Green Assessment of Imports and Exports of Wooden Forest Products Based on Forest Processing Industry: A Case Study of China

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Abstract: The research on international trade competitiveness is progressing continuously. Environmental factors have been gradually considered in the competitiveness of international trade. However, the green assessment system of international trade competitiveness is not perfect. Building a model based on the trade economy is complex. This study combines environmental pollution data based on the forest processing industry with trade flows. Environmental trade competitiveness, pollution treatment, and trade scale were selected as the three criterion levels to construct an assessment system. The weight and score of each index were calculated by the overall entropy method. The overall entropy method is more comprehensive than the traditional entropy weight method due to introduce longitudinal comparisons of time and category. This method is a dynamic evaluation model with analysis of three-dimensional sequential data tables. The use of this method enables the assessment model to analyze more comprehensively the green level of a country’s trade in wooden forest products in terms of time and product category. The green level of chemical wood pulp and sawn timber trade in China is at a high level. The pollution treatment and trade scale of chemical wood pulp and sawn timber attained a medium level of matching. The trades in particle board, hardboard, newsprint, carton board, and wrapping paper are at medium levels of green. The trades in medium density fiberboard and plywood have poor levels of green and need to improve their green production capacity. It is suggested that China should increase investment in scientific research, as well as establish policies to restrict and treat pollution in the industry of wooden forest products, while increasing the export volumes of products with high added value. China should attach importance to the pollution resulting from the manufacture of wooden forest products. The state should support policies for these producers reducing production emissions.

Keywords: wooden forest products; foreign trade; pollution

1. Introduction

In recent decades, China has quickly become a major trading country in forest products and it plays a key role in the global forest product trade market. The trade in forest products is conducive to the country’s comparative advantages and promoting the development of China’s forestry industry. China’s forest products industry has gradually emerged from its large-but-weak position and begun to mature and participate more competitively in global value chains. As a result of low-cost manufacturing and the surge in foreign demand, China has become a center for the remanufacturing and redistribution of wooden products [1–3]. However, the studies of Moinul et al. (2016) have shown that imports and exports of wooden forest products can result in pollution, and the environmental impacts of trade in wooden products have aroused great concern [4].

The forestry industry has relatively high levels of energy consumption and material consumption [5]. The development of the forestry industry will impact not only the...
environment but also the economy [6]. In the trade of wood products, exports cause pollution-intensive production, and imports relieve environmental pressure to some extent [7]. Forest industry companies are the main exploiters of forest resources, and their actions may have a significant impact on the sustainable development of forests [8]. Production and trade statistics for forest products are the basis for studying the economic and environmental performance of the forest sector [9]. At this stage, the technology and facilities in the production and processing of wooden forest products are imperfect, and their industrial design is limited. The development of the circular economy has set up obstacles [10,11]. The effects of the production and trade of a country’s forest products on the economic environment should be considered. The contradiction between economic benefits and the ecological environment should be urgently coordinated, while optimizing the economic strategy of the country for wooden forest products. Therefore, it is necessary to study the green development of the forest product trade, which is conducive to the improvement of national innovation and strategy in the manufacturing and trading of wooden forest products.

Large scale forest loss and degradation are occurring in the world [12]. Deforestation has been further increased by wooden forest products trade activities, which put pressure on global forest resources [13,14]. Most of the research on the trade competitiveness of wooden forest products is based on trade flow [15–19]. They use these indicators to measure trade competitiveness. These indicators include RCA (revealed comparative advantage), TC (trade competitiveness), CTB (index of contribution to the trade balance) and so on. Forest resources face the threat of degradation and depletion by various factors including illegal logging. Illegal logging and related trade in wooden forest products are the main causes of deforestation and forest degradation in many developing countries [20]. Issues of global forests and the trade of illegal logging have become global issues, and countries are exploring ways to prevent illegal logging and illegal trade in timber. Illegal logging is generally defined as the logging, processing, transportation and sale of wooden forest products that is in violation of a national or international law (WWF, 2016). The traceability of imported timber has been called for in the world now. The illegal logging of timber and destruction of the forest ecological environment caused by trade restricts the sustainable development of forestry [21]. Recent studies have also examined environmental laws and regulations on environmental pollution. Many scholars think that forest governance can contribute to the reduction of deforestation [22]. Richard et al. (2020) researched market instruments involving the trade in forest certificates [23]. The wooden forest industry should have high criteria on both input and output when striving for legitimacy. State and non-state governance modalities which have legitimacy also contribute to reduce deforestation [24].

The wooden forest industry is a key sector of the economy, and it includes a series of industries—such as forest cultivation and wooden processing—that have a relatively complete production system and that rely on forest resources. The causes of environmental impact differ among the different stages of the forest industry production [25]. In the production process, the composition of the pollutant sources in the pollutant emissions is complex, which causes certain difficulties for the end treatment. The enterprises engaged in the forest products industry have different production processes for the same type of products, resulting in differing pollutant emissions according to the varying technologies at the end of treatment [26]. Medeiros et al. (2020) found that more efficient machines and equipment should be adopted in the forestry sector to improve the environmental and economic performance [7]. From the perspective of the ecological environment, international trade is a non-equivalent exchange. International trade separates the pollution generated in the manufacture of wooden forest products from their consumption [27]. China is relatively highly dependent on the import of primary products for wooden forest products, so China has a relatively high risk of dealing with the deterioration of the trade environment. In the import and export process, pollution and emissions from production are attached to forest products, which not only create economic benefits but also pose a certain threat to
the ecological environment of the country [28,29]. Traditional factor endowments, such as forest area and the labor force, are no longer decisive factors for the export competitiveness of forest products and environmental regulations will reduce the competitiveness of a country’s forest products [30].

However, the green assessment of trade in wooden forest products has not been completed, so it is necessary to establish a green assessment system of the trade in wooden forest products. In summary, environmental trade competitiveness, pollution treatment, and trade scale were selected in this study. Regarding green assessment methods, scholars have adopted various methods. Some typical evaluation methods such as entropy weight method, TOPSIS (technique for order preference by similarity to ideal solution) [31], LCA (life cycle assessment), principal component analysis, material flows analysis [32] and input–output analysis [20] have been widely used in environmental economic studies to build evaluation models [33–37]. This study adopted the overall entropy method, which is more comprehensive than the traditional entropy weight method, that was used to introduce longitudinal comparisons of time and category [38]. This method enables a comprehensive assessment, including an assessment of the status quo, and shows temporal characteristics and type of product characteristics. This research is based on the forest processing industry. The green assessment does not take into account only the problem of production of pollution. This research analyzes the green situation of wooden forest products trade through three aspects: environment, pollution and economic benefit. This paper analyzes the current situation of the green development of wooden forest products trade in a country, and makes planning suggestions accordingly. The traditional entropy method can only realize the analysis of two-dimensional data (index-region or index-time). When using three-dimensional data tables of index, region and time, the evaluation results of different data tables will be from top to bottom in chronological order. The overall entropy method is a dynamic evaluation model with analysis of three-dimensional sequential data tables [39]. The green assessment system of international trade competitiveness is not perfect. Building a model based on the trade economy is unit. This study combines environmental pollution based on forest processing industry with trade flows. The overall entropy method will introduce longitudinal comparisons of time and category to this study. TP [28] and WGTC [2,40] indexes were adopted for the perspectives of environmental trade competitiveness. PTT [41–43] and UPC [6] indexes were adopted for the perspectives of pollution treatment. The above indicators are described in Section 2.1. The perspectives of the trade scale adopt both the export trade volume and import trade volume. There are many programs of the selection of research subjects for pollutant emissions in the perspectives of pollution treatment. Xu et al. (2020) compared the air pollution emissions generated for exports and imports in the US [20]. The study of Eirik et al. (2019) adopted biofuel implementations to find the impacts in forest sector [44]. Stahls (2011) chose carbon dioxide as the environmental indicator and concluded that the export trade of wooden forest products in Finland suppressed green developments [45]. Bajona et al. (2012) used pollution emission indexes, such as soot, sulfur dioxide, dust, and chemical oxygen demand, in their study and took the increase or decrease in trade subsidies as the factors affecting pollutant emissions [40]. Therefore, 12 pollutants were selected with previous studies to participate in this study.

The remaining sections of this paper introduce the materials and methods adopted in this paper, then present the calculated results based on the data and methods, which are followed by conclusions and discussions based on the calculated results.

2. Materials and Methods

This section consists of three parts. Section 2.1 introduces the contribution to global deforestation and forest degradation. Section 2.2 introduces governance modes and policy instruments. Section 2.3 introduces the green evaluation system of trade in wooden forest products.
2.1. The Contribution to Global Deforestation and Forest Degradation

According to World Bank data, seven countries with forest area over 1 million square kilometers have been measured change value in forest area. The contribution to global deforestation and forest degradation as measured with rate of contribution.

\[
\text{Contribution rate (\%)} = \frac{\Delta \text{forest area (a country)}}{\Delta \text{forest area (World)}} \times 100\%
\]  

(1)

2.2. Governance Modes and Policy Instruments

In this part, we will discuss the import timber legitimacy policy of the countries with the largest import timber in the world. Figure 1 shows the import volume of the world’s major timber importing countries in 2017. The timber legitimacy policy of countries with more imported timber is a part of this study.

Figure 1. Timber imports (1000 m³).

The problem of illegal logging and related trade has a global character and involves a series of international rule of law issues, such as international environmental law, international trade norms and so on (Figure 2). The reasons for illegal logging are very complex, not only because of the forestry sector, but also due to the absence of forestry policy and legal framework, and the invalidation of laws and regulations. It is necessary to form a pluralistic cooperative mechanism of international rule of law.

Figure 2. The rule of law for global governance of illegal logging and trade in forests.

2.3. Green Evaluation System of Trade in Wooden Forest Products

In international trade, the pollution generated by the manufacture of products does not flow with the cross-border transfers of the products [46]. The pollution remains in the manufacturing country and has certain effects on the ecological environment of this country. This study examined the emissions resulting from the manufacture of wooden forest products and constructed an assessment system of the level of the green of trade in wooden forest products by taking into account the import and export volumes of the products.
Based on previous scholars’ research, this article selects three criterion levels: environmental trade competitiveness, pollution treatment, and trade scale (Table 1). Environmental trade competitiveness is composed of green trade competitiveness indicators and trade pollution conditions indicators, indicating that the trade competitiveness in wooden forest products. The competitiveness of trade in the case of emissions is suitable for the definition of green development, which refers to getting rid of the pressure of environmental pollution to achieve the purpose of promoting economic development \[12,41,47,48\]. The pollution treatment represents the intensity of pollution emissions created by the manufacture of wooden forest products for trade. The pollutant types were selected according to the pollutant selection method of previous studies, and the pollutant indexes were selected according to the actual environmental monitoring statistics \[20,40,44,49,50\]. The scale of the trade in pollution treatment takes on the volumes of imports and exports as the index. The scale of trade is an important guarantee for the economic benefits from the trade in wooden forest products and an important influencing factor for the green evaluation of trade in wooden forest products \[20–24\]. The description of the pollutant measurement unit is in Appendix B.

Table 1. Green evaluation system of trade in wooden forest products.

| Target Level | Guidelines Layer | Indicator Layer |
|--------------|------------------|----------------|
| Green assessment of trade in wooden forest products. | Environmental trade competitiveness | Green trade competitiveness |
| | | Trade pollution conditions |
| | Pollution treatments (types of pollutants) | Unit emission intensity |
| | | Pollution production of exported wooden forest products |
| | | Emissions from exports of wooden forest products |
| | | Net pollutant emissions |
| | | Export trade factors containing pollution |
| | | Import trade factors containing pollution |
| Trade scale | Export trade volume | Volume of imports |

2.3.1. Net Pollutant Emissions

The total amount of pollutant output and emissions implied in the imports and exports of wooden forest products was estimated according to the pollution emission factor of the manufacture of wooden forest products. It is calculated in accordance with the data Ministry of Ecological Environment of the people’s Republic of China provides and the measurement contained in the data.

\[
EP_j^{ik} = \partial_j^k \times Ex_j^i \\
DEP_j^{ik} = \lambda_j^k \times Ex_j^i \\
IP_j^{ik} = \partial_j^k \times Ix_j^i \\
DIP_j^{ik} = \lambda_j^k \times Ix_j^i
\]

In the above formula, \(\partial_j^k\) is the pollution output coefficient, which represents the pollutant production coefficient of the wooden forest products participating in trade; \(\lambda_j^k\) is the pollution emission coefficient, which indicates the amount of pollution discharged per unit of pollutants discharged by different types of products of wooden forest products participating in the trade after the terminal pollution treatment, \(j\) represents the type number of the product and \(k\) represents the type number of the discharged pollutant. \(EP_j^{ik}\) and \(IP_j^{ik}\) represent respectively the emissions of type \(k\) pollutants of exports and imports of type \(j\) wooden forest products. \(EP_j^{ik}\) is pollution production of exported wooden forest products. \(DEP_j^{ik}\) and \(DIP_j^{ik}\) represent the emissions of type \(k\) pollutants from exports and imports of type \(j\) wooden forest products. \(i\) is the year. DEP is emissions from exports of
wooden forest products. $Ex_i^j$ and $Ix_i^j$ are the type $j$ wooden forests respectively exported and imported by the country in year $i$. The total trade volume of products. $TP_i^{j,k}$ represents the difference in the emissions of type $k$ pollutants in the imports and exports of wooden forest products in year $i$.

$$TP_i^{j,k} = \sum_{k} DIP_i^{j,k} - \sum_{k} DEP_i^{j,k} = \sum_{k} \lambda_i^{k} \times Ix_i^j - \sum_{k} \lambda_i^{k} \times Ex_i^j$$ (4)

To estimate the net emissions of pollutants from the imports and exports of wooden forest products. $TP_i^{j,k}$ is the total trade in net pollutant emissions. Exports and imports of these emissions may vary considerably between countries and groups of countries [28,46]. The critical value of this indicator is zero. If this value is positive, it means that the pollutant emissions of wooden forest products during the production process are greater than that of exports. The pollutant emissions of products indicate that the wooden forest product trade is in a trade deficit in terms of the environmental concept, and the production process of wooden forest product trade is unfavorable to the ecological environment of a country; if this value is negative, it means that the pollutant emissions of the export of wooden forest products during the production process are greater than that of the imported in this year, indicating that wooden forest product trade is in a trade surplus in terms of the environmental concept. The ecological environment of the country has a positive effect; if this value is zero, it means that wooden forest product trade in this year is in an environmentally balanced state, and trade has little impact on the country’s ecological environment.

2.3.2. Unit Emission Intensity

$UPC_i^{j,k}$ stands for unit pollution intensity [6]. The range of this indicator is 0–1. When the index value is 0.5–1, it means that the pollution emission rate during the production of this wooden forest product is high. On the basis of factors, the production process of such products in the country has high environmental costs. Therefore, the import in the trade process is greater than the export, that is, the trade deficit on such products is beneficial to the country’s ecological environment and can be understood as export products. It is equivalent to imported pollution; When the index value is 0–0.5, it means that the pollution emission rate in the production of this wood forest product is low. After such products are produced in the country and the pollution treatment factors at the end of the production are removed, there is a low, in the course of trade, imports are less than exports, that is, the existence of trade smoothness on such products is beneficial to the country’s ecological environment.

$$UPC_i^{j,k} = EP_i^{j,k} / IP_i^{j,k}$$ (5)

$EP_i^{j,k}$ and $IP_i^{j,k}$ in Equation (5) are different from those in Equation (4). Here, Equation (5) represents the ratio of the pollution emissions per unit of wooden forest products to the pollution created by the manufacture of the same product.

2.3.3. Trade Pollution Conditions

Antweiler [41] first put forward the concept of “trade pollution conditions” (PTT) and its measurement formula in 1996. $\mu$ represents the export trade factors containing pollution. $\gamma$ represents the import trade factors containing pollution. $VE_i^{j,k}$ and $VI_i^{j,k}$ represent the trade volume of exported and imported wooden forest products. $PTT$ represents the amount of pollution contained in the export value of unit currency and the value of unit currency. The ratio of the pollution amount contained in the import value is the ratio of the export pollution trade factor to the import pollution trade factor, which is called the trade pollution condition [43].

$$\mu = EP_i^{j,k} / VE_i^{j,k}$$ (6)
\[ \gamma = \frac{IP_{ij}^k}{VI_{ij}^k} \]  

\[ PTT = \mu / \gamma = \left[ \frac{EP_{ij}^k}{VE_{ij}^k} \right] / \left[ \frac{IP_{ij}^k}{VI_{ij}^k} \right] \]  

2.3.4. Green Trade Competitiveness Index of Wooden Forest Products

As the most commonly used indicator to analyze the trade competitiveness of a country or region, the trade competitiveness index represents the proportion of a country’s trade balance to the total trade volume. It reflects the level of a country’s foreign trade competitiveness in a certain sector. The competitiveness of the product’s foreign trade is relatively representative [51], where \( TC \) in the Equation (9) represents the trade competitiveness index, and \( T_e \) and \( T_i \) respectively represent a country’s export trade volume and import trade volume [52].

\[ TC = \frac{(T_e - T_i)}{(T_e + T_i)} \]  

Based on the above model of trade competitiveness, this study introduces the green trade competitiveness index of wooden forest products. According to the performance of its index, the green trade competitiveness of wooden forest products trade is standardized. Add pollution factors to the calculation formula of international trade competitiveness. \( C_e \) and \( C_i \) represents production emissions from exports and imports. The change from 9 to 10 is a shift from the amount of pollution contained in trade to the amount of trade.

\[ WGTC = \frac{(C_e - C_i)}{(C_e + C_i)} \]  

WGTC stands for the green trade competitiveness index of wood forest products. According to the subdivision criteria of trade competitiveness [40], combined with the characteristics of pollution emissions in the production process of wooden forest products, the green evaluation criteria for trade competitiveness of wood forest products are formulated. The range of values (Table 2) calculated by the formula of the pollution emissions generated during the trade of wooden forest products is to rate the green of the trade of wood forest products of this species.

| WGTC  | Green Trade Competitiveness Rating | WGTC  | Green Trade Competitiveness Rating |
|-------|-----------------------------------|-------|-----------------------------------|
| 0.8–1.0 | High green trade competitiveness | −0.5–0 | Low pollution trade competitiveness |
| 0.5–0.8 | Medium green trade competitiveness | −0.8–−0.5 | Medium pollution trade competitiveness |
| 0–0.5 | Low green trade competitiveness | −1--−0.8 | High pollution trade competitiveness |

2.3.5. Green Evaluation of Trade in Wooden Forest Products

The overall entropy method is used to determine the index weights of the above indicators. The principle is that the tables are arranged from top to bottom according to the time order, and then evaluated by the traditional entropy method. The traditional entropy method can objectively assign weights to the indicators, but it uses cross-sectional data, it cannot be used to determine the trade of wooden forest products in this study. The characteristics of green level and evolution are dynamically analyzed. Therefore, this study selected the overall entropy method, which avoids the subjective expert scoring method and uses the global idea to longitudinally analyze the data used from the perspective of dynamic changes. The combined analysis method provides a more comprehensive
evaluation of the dynamic process of green level of wooden forest product trade. The specific steps are as follows [39]:

\[ A = \{a_{ij}\}_{mt \times n} \quad (i = 1, 2, \ldots, t) \]
\[ (j = 1, 2, \ldots, m) \]
\[ (l = 1, 2, \ldots, n) \quad (11) \]

We construct the matrix shown in Equation (11), where \( a_{ij} \) represents the value of the evaluation index of item \( l \) of the wooden forest products of classes \( i \) and \( j \).

\[ B^+ = \left[ a_{ij} - a_{lmin} \right] / \left[ a_{lmax} - a_{lmin} \right] \quad (12) \]
\[ B^- = \left[ a_{lmax} - a_{ij} \right] / \left[ a_{lmax} - a_{lmin} \right] \quad (13) \]
\[ B = \{b_{ij}\}_{mt \times n} \quad (14) \]

The \( A \) matrix in Equation (11) is dimensionless and the \( B \) matrix is obtained by removing the order of magnitude existing in the original data, as well as the difference between the positive and negative index orientations.

\[ C = \{c_{ij}\}_{mt \times n} \quad (15) \]

Perform global coordinate translation processing on \( B \) matrix, \( C = B + A \), where \( A \) is the amplitude of translation.

\[ e_l = -k \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} \ln c_{ij}, e_l \in [0, 1] \quad (16) \]
\[ k = \frac{1}{\ln mt}, d_l = 1 - e_l \quad (17) \]

\( e_l \) is the information entropy of the evaluation index of item \( l \) and \( d_l \) is the redundant value of the information entropy of the evaluation index of item \( l \).

\[ w_l = d_l / n - \sum_{i=1}^{n} d_i \quad (18) \]
\[ g_l = \sum_{i=1}^{n} d_i (c_{ij}) \quad (19) \]

\( w_l \) is the weight of the evaluation index of item \( l \) and \( g_l \) is the comprehensive score of \( j \) kinds of wooden forest products in the first year of a country.

2.3.6. Data

The data of forest area is from World Bank (https://data.worldbank.org/). Trade flow data is from FAO (Food and Agriculture Organization of the United Nations). The data of pollution and emission about wooden forest products industry was taken from China’s industrial source emission statistics (Ministry of Ecological Environment of the people’s Republic of China) and China’s Environmental Statistics Yearbook [53].

In this paper, China’s wooden forest products are divided into the following six categories taken from the FAO’s statistical standards on trade in wooden forest products and relevant statistical data. This study refers to the product categories determined in the China Industrial Source Emissions Manual, combined with the results of the FAO’s trade flows statistics, to screen out ten categories of wooden forest products: sawn timber,
plywood, particleboard, medium density fiberboard, hard fiberboard, other fiberboard, chemical wood pulp, newsprint, carton board, and wrapping paper to research on (Table 3). Since the content of this paper does not cover the manufacturing industry of wooden forest products, the standard specification products assumed in this paper had been manufactured according to the same manufacturing processes and the pollution output rate had been calculated according to its mathematical average. It was expressed $\alpha$ and $\lambda$ in the Equations (2) and (3).

Table 3. Codes of sources of trade pollution of wooden forest products.

| Category                          | Code  |
|-----------------------------------|-------|
| Sawn timber                       | 2011  |
| Plywood                           | 2021  |
| Particle board                    | 2023  |
| Medium density fiberboard         |       |
| Hardboard                         | 2022  |
| Other fiberboard                  |       |
| Chemical wood pulp                | 2210  |
| Newsprint                         | 2221  |
| Carton board                      |       |
| Wrapping paper                    |       |

The classification of environmental pollutants in manufacture of wooden forest products in China is described in Figure 3. The main pollutants produced and discharged from the production of wooden forest products are determined with reference to the pollutant type indicators measured in the China Industrial Source Emission Manual and pollution output coefficient is also from it ($\alpha$ and $\lambda$ are in Section 2.3.1). There are mainly 12 types of pollutants including industrial effluents, COD, industrial exhaust volume, 5-day biochemical oxygen demand, industrial dust, ammonia nitrogen, industrial solid waste (sludge), HW21 and HW24 Hazardous waste (arsenic and chromium wastes), arsenic, Hexavalent chromium, HW21 and HW24 Hazardous waste (anticorrosive sawdust containing arsenic and chromium), Volatile phenol.

![Diagram](https://example.com/diagram.png)

**Figure 3.** Classification of environmental pollutants in manufacture of wooden forest products in China.
3. Results
According to World Bank data, seven countries with forest areas of over 1 million square kilometers have been measured for change in value of forest area (Figure 4). Forest area is in decline in the world. Forest area is rising in China, United States and Australia. The other countries have the same trends in forest area as in the world.

![Figure 4. Forest area change and contribution to world forest area.](image)

As can be seen from the Figure 5, in terms of environmental trade competitiveness (a), the difference between various products is not big and the annual change is not obvious. This is because the production process of the research object has not changed obviously in the research years, or the production process of the research object has changed, but the improvement in the production pollution emission is not obvious. From the perspective of pollution treatment (b), the score of the medium density fiberboard is the lowest, whereas the score of chemical wood pulp is the highest and has the highest growth rate from 2013 to 2017. From the perspective of trade scale (c), the comprehensive score of the trade scale of plywood is the highest, whereas that of chemical wood pulp is the lowest and the annual growth rate of carton board is the highest at this level.

![Figure 5. Pollution treatment at the level of green of China’s trade in wooden forest products and comprehensive score results of environmental trade competitiveness (a), pollution treatments (b), trade scale (c).](image)

As shown in the Figure 6, the following conclusions can be drawn from a more intuitive analysis: chemical wood pulp has the highest score on the comprehensive score and the annual growth rate also ranks first. The comprehensive score has a large gap with the other nine wooden forest products, indicating its trade level of green is very high, but it is at a relative disadvantage in terms of the scale of trade. Therefore, chemical wood
pulp can further reduce its relative disadvantage by increasing profits. The comprehensive score of medium density fiberboard is the lowest and its disadvantage lies in the pollution treatment level. Therefore, the pollution treatment technology at the end of the production of medium density fiberboard should be increased so as to enhance the green level of its trade. The overall score of sawn timber is on the rise, which indicates that the trade in sawn timber wooden forest products from 2013 to 2017 has a trend of a gradual increase in the level of green, indicating that its pollution treatment technology has gradually improved and its trend of decline at the economic level is its relative disadvantage. The comprehensive score of plywood ranks the second from the bottom. Its green level is low, but its trade scale score is high. The pollution emissions from production and pollution treatment at the end of production are the key points to the improvement of its green level. The comprehensive scores of other fiberboards show significant changes and a large downward trend in 2016. The comprehensive scores of particle board, hardboard, newsprint, carton board, and wrapping paper all tend to be flat while the scores are in the middle, indicating that the green level is good.

![Figure 6. Comprehensive scores of entropy weight method.](image)

4. Discussion

The legality of wooden products is required in the international market in order to address the issues of illegal logging and illegal trade. The Governance modes and policy instruments of timber in different countries is not completely consistent but has similarities. The China natural forest protection project was formally implemented in 2000. It is the main factor in the change rate of the forest area, in contrast to the rest of the world. The long-term goal of this project is to restore the natural forest resources. China’s newly revised Forest Law was formally implemented in 2020, which clearly stipulates that wood processing enterprises shall establish accounts for the entry and storage of raw materials and products in order to combat the acquisition, processing and transport of illegal timber. The US has the amended Lacey Act to prohibit the import of illegally harvested or traded timber in 2008 [38]. The Australian Congress passed an Illegal Logging Prohibition Act in 2012 which
prohibits the import of illegally harvested wood and prohibits the use of illegally harvested wood in domestic processed products. The European Union Timber Regulation is part of the EU’s Forest Law Enforcement, Governance and Trade (FLEGT) action plan. This policy started in 2003 which aims to combat illegal logging and related trade. Japan passed the Legal Timber Act in 2016. Korea officially promulgated the Amendment to the Law on the Sustainable Use of Timber in 2017 in order to strengthening control over timber imports. International governance models also exist. Forest certification plays an important role in the global legal and sustainable logging trade [54].

From an environmental perspective, wooden forest products have a deficit in the four pollutants of industrial dust, industrial exhaust volume, industrial effluents, and industrial solid waste (sludge) The deficit in the environmental sense shows that the trade of China wooden forest product is beneficial to the ecological environment of China in terms of the above four pollutants. Ultimately, the export of wooden forest products will speed up the country’s carbon dioxide emissions [45], which is consistent with the conclusion of change with the opposite direction in this study. HW21 and HW24 hazardous waste (arsenic and chromium waste), arsenic, hexavalent chromium, HW21 and HW24 hazardous waste (anticorrosive sawdust containing arsenic and chromium), COD, five-day biochemical oxygen demand, volatile phenol, and ammonia nitrogen have a trade surplus from the environmental perspective. The impact of various pollutants on the country’s ecological environment is negative [28]. This study is based on the production and emission coefficient of wooden forest products from China according to the theory of environmental cost transfer. When a country engages in pollution-producing products in the normal import and export, pollutants will be left in the producing country [46]. Sweden has used international trade to weed out some of its biggest polluters. Therefore, the trade balance of a country’s wooden forest products from the perspective of the environment changes in opposite directions, but there are differences in this respect between different categories of products. The conclusion that different types of pollutants are selected for the same index will be differentiated [55]. The results (Annex1) show that, compared with other pollutants, industrial dust emissions are the main pollutants in the production of wooden forest products and the pollution treatment at the end of production is relatively ideal with the pollution emission rates below 50%. In terms of industrial dust treatment, China relies on the scale effect, structure effect, and technical effect. Compared with other pollutants, industrial dust experiences a better emission reduction effect at its source [56]. The effects of the pollution treatments of industrial waste gas, industrial wastewater, and industrial solid waste are not obvious because they are mostly discharged directly, so the discharge rate is close to 100%. Wastewater treatment technology in China’s forest product industry needs further improvement. In the manufacture of wooden forest products, cooking, hot grinding, and other processes will produce industrial wastewater of different levels of quality. The existing extensive production mode will mix pollutants into the wastewater treatment system, causing certain obstacles to the terminal sewage treatment technology. Effective forest management should be adopted to achieve energy conservation and environment protection [57,58]. The unit of pollutant discharge intensity of Chinese wooden forest products trade is in Appendix A. The treatment of toxic and hazardous wastes containing arsenic and chromium has an average discharge rate of 50%. In terms of the degree of harm to the environment, the pollution treatment at the production end of these pollutants is far from enough. The pollution from chemical oxygen demand (COD) emissions depends on the category of the product. The pollutant emission rate of the 5-day biochemical oxygen demand is relatively low. Volatile phenol only exists in the production process of chemical wood pulp, and its pollution emission rate varies with the change of its production process, and its average value is 53.79%.

From the data related to trade and pollution emissions of wooden forest products in China from 2013 to 2017, the green trade competitiveness indexes of these 10 products were calculated. The overall entropy method is more comprehensive than the traditional entropy weight method due to the introduction of longitudinal comparisons of time and
category. This method is a dynamic evaluation model with analysis of three-dimensional sequential data tables. The use of this method enables the assessment model to analyze more comprehensively the green level of a country’s trade in wooden forest products in terms of time and product category. It can be found that the index values of sawn timber, particleboard, other fiberboards, chemical wood pulp, newsprint and wrapping paper are negative in the rating standard of green trade competitiveness. It shows that these six products are competitive in polluting trade, whereas using classified analysis by its index value, sawn timber, particleboard, newsprint and wrapping paper have low pollution trade competitiveness. Other fiberboards have high pollution trade competitiveness. Chemical wood pulp has medium pollution trade competitiveness. The emission intensity and total emissions of the paper industry are high than those of the wood sector. The index values of plywood, medium density fiberboard, hard fiberboard, and boxboard are positive, indicating that these four products have green trade competitiveness. They were classified and analyzed according to their index values: plywood, medium- and high-density fiberboard. Hard fiberboard has high green trade competitiveness, whereas boxboard has low green trade competitiveness.

5. Conclusions

We constructed an assessment system including environmental trade competitiveness, pollution treatment, and trade scale for evaluating the green level of wooden forest product trade, which aims to make a longitudinal assessment of the current development of wooden forest products from the perspective of green ecology. The overall entropy method was applied to evaluate the green level. China is a case in this study. Pollution emissions of wooden forest in China’s production and processing links are relatively serious. The adoption of the overall entropy method is conducive to the longitudinal comparison of the development of a country’s trade in wooden forest products. This method can more clearly show the trends, and make comparisons of the green level which is based on time series. Compared with the traditional entropy weight method, it is more effective. The results of this study regard the green level of trade in ten wooden forest products with Chinese pollution emission and trade-related data of 10 major traded forest products from 2013 to 2017. The green level of chemical wood pulp and sawn timber trade in China is at a high level. Pollution treatment and trade scale of chemical wood pulp and sawn timber reach a medium level of matching. The trades in particle board, hardboard, newsprint, carton board, and wrapping paper are at medium levels of green. The trades in medium density fiberboard and plywood have poor levels of green and need to improve their green production capacity.

We drew the following conclusions. First, we selected indicators for environmental trade competitiveness, pollution emission, and trade scale, then used the overall entropy method for weighting, improved the lack of cross-sectional data selected by the entropy value method, and constructed a more comprehensive system for the evaluation of the green level of trade in wooden forest products. Secondly, based on the hierarchical scores and comprehensive scores from 2013 to 2017, it is concluded that China’s chemical wood pulp and sawn timber trade has a relatively high level of green, and its pollution treatment and trade development at the end of production have reached a high level of matching. Particleboard, hard fiberboard, newsprint, carton board, wrapping paper and packaging paper are at a relatively good level of green trade, and the trend is relatively stable. Medium density fiberboard and plywood have poor green trade power and need to have improved green production capacity.

Different types of wooden forest products have different levels of green trade, such as “ecological deficit” and “ecological surplus”. Therefore, it is necessary to take into account the differences in different types of wooden forest products in policy-making in order to improve policies such as green trade policies for wooden forest products and production emission restriction. The level of green is related to the measures taken by the state for the manufacturing environment of wooden forest products and the adjustment of trade.
structures. The industrial structure of wooden forest product trade has been optimized and upgraded. Wooden forest products with a relatively high level of green have little advantage in their trade scale. We should pay attention to the economic benefits brought by trade and consider environmental pollution, optimize the structure of wooden forest product trade, and relatively reduce the environmental impact of the wooden forest product trade on the country’s ecological environment. Illegal logging and trade are problems that go beyond one country and one region and need coordinated development of domestic and international governance.

We can put forward the following suggestions. First, we must improve the pollution treatment equipment at the end of the fiberboard and plywood production. The pollution control of the production of wooden forest products is still not in place, and the scientific research investment and policy restrictions on pollution control and treatment in the industry should be increased. The two types of fiberboard and plywood products should speed up technical improvements. Secondly, while increasing the export volumes of products with high added value, attention should be paid to the pollution associated with products. The state should support policy for these producers and subsidize investments in formaldehyde or dust reduction. The above measures would be conducive to the ecological environment and green development, which is also the key to the sustainable development of the trade in forest products.

Author Contributions: W.Y. and G.T. helped in conceptualizing the idea of the study design; T.T.H.V. and W.Y. performed the statistical analysis and contributed to writing—review and editing; G.-Y.M. had an equal contribution and contributed by provided his intellectual insight. All authors have read and agreed to the published version of the manuscript.

Funding: The study presented in this paper is supported by the Philosophy and Social Science Research Programme of Hei Long-jiang Province, China, grant number 19GJD208.

Data Availability Statement: Publicly available datasets were analyzed in this study. This data can be found here: https://data.cnki.net/yearbook/Single/N2019030257; https://data.worldbank.org; http://www.fao.org/home/en/; https://email.mee.gov.cn/.

Acknowledgments: We would like to acknowledge the financial support from the Philosophy and Social Science Research Programme of Hei Long-jiang Province, China, as well as assistance from the School of Economics and Management of the Northeast Forestry University. The authors are grateful to the anonymous reviewers whose comments have contributed to improving the quality of this paper.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

| Category of the Product | The Rate of Discharge of Pollutants. |
|-------------------------|-------------------------------------|
|                         | Industrial dust 40.15%              |
|                         | Industrial exhaust volum 100%       |
|                         | HW21 and HW24 Hazardous waste (arsenic and chromium wastes) 50% |
|                         | Arsenic 50%                         |
|                         | Hexavalent chromium 50%             |
|                         | HW21 and HW24 Hazardous waste (anticorrosive sawdust containing arsenic and chromium) 50% |
| Plywood                 | Industrial dust 6.07%               |
|                         | Industrial exhaust volum 91.47%     |
|                         | Industrial effluents 89.14%         |
|                         | Chemical oxygen demand (COD) 89.14%|
| Chipboard               | Industrial dust 2.02%               |
|                         | Industrial exhaust volum 100%       |
|                         | Industrial effluents 100%           |
|                         | Chemical oxygen demand (COD) 27.52%|
| Medium and high-density fibreboard | Industrial dust 0.65% |
|                         | Industrial exhaust volum 100%       |
|                         | Industrial effluents 90.91%         |
|                         | Chemical oxygen demand (COD) 16.14%|
|                         | Industrial Solid Waste (Sludge) 100%|
Table A1. Cont.

| Category of the Product | The Rate of Discharge of Pollutants. |
|-------------------------|--------------------------------------|
| Hard fibre board        | Industrial exhaust volum 100%        |
|                         | Industrial effluents 90%             |
|                         | Chemical oxygen demand (COD) 16.20% |
|                         | Industrial Solid Waste (Sludge) 100%|
| Other fibreboard        | Industrial exhaust volum 100%        |
|                         | Industrial effluents 90%             |
|                         | Chemical oxygen demand (COD) 16.20% |
|                         | Industrial Solid Waste (Sludge) 100%|
| Chemical wood pulp      | Industrial effluents 100%            |
|                         | Chemical oxygen demand (COD) 32.65% |
|                         | 5-day biochemical oxygen demand 20.22% |
|                         | Volatile phenol 53.79%              |
| Newsprint               | Industrial effluents 100%            |
|                         | Chemical oxygen demand (COD) 8.41%  |
|                         | 5-day biochemical oxygen demand 6.76%|
| Carton board            | Industrial effluents 100%            |
|                         | Chemical oxygen demand (COD) 9.18%  |
|                         | 5-day biochemical oxygen demand 9.89%|
| Wrapping paper          | Industrial effluents 100%            |
|                         | Chemical oxygen demand (COD) 15.44% |
|                         | 5-day biochemical oxygen demand 12.27%|

Appendix B

Table A2. Description of pollutant measurement unit.

| Pollutant Category | Unit                  | Pollutant Category | Unit                  |
|--------------------|-----------------------|--------------------|-----------------------|
| Industrial dust    | kg/m³                 | Industrial effluents| tons/m³               |
| Industrial exhaust volum | m³/m³               | Chemical oxygen demand (COD) g/m³ |
| HW21 and HW21 and HW24 Hazardous waste (arsenic and chromium wastes) | kg/m³ | Industrial Solid Waste (Sludge) tons/m³ |
| Arsenic            | g/m³                  | 5-day biochemical oxygen demand g/ton |
| Hexavalent chromium| g/m³                  | Ammonia            | g/ton                 |
| HW21 and HW24 Hazardous waste (anticorrosive sawdust containing arsenic and chromium) | g/m³ | Volatile phenol g/ton |

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