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Evaluating the International Competitiveness of Vietnam Wood Processing Industry by Combining the Variation Coefficient and the Entropy Method

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Abstract: Indicators measuring industrial international competitiveness are being continuously improved. However, so far, there is no unified perfect indicator to measure the level of international competitiveness of the industry. Based on the market share index (MS), trade competitiveness index (TC), revealed comparative advantage index (RCA), and relative trade advantage index (RTA), we constructed a comprehensive international competitiveness index by combining the variation coefficient and the entropy method. This study aims to compare and evaluate the international competitiveness of the wood processing industry (ICWPI) in Vietnam using a comprehensive international competitiveness index. The data is collected from the top 22 countries and the total import and export volume of the wood processing industry from the repository of official international trade statistics (UN Comtrade) database for 2001–2017. The results found that it is more accurate to use the combined variation coefficient and the entropy method to evaluate the international competitiveness of the wood processing industry, compared to using only a single index. The growth rate of international competitiveness of Vietnam increased rapidly from 2001 to 2007 but slowed from 2008 to 2017. Vietnam has the advantages of natural resources, low labor costs and favorable geographical location. However, the low productivity gains and added industry value have led to a gradual decline in the international competitiveness growth rate of Vietnam's wood processing industry.

Keywords: wood processing industry; international competitiveness; Vietnam; productivity gains; added industry value

1. Introduction

Vietnam's wood processing industry developed gradually in the 1990s, however, growth development has then enhanced since the 2000s [1]. In 2017, wood and processed wood product exports continued to achieve positive results, with a turnover of 5.7 billion USD. This was an increase of 2.7 times compared to 2007 (2.3 billion USD), and occurred despite difficulties such as competition, technical barriers, and requirements for ensuring legal timber origin in many markets [2]. After China, Germany, and Italy, Vietnam is considered as the fourth biggest furniture-exporting developing country in the world [3]. The development of the wood processing industry has significantly alleviated poverty, has increased the employment of mountain farmers, and has improved the social and economic development of mountainous areas [4].

In this new historical context, Vietnam's wood processing industry also faces many new challenges. These are caused by financial crises, the increasingly detailed division of labor in the international market, the decreased demand for wood processing industries in national and international markets, and the increased cost of labor in Vietnam. The international competitiveness of the processing industry has had a significant negative impact, impacting the comparative advantage established using low-cost labor. Countries with resource endowments, such as those in Southeast Asia, have gradually joined the international market, the cost of import and export trade has increased, and green barriers and technical barriers have grown in foreign markets. In addition to trade barriers, domestic market-oriented reforms and processes, technological innovations and other factors also affect the development of Vietnam's wood processing industry [2]. This makes it important to consider ways to break through the new challenges that foreign trade create for the wood processing industry, and ways to adjust the international competitive strategy of Vietnam's wood processing industry.

International competitiveness is an important and a significant concept and consists of two main objectives. First, it enhances the capacity of a country or government to increase their national level of wealth and income. Second, it considers ways to improve the competitive performance position of a country with respect to imports and exports [5,6]. Economic outcomes, including exports, imports, and balance of trade, have become trade-related dealings, because they are associated to cost and prices at an industry-specific level as well as countrywide. Key measures comprise real exchange rates grounded on unit labor costs and consumer prices in tradeable goods. Turner and Dack [7] and Marsh and Tokarick [8] studied procedures of trade competitiveness grounded in relative costs and prices. They observed that these methods have difficulty straight connecting fluctuations in competitiveness built on trade flows. In addition, with these, other indicators such as quantity indicators for exports and imports and the trade balance are also used to measure competitiveness. Overall, the trade competitiveness index (TC), the market share index (MS), the relative trade advantage index (RTA) and the revealed comparative advantage index (RCA) are adopted to evaluate international competitiveness [9–13].

Some researchers between different countries have compared the global competitiveness of the forest-related products. Souza et al. [14] analyzed the competitiveness of Brazilian tropical wood on the worldwide market, using the two approaches of the revealed comparative advantage index and constant market share model. The results show that sawn wood products were beneficial and provided competitive advantages over the evaluated period. Furthermore, Maksymets and Lönnstedt [11] also used a cross-country relative competitiveness index to measure changes in the global competitiveness of forest-related product industries in three countries (the United States (US), Sweden, and Ukraine) during the years before, during, and after the current financial crisis. They revealed that comprehensive measurement of competitive and comparative advantages are very necessary for defining why an industry in a certain country is going to do well or badly.

Parobek et al. [15] used competitiveness indicators (revealed comparative advantage, market share, net exports revealed comparative advantage) to evaluate the competitiveness of nominated central European countries in the European Union (EU) forest product market, with an emphasis on Slovakia. The study found that the comparative advantages change with the level of wood products processing. In specific, the advantages decrease with the increasing value added to the forest products. Sujová and Hlaváčková [16] evaluated and compared the development and level of competitiveness of the wood processing industry in the Czech and Slovak Republics, by establishing indicators based on imported trade data for the forest industry using statistical and mathematical methods. The resulting indicators showed that, even though the wood processing industry produces dynamic imported trade stability and can contribute to the country's spare balance, the industry slowly loses its competitive capability. The low competitive ability of the wood processing industry is due to the limited specialization and expertise of the country in the commodity group. Similar studies to assess the competitiveness of wood products and agriculture in the global markets were completed by Gonuguntla [17], Dieter and Englert [18], Mäkelä [19], Zhang et al. [10], Yercan and Isikli [20] and Hajduchova and Hlavackova [21].

In summary, indicators measuring industrial international competitiveness are being continuously improved based on actual needs. Nevertheless, so far, there is no integrated perfect indicator to quantity the level range of global competitiveness of this industry. As such, using a single indicator or integrated multiple indicators is the best option. Li and Fan [22] selected the RCA, MS, TC, and CA as measurement indexes and weighted each index and time sequence using the entropy method to systematically measure the international competitiveness of the Chinese information and communication technology (ICT) industry. The results show that the international competitiveness of the Chinese ICT industry ranks second place among 15 countries, with a higher level of international competitiveness. Similarly, Chen et al. [23] used MS, TC, and RTA to compare and analyze Chinese wood processing industrial international competitiveness, using the entropy weight method. The study found it was more accurate to use the entropy weight method to assess the international competitiveness of China's wood processing industry compared to using only a single index, and the Chinese wood processing industry has strong international competitiveness. However, the distribution of the index weights obtained by the entropy weight method may appear to have defects in balance [24]. The variation coefficient method can enhance the workload, and mitigate the negative effects of irregular values [25]. Furthermore, combining the variation coefficient and entropy weight method effectively adjusts the problems seen in the entropy weight method [24,26]. Therefore, to minimize the shortcomings of each single indicator, this study applied the RCA, TC, MS, and RTA, and applied the combination of the variation coefficient and the improved entropy method to provide the weight of the individual indicator. This resulted in a comprehensive indicator to evaluate wood processing industrial worldwide competitiveness for each country. The main objective of the current study is to evaluate the international competitiveness of the wood processing industry in Vietnam by using a comprehensive international competitiveness index.

The current study has two major broad objectives: (i) Based on the international competitiveness index (MS, TC, RTA and RCA), we constructed a comprehensive international competitiveness index by combining the variation coefficient and the entropy method on export and import data from the repository of official international trade statistics UN Comtrade database. (ii) To measure the international competitiveness of changes in the wood processing industry of Vietnam using the comprehensive international competitiveness index and compared with the world leading exporters, with analysis of the effect of factor on the comprehensive international competitiveness index. The wood processing industry is understood as the manufacturing and processing of wood and non-timber forest products (rattan, bamboo, neohouzeaua, etc.). These production activities include all levels (woodchip, sawn, dried, semi-finished processing, processing of finished products). Due to the limitation of primary data used to study non-timber forest products in Vietnam, this article only studies the international competitiveness of manufacturing and processing of wood. The main product groups of the wood manufacturing and processing industry include: round wood, wooden products, sawn wood, wood-based panels, wood pulp, wooden furniture, paper and paperboard.

The remainder of this paper is organized as follows. Section 2 introduces the Materials and Methods. We interpret the results in Section 3. Lastly, in Section 4, we present a discussion, and the final section summarizes the conclusions.

2. Materials and Methods

This section has two sub-sections. Section 2.1 shows the method used to compute the international competitiveness index (RCA, RTA, MS and TC). Section 2.2 explains the study's main methodology, which constructs a comprehensive international competitiveness index by combining the variation coefficient and entropy weight method. The details of both methods are discussed below.

2.1. International Competitiveness Index

2.1.1. Revealed Comparative Advantage (RCA)

RCA reflects international competitiveness, and it is often used to analyze a country's export performance for an industry or product. It was suggested by Balassa [27], and it defines the relative share of country (a) export of the product (b) in worldwide exports. It is expressed as follows:

$$RCA_{ab} = (X_{ab}/X_a)/(X_{wb}/X_w) \tag{1}$$

In Equation (1), RCA_{ab} shows the comparative advantage of product b of country a, X_{ab} shows the exports of product b from country a, X_a shows the total exports of country a, X_{wb} shows the world exports of product b, and X_w shows the worldwide total exports of all goods. When RCA > 2.5, the export competitiveness of product b is strong, when 1.25 < RCA ≤ 2.5, the export competitiveness of product b is relatively strong, when 0.8 < RCA ≤ 1.25, the export competitiveness of product b is medium, and when RCA ≤ 0.8, the export competitiveness of product b is low.

2.1.2. Market Share (MS)

MS shows the ratio of a certain product's exports from a country or region to the international exports of that product. The MS index straight reflects product competitiveness, and objectively reflects a country's or region's share of the international market. This indicator is calculated as:

$$MS = X_{ab}/X_{wb} \tag{2}$$

This index is the most direct and simple indicator reflecting the level of an industry's international competitiveness: the greater the value is, the stronger the industry's international competitiveness is.

2.1.3. Trade Competitiveness (TC)

TC is determined by dividing net exports to total trade. The net export is calculated by the difference between the total amount of exports and imports. It usually explains the status of a country's foreign trade balance, and is the core indicator reflecting the role of foreign trade in the domestic economy. It is calculated as:

$$TC_{ab} = (X_{ab} - M_{ab})/(X_{ab} + M_{ab}) \tag{3}$$

In Equation (3), TC_{ab} shows the trade competitiveness index of product b from country a, and M_{ab} represent the import volumes. The TC index ranges from −1 to 1.

When 0.8 < TC ≤ 1, the product b has an outstanding competitive advantage. When 0.5 < TC ≤ 0.8, the product has a higher competitive advantage. When 0 < TC ≤ 0.5, the product b has no significant competitive advantage. The closer the index is to −1, the more competitive the product b is, the closer the index is to 1, the stronger the international competitiveness of the product b is. The closer the index is to 0, the closer the level of competitiveness is to average.

2.1.4. Relative Trade Advantage (RTA)

The RTA was proposed by Vollrath [28]. The RTA reflects the impact of imports and exports on a country's industries, solves the problem of intra-industry trade imbalances, and is an effective way to analyze the international competitiveness of a country's industries.

$$RTA_{ab} = \frac{X_{ab}/X_a}{X_{wb}/X_w} - \frac{M_{ab}/M_a}{M_{wb}/M_w} \tag{4}$$

The variable M_a shows the total imports of country a, M_{wb} shows the world imports of product b, and M_w shows worldwide total imports of total goods.

If the RTA index is less than 0, an industry does not have a comparative advantage, if the RTA index is close to 0, an industry is self-balancing, and if the RTA index is greater than 0, the industry has a comparative advantage.

2.2. Evaluating the International Competitiveness

The entropy-weight method is constructed base on Shannon entropy, initially developed by Shannon [29]. Shannon entropy measures doubt in information and is determined in terms of probability theory. This method is often used to assess the weights used by a technique, and ordering the methods based on their similarity to the ideal solution [30]. The entropy method adequately reflects the information provided by values associated with all the monitoring sections, to balance the relationship among many evaluated objects. This makes it a suitable and useful choice for our study. The subsequent research on Shannon entropy has contributed to the resolution of a range of problems in different disciplines. Examples include: clinical neurophysiology [31], transport systems [32], environmental time series data [33], fault detection [34], environmental conflict [35] and nuclear power plants [26].

The entropy-weight method was explained using the following definition [23,26]. Assume there are n evaluated objects, and each has m evaluation criteria. This forms a decision matrix:

$$X = \begin{bmatrix} X_{11} & X_{12}\ldots & X_{1n} \\ X_{21} & X_{22}\ldots & X_{2n} \\ \cdots & \cdots & \cdots \\ X_{m1} & X_{m2}\ldots & X_{mn} \end{bmatrix} \tag{5}$$

The matrix is then normalized to generate Equation (6):

$$R = \left[r_{ij}\right]_{m\times n} \tag{6}$$

where, r_{ij} is the data of the jth evaluating object on the indicator, and $r_{ij} \in (0,1)$.

Between these indicators, where the bigger value is better, we get Equation (7):

$$r_{ij} = \frac{x_{ij} - \min\limits_{j}\left(x_{ij}\right)}{\max\limits_{j}\left(x_{ij}\right) - \min\limits_{j}\left(x_{ij}\right)} \tag{7}$$

In contrast, where the smaller values are better, we get Equation (8):

$$r_{ij} = \frac{\max\limits_{j}\left(x_{ij}\right) - x_{ij}}{\max\limits_{j}\left(x_{ij}\right) - \min\limits_{j}\left(x_{ij}\right)} \tag{8}$$

The process for calculating the index weight using the entropy-weight method is shown as follows:

The entropy of the ith indicator is determined as:

$$H_i = -\frac{1}{\ln n}\sum_{i=1}^{n} f_{ij}\ln f_{ij}(i = 1,2,\ldots m) \tag{9}$$

where, f_{ij} is the value of specific gravity for each r_{ij} and $f_{ij} = \frac{r_{ij}}{\sum_{j=1}^{n} r_{ij}}$. Assume if $f_{ij} = 0$ then $f_{ij}\ln f_{ij} = 0$.

The weight of entropy of the ith indicator can be determined as:

$$w_i = \frac{1 - H_i}{m - \sum_{i=1}^{m} H_i} \tag{10}$$

where, $0 \le w_i \le 1$, $\sum_{i=1}^{m} w_i = 1$

The variation coefficient weighting method is a method of weighting according to the degree of variation of the observed value of the index compared to the object to be evaluated [36]. This method has been combined with specific other methods in other fields, such as with the grey relation projection method for evaluating water quality [37], and with the analytic hierarchy process (AHP) to evaluate equipment renewal [38]. According to Yan et al. [26], the full process of calculation of the weight based on the variation coefficient is defined as follows:

First, we determine the mean square deviation of the ith influencing factor:

$$\overline{r_i} = \frac{\sum_{j=1}^{n} r_{ij}}{n} \quad (11)$$

$$\sigma_i = \sqrt[2]{\frac{1}{n-1}\sum_{j=1}^{n} (r_{ij} - \overline{r_i})^2}, \quad (i = 1,\ 2,\ \ldots m) \quad (12)$$

where, $\overline{r_i}$ explains the average value of the ith influencing factor and σ_i is the mean square deviation.

We then determine the variation coefficient of the ith influencing factor:

$$E_i = \frac{\sigma_i}{\overline{r_i}}(i = 1,2,\ldots m) \quad (13)$$

Normalizing the variation coefficient of each influencing factor leads to a calculation of the weights as follows:

$$\delta_i = \frac{E_i}{\sum_{i=1}^{m} E_i}(i = 1,2,\ldots m) \quad (14)$$

where, $0 \le \delta_i \le 1$, $\sum_{i=1}^{m} \delta_i = 1$.

The result of the combination of the variation coefficient and the entropy-weight method is presented in Equation (15):

$$\omega_i = \gamma w_i + (1-\gamma)\delta_i \quad (15)$$

where, γ is the preference factor, and $\gamma \in (0,1)$; $A = (\omega_i) = (\omega_1 \omega_2 \ldots \omega_m)$.

After using Equation (15) to calculate the weight of each indicator, the comprehensive evaluation values of m evaluated objects were obtained:

$$V_i = \sum_{i=1}^{m} \omega_i X_{ij} \quad (16)$$

2.3. Data

This study examined the top 22 countries engaged in total imports and exports of the wood processing industry in 2017. These countries include China, the United States, Germany, Canada, Japan, Austria, the United Kingdom (UK), France, Italy, Russia, Sweden, Belgium, Poland, the Netherlands, Indonesia, Finland, Brazil, Malaysia, Spain, Vietnam, Korea, and Mexico. These 22 countries accounted for 75.8% of the world's total gross domestic products (GDP) in 2017 (World Bank database), and for 69.8% of the total import and export volume of the wood processing industry worldwide. The export volume accounted for 72.3% of the world's total, and the import volume accounted for 63.3% of the world's total.

The countries' wood processing industry imports and exports totaled more than $4 billion (UN Comtrade, 2017). Therefore, these 22 countries represent the world's wood processing industry. This study examined 7 groups of commodity codes (HS codes) involved in the wood processing industry (Table 1). The import and export volume data for the wood processing industry for the 22 countries, the import and export data of goods, and the total import and export data of the world's goods all came from the UN Comtrade database (https://comtrade.un.org/data/). The time series was 2001–2017.

Table 1. The commodity codes (HS codes) involved in the wood processing industry.

Category	HS Code
Round wood	4401.10; 4403
Wooden products	4401.21/22; 44.14/15/16/17/18/19/20/21; 960910
Sawn wood	44.06/07/09
Wood-based panels	44.08/10/11/12
Wood pulp	47.01/02/03/04/05/06
Paper and paperboard	4407; 48; 49
Wooden furniture	9401161; 9401169; 9403.30/40/50/60

3. Results

The weight of each indicator (ω_i) was calculated based on the combination of the entropy weights and the variation coefficient method, the values are shown in Table 2.

Table 2. The results of the weight combinations (with $\gamma = 0.5$).

Index (Xij)	Entropy Weight (w_i)	Coefficient of Variation (δ_i)	Combination Weighting (ω_i)
Relative trade advantage index (RTA)	0.241	0.201	0.221
Revealed comparative advantage index (RCA)	0.240	0.205	0.222
Market share index (MS)	0.249	0.212	0.230
Trade competitiveness index (TC)	0.270	0.383	0.327

Table 3 presents the results of the comprehensive international competitiveness index (V_i) for the world highest 22 exporters of the wood processing industry for 2001–2017. Table 3 shows that the calculated V_i value for the 22 selected countries shows that the patterns differed between countries. In general, V_i values have a wide range. To further judge and clearly compare the international competitiveness of the wood processing industry (ICWPI), after finding the V_i index of each country, the study applied the combination weight method to determine the time series weight (the last row of Table 3). This generates the overall level of the average ICWPI index of each country (the last column of Table 3). Figure 1 indicates the V_i values for the world highest 22 exporters of the wood processing industry for 2001–2017. Figure 2 shows the average ICWPI values, with the 17-year value of ICWPI on the horizontal axis and the 17-year average annual per capita GDP growth rate on the vertical axis. The bubble size indicates the average export value of wood products in US dollars.

Table 3. Comprehensive international competitiveness index (V_i) of the 22 selected countries. ICWPI: international competitiveness of the wood processing industry.

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Average ICWPI Index
Canada	1.78	1.74	1.68	1.77	1.72	1.87	1.85	1.72	1.62	1.70	1.67	1.70	1.56	1.77	1.84	1.67	1.71	1.56
Sweden	1.67	1.68	1.65	1.52	1.55	1.88	1.52	1.66	1.80	1.75	1.75	1.80	1.76	1.66	1.56	1.46	1.49	1.49
Indonesia	1.72	1.75	1.59	1.43	1.43	1.71	1.35	1.25	1.18	1.11	0.90	1.06	1.09	1.15	1.32	1.25	1.26	1.16
Finland	1.41	1.37	1.38	1.25	1.23	1.29	1.31	1.00	1.28	1.29	0.96	1.15	1.17	1.27	1.14	1.27	1.25	1.10
Poland	0.94	1.01	1.09	1.14	1.15	1.30	1.07	1.06	1.04	1.05	1.09	1.06	1.08	1.09	1.05	1.07	1.11	0.97
Brazil	1.00	1.05	1.19	1.15	1.09	1.21	1.01	0.96	0.92	0.93	0.81	0.86	0.92	1.00	1.20	1.23	1.24	0.93
Austria	0.73	0.77	0.80	0.74	0.77	1.01	0.85	0.85	0.79	0.78	0.82	0.85	0.81	0.77	0.76	0.76	0.72	0.72
Malaysia	0.66	0.62	0.69	0.66	0.69	0.86	0.69	0.66	0.69	0.68	0.65	0.72	0.69	0.67	0.72	0.66	0.81	0.63
Russia	0.54	0.55	0.50	0.48	0.49	0.55	0.51	0.33	0.12	0.51	0.50	0.54	0.58	0.42	0.54	0.65	0.71	0.46
China	−0.06	0.01	0.07	0.11	0.22	0.36	0.33	0.25	0.29	0.41	0.47	0.55	0.67	0.69	0.74	0.76	0.81	0.42
Vietnam	0.02	0.08	0.16	0.34	0.37	0.55	0.60	0.53	0.44	0.48	0.48	0.49	0.50	0.50	0.51	0.52	0.53	0.40
Italy	0.38	0.40	0.38	0.36	0.38	0.47	0.37	0.42	0.42	0.40	0.40	0.45	0.43	0.43	0.40	0.40	0.45	0.37
Germany	0.31	0.33	0.32	0.31	0.41	0.52	0.42	0.45	0.45	0.42	0.41	0.39	0.37	0.34	0.31	0.30	0.40	0.34
Belgium	0.34	0.33	0.33	0.30	0.34	0.44	0.31	0.33	0.28	0.29	0.28	0.27	0.26	0.22	0.27	0.23	0.26	0.26
Spain	0.18	0.17	0.14	0.13	0.15	0.25	0.16	0.21	0.19	0.30	0.26	0.28	0.27	0.24	0.21	0.21	0.25	0.20
USA	0.08	0.04	0.04	−0.02	0.03	0.12	0.09	0.15	0.17	0.20	0.23	0.21	0.17	0.14	0.11	0.08	0.12	0.12
France	0.09	0.09	0.09	0.06	0.10	0.18	0.10	0.09	0.07	0.06	0.07	0.07	0.06	0.06	0.06	0.04	0.05	0.07
Netherlands	0.01	0.02	0.06	0.02	0.05	0.11	0.04	0.04	0.07	0.08	0.08	0.06	0.06	0.06	0.06	0.05	0.07	0.05
UK	−0.12	−0.10	−0.09	−0.14	−0.10	−0.07	−0.15	−0.10	−0.08	−0.13	−0.12	−0.09	−0.11	−0.13	−0.15	−0.14	−0.14	−0.10
Korea	−0.07	−0.13	−0.11	−0.10	−0.10	−0.11	−0.16	−0.14	−0.11	−0.12	−0.10	−0.10	−0.10	−0.13	−0.17	−0.16	−0.16	−0.11
Mexico	−0.17	−0.17	−0.18	−0.21	−0.16	−0.14	−0.20	−0.22	−0.21	−0.23	−0.22	−0.23	−0.24	−0.23	−0.22	−0.21	−0.22	−0.19
Japan	−0.37	−0.33	−0.34	−0.37	−0.30	−0.30	−0.28	−0.22	−0.25	−0.22	−0.26	−0.29	−0.31	−0.30	−0.28	−0.29	−0.30	−0.26
Combination time serial of weight	0.051	0.053	0.050	0.053	0.057	0.052	0.055	0.051	0.048	0.055	0.060	0.065	0.067	0.068	0.072	0.071	0.072	

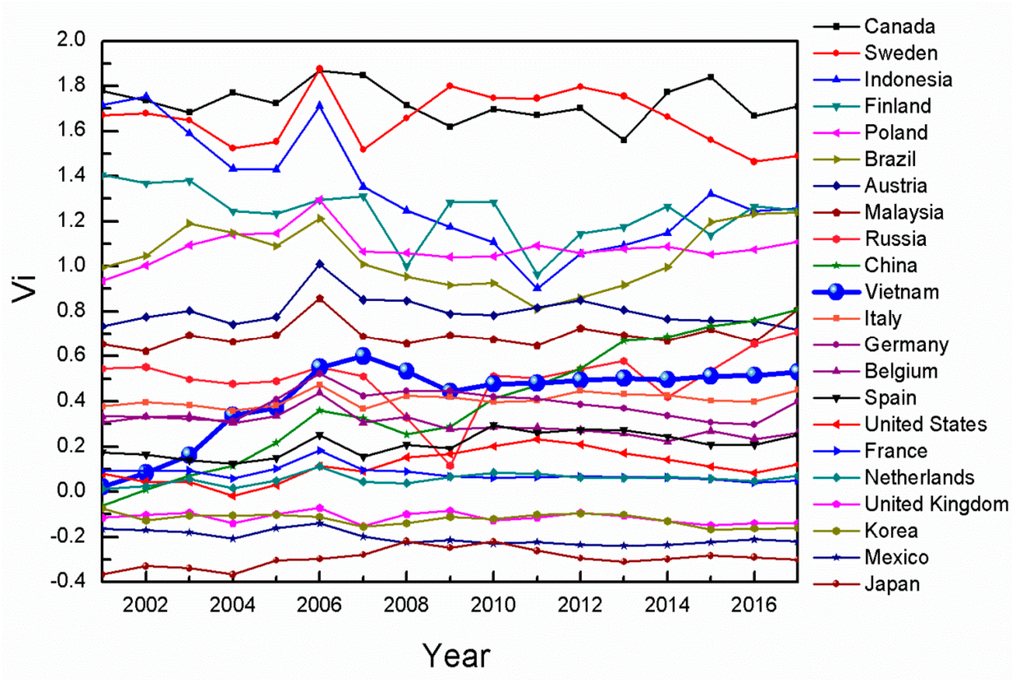

Figure 1. The comprehensive international competitiveness index for the world top 22 exporters of the wood processing industry for 2001–2017.

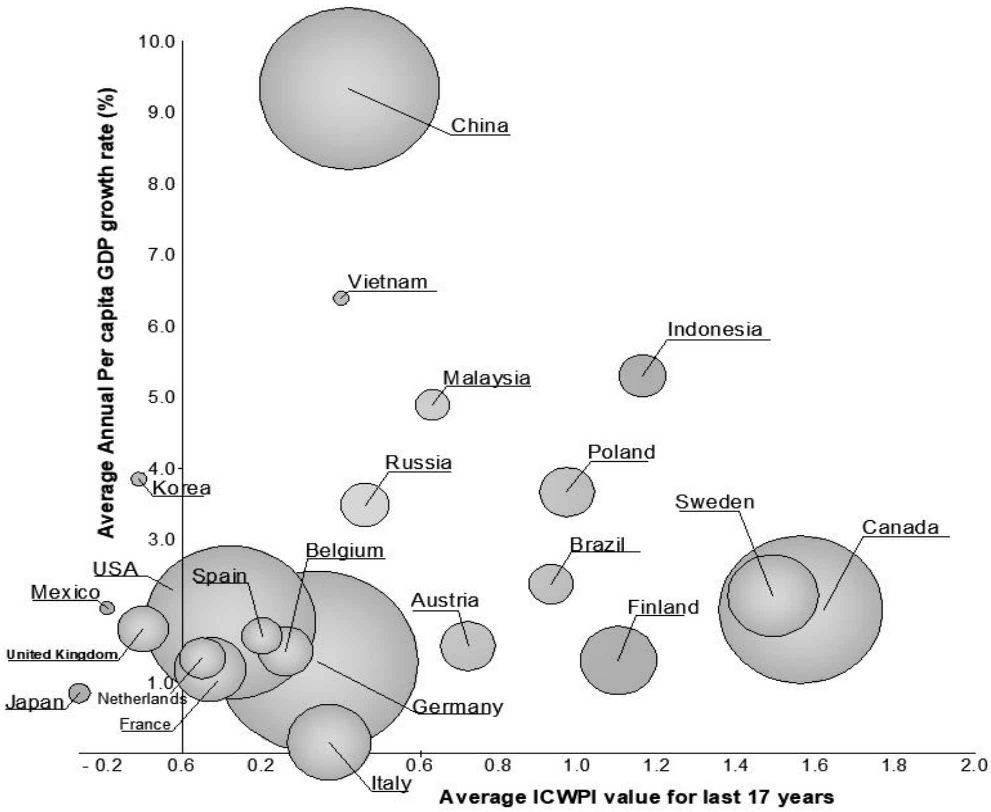

Figure 2. Average ICWPI index of selected countries for 2001–2017.

The results show that only six countries show high international competitiveness in the wood processing industry: Canada, Sweden, Indonesia, Finland, Poland and Brazil. Canada has the highest ICWPI value and shows the highest international competitiveness in the wood processing industry. Germany, China and the US are the three countries with the largest market share in the world, however, they do not have a high index of international competitiveness. This result also shows that two countries (France and Netherlands) had an international competitiveness factor of less than 1. Four countries (United Kingdom, Korea, Mexico, Japan) had a negative international competitiveness value. These are countries that specialize in net imports. Vietnam had a positive international competitiveness value (0.40), ranking 11th out of 22 selected countries. The growth rate of international competitiveness of Vietnam increased rapidly from 2001–2007. In 2007, the growth rate (0.60) increased 30 times compared with 2001 (0.02). However, Vietnam's international competitiveness index fell in 2008 and 2009 (in 2009 it was 0.44). The growth rate also slowed from 2010 to 2017 (in 2017, it was 0.53).

Figure 3 shows the changes in the V_i value and export growth rate in the last 17 years. Most countries have improved their international competitiveness in the wood processing industry. China improved the most, as its V_i value reflects an increasing trend in the study period. This was followed by Vietnam, with the second highest international competitiveness growth rate. Both China and Vietnam have experienced a rapid growth rate in wood products exports. Some countries experienced a decrease in international competitiveness, including Canada, Sweden, Indonesia, Belgium, US, and Japan.

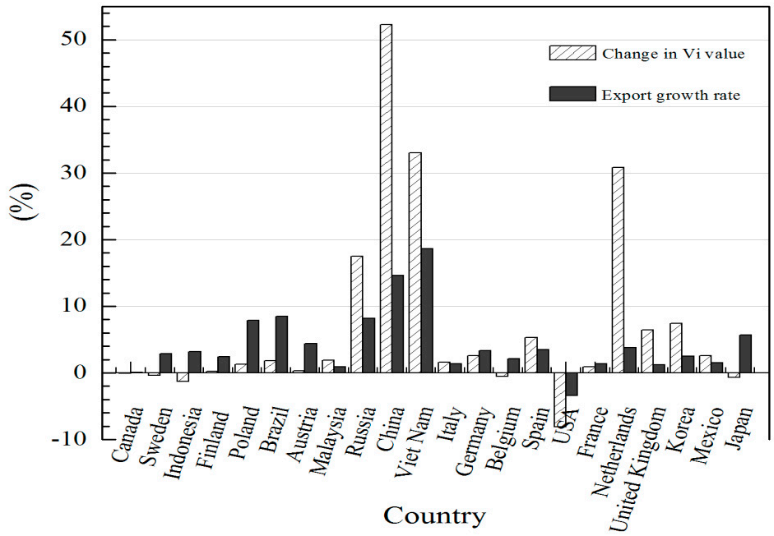

Figure 3. Changes in comprehensive international competitiveness index and export growth rate for selected countries.

4. Discussion

The study used the combination of entropy and variable coefficient methods as an approach to investigate the international trade competitiveness of the wood processing industry among 22 major wood exporting countries. There is no specific research on wood processing industry competitiveness. All previous researchers ([11,14–17] and several others) used RCA, CMS, MS, TC, RTA and net export index to measured competitiveness of forest products. This has not been performed specifically before in wood processing industry research. The key contribution of this research was to construct a comprehensive international competitiveness index and to assess its international competitiveness of changes in the wood processing industry of Vietnam by using a comprehensive international competitiveness index. The new finding of the current research shows that Vietnam's wood processing industry has been increasing its global competitiveness since the last decade, which is a nice indication of the country's economic growth in the forest industry. Nonetheless, it is still a fact that the growth rate of the international competitiveness of Vietnam slowed from 2008 to 2017. These findings are backed by the study of Hieu et al. [1] and Hieu et al. [39], who found that Vietnam has a comparative advantage in wood processing products exports, even though they did not use the international competitiveness index framework.

Using a combination of entropy and variable coefficient methods makes it easier to determine the position and trend of international competitiveness in the wood processing industry of each country. On that basis, it is more efficient to compare, analyze and evaluate international competitiveness in each country's wood processing industry than to use only one indicator. The results of this study reflected the actual situation of international competitiveness in the wood processing industry of selected countries. These results show that countries with international competitiveness of high wood processing industries include Canada, Sweden, Indonesia, Finland, Poland, Brazil, Austria, Malaysia and Russia. These countries all had positive TC, RTA values, and tended to increase (Figure 4a,b). This shows that these countries specialized in net exports. In addition, RCA values tended to increase (Figure 4d), showing there was growth in the proportion of export value of processed wood goods to the country's total export value. The group is made of countries with a lengthy and successful tradition of forest industry, including Finland, Canada, Austria and Sweden. The group also includes nations with an emerging forest sector, such as Poland, Indonesia, Malaysia, and Brazil. These countries all have large forest regions as an abundant factor in manufacturing [40]. Unlike other countries with comparable natural endowments, these countries have managed to create a competitive sector for further processing. Within Asia, China has become an exceptional wood product market, with average annual growth rates of 14.6% and 52.3% respectively, for exports and ICWPC. Referring to the Heckscher–Ohlin theorem, the production of raw wood in these countries is less expensive compared to other countries. These countries therefore export more raw timber than other countries with less favorable resource endowments. This result is understandable, as most of the countries have big natural forest regions at their disposal, that do not generate management expenses as long as they are not harvested [19,40].

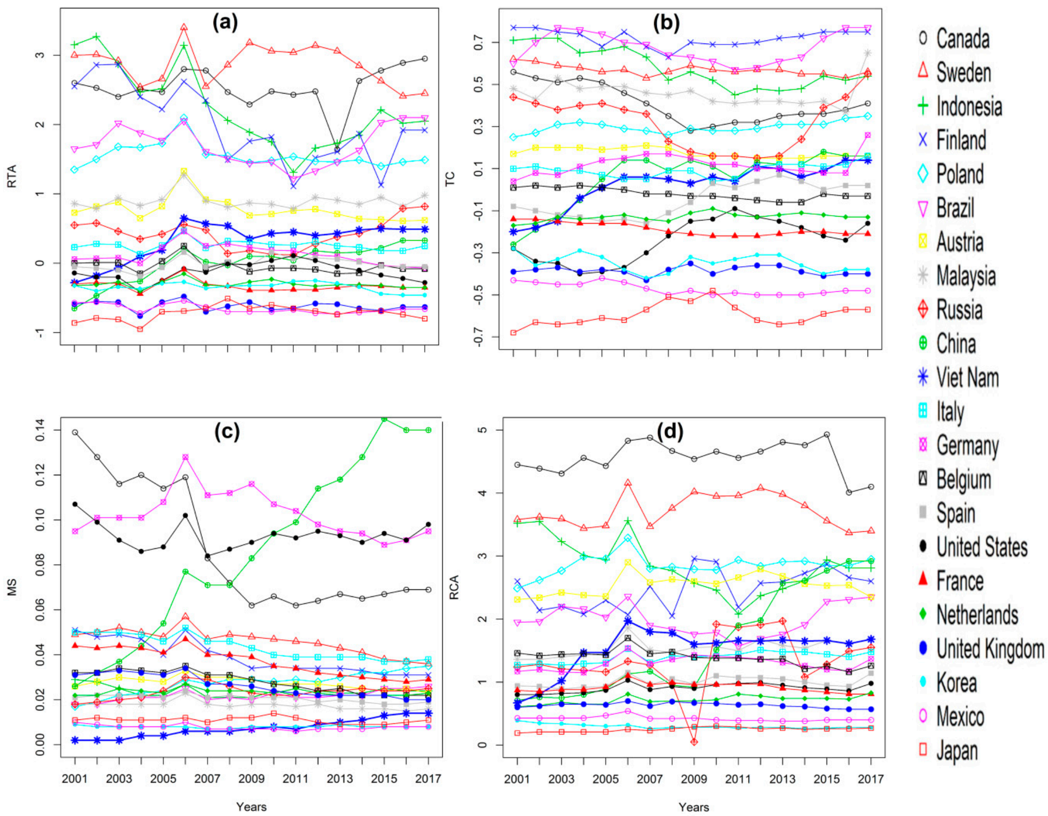

Figure 4. Changes in international competitiveness index values for selected countries for 2001–2017: (**a**) Relative trade advantage index (RTA); (**b**) Trade competitiveness index (TC); (**c**) Market share index (MS) and (**d**) Revealed comparative advantage index (RCA).

The comparative advantage of Finland can be due to the abundance of lumber and water and the huge population that has enabled the pulp and paper industry to prevent disputes over unpleasant odors. The economy of Austria is strongly incorporated with nations of Eastern Europe, creating a favorable climate for cross-border cooperation and investments in the wood industry. Austrian wood companies, one of the European leading innovation investments, outsourced Eastern Europe with more skill intensive manufacturing phases. In these nations, this has improved productivity [41–43]. In addition, Austria is the largest foreign direct investor in Eastern Europe'wood sector [44–46]. The Austrian wood panel sector is highly oriented toward export, which accounted for 87% of the total production in 2007. In furniture products, Sweden and Finland had comparative advantages, particularly, extensive technology use, high levels of technical competence, automation, and design [43,47]. In contrast, due to lower than average export performance, Canada, the US, Finland and France lost market shares (Figure 4c). In terms of net exports, owning to an elevated rate of imports, France and the US have an adverse trade balance in wood products (TC < 0). This applied to wood furniture and woodworking products [40].

Over the past decade, many Western countries' timber processing industries have experienced costless challenges connected with rising labor and energy costs, price pressures, limited upgrade possibilities, and low investment expenditures. Germany is a country with a large market share (the average value of MS is 10.3%), however, international competition is not high (average values of TC and RTA are low). For the wood-panel and furniture industry since 2000, Germany has been characterized by reduced investments and innovations. This was triggered by external factors such as a reduction in consumption of national furniture and increased pressure through imports from abroad, particularly Asia. In reaction, parts were strongly outsourced to Poland by German furniture manufacturers. These enabled them to stabilize their manufacturing and gains in competitiveness. Due to this phase, however, and further impacted by company mergers and relocation, the German furniture industry lost over 25% of its staff over less than a decade. The amount of new employment in Eastern Europe has not counterbalanced these losses [43,44].

Within Asia, China, Indonesia, Malaysia, and Vietnam all experienced a rapid increase in average annual per capita GDP growth rate and export growth rate (Figures 2 and 3), especially China and Vietnam. This is the basis for the increased international competitiveness in processed wood products within these countries. China's export market for processed wood products rose very fast. In 2017, it became the world's biggest market share exporter (MS = 14.0%), surpassing the nations with the largest traditional export market share worldwide, such as the US, Canada, and Germany (Figure 4c). During this time period, China's exports in wood products multiplied, it particularly experienced high performance with respect to exports of wood furniture and wood products (panels, parquets) [40].

Over the last decade, the global trade in wood products has developed considerably. This trade was connected to development in packaging and shipping logistics and reduced obstacles to world trade [48]. This global shift gradually decreased the large exports and market share of the wooden furniture trade (e.g., Italy, Germany, US) from high-income countries. Because of their cheap labor and production costs and location benefits, these countries lost their comparative advantage to Eastern Europe, Asia, and Latin America. The decline of jobs in the US wood processing sector was also associated with increased imports of semi-finished and finished furniture from low-cost nations such as China, Vietnam, or other Southeast Asian countries. This resulted in demands of anti-dumping requirements in the US and the EU [43,49]. The fact that wood products are a non-essential item and can be postponed in purchasing suggests that sales of wood products will be the first to be impacted during an economic downturn [50]. In 2008, as an example, the global financial crisis caused demand for the wood processing industry in the international market to become sluggish.

Most nations with elevated absolute development in exports at the moment encountered only low (relative) growth rates in exports. This was especially true for leading timber exporters like Canada, the US, Germany or other Western European nations. In comparison, there was elevated relative growth in several countries with reduced export development in absolute terms. These nations may expect a high position in the global timber markets. The timber export growth rate of a country and its competitiveness effect (Figure 3) has a clear positive relationship. Nearly all export growing countries are distinguished by a high rate of growth in competition growth rate on the global timber markets. In contrast, despite significant positive overall export growth, most of the major exporters experienced negative competitiveness effects. This finding proves the assumption: in the future, countries with high export growth rates and competitiveness growth rates will be able to gain significant additional market shares.

Vietnam has recently experienced a high growth rate of GDP per capita. The average over 17 years was 6.39%, ranking second after China in the group of selected countries. This was one of the factors supporting the development of the wood processing industry. The export turnover of processed wood increased rapidly, with an average growth rate of 18.6%. The international competitiveness of Vietnam's wood processing industry is still not high (ranked 11th among selected countries), despite the recent rapid growth (ranked second after China). This result was due to increases in TC, RTA, RCA, and MS coefficients (average RTA and TC values over 17 years were greater than 0, RCA = 1.51, TC = 0.02, RTA = 0.30). These coefficients all show that Vietnam's wood processing industry has a comparative advantage (Figure 4). This growth is due to a rapid increase in Vietnam's processed wood products exports, and a reduced import rate. The rapid increase in exports mainly comes from two types of furniture products and woodchips. Vietnam's processed wood products are mainly exported, and the domestic consumption rate is small, at only approximately 20% [51].

During the study period, the export sales of wood processing goods exceeded many other significant commodities, including rice, pepper, rubber, and coffee [1]. The furniture industry grew exponentially with the improved trade possibilities. There were about 4000 wooden furniture manufacturers in Vietnam in 2013, with 16% receiving foreign direct investment [52]. Among other factors, the availability of comparatively cheap labor and a geographical positional advantage are key drivers of Vietnamese forest enterprises for the increasing popularity among national and foreign investors [3,53]. Previous research studies about the competitiveness of the Asian furniture manufacturing and forest enterprise have shown that reduced production costs provide a primary advantage for the regional enterprises [4,50]. Vietnam is one of the countries in this group.

Vietnam's forest area expanded by about 5 Mha in the 25 years from 1990 to 2015 (from 9 Mha in 1990 to 14 Mha in 2015) [54,55]. In this increase, planting activities played a significant role [56]. Vietnam planted forests which covered about 3.6 Mha of land in 2015. It is anticipated that this land coverage will increase to 4.15 Mha by 2020 [57]. Before 2010, the amount of imported wood in processing products consistently accounted for approximately 70% of the total demand for wood in processing and production. In 2013, this proportion fell to approximately 40%. In 2017, the amount of imported wood used for processing accounted for only approximately 25% of total production demand of raw materials [2]. The area covered by plantation forests in Vietnam grew rapidly, with an average growth rate of 5.5% per year (107.8 thousand ha per year) from 1990–2015 [57]. The production of timber harvested from planted forests increased rapidly, with an average growth rate of 8% per year [58]. Vietnam's export of wood and wood products is a significant component of the country's economy. The country is now the biggest exporter of hardwood woodchips in the world and the fourth largest exporter of wood furniture. Recent studies from industry analyst Resource Information Systems Inc (RISI) of Vietnam's woodchip exports found that hardwood woodchip exports to Japan, China, Korea, Taiwan, and India amounted to 7.9 M bone dry metric ton (BDMT) in 2015. This was almost all acacia, making Vietnam the world's biggest exporter of hardwood woodchip [59]. The product was mainly rubber wood in the south and acacia in central and northern Vietnam [60].

Vietnam has advantages in natural resources, low labor costs, skilled manual labor, favorable geographical position, and a high demand for its inexpensive products. This led to an increase in the country's international competitiveness of processed wood products during the study period. Although the export market shares of processed wood products in Vietnam increased, the overall proportion remained small. In 2001, it accounted for 0.16%, and in 2017, it accounted for 1.39%

(Figure 4c). According to Porter (1998), the growing export numbers may be due to either: (1) incremental capital inputs (i.e., labor, raw materials, and number of manufacturing equipment), which increase export growth, or (2) sector productivity development which stimulates export performance. Actual productivity gains are the prime determinant to increase export performance and improve competitiveness. However, Vietnam wood-processing factories have comparatively small production scales in terms of capital investment, number of staff, manufacturing capacity and design [39]. Previous research found relatively low productivity gains in the Asian furniture industry: technology productivity gains were 22%, human capital productivity gains were 6%, and industrial growth was accounted for based on incremental capital inputs (raw material is 14%, labor is 18%, and capital is 40%). As such, incremental capital inputs have been the primary growth driver for the Asian furniture industry [50], this is also true for Vietnam. The cheap production inputs available in Vietnam appear to have propelled industrial growth through incremental inputs rather than actual productivity gains. As such, the low productivity gains and low industry added value have resulted in a gradual decrease in Vietnam's wood processing industry global competitiveness growth rate. This suggests that to increase productivity and improve competitiveness, the government should try to encourage and accelerate technology transformation and industrialization in the wood processing industry [61]. Restructuring the sector and integrating the essential aspects of design and marketing to be the strategy for the Vietnam wood processing industry's strategy for sustainable development [62].

5. Conclusions

Based on the international competitiveness index (MS, RCA, TC, RTA), this study constructed a comprehensive international competitiveness index by combining the variation coefficient and the entropy method. This study aimed to evaluate the international competitiveness of changes in Vietnam's wood processing industry using a comprehensive international competitiveness index and compared with the world leading exporters. For this purpose, the current study has been implemented based on the panel data of the top 22 countries in 2017 and the total import and export volume of the wood processing industry from the UN Comtrade database for 2001–2017.

The study concluded the following: First, using the combination of the variation coefficient and the entropy method is more accurate than using only a single indicator to evaluate the international competitiveness of the wood processing industry. This mitigates the lack of evaluation of individual indicators. Second, from 2001 to 2017, Vietnam's wood processing industry has improved rapidly, benefiting from Vietnam's inexpensive labor and having a cost advantage in the international market. In addition, advantages in natural resources, skilled labor workers, favorable geographical location, and high worldwide demand for Vietnam's inexpensive products has increased Vietnam's international competitiveness with respect to processed wood products. However, the growth rate of international competitiveness of Vietnam slowed from 2008 to 2017. In 2008, the global financial crisis caused demand for the wood processing industry in the international market to become sluggish. The low productivity gains and added industry value has led to a gradual decline in the international competitiveness growth rate of Vietnam's wood processing industry.

The analysis above reveals two recommendations. First, Vietnam should accelerate the transformation and upgrading of its wood processing industry. It will be important to increase research investments and talent cultivation in the wood processing industry. This includes actively promoting the technological innovation of the wood processing industry, and improving production. The second key recommendation is to increase the added value of products in Vietnam's wood processing industry. This will ensure that product quality meets international leading standards, will produce high value-added products, and continuously meet the needs of consumption upgrades and diversification. This will ultimately result in improvements in Vietnam's wood processing industry's international competitiveness. Restructuring the industry and incorporating the vital elements of design and marketing to be the strategy for the sustainable development of Vietnam's wood processing industry.

Author Contributions: The following is the description of the authors' contribution. First, T.T.H.V. and G.T. helped in conceptualizing the idea of the study design. Second, N.K and M.Z. performed the statistical analysis and contributed to writing (review and editing). Hence, N.K. and T.T.H.V. had an equal contribution. B.Z. and T.V.N. contributed in the collection of data and provided their intellectual insight.

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