry exports through Formulas (9) and (10). The quality measurement value is generally between 0 and 100. The greater the measurement value is, the higher the product quality is, and vice versa. In addition, the product quality gradient is calculated from Formula (11). The product quality gradient measures the heterogeneity between the products. The greater the gradient value is, the greater the difference between similar export products is, and vice versa.

Table IV illustrates the measurement results of the average quality and quality gradient of China's main forestry exports from 2000 to 2014. It can be found that: first, overall, the characteristics of the forestry exports reveal a decline trend regarding the current export quality of plywood and fiberboard. The export quality of particleboard and paper and paperboard is on the rise, but the rate of average annual quality change is not big. Second, the average export quality of China's main forestry exports from large to small is in the order of plywood, paper and paperboard, fiberboard and particleboard. The average export quality of plywood is relatively high, which is more than 90, while the average export quality of particleboard is relatively low, which is less than 40. Third, regarding the country-based results, the differences of the export quality is small in terms of the forestry exports from China to those export destination countries. The measured value of the export quality of fiberboard, plywood and paper and paperboard is greater than 50. The quality of particleboard is relatively lower than other products. Fourth, in terms of the average quality gradient of the forestry exports, the values of the products are relatively small, reflecting that the quality difference between the products is not obvious. It may be related to the similar access thresholds for products of the importing country.

Empirical results of the influencing factors on export quality of forest products

Test results of model applicability

In order to test the existence of multicollinearity in the main explanatory variables, the correlation coefficient matrix is first used for observation (as Table V shows). From the table, it can be found that the mutual correlation coefficients of the explanatory variables are integrally small. For further accurate verification, variance inflation factor (VIF) is sequentially used for observation. From Table V, the maximum value of VIF does not exceed 10 and the minimum is not less than 0, which indicates that there is no multicollinearity in the explanatory variables.

In addition, panel data regression is generally divided into the mixed estimates, fixation effects and random effects. To identify an appropriate regression, Breusch–Pagan test is needed to decide whether choosing a mixed estimate, a fixed effect or a random effect.

State/Average mass gradient	Fiberboard	Particleboard	Plywood	Paper and paper board
Japan	53.5	32.2	95.5	77.7
Canada	48.2	30.5	95.0	78.3
Belgium	52.8	32.2	91.9	79.3
Britain	52.2	33.1	96.7	79.8
Germany	52.5	34.0	96.0	80.0
France	51.4	32.8	93.9	79.4
Italy	52.2	32.7	94.0	78.8
The Netherlands	52.6	34.0	95.0	80.1
USA	51.1	34.8	94.6	79.4
Australia	54.1	29.6	92.5	77.5
Average quality	52.1	32.6	94.5	79.0
Annual average growth rate	−2.4	0.6	−0.7	1.1
Average quality gradient difference	1.4	0.6	1.0	0.7

Note: The quality gradient is the 2000~2014 annual average annual mass gradient

Table IV.
Quality measurement results of the forestry exports

Variable	*llpgdp*	*llgdp*	*lIopen*	*lDistance*	*lEfinvestment*	*lEfedu*	*lifvalue*	*lApec*
llpgdp	1.000							
llgdp	0.321	1.000						
lIopen	0.233	0.011	1.000					
lDistance	0.133	0.030	0.087	1.000				
lEfinvestment	0.177	0.047	0.229	0.053	1.000			
lEfedu	0.490	0.237	0.082	0.345	−0.024	1.000		
llfvalue	0.242	0.380	0.290	0.100	0.045	0.181	1.000	
lApec	0.146	0.352	0.152	−0.281	0.000	0.000	0.084	1.000
VIF	3.610	1.480	1.290	1.360	1.170	3.600	1.320	1.340
1/VIF	0.277	0.674	0.775	0.734	0.852	0.278	0.757	0.748

Test	Test index	$Q_{\text{Fibre board}}$	$Q_{\text{Particle board}}$	Q_{Plywood}	$Q_{\text{Paper and paperboard}}$
Breusch–Pagan test	$\overline{\chi}^2(01)$	23.23	86.09	528.78	55.18
	p-value	0.0000	0.0000	0.0000	0.0000
Hausman test	$\chi^2(5)$	5.61	9.02	14.54	8.48
	p-value	0.5865	0.1083	0.0241	0.1315
LLC test	Adjusted *t**	−3.743	−0.783	−3.514	−4.1184
	p-value	0.0001	0.0067	0.0002	0.0000

Table V.
Results of model applicability test

Table V shows that the *p*-value is less than 0.05; therefore, it refuses the mixed estimation of null hypothesis. The model should choose either the fixed effect or the random effect based on the result of a Hausman test. The Hausman test result is greater than the STATA13.0 software default hypothesis with the value of 0.05 (i.e. to accept the original hypothesis), which indicates that the random effects should be selected for regression estimates. Because the sample data are based on 15 years of long panel data in ten countries, the unit root test is also required to verify the stability of each variable sequence of the samples. For this purpose, adopting the unit root test method suitable for the long panel data, i.e., LLC test. From Table V, it can be found that the statistics (Adjusted *t**) are significantly negative and *p*-values are less than 0.05, which strongly reject the original hypothesis of panel data containing a unit root. Therefore, the panel data are relatively stable.

Regression results of panel data random effect

The regression results of the influencing factors on China's forestry exports to the main developed countries are shown in Table VI. Through the regression results, we can find that: regarding the influencing factors on the export quality of fiberboard, the export value of forest products of the importing country has a significantly positive effect on the fiberboard quality of the exporting country ($p < 0.01$). The total GDP of the importing country has a

Variable	$Q_{\text{Fibre board}}$	$Q_{\text{Particle board}}$	Q_{Plywood}	$Q_{\text{Paper and paperboard}}$
llpgdp	−0.0138 (−0.81)	0.00470 (0.21)	0.00167 (0.26)	0.0104*** (2.88)
llgdp	0.00681* (1.36)	0.0302*** (2.82)	0.0158*** (3.30)	0.00206** (2.09)
lIopen	0.00696 (0.42)	−0.0156 (−0.85)	−0.000368 (−0.10)	−0.00426 (−1.32)
lDistance	−0.00372*** (−2.78)	−0.00235 (−0.39)	0.00125 (0.67)	−0.00118* (−1.90)
lEfinvestment	0.0117 (0.99)	−0.0116* (−1.68)	−0.000179 (−0.13)	−0.00159 (−1.27)
lEfedu	0.0104 (1.11)	0.0294*** (2.58)	0.00596** (2.42)	0.00682*** (3.58)
llfvalue	0.0249*** (4.52)	0.00931 (1.00)	0.0109*** (3.66)	0.00382*** (4.07)
lApec	−0.0154* (−1.43)	−0.0696*** (−3.38)	−0.0102 (−1.09)	−0.0206*** (−10.89)
_cons	4.122*** (29.77)	3.479*** (23.28)	4.530*** (120.89)	4.313*** (176.67)
n	150	150	150	150

Notes: *t*-statistics in parentheses. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

Table VI.
Regression results of the factors affecting the quality of forestry exports

certain positive effect on the fiberboard export quality of the exporting country ($p < 0.1$). In addition, the bilateral distance cost has a significantly negative effect on the fiberboard quality of the exporting country ($p < 0.01$). Whether an APEC member state has a certain negative effect on the fiberboard export quality of the exporting country ($p < 0.1$). Second, in terms of particleboard, the total GDP of the importing country has a significantly positive effect on the particleboard's export quality of the exporting country ($p < 0.01$). The number of forestry higher education graduates of the exporting country has a significantly positive effect on the particleboard's export quality ($p < 0.01$), whether an APEC member state has a significantly negative effect on the particleboard's export quality of the exporting country ($p < 0.01$). The forestry fixed investment of the exporting country has a certain effect on the particleboard export quality ($p < 0.1$). Third, for plywood, the total GDP of the importing country has a significantly positive effect on the plywood's export quality of the exporting country ($p < 0.01$). The export value of forest products of the importing country has a significantly positive effect on the plywood's quality of the exporting country ($p < 0.01$). The number of forestry higher education graduates of the exporting country has a strong, positive effect on the export quality of plywood ($p < 0.05$). Fourth, for paper and paperboard, the per capita GDP of the importing country has a significantly positive effect on the quality of the paper and paperboard of the exporting country ($p < 0.01$). The number of forestry higher education graduates of the exporting country has a significantly positive effect on the export quality of paper and paperboard ($p < 0.01$). The export value of forest products of the importing country has a significantly positive effect on the quality of the paper and paperboard of the exporting country ($p < 0.01$). The total GDP of the importing country has a strong, positive effect on the export quality of paper and paperboard of the exporting country ($p < 0.05$) whether an APEC member state has a significantly negative effect on the export quality of paper and paperboard of the exporting country ($p < 0.01$). The bilateral distance cost has a certain negative effect on the quality of paper and paperboard of the exporting country ($P < 0.1$).

Discussion

This research has measured the quality of four varieties of forestry exports from China to ten developed countries from 2000 to 2014. Meanwhile, the influencing factors have also been analyzed to understand how to improve forestry exports' product quality. The research findings show that the quality of plywood is the highest, which may be related to the quality supervision of the relevant administrative departments, total export volume of the products and trade barriers of the developed countries. For example, the National Standard of Artificial Board-Molded Plywood formulated by China's National Quality Supervision Bureau was officially approved and issued in March, 2009. This has a certain promoting effect on the improvement of the export quality of the plywood. In addition, according to the data of *Statistical Yearbook for Forestry of China from 2000 to 2014*, the average annual export volume of plywood was more than 8m cubic meters. The average annual export volumes of fiberboard, particleboard and paper and paperboard were 2m cubic meters, 0.3m cubic meters and over 5m tons. Therefore, in terms of the quantity, the export volume of plywood was the largest and its production process was relatively mature. In addition, external factors are also important factors that force forest exports to improve product quality. Especially in recent years, China's forest exports have encountered trade barriers and frequent product quality surveys, which makes enterprises more seriously to ensure the high-quality products in order to achieve higher international market requirements. According to the statistics from the website of China's Ministry of Commerce, the number of investigations on "Anti-dumping and countervailing" for plywood in the ten developed countries was at the most. For example, in America, the investigations on plywood from 2000 to 2014 were more than 15 times. It implies that this kind of trade barriers may cause the improvement of China's export plywood quality.

When analyzing the changes of the characteristics of the product quality, we have found that the current export quality of plywood and fiberboard shows a trend of decline. The export quality of particleboard, paper and paperboard is on the rise, but the average rate of the change of annual quality is not big. The main reason for the decline of the export quality of plywood and fiberboard is likely as follows. The international market has large demand for plywood and fiberboard. However, some export enterprises ignore the quality improvement of export products when chasing the growth of total export volume. By contrast, particleboard, paper and paperboard are in the initial stage in the export market. Their export volume is relatively smaller than plywood and fiberboard. In order to participate in the competition of international market, export manufacturers of particleboard, paper and paperboard must improve the quality of their products to develop the international market. Therefore, these are important reasons for the improvement of the export quality of particleboard, paper and paperboard.

In terms of the factors that influence the quality of forestry exports, the GDP of the importing country, the forestry export value of the importing country, the number of forestry higher education graduates of the exporting country and whether an APEC member state are the main factors influencing the quality of China's forestry exports. Since the sample countries in our research are all the developed countries, they have high economic development level, high import threshold and product quality standard. Specifically, on the demand for forest products, the sample countries also strictly control the quality of the forestry imports. The higher the forestry export value of sample countries is, the higher the overall forestry production level is and the stricter the demand for the quality of forestry imports forest products is. This reversely forces China to improve the quality of forestry exports to the above developed countries. In addition, the number of forestry higher education graduates of the exporting country reflects the human capital reserves of the forestry industry. It especially has a strong promotion effect for the wood processing industry. Statistics show that the number of forestry higher education graduates in China in 2000 was 33,000 people, and 154,000 in 2014, with an annual growth rate of 25 percent (China forestry statistical yearbook, 2000–2014). The majors such as wood processing, forestry and paper making are the advantages of China's forestry colleges. The practitioners trained by professional forestry majors can strongly promote the production of forest products with high quality.

In addition, as an important economic organization, APEC can enhance the level of trade liberalization and reduce the access threshold of trade. Therefore, enrolling APEC has promoted the growth of the total volume of trade between China and APEC member countries. And it also has a negative effect on the quality of trade products due to the lower access threshold. Distance cost has a certain negative effect on the export quality of fiberboard, paper and paperboard. This is contrary to our expectations, Harrigan *et al.* (2015) suggested that only the products with the best advantage can be exported to further afield, while the fiberboard, paper and paperboard exported by China are not in accordance with this view. The possible reason may be that the international demand of fiberboard and paper and paperboard are large, and meanwhile the fiberboard and paper and paperboard made in China have substantial price advantages. The countries with more remote markets incur high transportation costs and cause small profits. Thus, manufacturers may decrease the product quality in order to cut production cost and make more profits.

Conclusion

In this contribution, Khandelwal (2010) model was used to measure the quality of forest products exported by China to ten major developed countries from 2000 to 2014. Meanwhile, the factors affecting the quality were analyzed in the empirical research. It was found that the quality of plywood and fiberboard exported by China was declining, while the quality of particleboard and paper products was on the rise. The average annual variation of forest

product quality was relatively small. Further empirical analysis showed that the GDP of the importing countries and the number of graduates of forestry higher education in the exporting countries had a significant effect on the quality of forest exports. Moreover, the bilateral distance cost of the exporting and importing country had a certain negative effect on product quality. In the future, China should continue to strengthen the trade links with the developed countries and continue to expand trade scale. In addition, it is imperative for government to implement the policies to enhance product quality, such as gradually improving the education level of employees of forest exports, strengthening vocational skills through training, and improving the production level of forest exports. Besides, transportation infrastructures should be further improved to reduce transportation costs of the domestic forest products.

In March 2015, the executive meeting of China State Council had passed Made in China 2025. Furthermore, the Planning for Standardization of Equipment Manufacturing Industry and Quality Improvement had been passed in April 2016, which was required to implemented Made in China 2025. These documents clearly emphatically propose that the manufacturing of industrial goods shall focus on the standard of "Quality first" for production. As the implementation of the policy and planning, improving the quality of forestry exports has become essential. Through the research on the quality of China's main forestry exports, we consider that the quality does not only relate to corporate interests, but also involve the welfare of consumers. The developed countries and economies are the important markets for China's forestry exports. The quality of the exports must be improved to meet the import standards of the developed countries, so as to enhance the international competitiveness of China's forest products. Moreover, if the quality and international competiveness of China's forestry exports want to be improved, the research and development investment should be increased to accelerate the innovation ability of wood processing enterprises. Higher production quality and affordable price of forest products through the improvement of industrial upgrading and innovation ability can meet the growing demand of the international market of wooden forest products.

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