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The Status, Trend, and Global Position of China's Forestry Industry: An Anatomy Based on the Global Value Chain Paradigm

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Abstract: This study aims to systematically examine the developmental attributes and trends within China's forestry sector through the lens of a global value chain (GVC) framework. To this end, this research analyzes the Organization for Economic Co-operation and Development Inter-Country Input–Output (OECD-ICIO) database, using a cohesive set of GVC methods, including the forward decomposition of industry value-added, an assessment of industry upstream and downstream positions, the decomposition of export values, and analysis of trade competitiveness indicators. The trajectory of China's forestry industry hinges upon the interplay between foreign demand and domestic demand. The results reveal a transition in China's forestry sector development model from export-focused to a domestically driven approach. The proportion of value-added that is devoted to meeting domestic demands within the wood processing and papermaking industries has surged to 76% and 82%, respectively. Among the major economies, China has the highest output upstream index and input downstream index in the forestry industry, playing a vital role in propelling and pulling other industries into the global value chain system. The proportion of domestic added-value in China's forestry industry exports ranks among the top, reflecting strong self-sufficiency in export production. Although China's forestry industry possesses a high world market share, its overall international competitiveness is weak, especially with clear signs of weakening comparative advantages in the wood processing industry.

Keywords: global value chain; value-added decomposition; forestry industry competitiveness

Citation: Jiang, Y.; Su, H. The Status, Trend, and Global Position of China's Forestry Industry: An Anatomy Based on the Global Value Chain Paradigm. *Forests* **2023**, *14*, 2040. https://doi.org/10.3390/f14102040

Academic Editor: Davide M. Pettenella

Received: 12 September 2023
Revised: 10 October 2023
Accepted: 11 October 2023
Published: 12 October 2023

1. Introduction

In recent years, a conspicuous revival in trade protectionism, coupled with the adverse impacts of the global pandemic on international supply chains, has cast a shadow of doubt on the potential for consistent and enduring expansion in global trade. The escalation of geopolitical tensions further amplifies the uncertainty surrounding the trajectory of global economic and trade development. Nevertheless, the fundamental characteristics of interdependence in the global economic structure remain impervious to transient international conflicts. For example, tackling climate change stands as a global issue; no solitary country or nation can effectively address it in isolation. This endeavor concurrently serves as the most direct and pragmatic application of the concept of a "community of shared human destiny". While the impetus of globalization might have waned, its fundamental direction is irreversible. Extended periods of economic integration have formed a global resource allocation model of "buy globally, sell globally", with forest products as international commodities deeply embedded in the global economic cycle.

The global demand for forest products continues to rise, driven by factors such as population growth, improved living standards, prolonged life expectancy, and low-carbon development. Meanwhile, the extended lifecycle and multifunctional attributes of forest resources have established a bottleneck within the worldwide timber supply capacity.

Disparities in forest resource endowments, levels of forest management, wood processing capacities, and downstream market scales are the fundamental prerequisites for engaging in international trade involving timber and wood products. The evolution of worldwide industrial and value chain structures plays a motivating role in the market mechanism of global forest products. This dynamic functionally regulates the production and consumption patterns of forest products in various countries, thereby fostering a global equilibrium in supply and demand dynamics.

China is one of the largest countries in the world regarding the production, consumption, and trade of forest products. For this reason, its trade pattern characterized by large imports of raw materials (e.g., logs, sawn timber, and wood pulp) and significant exports and finished products (e.g., paper products, wooden furniture, wood-based panels, and wooden articles) is a clear manifestation of the global value chain (GVC) paradigm. Nevertheless, compared to greatly developed economies in the US and Europe, China still faces issues such as the scarcity of natural resources, a large but relatively underperforming forestry sector, and a lack of robust core competitiveness. With a declining birth rate and accelerated aging, signs of labor shortage have emerged, posing significant challenges to the labor-intensive forestry industry. Furthermore, ongoing global economic deceleration, accompanied by persistent trade tensions and amplified opposition to economic globalization, has culminated in China experiencing diminished external demand. Against this backdrop, accelerating the construction of a new development pattern, dominated by the domestic big cycle while mutually promoting interactions between international and domestic dual cycles, has become an inherent requirement for the high-quality development of China's forestry industry. Therefore, analyzing developmental trends and fluctuations in China's forestry industry under the new international political and economic situation is helpful not only for discerning the future direction of China's forestry industry but also for anticipating changes in the global supply–demand pattern of forest products.

In the international economic community, research on global value chains initially appeared with concepts such as the intermediate product trade, supply chain trade, or vertical specialization [1,2]. Only in the past decade or so has it been more commonly expressed as global value chains or value-added trade. As early as the 1970s, trade in intermediate goods attracted the attention of economists. However, because data on intermediate goods and final goods are difficult to obtain, relevant research has not made significant progress. Although intermediate products and final products can be visually distinguished based on HS codes and their product descriptions, the trade in intermediate products cannot be completely and comprehensively identified. Thanks to the development of the inter-country input–output model, the research paradigm of global value chains has expanded from qualitative analysis and specific case studies to quantitative analysis and general international comparisons, allowing for a more systematic discussion of the effect that globalization has on economic growth, unemployment, and income inequality [3–7]. Value-added export accounting is mainly based on the structural decomposition analysis of the input–output model, which decomposes the gross export of a certain industry into value-added from different sources. On the basis of a single-country input–output table, an industry's export can be decomposed into the value-added of each domestic industry and the import, but the latter part cannot be traced back to the value-added of trading partners. On the basis of the inter-country input–output table, the gross export of a certain industry can be completely decomposed into the value-added of domestic industries and the value-added of foreign industries.

The robust progression of GVC research owes its advancement to the utilization of international input–output tables as foundational data and the employment of value-added accounting as a pivotal analytical instrument. In recent years, the GVC has had too much room for further research due to the unceasing expansion of international input–output databases, such as the World Input–Output Database, the Organization for Economic Cooperation and Development's International Input–Output Tables, the Asian Development Bank's Multiregional Input–Output Tables, and the Global Trade Analysis Project

Database [8–11]. A comparison of different databases can be found in Taglioni and Winkler (2016) [12]. Subsequent to China's accession to the World Trade Organization (WTO), the notable prominence of processing trade has prompted the exploration of value-added trade within the context of a gross trade volume, emerging as a focal point of interest within the international economic discourse. Koopman et al. (2014) introduced a comprehensive framework for decomposing the value-added of export trade into four primary components: domestic value-added in exports, returned domestic value-added, foreign value-added, and double-counting [13]. However, the scope of this framework is confined solely to decomposing one country's aggregate exports. Wang et al. (2013) further extended this approach to involve bilateral, industry, and bilateral-industry levels, establishing a multidimensional method for dissecting export trade that is value-added [14]. Wang et al. (2022) conducted forward and backward decompositions of industry value-added and final products, respectively [15]. This methodology aimed to discern between conventional trade and GVC trade while also generating indices to quantify both forward and backward GVC involvement. Miroudot and Ye (2021) posited that the results of existing export value decomposition depend on the perspective (world, country, bilateral) and the definition of double-counting, and researchers need to choose appropriate methods for different problems [16]. Thus, researchers should meticulously select methodologies tailored to specific problems. Innovatively, Borin and Mancini (2023) introduced a streamlined analytical structure to involve various decomposition techniques focusing on the key content of value-added trade research [17].

According to the GVC paradigm, studies on the development of China's forestry industry have three main categories: (1) through case studies, a qualitative analysis of China's unique role in global forest product production and sales chains can be obtained, as well as its indispensable role in global forest governance; (2) employing decomposition methods can quantify the value composition of China's foreign trade in the forestry sector, accompanied by cross-national comparative evaluations; and (3) the decomposition results can be used as either dependent or independent variables in econometric analysis, such as the determinants shaping alterations in GVC engagement. Sun et al. (2009), in a case study, compared the similarities and differences of the Mozambique–China, Russia–China, and New Zealand–China forest product value chains, showing the essential role of China in promoting global and sustainable forest management [18]. Then, Kaplinsky et al. (2011) scrutinized the effect of Gabon's transition in timber export destinations, shifting from Europe to China, on its timber industry [19]. The results revealed that Gabon transitioned toward exporting semi-processed goods, a consequence driven by comparative advantages. This shift yielded augmented economic and social advantages for Gabon. Applying the GVC decomposition technique, Jiang and Chen (2016) examined the trade competitiveness of China's forestry sector [20]. Their analysis indicated a decline of three percentage points in the proportion of domestic value-added within China's forestry industry exports. Jiang et al. (2018), based on the updated version of WIOD data, compared China's forestry industry development before and after the global financial crisis, finding that the domestic value-added in China's forestry industry exports went through a process of first declining and then rising [21]. Su et al. (2020) used data from the Organization for Economic Cooperation and Development—Trade in Value-added (OECD-TIVA) database to evaluate the international competitiveness of China's forestry industry [22]. The findings revealed that China's forestry industry's forward GVC participation increased while the backward one declined, constantly improving its position in the GVC. Employing regression analysis, Xiong (2019) examined the determinants influencing the GVC position index in the forestry industry, indicating the significantly positive effect of overall export complexity and the number of patent applications in the economy [23]. Moreover, Hou et al. (2023) calculated the GVC involvement within China's provincial-level timber industry and scrutinized its constructive influence on the total factor productivity across various provinces' timber sectors [24].

However, the generalizability of conclusions from case studies is challenging due to their context-specific nature. Deliberations regarding international competitiveness based on GVC decomposition outcome, predominantly concentrate on export accomplishments, disregarding foundational facets of production and consumption. Moreover, the econometric scrutiny of GVC indicators remains insufficient in addressing the issue of endogeneity arising from reverse causality. This paper's substantive contribution lies in its cohesive GVC analysis of value-added flow within the forestry sector, including the trajectory from initial inputs to ultimate consumption, coupled with an exploration of trade competitiveness. Therefore, this research provides a systematic portrayal of China's forestry industry's developmental status and intrinsic attributes, providing future research with new insights into China's forestry industry.

2. Materials and Methods

2.1. Data

Considering aspects such as update frequency, broad economic representation, and accessibility, this paper selected the Organization for Economic Co-operation and Development Inter-Country Input–Output Table (OECD-ICIO table) as the foundational dataset. The latest version of the OECD-ICIO database was released in November 2021, in a period from 1995 to 2018, covering 66 distinguishable economies and 45 industries, with an increase in 3 economies and 9 industries compared to the previous version. Collectively, these 66 economies contributed to 93% of the global GDP and 92% of total global exports, while the remaining part of the global economy was referred to as "the rest of the world". The official OECD website has more details regarding this database's structure and its application analysis. Within the OECD-ICIO table, two distinct codes pertain to the forestry sector. Specifically, Industry Code 16 denotes wood processing and wood products, whereas Industry Code 17T18 covers papermaking and paper products. According to the timeline of the "Belt and Road Initiative", this analysis focuses on the years 2012, 2014, 2016, and 2018. Figure 1 displays the basic structure of the OECD-ICIO table. Both data management and quantitative analysis have been performed in the R4.1.2 software.

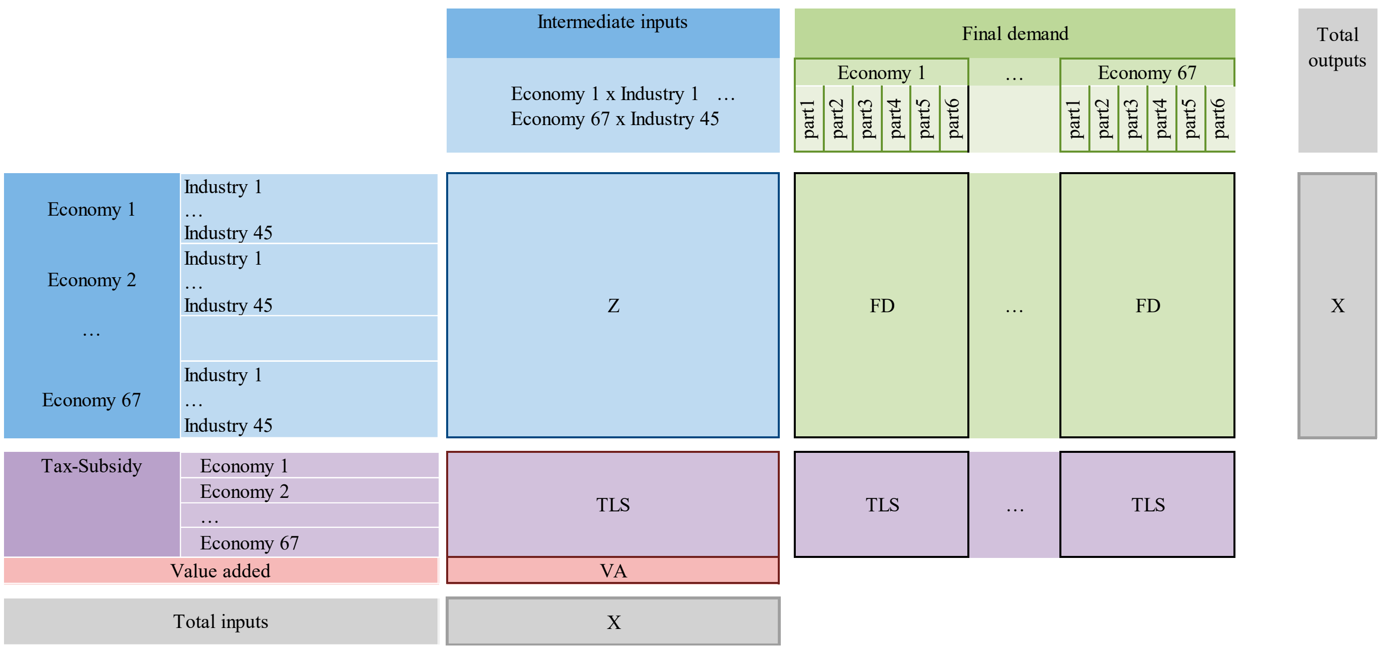

Figure 1. Structure of the OECD-ICIO table.

2.2. Decomposition of Industry Value-Added

Let X symbolize the output vector, A denote the input–output coefficient matrix, Y represent the final demand vector, B signify the Leontief inverse matrix, and V stand for the value-added coefficient matrix. Let s and r represent two countries, and 1 and 2 represent two industries. Then, the following equation represents this two-country, two-industry, value-added decomposition model:

$$\begin{aligned} VBY &= \begin{bmatrix} v_1^s & 0 & 0 & 0 \\ 0 & v_2^s & 0 & 0 \\ 0 & 0 & v_1^r & 0 \\ 0 & 0 & 0 & v_2^r \end{bmatrix} \begin{bmatrix} b_{11}^{ss} & b_{12}^{ss} & b_{11}^{sr} & b_{12}^{sr} \\ b_{21}^{ss} & b_{22}^{ss} & b_{21}^{sr} & b_{22}^{sr} \\ b_{11}^{rs} & b_{12}^{rs} & b_{11}^{rr} & b_{12}^{rr} \\ b_{21}^{rs} & b_{22}^{rs} & b_{21}^{rr} & b_{22}^{rr} \end{bmatrix} \begin{bmatrix} y_1^s & 0 & 0 & 0 \\ 0 & y_2^s & 0 & 0 \\ 0 & 0 & y_1^r & 0 \\ 0 & 0 & 0 & y_2^r \end{bmatrix} \\ &= \begin{bmatrix} v_1^s b_{11}^{ss} y_1^s & v_1^s b_{12}^{ss} y_2^s & v_1^s b_{11}^{sr} y_1^r & v_1^s b_{12}^{sr} y_2^r \\ v_2^s b_{21}^{ss} y_1^s & v_2^s b_{22}^{ss} y_2^s & v_2^s b_{21}^{sr} y_1^r & v_2^s b_{22}^{sr} y_2^r \\ v_1^r b_{11}^{rs} y_1^s & v_1^r b_{12}^{rs} y_2^s & v_1^r b_{11}^{rr} y_1^r & v_1^r b_{12}^{rr} y_2^r \\ v_2^r b_{21}^{rs} y_1^s & v_2^r b_{22}^{rs} y_2^s & v_2^r b_{21}^{rr} y_1^r & v_2^r b_{22}^{rr} y_2^r \end{bmatrix} \end{aligned} \tag{1}$$

The results of value decomposition according to forward linkage are shown in the rows of the matrix. For example, the value-added of industry 1 in country s can be decomposed into the following four parts:$v_1^s b_{11}^{ss} y_1^s$, $v_1^s b_{12}^{ss} y_2^s$, $v_1^s b_{11}^{sr} y_1^r$, $v_1^s b_{12}^{sr} y_2^r$. The first two items are absorbed by the country, s, meeting domestic demand, while the last two items represent the value-added export of country s (including direct and indirect channels), meeting foreign demand.

2.3. Upstream and Downstream Measures of the Industry

Let i be the industry, x_i show the total output of that industry, z_{ij} signify the intermediate goods supplied to industry j, and f_i denote the final use. From the perspective of the output, let the input coefficient be:

$$a_{ij} = z_{ij}/x_j, \tag{2}$$

Then, the output of i can be written as:

$$x_i = f_i + \sum_j a_{ij} x_j, \tag{3}$$

With continuous substitution, we can obtain the following equation:

$$x_i = f_i + \sum_j a_{ij} f_j + \sum_{jk} a_{ik} a_{kj} f_j + \sum_{jkl} a_{il} a_{lk} a_{kj} f_j + \cdots, \tag{4}$$

which can be seen as the output supply chain of industry i.

From the input perspective, the output of the industry, x_i, is equal to the primary input v_i plus the intermediate goods purchased from each industry $\sum_j z_{ji}$. Let the output coefficient be:

$$b_{ji} = z_{ji}/x_j \tag{5}$$

Then, the input of i can be written as:

$$x_i = v_i + \sum_j b_{ji} x_j, \tag{6}$$

After continuous substitution, the input demand chain for industry i can be obtained.

According to the definition by Antras et al. (2012) [25], the following equation represents the output upstream degree of industry i:

$$u_i = 1 \cdot \frac{f_i}{x_i} + 2 \cdot \frac{\sum_j a_{ij} f_j}{x_i} + 3 \cdot \frac{\sum_{jk} a_{ik} a_{kj} f_j}{x_i} + 4 \cdot \frac{\sum_{jkl} a_{il} a_{lk} a_{kj} f_j}{x_i} + \cdots, \tag{7}$$

which can also be seen as the average distance between the industry and the final demand.

According to Miller and Temurshoev (2017) [26], the following equation represents the input downstream degree of industry i:

$$d_i = 1 \cdot \frac{v_i}{x_i} + 2 \cdot \frac{\sum_j v_j b_{ji}}{x_i} + 3 \cdot \frac{\sum_{jk} v_j b_{jk} b_{ki}}{x_i} + 4 \cdot \frac{\sum_{jkl} v_j b_{jk} b_{kl} b_{li}}{x_i} + \cdots, \tag{8}$$

and this can be seen as the average distance between the industry and the initial input. In the specific calculation process, we use matrix operations to process the OECD-ICIO table.

2.4. Decomposition of Industry Export Value

Currently, the most refined method of export value decomposition is that of Wang et al. (2013), which we use in the decomposition of value-added in forestry industry exports [14]. Suppose there is a 3×2 (3 countries, 2 sectors) input–output model, where s represents the exporting country, r is the direct importing country, t shows the third country, E indicates the gross export vector, Y denotes the final demand vector, A signifies the input–output coefficient matrix, X presents the total output vector, V shows the value-added coefficient vector, B is the international Leontief inverse matrix, and L represents the domestic Leontief inverse matrix. Then, exports from s to r can be decomposed into 16 items according to the following accounting framework:

$$\begin{aligned} E^{sr} &= (V^s B^{ss})' * Y^{sr} + (V^s L^{ss})' * (A^{sr} B^{rr} Y^{sr}) + (V^s L^{ss})' * (A^{sr} B^{rt} Y^{sr}) \\ &+ (V^s L^{ss})' * (A^{sr} B^{rt} Y^{rt}) + (V^s L^{ss})' * (A^{sr} B^{rt} Y^{tr}) \\ &+ (V^s L^{ss})' * (A^{sr} B^{rt} Y^{rs}) + (V^s L^{ss})' * (A^{sr} B^{rt} Y^{ts}) + (V^s L^{ss})' * (A^{sr} B^{rs} Y^{ss}) \\ &+ (V^s L^{ss})' * \left[A^{sr} B^{rs} (Y^{sr} + Y^{st})\right] + \left[V^s (B^{ss} - L^{ss})\right]' * (A^{sr} X^r) \\ &+ (V^r B^{rs})' * Y^{sr} + (V^r B^{rs})' * (A^{sr} L^{rr} Y^{rr}) + (V^r B^{rs})' * (A^{sr} L^{rr} E^{r*}) \\ &+ (V^t B^{ts})' * Y^{sr} + (V^t B^{ts})' * (A^{sr} L^{rr} Y^{rr}) + (V^t B^{ts})' * (A^{sr} L^{rr} E^{r*}) \end{aligned} \tag{9}$$

The 1st term on the right side of the equation represents the inclusion of domestic value-added in the exports of final goods (DVA_fin). The 2nd term corresponds to the domestic value-added that is assimilated by the direct importer within the exports of intermediate goods (DVA_int). The sum of the 3rd to 4th terms corresponds to the domestic value-added within the export of intermediate goods, which is subsequently re-exported to a third country by the direct importer (DVA_intrex). The sum of DVA_fin, DVA_int, and DVA_intrex is the domestic value-added in exports (DVA). The summation of the 6th through to 8th terms corresponds to the domestic value-added that is returned to the home country (RDV). Furthermore, the combined effect of the 11th and 12th terms quantifies the value-added originating from the direct importer (MVA). The sum of the 14th and 15th terms represents the value-added when contributed by a third party (OVA). The sum of MVA and OVA is the inclusion of total foreign value-added in exports (FVA). The sum of the 9th and 10th terms is double counting from the domestic source (DDC). The sum of the 13th and 16th terms is double counting from the foreign source (FDC). The total double counting in exports (PDC) is the sum of DDC and FDC. Moreover, the vertical specialization of the export (VS or foreign part) is the sum of FVA and PDC. FVA can be further decomposed into the foreign value-added that is included in the export of final goods (FVA_fin) and intermediate goods (FVA_int). The former constitutes the sum of the 11th and 14th terms, whereas the latter establishes the summation of the 12th and 15th terms. For the sake of enhancing clarity, Figure 2 succinctly illustrates the compositional aspects of the exports' value, along with the elements of vertical specialization and double counting. Specifically, export value (E) can be disaggregated into domestic value-added (DVA), returned value-added (RDV), foreign value-added (FVA), and double counting (PDC):

$$\text{E} = \text{DVA} + \text{RDV} + \text{FVA} + \text{PDC} \tag{10}$$

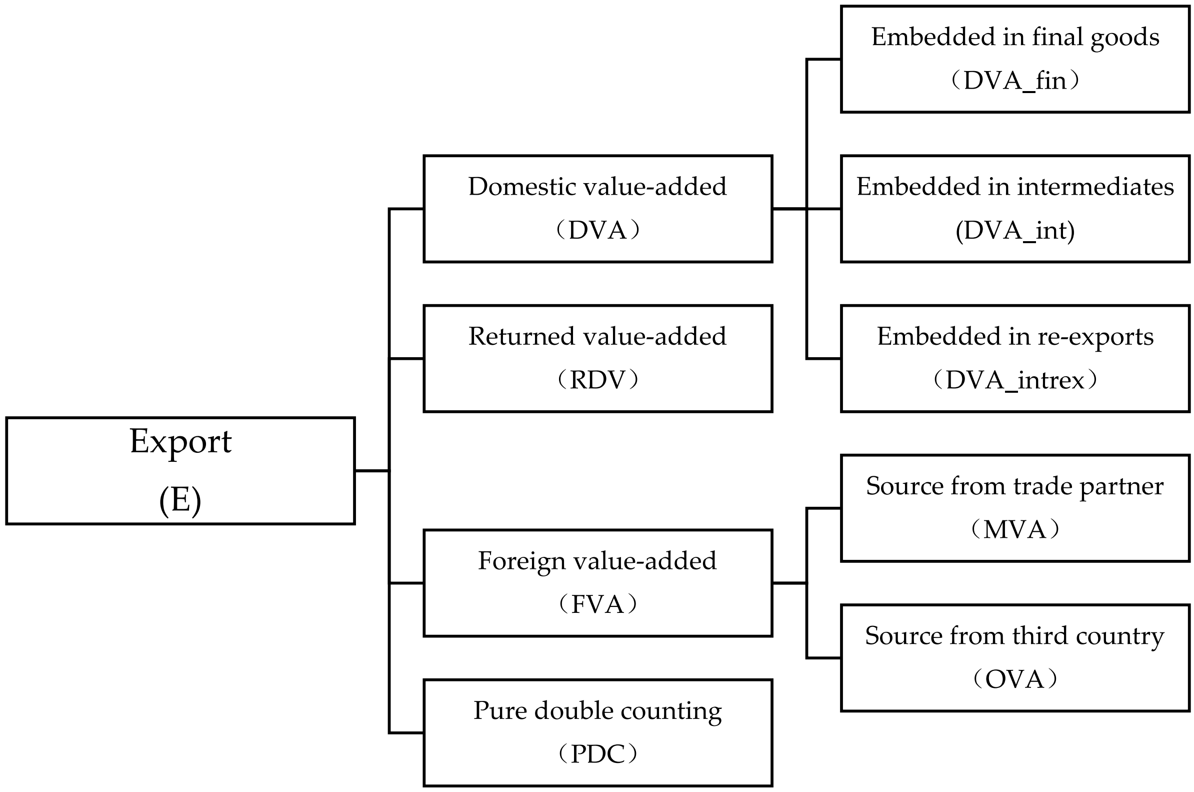

Figure 2. Decomposition of gross export.

2.5. International Competitiveness Indicators

Let s show the exporting country, i denote the industry, E represent exports, and M signify imports. The domestic value-added exports in country s and industry i can be represented as $E_{s,i}$, and the foreign value-added imports can be shown as $M_{s,i}$. The Balassa Index based on trade in value-added can be shown as:

$$RCA_{s,i} = \left(E_{s,i}/\sum_i E_{s,i}\right)/\left(\sum_s E_{s,i}/\sum_i \sum_s E_{s,i}\right), \tag{11}$$

A Balassa Index exceeding 1 signifies a comparative advantage for the exporting economy in that specific industry, with a stronger advantage indicated by a higher value. The Balassa Index solely involves exports, not imports, in its calculation. In instances of substantial intra-industry trade, this index's assessment of a country's comparative advantage might be subject to bias. The Lafay Index attenuates the abovementioned issue to some extent, and its expression is as follows:

$$Lafay_{s,i} = \left[\frac{E_{s,i} - M_{s,i}}{E_{s,i} + M_{s,i}} - \frac{\sum_i (E_{s,i} - M_{s,i})}{\sum_i (E_{s,i} + M_{s,i})}\right] * \frac{E_{s,i} + M_{s,i}}{\sum_i (E_{s,i} + M_{s,i})} * 100 \tag{12}$$

A Lafay Index greater than 0 indicates that a country has a specialization advantage in industry i, and the higher the value, the stronger the trade specialization advantage. Conversely, a Lafay Index less than 0 indicates that a country lacks specialization advantages in industry i, and the lower the value, the weaker the specialization advantage.

While the global market share indicates the export volume of the forestry industry, the Balassa Index gauges if a specific industry's export advantage surpasses the global average, and the Lafay Index assesses whether a particular industry possesses a distinct specialization advantage. To some extent, the world market share quantifies the magnitude of a country's forestry industry trade, whereas the Balassa Index and Lafay Index gauge the advantages derived from a country's forestry industry trade. By definition, if the Balassa Index (or revealed comparative advantage, RCA) of an industry is greater than 1, then the country has a comparative advantage in that industry, whereas if the Lafay Index is greater than 0, the country has a specialization advantage in that industry. Utilizing the threshold values of the Balassa Index and Lafay Index, we rendered evaluations on the global competitiveness of distinct industries in Table 1. If an industry's Balassa Index surpasses 1 and its Lafay Index exceeds 0, it possesses a global competitive advantage within that sector. Conversely, if the Balassa Index does not surpass 1 and the Lafay Index remains below 0, it indicates an international competitive disadvantage for the nation in that particular industry. When the Balassa Index remains below 1 while the Lafay Index surpasses 0, it suggests a limited specialization advantage within the industry. On the other hand, if the Balassa Index exceeds 1 while the Lafay Index remains below 0, it signifies a minor comparative advantage within that industry.

Table 1. Determination of international competitiveness in the forestry industry.

	$0 \leq$ RCA ≤ 1	**RCA > 1**
Lafay > 0	Minor specialization advantage	International competitive advantage
Lafay ≤ 0	International competitive disadvantage	Minor comparative advantage

3. Results

3.1. Destination of China's Forestry Industry Value-Added

Table 2 represents the value-added in the forestry industry in China. According to Table 1, the value-added of China's wood processing industry witnessed an increasing trend from USD 44.032 to USD 54.204 billion between 2012 and 2018, reflecting a notable expansion of 23.1%. Within this context, the segment oriented toward domestic demand observed a surge from USD 30.211 to USD 42.343 billion, signifying a substantial growth of 36.85%. By contrast, the portion aligned with foreign demand experienced a transition from USD 13.821 to USD 12.861 billion, marking a decrease of 6.94%. The share of domestic demand rose from 68.91% to 76.27%. During the same period, the value-added of the papermaking industry increased from USD 77.461 to USD124.683 billion, a 60.96% rise, while the domestic demand rose from USD 58.952 to USD 101.83 billion, a 72.73% growth. In addition, foreign demand increased from USD 18.509 to USD 22.853 billion, which is equal to a 23.47% increase, while the share of domestic demand rose from 76.11% to 81.67%. According to these figures, since 2012, the evolution of China's forestry industry has been fundamentally driven by shifts in domestic demand, with the pivotal role of domestic demand persistently intensifying.

Table 2. Forestry industry value-added in China decomposed into domestic and foreign demand from 2012 to 2018.

Year	**Wood Processing and Wood Products**			**Papermaking and Paper Products**		
	Value-Added, bn USD	**Domestic, bn USD**	**Foreign, bn USD**	**Value-Added, bn USD**	**Domestic, bn USD**	**Foreign, bn USD**
2012	44.032	30.211	13.821	77.461	58.952	18.509
2014	52.415	38.167	14.248	91.829	71.86	19.969
2016	48.266	36.690	11.576	94.775	77.308	17.467
2018	54.204	41.343	12.861	124.683	101.83	22.853

Data source: authors' calculations based on OECD ICIO.

Table 3 provides a comparative analysis between China and economies that possess a significant international market share in the forestry industry. Whether in the wood processing or papermaking sectors, China emerges as the foremost contender in terms of its industrial scale, holding a conspicuous advantage in terms of volume. In 2018, China's value-added in the wood processing sector surpassed that of the United States, Canada, Germany, India, and Indonesia, 1.3, 5.94, 6.17, 7.33, and 10.59 times, respectively. Within the papermaking industry, China's value-added exceeded that of the United States, Germany, Brazil, Italy, and France, 1.21, 5.34, 9.6, 9.7, and 10.86 times, respectively. China's wood processing industry allocates 23.73% of its value-added to foreign demand, which is only higher than that of the United States and equal to 11.9%. Similarly, China's papermaking industry dedicates 18.33% of its value-added to foreign demand, a proportion close to that of the United States. These observations highlight China's global position as a key production hub and consumer market for forest products.

Table 3. The share of value-added and foreign demand in the forestry industry among major economies in 2018.

	Wood Processing and Wood Products			Papermaking and Paper Products	
Economy	**Value-Added, bn USD**	**Foreign Demand, %**	**Economy**	**Value-Added, bn USD**	**Foreign Demand, %**
China	54.204	23.73%	China	124.683	18.33%
USA	41.784	11.90%	USA	103.13	18.21%
Canada	9.132	52.27%	Germany	23.346	54.32%
Germany	8.786	42.53%	Brazil	12.987	38.40%
India	7.39	38.45%	Italy	12.853	40.04%
Indonesia	5.119	31.97%	France	11.486	43.76%
Russia	4.441	55.25%	Canada	11.163	56.43%
Poland	3.926	60.01%	Indonesia	9.408	42.87%
Austria	3.424	60.75%	Sweden	7.047	75.35%
Sweden	3.184	51.78%	Finland	5.42	77.96%

Data source: authors' calculations based on OECD ICIO.

3.2. Upstream and Downstream Degrees of China's Forestry Industry

Table 4 outlines the shifts in the upstream and downstream orientations of China's forestry industry. According to Table 4, the wood processing and papermaking sectors exhibit higher upstream degrees than the industry average since manufacturing industries hold a position closer to the upstream compared to the service sector within the contemporary economic framework. In addition, from 2012 to 2018, the upstream degree of the wood processing industry gradually decreased from 3.29 to 3.16, and the upstream degree of the papermaking industry reduced stepwise from 3.73 to 3.50 in China. These findings underscore the reduction in the global economic system's distance between Chinese forestry products and their final demand, mainly due to the increasingly high degree to which China's forestry industry meets its domestic demand. During the same period, the forestry industry showed a relatively minor change in its downstream trend, but an overarching trend is evident in its decreasing span from initial inputs, resulting from the increased utilization of domestic production factors.

Table 4. Changes in the upstream and downstream degrees of China's forestry industry from 2012 to 2018.

	All Industry Average		Wood Products		Paper Products	
Year	**Up**	**Down**	**Up**	**Down**	**Up**	**Down**
2012	2.64	2.61	3.29	3.05	3.73	3.09
2014	2.76	2.67	3.27	3.15	3.72	3.20
2016	2.73	2.62	3.24	3.09	3.59	3.18
2018	2.62	2.52	3.16	3.08	3.50	3.04

Data source: authors' calculations based on OECD ICIO. Note: up is short for upstream degree, down is short for downstream degree, and both indices are without units.

According to Table 5, compared with other prominent economies, China exhibited the most substantial degrees of both upstream and downstream positioning in the forestry industry in 2018. This observation indicates that China's forestry industry is at a considerable distance from final demand and initial input. Thus, China's forestry industry holds a crucial role in driving and attracting other parts within the global economic system.

Table 5. Upstream and downstream degrees of the forestry industry in major economies in 2018.

	Wood Products			Paper Products	
Economy	**Up**	**Down**	**Economy**	**Up**	**Down**
China	3.16	3.08	China	3.50	3.04
Poland	2.83	2.57	Indonesia	3.19	2.39
Russia	2.74	2.34	Finland	2.96	2.60
Sweden	2.73	2.56	Italy	2.91	2.53
Canada	2.65	2.43	Brazil	2.90	2.31
Austria	2.62	2.55	France	2.85	2.35
Germany	2.55	2.50	Germany	2.77	2.40
Indonesia	2.51	2.28	Sweden	2.76	2.30
USA	2.50	2.37	Canada	2.72	2.35
India	2.35	2.16	USA	2.64	2.30

Data source: authors' calculations based on OECD ICIO. Note: up is short for upstream degree, and down is short for downstream degree. Both indices are without units.

3.3. Decomposition of China's Forestry Industry Gross Export

According to Table 6, influenced by domestic environmental policies and foreign trade restrictive policies, the export of the wood processing industry experienced a U-turn in China from 2012 to 2018, dropping from USD 12.635 to USD 9.216 billion and then rising to USD 12.26 billion. Throughout this period, the proportion of domestic value-added in this export exhibited stability at approximately 85%, while the corresponding foreign value-added maintained consistency at around 11%. In addition, China's paper industry export volume surged from USD 9.64 to USD 12.643 billion, indicating a notable increase of 31.14%. The noteworthy growth phase occurred between 2016 and 2018, clearly influenced by the "rush to export" phenomenon stemming from the China–United States trade war. In 2018, the proportion of domestic value-added in this export was approximately 82%, while the foreign value-added accounted for around 11%.

Table 6. Export decomposition in China's forestry industry from 2012 to 2018.

Industry	Export Decomposition	2012	2014	2016	2018
Wood processing and wood products	Export value, bn USD	12.635	10.756	9.216	12.260
	Domestic value-added, %	85.09%	85.10%	86.86%	84.56%
	Returned value-added, %	1.22%	1.63%	1.48%	1.59%
	Foreign value-added, %	11.15%	10.80%	9.64%	11.37%
	Double counting, %	2.54%	2.47%	2.01%	2.48%
Papermaking and paper products	Export value, bn USD	9.640	10.085	9.718	12.643
	Domestic value-added, %	81.47%	80.31%	82.80%	82.91%
	Returned value-added, %	3.62%	4.97%	4.32%	2.95%
	Foreign value-added, %	10.86%	10.61%	9.46%	10.66%
	Double counting, %	4.05%	4.11%	3.41%	3.49%

Data source: Authors' calculations based on OECD ICIO. Note: the total of four decomposition items in each year for each industry is 100%. Due to decimal preservation, there are possibly some rounding errors.

As shown in Table 7, China's wood processing industry achieved the top global rank in export volume in 2018, surpassing Canada by a factor of 1.14, Germany by 1.78, the United States by 1.87, Russia by 2.06, and Austria by 2.52. Although the US's domestic value-added proportion is only 80.02%, its returned value-added proportion reached 6.56%, the highest among all economies, reflecting the position of the US as a world final consumer market.

Table 8 presents the export of paper products and the decomposition of major economies in 2018. China's paper industry export volume held the fourth position globally, trailing the United States, Germany, and Canada. Notably, Canada exhibits a higher proportion of foreign value-added in its exports, but export production self-sufficiency falls short of that in China. The proportion of domestic value-added in the paper industry exports of China is only lower than that of Brazil, indicating that China's domestic industrial chain system is more complete and more value-added is generated when exporting. Conversely, economies like Germany, Finland, Sweden, Italy, France, and Austria, which are European Union members, exhibit higher proportions of foreign value-added in their exports due to their enhanced production cooperation within the EU framework. While the domestic value-added in US paper industry exports accounts for 79.62%, i.e., the lowest one among major economies, its low foreign value-added proportion suggests that the self-sufficiency of the US paper industry in producing exports is not as low as it seems.

Table 7. Export of wood products and the value decomposition of major economies in 2018.

Economy	Export Value, bn USD	Domestic Value-Added, %	Returned Value-Added, %	Foreign Value-Added, %	Double Counting, %
China	12.260	84.56%	1.59%	11.37%	2.48%
Canada	10.743	80.66%	0.62%	16.79%	1.93%
Germany	6.901	72.48%	2.62%	17.52%	7.37%
USA	6.547	80.02%	6.56%	10.17%	3.24%
Russia	5.957	86.50%	0.45%	10.24%	2.81%
Austria	4.858	68.08%	0.53%	22.74%	8.65%
Poland	4.065	72.76%	0.50%	19.65%	7.09%
Indonesia	3.930	86.74%	0.22%	10.83%	2.22%
Sweden	3.883	72.87%	0.38%	21.85%	4.91%
India	3.530	83.18%	0.22%	15.38%	1.22%

Data source: authors' calculations based on OECD ICIO. Note: the total of four decomposition items for each economy is 100%. Due to decimal preservation, there are possibly some rounding errors.

Table 8. The export of paper products and the value decomposition of major economies in 2018.

Economy	Export Value, bn USD	Domestic Value-Added, %	Returned Value-Added, %	Foreign Value-Added, %	Double Counting, %
USA	23.111	79.62%	8.05%	8.74%	3.59%
Germany	20.582	71.10%	3.00%	16.79%	9.11%
Canada	12.943	73.89%	0.77%	21.19%	4.16%
China	12.643	82.91%	2.95%	10.66%	3.49%
Finland	11.665	72.76%	0.18%	19.47%	7.59%
Sweden	11.349	74.50%	0.47%	17.23%	7.80%
Brazil	8.596	85.68%	0.31%	10.98%	3.04%
Italy	7.436	75.40%	1.20%	16.24%	7.16%
France	6.986	72.64%	1.93%	17.11%	8.31%
Austria	6.419	65.52%	0.54%	22.65%	11.28%

Data source: authors' calculations based on OECD ICIO. Note: the total of four decomposition items for each economy is 100%. Due to decimal preservation, there are possibly some rounding errors.

3.4. Trade Competitiveness of China's Forestry Industry

Table 9 shows the trade competitiveness of China's forestry industry from 2012 to 2018. The global share of China's wood processing industry dropped from 13.92% to 11.5%, reflecting a decline in its ability to occupy the international market, which was also confirmed by changes in trade competitiveness indices. During the same period, the global market share of China's papermaking industry rose slightly from 5.37% to 6.72%, reflecting the enhanced international market share capture ability. However, the Balassa Index and Lafay Index in 2018 were 0.53 and −0.22, respectively, indicating that China's papermaking industry does not essentially have an international competitive advantage.

Table 10 lists the forestry industry trade competitiveness indicators of major economies in 2018. Intuitively, Figures 3 and 4 illustrate cross-country comparisons of the competitiveness experienced for wood products and paper products, respectively. According to Table 10, China maintained its position as the world's leading exporter of wood processing and wood products in 2018, as measured by domestic value-added exports. However, China's Balassa Index and Lafay Index ranked last among the major economies. As a comparison, Canada's Balassa Index and Lafay Index of wood products were 4.12 and 0.9, respectively, standing out prominently among major economies (Figure 3). Despite a low global market share, Finland's wood processing industry boasted a Balassa Index of 6.14 and a Lafay Index as high as 1.41. According to domestic value-added exports, China's paper industry's global market share was 6.72%, ranking third only behind the United States and Germany. However, China's paper industry Balassa Index ranked last among major economies, with the Lafay Index showing a significant negative value. By contrast, despite a lower market share compared to China, Finland's paper industry had Balassa Index and Lafay Index values of 12.88 and 5.52, respectively, implying a substantial lead over other major economies (Figure 4). Thus, China's forestry industry shows relatively weak overall trade competitiveness, particularly in the paper industry. This pattern of trade competitiveness aligns well with China's production factor endowment.

Table 9. Changes in trade competitiveness of China's forestry industry from 2012 to 2018.

	Wood Processing and Wood Products			Papermaking and Paper Products		
Year	**World Share, %**	**Balassa Index**	**Lafay Index**	**World Share, %**	**Balassa Index**	**Lafay Index**
2012	13.92%	1.39	0.18	5.37%	0.53	−0.07
2014	11.18%	0.99	0.03	5.38%	0.48	−0.19
2016	10.58%	0.90	−0.01	5.94%	0.50	−0.20
2018	11.50%	0.97	0.00	6.72%	0.57	−0.22

Data source: authors' calculations based on OECD ICIO. Note: all measures are based on domestic value-added exports. Both the Balassa Index and Lafay Index are without units.

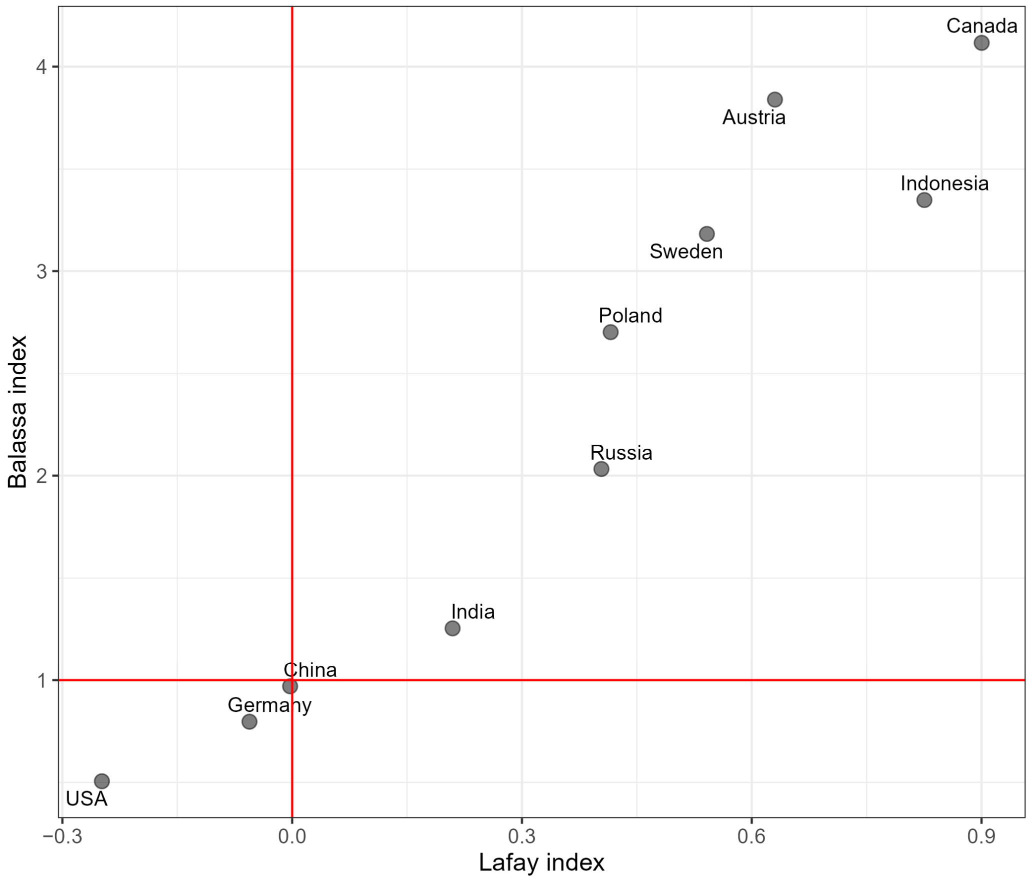

Figure 3. Wood processing industry competitiveness of major economies in 2018. The horizontal red line highlights the critical value for the Balassa Index, and the vertical red line highlights the critical value for the Lafay Index. Both indices are based on domestic value-added exports.

Table 10. Major economies' forestry industry trade competitiveness in 2018.

Wood Products				Paper Products			
Economy	**Market Share, %**	**Balassa**	**Lafay**	**Economy**	**Market Share, %**	**Balassa**	**Lafay**
China	11.50%	0.97	0.00	USA	11.79%	1.03	0.06
Canada	9.61%	4.12	0.90	Germany	9.38%	1.35	0.06
USA	5.81%	0.51	−0.25	China	6.72%	0.57	−0.22
Russia	5.71%	2.03	0.40	Canada	6.13%	2.62	0.66
Germany	5.55%	0.80	−0.06	Finland	5.44%	12.88	5.52
Indonesia	3.78%	3.35	0.83	Sweden	5.42%	5.49	2.13
Austria	3.67%	3.84	0.63	Brazil	4.72%	3.32	1.35
Poland	3.28%	2.70	0.42	Italy	3.59%	1.22	−0.01
India	3.26%	1.26	0.21	France	3.25%	0.90	−0.10
Sweden	3.14%	3.18	0.54	Indonesia	3.04%	2.69	0.76

Data source: authors' calculations based on OECD ICIO. Note: all measures are based on the domestic value-added exports. Both the Balassa Index and Lafay Index are without units.

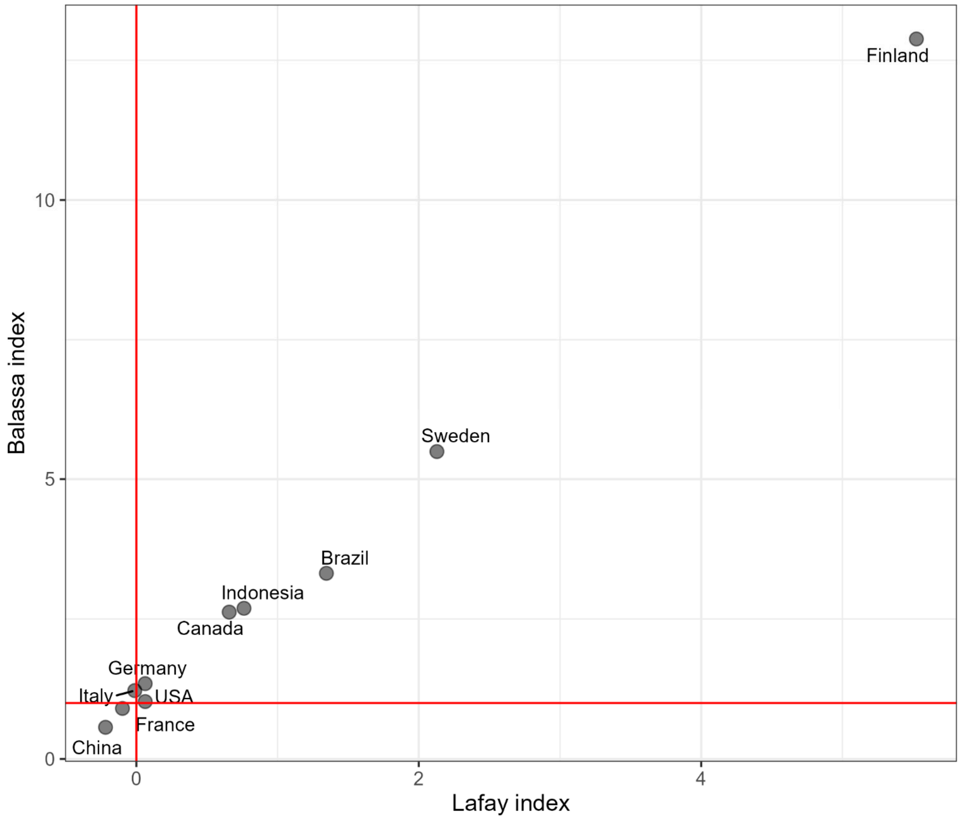

Figure 4. Paper industry competitiveness of major economies in 2018. The horizontal red line highlights the critical value for the Balassa Index, and the vertical red line highlights the critical value for the Lafay Index. Both indices are based on domestic value-added exports.

4. Discussion

4.1. What Drives Inward Orientation of China's Forestry Industry

As documented by Jiang et al. (2018), the foreign markets of Chinese forest products grew more robustly than the domestic market for almost a decade following China's WTO accession [21]. However, since 2012, while developed economies have gradually emerged from the aftermath of the financial crisis, their economic growth has not been able to fully recover from the robustness observed prior to this crisis. The modest expansion of the international market, coupled with escalating domestic wealth inequalities and the emergence of unemployment as pressing concerns, has prompted the prevalence of trade protection policies aimed at curbing the influx of foreign goods. This lackluster expansion of the international market entails a contraction in foreign demand for the economy of China with an export-oriented policy especially targeting developed economies. Conversely, the transition of China's economic development into a new paradigm has shifted the mechanism of its economic growth. This shift emphasizes the holistic advantages spanning economic, social, and environmental domains while also embracing the consensus of optimizing domestic supply to cater to the domestic market. These adjustments in the internal and external macro-environmental dimensions have significantly shaped the trajectory of China's forestry industry development, which is reflected in the empirical results.

4.2. The Important Role of Being Both GVC Input Supplier and Output Demander

A substantial segment of China's forestry output serves as intermediary inputs for various industries, while this sector also incorporates the output of numerous industries as intermediate inputs. Significantly, the papermaking industry indicates a higher upstream degree compared to the wood processing sector, implying a more pronounced influence on other industries. Although the United States is also a significant producer of forest products, both the upstream and downstream degrees of its forestry industry are lower than those of China, mainly because its consumption scale far exceeds its production scale. It is worth noting that researchers usually apply the GVC methodology to analyze high-tech industries, such as automobiles and electronics [27–30]. These industries are more downstream than forestry industries by nature. Based on WIOD, Ye et al. (2015) have shown that manufacturing industries that produce fundamental intermediate inputs, such as wood processing, pulp, and paper, are more upstream in their global value chains, which lends support to our quantitative results [31].

In terms of raw material-dependent industries, the domestic value-added of wood and paper products is higher than that of parts and components in intensive industries. Among the major economies, the proportion of domestic value-added in China's forestry industry exports is only lower than in resource-exporting countries, such as Brazil, Indonesia, and Russia. This reflects China's robust self-sufficiency in producing manufactured forest products to serve the global market. It can be noted that, despite the fact that Vietnam's forestry industry cannot be compared yet with that of China in terms of volume, it is progressing toward the position of a world factory. In particular, the end of the ever-growing Sino–US trade intimacy has enhanced cross-border production sharing between Vietnam and the world.

4.3. "Big Yet Not Strong" Is Still the Issue for China's Forestry Industry

In 2012, China's wood processing industry indicated a Balassa Index, signifying a comparative advantage, and a Lafay Index, indicating a specialization advantage. However, by 2018, both the Balassa Index and Lafay Index of China's wood processing industry could barely approach their critical values. These changes indicate a notable weakening of the overall comparative advantage of China's wood processing industry. In the absence of the availability of inter-country input–output tables, it is natural to use trade data to measure international competitiveness [32]. Noticeably, there are studies using traditional trade statistics to showcase China's competitiveness in some specific products, such as wooden furniture, wood-based panels, and wooden articles [33–35]. However, China is also the world's largest importer of log and lumber, and these imported raw materials are major inputs of manufactured wooden products. Given this fact, discerning trade in value-added is more appropriate to gauge China's competitiveness.

During the same period, the global market share of China's papermaking industry rose slightly; however, the Balassa Index and Lafay Index were still below critical values, indicating that China's paper products industry is still internationally uncompetitive. In particular, compared to economies with similar world market shares, China's forestry industry is big but not strong. By decomposing WIOD, Xiong et al. (2022) similarly found that the domestic value-added (DVA) ratio of Chinese forest product exports was about 80%, and the genuine performance of China's forest product exports was overestimated [36].

We do not disagree with this conclusion, but it should be pointed out that the DVA ratio alone is not a sufficient measure to assess international performance. For example, the DVA ratio of Finland's paper product exports is lower than that of China, but Finland has a much higher trade competitiveness index.

4.4. Implications

In recent years, amid the complex interplay of trade protectionism, global pandemics, and geopolitical tensions, the outlook for consistently stable growth in global trade appears less optimistic. While the impetus behind the expansion of the global value chain has waned, its inherent trajectory remains unalterable. China should move toward a central position within the global value chain framework, gradually transforming volume advantages into quality advantages and upgrading from a manufacturing center to an innovation hub. The following policies are required to achieve this purpose.

First, decision makers should fully implement a new development concept, continue to deepen reforms, expand opening up, and maintain a strategic focus on green, high-quality development in China's forestry industry. Currently, China's forestry industry faces a high degree of homogeneous competition, with too much low-level repeated production, poor quality, overcapacity, and thin profits. The primary reason for this lies in the lack of innovation and a low degree of heterogeneous competition. However, innovation requires distinction and differentiation, and this means encouraging the initiative of enterprises and individuals and expanding their autonomous decision-making rights. This relies on the government's creation of more transparent and fair basic market rules and ensuring comprehensive and vigorous enforcement, allowing efficient and high-quality enterprises to stand out and inefficient and low-quality enterprises to exit the market. A focused effort is needed to improve the supply efficiency of domestic forest products. This includes stabilizing fluctuations in external supply, demand, and circulation through the synergistic growth of internal supply, demand, and circulation and guarding against unexpected and unconventional market disruptions. Overall, the government should provide a supportive environment to help firms who are attempting to access national and global markets, including education and training to upgrade the skills of the labor force and predictable regulations to mitigate market uncertainties [37].

Second, China should make full use of the "Belt and Road" initiative policy platform to further reduce trade costs, bottlenecks, and obstacles in the global value chain while optimizing the investment and trade layout of the forestry industry. Through the continuous expansion and deepening of the "Belt and Road" initiative, more and more countries and organizations are participating, expanding their scope from infrastructure construction to encompassing diverse industries and involving state-owned, private, and foreign-funded enterprises. This provides opportunities for the global layout of China's forestry industry. The activities of this industry should gradually spread from traditional locations such as Russia, New Zealand, and Southeast Asia to prospectively important players in the "Belt and Road", especially in Eastern Europe, South America, and Africa. The more Chinese-funded enterprises that enter could significantly improve the local business environment and form a cluster effect.

Third, China should more actively integrate into the rule-based global economic and trade governance system, effectively and decisively dealing with the trade protectionism of developed economies. Although the United States and other developed economies have repeatedly bypassed the WTO in pursuing unilateral trade protectionism, multilateralism is still the cornerstone of today's global economic and trade order. Utilizing the rules under the WTO framework to challenge and counteract the United States' unjust trade restrictions is beneficial for maintaining China's image as a large and responsible country and helps China gain more support from member countries to avoid being isolated or outnumbered.

5. Conclusions

Utilizing the 2021 edition of the OECD-ICIO database, this study employed industry value-added decomposition, upstream and downstream assessments, export value analysis, and trade competitiveness metrics to comprehensively analyze the developmental trajectory of China's forestry sector within the context of the global value chain framework from 2012 onwards.

According to the results, China's forestry industry has transitioned from an export-focused orientation to one centered on domestic demand. Specifically, the wood processing and paper-making sectors allocate around 76% and 82% of their value-added shares to meet domestic demand, highlighting the prominent role that domestic consumption plays in driving China's forestry sector. Among its major economies, China's forestry industry demonstrates the highest degree of integration and influence across both upstream and downstream sectors, exerting a significant impact on various industries. China's forestry exports display a considerable domestic value-added share, signifying robust self-reliance in export-oriented production. However, despite its substantial global market share, a noticeable reduction in comparative advantages is observed in China's forestry sector, particularly within the wood processing industry.

Due to intensive cross-border production sharing over the past two decades, the value-added distribution has drawn considerable attention. Multiregional input–output tables have been developed to aid the analysis of this economy's position along GVCs. Despite its usefulness as an accounting framework, strong underlying assumptions such as fixed price, homogeneity, and proportionality are obvious limitations. In other words, GVC accounting can be interpreted as an ex-post analysis of what happened yesterday but not as a tool to gauge what could happen tomorrow. Given mounting uncertainty and risks in the global economy, it is useful to build general equilibrium models with endogenous interactions to analyze the effect of exogenous shocks on the Chinese forestry industry.

Author Contributions: Conceptualization, H.S.; methodology, Y.J.; software, Y.J.; validation, H.S. and Y.J.; data curation, Y.J.; writing—original draft preparation, H.S. and Y.J.; writing—review and editing, H.S. and Y.J.; supervision, H.S.; project administration, H.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Forestry and Grass Administration: International Forestry Economic and Trade Cooperation Mechanism Supporting Projects: 500102-1763.

Data Availability Statement: Source data are publicly available on the OECD website (http://oe.cd/icio (accessed on 20 April 2022)), and the computer code for this study is available upon request from the corresponding author.

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

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