Analyzing the *Eucalyptus* Timber Value Chain in Thailand: Profit Distribution and Opportunities for Improvement

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Abstract: The Thai forestry sector relies greatly on *Eucalyptus* as a raw material. The rapid expansion of plantations during the last few decades and the high demand for *Eucalyptus* for several purposes has led to numerous supply chain practices. A comprehensive understanding of the *Eucalyptus* value chain is lacking in Thailand, which has consequences for optimization, sustainability, and profitability aspects. This study analyzed actors and their activities along the value chain and estimated added value and profit margin benefit distributions. The study method involved a value chain analysis approach, whereby input data were collected from the following groups: seedling suppliers and developers, farmers and tree growers, timber traders and collectors, intermediaries, processors, wholesalers, and consumers via key informant interviews, in-depth interviews, and group discussions. The results revealed the vertical integration of *Eucalyptus* timber businesses, where sapling breeders were the major input suppliers with a significant role in the value chain based on the role of controlling the majority of seedling production, promoting cultivation, and ensuring the raw material supply for the pulp industry through a full-cycle membership program. Total gross marketing margin was highest (90.6%) in the path of the pulp mill industry and lowest in the path of the biomass power plant (73.4%). The profit share of growers varied between 9.9% and 26.6% depending on the path and chain. The overall benefit distribution analysis demonstrated a positive gross profit margin but minor distribution to the growers. Our study determined that decision-makers should create supportive programs, funding opportunities, and infrastructural support for research and development, capacity building, and regulation to ensure suitable benefits for all actors in the *Eucalyptus* timber value chain in Thailand.

Keywords: *Eucalyptus* wood products; smallholder growers; wood processors; added value; wood-based industry

1. Introduction

Eucalyptus spp. is a fast-growing short-rotation tree and is widely cultivated in tropical and subtropical regions and beyond due to its rapid growth rate [1–6]. *Eucalyptus* is popular among farmers worldwide due to its adaptability to diverse climatic conditions. Over three decades, the global total plantation area increased from 13.4 million hectares in 1991 to 22.57 million hectares in 2021 [7]. Similar progress has occurred even more rapidly in Thailand over 30 years, where the plantation area has increased from 94,000 ha in 1987 to 846,708 ha in 2023 [8,9]. The increasing rate of *Eucalyptus* plantation in Thailand has been about ten-fold while globally it has been two-fold. *Eucalyptus* timber is in high demand for various applications in Thailand, including construction, pulpwood, fiber

and particle boards, wood chips, and pellets. Furthermore, a significant increase in the global consumption of pulp and paper has occurred [10,11]. This increasing demand has resulted in higher demand for *Eucalyptus* plantations; however, a lack of sufficient supply of *Eucalyptus* timber with the desired volume and quality to meet the needs of the wood processing industry remains.

In 2005, over 64% of the total *Eucalyptus* area was managed by small-scale Thai farmers, and about half of the plantation area was located to the northeast of the country [12]. *Eucalyptus* is socio-economically important, with a crucial role in enhancing the overall well-being of rural communities, particularly in the eastern and northeastern parts of Thailand. *Eucalyptus* cultivation contributes to income generation and job creation; however, the current *Eucalyptus* yield per hectare is declining and the market system benefits traders and collectors more highly than farmers [13]. Existing *Eucalyptus* cooperatives lack the power to effectively compete with traders, resulting in an inability to provide the anticipated benefits to their members. Smallholders are compelled to sell *Eucalyptus* timber to local private traders, and the prices offered to farmers are considerably lower than actual market prices. Despite increasing demand for *Eucalyptus* in the pulp industry and bioenergy sectors, this leads to higher prices.

The value chain concept is defined as the range of activities required to bring a product or service from conception, through raw material sourcing and intermediate inputs and different phases of production, processing, marketing, and distribution, to the final consumer [14]. Value chain analysis is a rational and systematic framework for describing and evaluating the roles and inter-relationships of actors involved at each point of the chain. The application of value chain analysis reveals a clearer understanding of the timber value chain for formulating effective strategies for improvement involving market participants, policymakers, and stakeholders. In mapping the value chain in the context of *Eucalyptus* timber and wood products, the main challenge facing *Eucalyptus* timber is the expense of undesirable ecological consequences, which have been widely debated in previous studies. Growing *Eucalyptus* trees have substantial nutrient resource and higher water requirements during the initial stages compared with alternative plantations. This heightened demand for resources can potentially lead to environmental challenges, including even the risk of biodiversity loss [15,16]. In contrast, *Eucalyptus* cultivation offers numerous benefits for farmers as an important cash crop for low-income smallholders in rural areas [1,13]. *Eucalyptus* plantations have the potential to make significant contributions to global timber supply, while also serving to protect natural forests, enhance global carbon storage and sequestration, and contribute to mitigating global warming. Therefore, despite the high consumption of soil fertility associated with *Eucalyptus* cultivation, it is essential to continue growing *Eucalyptus* as its benefits outweigh this particular concern [5]. Considering the above, it is crucial to further investigate *Eucalyptus* value chains.

Considerable research on value chains has been conducted in the timber and wood product sector in Asian countries in recent years. Tham et al. [17] reviewed 31 published studies on the arrangements and operations of Asian timber value chains, the majority of which are focused in Indonesia, while other wood-based product suppliers include China, Malaysia, and Vietnam. In Indonesia, Irawanti et al. [18] conducted a study of the timber sengon (*Paraserianthes falcataria*) value chain to determine the stakeholders involved, how they achieved added value, and how benefits are distributed between stakeholders. Tham et al. [19] applied value chain analysis to compare the financial and economic performance of three typical acacia hybrid timbers, comprising wood chips and central Vietnamese Forest Stewardship Council (FSC)-certified and non-FSC-certified furniture. Maraseni et al. [20] compared benefits and returns for actors in the Laotian teak (*Tectona grandis*) value chain. Rand et al. [21] investigated the role of policies governing the conditions of management, exploitation, and trade on the teak timber value chain in Myanmar. Tham et al. [17] revealed significant knowledge gaps, indicating the need for broader geographic and thematic coverage and more transparent quantitative assessments in Southeast Asia. The review study did not identify any publications related to Thailand's

timber value chain; therefore, expanding the analysis to Thailand is needed based on these results. Furthermore, our literature reviews did not identify any previous *Eucalyptus*-related scientific articles conducted in Southeast Asia. When we sought *Eucalyptus* timber value chain research in the Global South, only a few articles were found. Tesfaw et al. [22] examined the *Eucalyptus* value chain in Ethiopia in terms of the actors engaged, the type and significance of channels, and margin analyses to identify key challenges and opportunities in developing value chains and the sustainable management of *Eucalyptus* timber and products.

At a conceptual level, timber value chain studies have focused on identifying the key actors in the value chain and developing descriptions of actors' characteristics, functions, operations, and interactions. Studies have evaluated the economic performance of the value chain using various indicators, including price, profit, and value added. The purpose of timber value chain studies is to develop recommendations and policy implications for sectoral upgrades. The key actors and stakeholders in the timber value chain are identified to describe each step involved in the chain. For instance, Aoudji et al. [23] mapped two categories of actors and stakeholders in the timber value chain, including direct and indirect agents. Direct agents are the owners of the product at various stages of the value chain such as nurserymen, planters, traders, local intermediaries, brokers, transporters, and consumers. In addition, indirect agents are facilitators or agents who intervene in value chain functioning. In line with the flow of actors from growers to consumers, value added maps each stage of processing and production by combining the raw materials or preliminary products with additional resources such as tools, labor, knowledge and skills, and other raw materials. As a product moves through the different stages of the value chain, its overall value progressively rises [18].

The circumstances in the Thai forestry sector raise concerns regarding the long-term sustainability of the *Eucalyptus* value chain in Thailand, highlighting the need for a comprehensive understanding of the nation's *Eucalyptus* value chain. Identifying the various stakeholders, value added contributions, and the distribution of benefits makes it possible to determine approaches for optimizing the value chain, improving market targeting, and ensuring long-term sustainability and profitability for the *Eucalyptus* industry. This study follows a set of comprehensive research questions to understand the structure of the *Eucalyptus* value chain in Thailand. The specific inquiries address various considerations, including the actors within the chain, the participation of different actors at different points in the chain, and access to and control over resources within the value chain, including the determination of the value added of prices among value chain actors. The results from this study can be used as information for policymakers to design strategies for the sustainable production and marketing of the *Eucalyptus* value chain. Specifically, it ultimately enables growers to obtain a higher share of the consumer price and benefits all actors within the *Eucalyptus* value chain.

2. Materials and Methods

The framework for this study maps the entire value chain of *Eucalyptus* timber in Thailand, the key actors and stakeholders involved in the process, volume from growers to consumers, and value added along the chain.

2.1. Description of the Study Areas

The study was primarily conducted in a privately owned plantation area in the central, northeastern, and eastern regions of Thailand (Figure 1). According to the Royal Forest Department Informatics and Space Technology Development Agency [24] in Thailand, the total *Eucalyptus* plantation area in 2023 was estimated to be 846,708 ha, from which 48% of these areas are in the northeast, 33% are in the east, and 13% are in the central region, corresponding to 94% of total *Eucalyptus* plantation area, and more than 95% of Thailand's *Eucalyptus* plantation area is privately owned. The northeastern and eastern regions of Thailand have a significant area dedicated to *Eucalyptus* plantations. The availability of land

and suitable environmental conditions have contributed to the establishment of *Eucalyptus* plantations in this region.
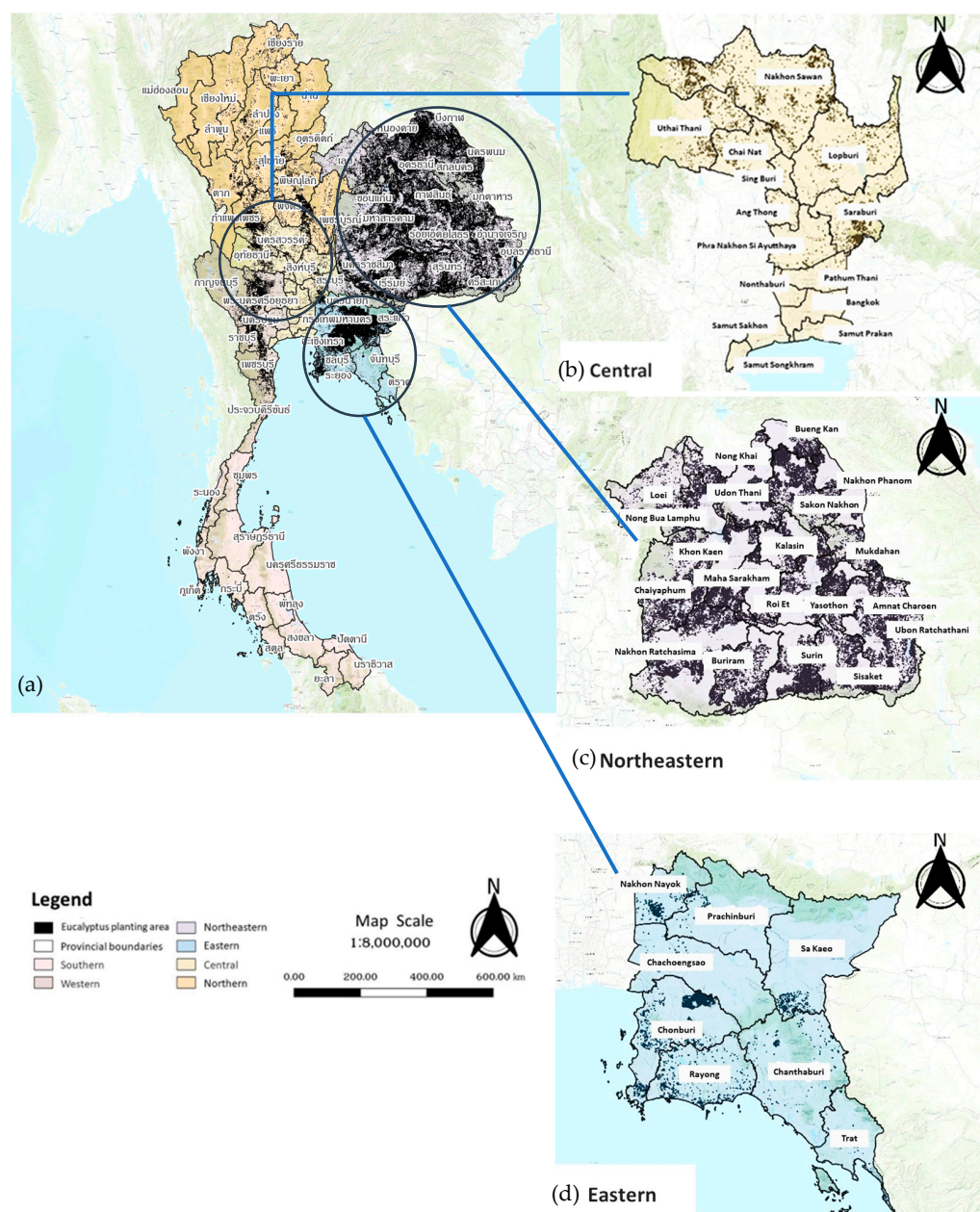
Figure 1. Map of *Eucalyptus* timber plantation density in Thailand (**a**): central (**b**), northeastern (**c**), and eastern (**d**).

2.2. Data Collection

We initially investigated secondary data to serve as a foundation for understanding the overall framework of Thailand's *Eucalyptus* industry, plantations, marketing structure, and policy evolution. The secondary data were obtained from the Royal Forest Department, the Fast-Growing Tree Business Association, and the Forest Industry Organization in Thailand. The secondary data included plantation area, number of growers, yields, farm gate prices, export prices, industry demand for *Eucalyptus* timber, the number of *Eucalyptus* entrepreneurs, and other relevant details.

We obtained primary data from the main actors in the *Eucalyptus* value chain, including key informant interviews, in-depth interviews, and group discussions following a method

presented and validated elsewhere [14]. The questionnaire was evaluated and reviewed by two value chain professionals prior to conducting the interviews. To map actors in the value chain, we collected data by employing the snowball sampling technique, identifying actors in the next stage of the value chain through referrals from respondents. The respondents consisted of (1) two suppliers and seeding developers; (2) 30 individual farmers and growers (10 smallholder farmers, 5 medium-scale growers, and 5 large-scale growers); (3) one local farmer group; (4) five traders and collectors; (5) three intermediaries; (6) one pulp and paper processing company; (7) two composite board processing companies; (8) one biomass energy processing company; and (9) three indirect agents including a government officer, a *Eucalyptus* association representative and a researcher.

Data collection began in January 2023 and continued until June 2023. We collected data for each stage of the value chain, including: (1) information regarding actors' characteristics; (2) actors' key activities in the value chain such as production, logistics, marketing, and services; (3) supporting activities that include procurement, technology, infrastructure, and human resources; (4) the costs and values associated with output; and (5) existing constraints and challenges.

2.3. Data Analysis and Value Chain Mapping

The study's data analysis primarily employed a qualitative approach, starting with transcribing the interviews and manually organizing the data according to each stage of the value chain. To achieve each specific objective, descriptive analysis primarily uses percentages and means. According to [14], we used a value chain analysis approach to analyze the actors and their functions along the *Eucalyptus* value chain. The application of value chain analysis in the study has two key aspects.

First, value chain mapping is the first step in this study to identify the relationships between actors in the value chain and their roles and links in each stage of production. We next quantify the share of the physical product flow of timber along the value chain. Value chain analysis systematically maps the different actors involved in the production, distribution, processing, marketing, and consumption stages [14], assessing the characteristics of actors, roles, and links, the flow of goods throughout the chain, and destinations and volume of domestic sales and exports. Such mapping reveals the structure and dynamics of the value chain.

Second, we analyzed profit margins or value added at each stage of the value chain, calculating the proportion of value added at each stage relative to the overall value added throughout the entire value chain. This is determined by subtracting the total cost from the revenue generated (value added = revenue − total cost), which is estimated to compare prices at various levels of the market chain within the same time frame by applying marketing margin analysis. We conducted this in relation to the final price or the price paid by the end consumer, which is expressed as a percentage. Examining these price differentials reveals insights into the distribution of value within the market chain and different agents' profitability [24]. Referencing [22] and [25], we estimated marketing margins along the chain using the following formulas:

Total gross marketing margin (TGMM):

$$\text{TGMM} = [(\text{End buyer price} - \text{First seller price})/(\text{End buyer price})] \times 100 \qquad (1)$$

where TGMM represents the proportion of the consumer price that goes to the producer or grower as their gross margin, reflecting earnings from product sales.

Producer's margin (GMMP):

$$\text{GMMP} = [(\text{End buyer price} - \text{Marketing gross margin})/(\text{End buyer price})] \times 100 \qquad (2)$$

where the producer's margin (GMMP) is the proportion of the producer's share of the consumer price.

Net marketing margin (NMM):

$$\text{NMM} = [(\text{Gross margin} - \text{Marketing costs})/(\text{End buyer price})] \times 100 \qquad (3)$$

where the NMM is the proportion of the consumer price earned by intermediaries as net income after deducting marketing costs. The NMM describes the role of farmers and growers in the value chain. A high NMM implies a small profit share for farmers.

3. Results

3.1. Overall Eucalyptus Value Chain Mapping and Flow

Thailand's *Eucalyptus* timber value chain begins with *Eucalyptus* growers and extends all the way to using *Eucalyptus* timber and selling related products to consumers. Figure 2 illustrates the value chain map of *Eucalyptus* timber, including different actors and activities that flow from input suppliers to growers and from growers to different actors to consumers. In addition, the proportion of timber volume flowing along the value chain shows outgoing timber volume from growers to consumers (16 M tonnes based on the average annual increment and estimated area). Value chain mapping involves a range of inputs in the beginning stage, including *Eucalyptus* saplings, fertilizers, equipment, land, and water, which are crucial for growers engaged in *Eucalyptus* timber production. The growers produce and sell *Eucalyptus* timber to traders and collectors, and large-scale growers sell directly to intermediaries. The findings reveal that 20% of *Eucalyptus* timber production flows from traders to local intermediaries, which are wood chip factories located nearby, while the remaining 80% is directed to large-scale wood chip factories. Factories distribute the wood chips and the products made from them to other industries for further processing and use. These include the paper industry or pulp mills, composite board mills, and biomass power plants for use as raw materials in energy production and use in construction such as poles, lumber, veneer, and charcoal. Some processed wood is also exported to other countries.
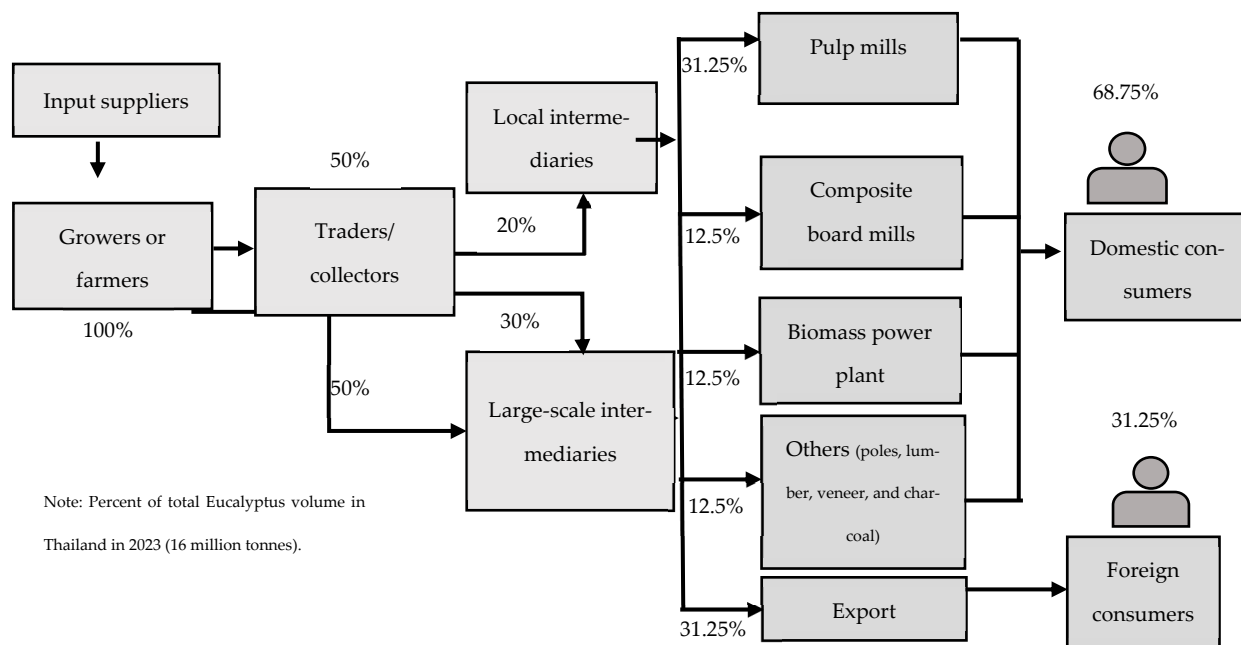
Figure 2. Flow and volume ratio of *Eucalyptus* timber in Thailand (2023).

3.2. Major Eucalyptus Value Chain Actors, Their Roles, and Links

Thailand's *Eucalyptus* value chain involves various actors participating directly or indirectly between producers and final consumers. These actors are categorized into seven levels within the study areas based on the specific roles they fulfil. The main actors within the *Eucalyptus* value chain include input suppliers, growers, traders and

collectors, intermediaries, processors (i.e., pulp mills, composite board mills, and biomass power plants), wholesalers, and consumers. Each of these participants contributes value to *Eucalyptus* timber and products. Multiple actors have overlapping functions within the *Eucalyptus* value chain (Figure 3). Direct actors have crucial functions throughout the *Eucalyptus* value chain and their major activities were identified as follows:

Figure 3. *Eucalyptus* timber value chain mapping and links in Thailand.

3.2.1. Input Suppliers

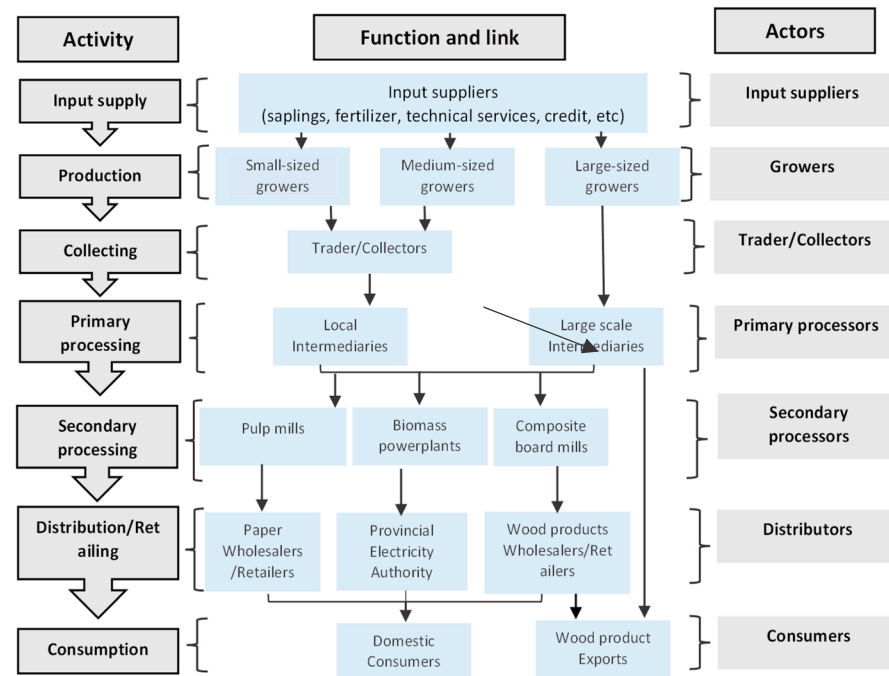Inputs provided by input suppliers in Thailand's *Eucalyptus* value chain include saplings, fertilizer, equipment, land, and water. Sapling breeders are the major input suppliers that have a substantial role in the study area to raise *Eucalyptus* value addition along the value chain. Most input suppliers are specifically identified as sub-companies or subsidiaries of larger paper companies. The main reason for this is that *Eucalyptus* timber serves as a primary raw material in the paper industry, which has been experiencing continuously growing demand. Sapling breeders are a crucial partner with pulp mill factories to ensure a consistent supply of *Eucalyptus* timber. The investment in research and development focuses on producing *Eucalyptus* varieties that exhibit rapid growth, resilience to environmental conditions, and fiber quality. Breeders typically engage in contract farming arrangements with growers, offering guidance on cultivation and maintenance and carrying out field visits to ensure adequate raw material supply for the paper industry, with a crucial role in controlling the main seedling quantities.

In Thailand, three influential *Eucalyptus* breeder groups contribute to the development of *Eucalyptus* strains, resulting in significant investments in time and money being required for strain improvement. These groups include (1) breeders developing *Eucalyptus* strains within the K lineage, such as K7, K58, and K62; (2) breeders developing *Eucalyptus* strains within the H lineage, such as H4, H42, and H46; and (3) other groups like the Reforestation Promotion Office of the Royal Forest Department and agricultural groups that independently cultivate strains from seeds and tissue cultures or strains from forestry industry organizations. Approximately 70% of the cultivated *Eucalyptus* strains in Thailand belong to the K lineage, followed by around 25% from the H lineage and roughly 5% from other strains developed by forestry industry organizations, or agricultural groups.

In terms of pricing and marketing, the breeders primarily set prices, which are usually around 10 Baht per seedling and not significantly high compared with production costs.

This pricing aims to encourage farmers to establish plantations and commit to becoming a partner with the distribution company via a membership program for full-cycle growth by offering seedlings with incentive prices. The competition for land use to cultivate crops like cassava and sugarcane, which are common among farmers, influences the decision to engage in *Eucalyptus* cultivation. Pricing and marketing strategies can motivate farmers to participate in full-cycle membership programs and emphasize service and sales, including advice, consultation, support for other production factors, technological assistance for monitoring and assessing tree cultivation among farmers, estimating stumpage price, and facilitating purchases.

3.2.2. Eucalyptus Growers

Growers are the most important direct actors with the primary function along the *Eucalyptus* value chain. Growers have control over crucial production elements such as capital, land, and labor. The extended duration and capital investment required compared with other forms of crop production significantly affect farmers' decision to engage in *Eucalyptus* cultivation. The provinces with the largest cultivation areas include Sa Kaeo, Nakhon Ratchasima, Prachinburi, and Chachoengsao, in descending order. However, as noted previously, *Eucalyptus* cultivation in Thailand for various industrial purposes has not expanded as much as anticipated for several reasons. One primary factor is the competition for land use among farmers for cultivating cassava or sugarcane, which takes less time to yield returns compared with *Eucalyptus* trees that require a longer duration of 4 to 7 years. Furthermore, the profits from *Eucalyptus* cultivation are comparatively low and do not attract significant interest among farmers to shift toward *Eucalyptus* cultivation.

The farming patterns of *Eucalyptus* cultivators in Thailand can be categorized into three groups based on the size of the cultivation area, using the Thai area unit (rai). (1) Small-holders (less than 10 rai or 1.6 ha) account for approximately 30% of *Eucalyptus* timber production in Thailand. The cultivation patterns in this group include monoculture planting and farmland boundary planting. Approximately 60% of smallholders practice farmland boundary planting, and the remaining 40% engage in monoculture planting. (2) Medium-sized growers (10–50 rai or 1.6–8 ha) represent about 60% of *Eucalyptus* timber production in Thailand. The majority of cultivation in this group involves monoculture planting for commercial farming or as part of farmer groups operating under company promotions. (3) Large-sized growers (more than 50 rai or 8 ha) account for about 10% of the *Eucalyptus* volume in Thailand. These large-scale cultivators require substantial initial investment and are primarily non-small-scale farmers.

Regarding the process of selling harvested timber, the majority of smallholders and medium-sized growers sell through contractors or aggregators, accounting for more than 90% of sales. These contractors assess the bulk price at the entire harvesting site and bring their own equipment for logging, loading, and transportation. However, larger-scale growers, who are partial investors and possess logging and transportation equipment, transport the harvested timber to factories themselves. The low purchase prices coupled with long waiting periods for returns often dissuade growers from expanding *Eucalyptus* cultivation. In particular, smallholders often cultivate *Eucalyptus* as a supplemental income source alongside their primary occupation.

3.2.3. Traders and Collectors

Traders and collectors have a crucial function in the value chain, particularly aggregating *Eucalyptus* timber produced by small-scale growers to distribute to various industries or businesses. These collectors account for approximately 50% of the *Eucalyptus* wood produced in the country. The remaining 50% is acquired directly by larger-scale growers or estates with sufficient resources, equipment, and technological capabilities for logging and transportation to factories. These collectors typically have prior experience in *Eucalyptus* cultivation, enabling them to effectively assess the quality and price of timber. Collectors can be categorized into two primary types: (1) independent collectors hold a 20% share

of the total wood quantity in the value chain, directly purchasing and evaluating prices at cultivation sites and primarily buying from small- and medium-scale growers. They own logging, processing, and transportation equipment. (2) Affiliated collectors or contractors account for 30% of Thailand's total *Eucalyptus* wood volume. These actors are either members of grower-associated companies or may work as promoters for the same entities. They collect timber primarily from contracted growers and hold a significant share in the value chain.

Collectors or traders start by identifying *Eucalyptus* planting areas near or within proximity to purchase points or collection yards to minimize transportation costs. The initial step involves surveying surrounding areas (typically within a 100-kilometer kilometer radius of the collection yards or factories) to locate interested growers who are willing to sell. Collectors then visit the planting areas to assess the timber's value based on size, height, weight, density, and planting duration. After securing farmers' consent, collectors proceed with logging, processing, and transporting the wood to the designated sales point for onward distribution.

3.2.4. Primary Processing and Intermediaries

The primary processing stages involve transforming *Eucalyptus* timber into wood chips for use in the pulp industry or other processing based on size requirements. Wood procurement can be categorized into two main groups: (1) local intermediaries that constitute approximately 20% of Thailand's total *Eucalyptus* timber production. These actors engage in basic wood processing for supply to factories and do not actively promote planting. Purchasing points are located near growing areas and large-sized collection yards linked to industrial factories. (2) Large-scale intermediaries cover approximately 80% of the total *Eucalyptus* timber production and engage in activities from developing or sourcing inputs to promoting planting, purchasing, and continuous business operation, including forest exploitation, and take responsibility for the harvesting, extraction, and transportation of the timber.

In terms of marketing, most intermediaries, particularly at the initial stages, supply pulp and paper companies, constituting over 80% of *Eucalyptus* timber production. This integration establishes a continuous supply chain with quality standards. However, local intermediaries also have a customer base, often through contracts or pre-arranged agreements for electricity generation or other purposes. Intermediaries are part of a midstream industry that controls and distributes raw materials to various downstream industries, generating added value for *Eucalyptus* timber segments in different continuous industries and playing a crucial role in negotiating and determining *Eucalyptus* timber prices with growers through traders or collectors and selling prices to downstream industries.

3.2.5. Secondary Processing

The secondary processing downstream industry encompasses various industries that use *Eucalyptus* timber as a factor for production. They can be divided into five primary downstream industries, including (1) the pulp industry, representing 31.25% of the total *Eucalyptus* timber volume in the country; (2) the biomass energy industry, accounting for 12.5%; (3) the composite board industry, accounting for 12.5%; (4) other industries, including chip wood, processed wood, compressed wood, hardboard, MDF, thin wood, and pallets, which collectively make up 12.5%; and (5) export, representing 31.25% of the total *Eucalyptus* timber volume in the country.

- *Pulp mills*

The Thai pulp industry relies significantly on primary fibre in which the source of origin is solely from *Eucalyptus*. Demand has consistently increased due to economic development, the growth of online shopping, shifting consumer practices, and rising needs for packaging boards. It has been projected that Thailand's demand for packaging board will continuously grow by at least 5% annually compared with the previous average growth of 3.5% per year [26].

The pulp and paper industries operate with integrated business models, controlling production factors from sapling to wood chips and then pulp. This level of vertical integration challenges the entry of new competitors into the market. This control also allows them to set prices, regulate quality, and adjust quantities based on processing needs. As a result, only two major players dominate the industry: namely, Double A group and SCG group. This circumstance impacts price determination and negotiation power in purchasing *Eucalyptus* timber and yields substantial profits.

Moreover, pulp factories have intricate supply chains that extend to sourcing raw materials from other countries, including Vietnam, Indonesia, Malaysia, and the Philippines. Following pulp production, products are then distributed to other industries for further paper production, packaging, and other purposes

- *Biomass power plants*

The biomass industry in Thailand uses approximately 12.5% of the *Eucalyptus* wood produced in the country. The industry relies on various raw materials for energy production, particularly from agricultural crops and agricultural residue, resulting in a relatively low proportion of *Eucalyptus* wood chips. Bioenergy production in Thailand comprises (1) biomass energy production for heat, constituting about 60% of Thai bioenergy production, which is predominantly used for industrial heating purposes. (2) Electricity generation from biomass, representing around 40% of production. According to data from [27], 76 biomass power plants are currently operating in Thailand, with 15 using raw materials derived from *Eucalyptus* wood, including bark, wood chips, and *Eucalyptus* wood residue. These power plants are primarily located in central, northeastern, and eastern regions. Most biomass power plants belong to the feed-in tariff system with fixed purchase rates, where boiler capacity is less than 10 MW and renewable energy sources are used. Intermediaries supplying wood chips to biomass power plants agree on quantities and purchase prices based on market references. Biomass power plants engage in contracts or agreements to purchase raw materials from various wood chip factories or purchasing areas, which mitigates risks in raw material procurement and reduces the fluctuations related to agricultural crop-based raw materials across different seasons. After electricity generation, power is sold to the electricity grid according to purchase agreements; however, a future trend toward biomass power plants selling electricity through auction systems is expected, leading to increased competition and highlighting the importance of cost management.

- *Composite board mills and others*

Other industries, such as composite board mills, hardboard (MDF), poles, lumber, veneer, and charcoal, collectively constitute 25% of the country's total *Eucalyptus* wood volume. This segment breaks down into composite board mills at 12.5% and poles, lumber, veneer, and charcoal at 12.5%. In this secondary wood processing industry, primary raw materials are sourced from various wood chip factories in purchasing areas. These suppliers are either affiliated with multiple networks or operate independently to provide procurement services. The imported raw materials are predominantly non-*Eucalyptus* and serve diverse purposes, contributing to a wide range of products.

In the manufacturing process, emphasis is placed on acquiring low-cost raw materials to maintain low production costs and market competitiveness. However, limitations in technological advancement and research and development exist, primarily due to the moderate scale of industry operators. The businesses are generally medium-sized, allowing adaptability and flexibility in operations.

Challenges impacting the wood processing industry involve the substitution of wood materials with alternatives that are more affordable and easily accessible, leading to increased user preference for non-wood materials. This trend is attributable to the comparatively higher cost of wood-based products, resulting in increased prices for processed products.

- *Export*

Exported wood chips account for 31.25% of Thailand's total *Eucalyptus* timber. In-creasing demand for wood chips in various industries in the global market has increased Thai wood chip exports. Thailand primarily exports wood chips to various countries, including China, Indonesia, Malaysia, Taiwan, and Japan. The export process involves foreign inspection companies examining products' characteristics such as the moisture level of wood chips, in compliance with standards like the Forest Stewardship Council (FSC) for sustainable sourcing. This includes random sampling, weighing a fresh sample, recording the results, and drying the samples. The selling format is often Free on Board, in which the seller's responsibility ends when the goods are placed on the ship at the originating port. Prices fluctuate based on global market rates.

3.2.6. Distribution

The distribution phase depends on products transformed from secondary processors linked to various industries, including the paper and packaging industry, electricity and thermal energy, furniture and construction, and exportation. In Thailand's *Eucalyptus* value chain, distribution plays a pivotal role in ensuring that the products made from *Eucalyptus* timber reach diverse industries and markets. This phase involves transporting and distributing processed goods from secondary processors to various wholesalers and retailers. This stage is crucial as it facilitates the integration of *Eucalyptus* products into multiple sectors, maximizing value across markets and applications.

3.2.7. Consumption

It is the final link in the value chain; consumers use *Eucalyptus* products across various sectors and applications. Consumer practices regarding *Eucalyptus* products can be influenced by factors like perceived quality, brand reputation, pricing, and utility. Consumers willing to pay more can be driven by product quality, environmental certifications, and specific uses. Traditional norms and cultural practices also impact the use of *Eucalyptus* products in Thailand. For example, traditional building methods and preferences for certain materials in the construction sector still influence the adoption of *Eucalyptus*-based construction materials.

3.2.8. Supporting Actors

The supporting actors in the value chain include external actors at each level of the value chain who contribute to efficiency and value creation. The *Eucalyptus* value chain in Thailand encompasses relationships and influence from external support organizations, including independent organizations (i.e., the Thai Pulp and Paper Industry Association and the Private Forest Plantation Cooperative), farmer groups (the Economic Timber Community Enterprise Network in various areas), business associations (the Fast-Growing Tree Business Association, the Thai Timber Association, and the Thai Timber Exporters Association), and others. These supporting organizations affect infrastructure, form collaborative networks, provide information, enhance members' knowledge and skills, and conduct research and development at various levels. These efforts contribute to elevating and adding value to the value chain.

3.2.9. Policy and Regulatory Functions

In Thailand, the government categorizes *Eucalyptus* as a fast-growing tree for industrial use, encouraging the development of the wood industry from planted forests; however, *Eucalyptus* is just one of 13 promoted fast-growing tree species including, e.g., acacia, sea pine, bamboo, and cassia. The government promotes the cultivation of such trees by granting land ownership and allowing tree cutting and sales. The goal is to expand the economic forest area, emphasizing the involvement of individuals and the private sector in supporting wood-based industries. Despite the absence of specific *Eucalyptus* policies and plans, the Royal Forest Department, specifically the Bureau of Forestry Economics, leads a project providing 1875 quality seedlings per ha and offering financial assistance of

18,750 THB per ha over 3 years. However, this support is limited to a specified number of participating areas.

3.3. Added Value Distribution

The value added within the value chain channels was examined concerning four main channels, which were investigated by separately considering the four paths through which *Eucalyptus* timber is supplied to secondary processors (Figure 3).

First path: Growers → Collectors → Primary Processors → Secondary Processors (pulp and paper mills) → Wholesalers → Retailers → Consumers

Starting with the pulp and paper industry value added analysis in the first path (Table 1), 31.25% of *Eucalyptus* timber from approximately 5.76 million tonnes of *Eucalyptus* timber is used as raw material in the industry. This generates added value throughout the value chain, totaling 3,103 THB per ton of *Eucalyptus* timber. The analysis data reveal that the proportion of *Eucalyptus* grower value added in the total value added is 8.1%, reflecting the proportion of value at the grower level, which is relatively low, while the majority of value addition occurs in secondary processing. The TGMM is 90.1%, indicating that 9.9% of the consumer price goes to the grower. The NMM of 48.6% describes the total margin in the ratio of consumer price, which is relatively high compared with other channels.

Table 1. Value added and marginal distribution of actors in the pulp industry. Unit: THB/Ton of *Eucalyptus* timber.

Value Chain Actors	Purchase Price	Value Addition Cost	Sale Price	Value Added	Degree of Value Addition (%)	The Producer's Margin (GMMP)
Growers		350	600	250	8.1%	41.7%
Collectors	600	413	1180	167	5.4%	14.2%
Primary Processor	1180	420	2000	400	12.9%	20.0%
Secondary Processors	2000	1100	4660	1560	50.3%	33.5%
Wholesalers	4660	466	5320	194	6.3%	3.6%
Retailers	5320	532	6384	532	17.1%	8.3%
			Total	3103	100.0%	
			Net marketing margin (NMM)			48.6%
			Total gross marketing margin (TGMM)			90.6%

Source: Authors' calculation from 2023 field survey data.

Second path: Growers → Collectors → Primary Processors → Secondary Processors (biomass power plants) → Consumers.

In the second path (Table 2), biomass power plants use approximately 12.5% of the volume of *Eucalyptus* timber to generate heat and electricity. Added value across the entire path amounts to 924 THB per ton of *Eucalyptus* timber. The *Eucalyptus* growers' proportion of value addition in the overall value added is 27.1%. The TGMM is 73.4%, implying that 26.6% of the consumer price contributes to the growers' share. Additionally, the NMM is 40.9%, depicting a ratio of total value added to the consumer price.

Third path: Growers → Collectors → Primary Processors → Secondary Processors (composite board mills) → Wholesalers → Retailers → Consumers

For the third path, value addition varies at each stage in Table 3, with significant contributions from growers, collectors, processors, and distributors until it reaches end consumers. Around 12.5% of the *Eucalyptus* timber volume is supplied to composite board mills. This use contributed to an added value of 1762 THB per ton of *Eucalyptus* timber. Within this pathway, *Eucalyptus* growers account for 14.2% of the overall value added. The TGMM is 84.3%, and the NMM is calculated at 40.9%.

Table 2. Value added and marginal distribution of actors in biomass power plants. Unit: THB/Ton of *Eucalyptus* timber.

Value Chain Actors	Purchase Price	Value Addition Cost	Sale Price	Value Added	Degree of Value Addition (%)	The Producer's Margin (GMMP)
Growers		350	600	250	27.1%	41.7%
Collectors	600	413	1180	167	18.1%	14.2%
Primary Processors	1180	420	2000	400	43.3%	20.0%
Secondary Processors	2000	152	2259	107	11.6%	4.7%
			Total	924	100.0%	
			Net marketing margin (NMM)			40.9%
			Total gross marketing margin (TGMM)			73.4%

Source: Authors' calculation from 2023 field survey data.

Table 3. Value added and marginal distribution of actors in composite board mills. Unit: THB/Ton of *Eucalyptus* timber.

Value Chain Actors	Purchase Price	Value Addition Cost	Sale Price	Value Added	Degree of Value Addition (%)	The Producer's Margin (GMMP)
Growers		350	600	250	14.2%	41.7%
Collectors	600	413	1180	167	10.2%	15.3%
Primary Processors	1180	420	2000	400	22.7%	20.0%
Secondary Processors	2000	44	2963	519	29.4%	17.5%
Wholesalers	2963	236	3407	209	11.9%	6.1%
Retailers	3407	221	3833	204	11.6%	5.3%
			Total	1762	100.0%	
			Net marketing margin (NMM)			46.0%
			Total gross marketing margin (TGMM)			84.3%

Source: Authors' calculation from 2023 field survey data.

Fourth path: Growers → Collectors → Primary Processors → Exporters → Consumers

In the fourth path, the export chain value addition in Table 4 showcases significant contributions to primary processors and distributors prior to export. About 31.25% of the *Eucalyptus* timber volume is exported, resulting in an added value of 1017 THB per ton of *Eucalyptus* timber. In the export pathway, *Eucalyptus* growers contribute 24.6% to value added. The TGMM stands at 76%, and the NMM is 40.7%.

Table 4. Value added and marginal distribution of actors for export. Unit: THB/Ton of *Eucalyptus* timber.

Value Chain Actors	Purchase Price	Value Addition Cost	Sale Price	Value Added	Degree of Value Addition (%)	The Producer's Margin (GMMP)
Growers		350	600	250	24.6%	41.7%
Collectors	600	413	1180	167	16.4%	14.2%
Primary Processors	1180	420	2000	400	39.3%	20.0%
Exporters	2000	300	2500	200	19.7%	8.0%
			Total	1017	100.0%	
			Net marketing margin (NMM)			40.7%
			Total gross marketing margin (TGMM)			76.0%

Source: Authors' calculation from 2023 field survey data.

4. Discussion

4.1. Value Chain Map, Actors, Roles, and Links

The value chain map for *Eucalyptus* timber highlights the direct and indirect participation of various actors involved between growers and final consumers in the value chain. Stakeholders in the *Eucalyptus* timber production value chain engage in a range of activities, spanning from plantation to consumption. Key actors include input suppliers, growers, traders, processors, distributors, and supporters of the chain. Similar findings were reported by [22,23,28], while some timber value chain mapping followed from growers to consumers [18,29,30].

Pulp industry seed and sapling breeders are major actors who set the foundation for value creation, which dictates prices and the direction of *Eucalyptus* production in the value chain. Ninety percent of the marketing margin goes to pulp industry seed and sapling breeders, especially along the supply chain to pulp and paper mills, which account for more than 30 percent of eucalyptus timber use. This indicates vertical integration in the *Eucalyptus* timber business through the significant role of sapling breeders as major input suppliers. Growers are actively linked to input suppliers through connections involving sapling purchase, promoting planting and cultivation, silvicultural contracting, and guaranteed sale prices. This arrangement contrasts with the Ethiopian context, in which public nurseries have a significant role as the primary actors providing seedlings to growers, revealing regional variations in value chain dynamics [22].

Growers, especially smallholders, are involved in various challenges from cultivation to final sale. However, their role in marketing participation remains low due to small-scale operations resulting in high unit costs, lack of infrastructure, information asymmetry, high logistical costs, financial constraints, and insufficient policy support. This reduces the smallholders' bargaining power and resources to access larger markets directly, forcing them to rely on intermediaries. Growers are met with multi-faceted challenges, including land use conflicts and extended harvesting rotation; however, participation in membership organizations offers benefits such as continuous cultivation support, price guarantees, and reduced risks regarding economic return. This aligns with Desta et al. who found that *Eucalyptus* cultivation in Ethiopia faces competitiveness challenges compared with shorter harvest cycles such as those for cereals and livestock [1].

Traders have a significant role in gathering and transporting timber, offering services for logging and transportation, possessing the necessary equipment and machinery, and negotiating prices with growers. These actors enhance the value of timber by grading and allocating different timber assortments to specific processing mills. This parallels the findings for Indonesia [18] and Lao PDR [20], which indicated that traders had a pivotal role as intermediaries within the timber industry, establishing and nurturing valuable relationships across various sectors.

For primary processing, wood chip mills manage raw material competition, processing wood to supply various industries and exporting chip wood abroad. Implementing market incentives such as self-collection, purchasing terminals, and forward contracts has established a guarantee of an adequate supply of raw materials for sustained production.

At the secondary processing stage, the industrial categories can be divided into pulp and paper, bioenergy, and wood processing industries. These sectors are linked through shared raw materials flowing into each industry. Some competition for raw materials is evident based on the various uses of *Eucalyptus* wood, which is a crucial element significantly adding value to the *Eucalyptus* value chain in Thailand. At the distribution level, *Eucalyptus* wood is a raw material for diverse industries, yielding various end products, and end products differ widely across markets. New entrants would find it challenging to compete due to high investment requirements and the vertical integration of production factors.

4.2. Value Added and Benefit Distribution

In terms of value-added distribution, *Eucalyptus* timber value chains demonstrate profitability for all involved actors (as indicated in Tables 1–4). The distribution of benefits

reveals the highest increasing allocation from growers toward wholesalers and retailers in the pulp industry. The highest margin occurs for secondary processors due to high-value product processing, economies of scale in operations, and efficient resource use. This aligns with [17], who found that downstream stakeholders that managed marketing networks captured most of the value created.

For the biomass industry, the distribution of benefits from *Eucalyptus* timber along the supply chain is relatively shorter and generates the fewest benefits compared with other supply chains. In the composite board mills chain, the ability to generate benefits along the chain ranks second and the proportion of margin is distributed more effectively. For exports, the distribution of margin to actors received a lower margin due to the short chain of *Eucalyptus* timber. Although the TGMM in all chains implies that growers receive low benefits in comparison to other actors along the chain, *Eucalyptus* growing remains a valid option for growers to plant in marginal land and farmland boundaries. This finding mirrors that of [31].

4.3. Opportunities and Constraints in the Value Chain

Eucalyptus timber demand is a positive driver based on various applications from the energy, pulp, construction, and furniture industries in Thailand and globally. The export and international trade of wood-based products have remarkable significance in Southeast Asia [19]. Furthermore, the potential for developing value-added products derived from *Eucalyptus* such as furniture, high-value chemicals, energy, and related sectors can establish a high benefit distribution for the value chain [19,28,32].

Some constraints that affect actors in the *Eucalyptus* value chain were revealed during our field survey. Input suppliers encounter challenges in research and development for producing clones—a process that demands a significant amount of investment and time. Additionally, suppliers face limitations in increasing sales due to competition for land use among growers. Growers face critical decisions that can require substantial investment and a waiting period for produce, which seems to be globally common among smallholders [1]. Moreover, the selling price often fails to attract growers, further impacting decision-making. The lack of supportive government policies can also be considered a challenging environment for growers [33]. However, smallholders in Thailand have significant opportunities to benefit from *Eucalyptus* plantations, particularly through the fast growth rate and high demand for *Eucalyptus*, ensuring that smallholders can generate revenue relatively.

Traders encounter competition for *Eucalyptus* raw materials and the extended transportation costs have a detrimental impact on profits. At the primary processing level, factories have been compelled to establish multiple purchasing terminals to expand the procurement area and ensure an adequate supply of raw materials, leading to additional costs in timber transportation and handling. At the secondary processing level, a shortage of raw materials presents a significant challenge, creating entry barriers for new manufacturers facing high investment requirements and the vertical integration business model. In distribution, customer needs concerning wood-based products and packaging change rapidly and frequently and retailers must adapt. These actors must have an active presence in multiple distribution channels and be prepared to act immediately in response to consumer demands. Exporters also face a shortage of raw materials and are encountering increased shipping costs, which impacts operations. Supporters at various levels are constrained by limited budgets and unclear policies, which contribute to a reliance on imports due to raw material shortages. In general, the additional challenge of fluctuating prices further complicates the situation for all stakeholders in the *Eucalyptus* timber value chain.

4.4. Study Limitations

This study has some limitations. First, it does not focus on a downstream perspective as data were not collected from wholesale and retail actors (e.g., supermarkets, retail shops, and furniture shops) and final consumers. However, information related to consumer

behavior and downstream chain activities in the *Eucalyptus* industry was obtained from intermediaries' interviews. Second, in-depth interviews and focus groups may constitute a methodology limitation due to a lack of random sampling. In addition, the growers' sample size was not determined following a statistical approach but using 30 individual farmers/growers to represent the minimum sample size for normality. Third, the study used cross-sectional data to analyze value added and benefit distribution. This might constrain our ability to effectively capture the changes in actors' performance in value chains over time.

5. Conclusions

This study analyzes the value chain of *Eucalyptus* timber in Thailand using secondary data analysis, in-depth interviews, focus groups, and surveys. This is the first empirical study to explore value chain actors, activities, and value added to Thailand's *Eucalyptus* industry. The results revealed that the value chain includes several important actors including sapling breeders, growers, traders, processors, wholesalers, and exporters. Our findings demonstrate vertical integration in the *Eucalyptus* timber industry, where input suppliers (particularly sapling breeders) play a major role in controlling the main seedling quantities, promoting cultivation, and ensuring *Eucalyptus* raw material inputs for the pulp and paper industry. The findings emphasize that growers benefit less compared with other actors along the *Eucalyptus* timber value chain. The highest benefits are distributed along the path of the pulp mill value chain and the lowest benefits are distributed in the path of biomass power plants. Understanding the structure of the value chain, the roles of key actors, and the links between actors can enable industry participants to optimize strategies, enhance collaboration, and ensure sustainable success in Thailand's *Eucalyptus* industry.

Based on our findings, the following recommendations are proposed to improve Thailand's *Eucalyptus* market performance: (1) the overall benefit distribution analysis revealed a positive gross profit margin but low distribution at the grower level. Growers should focus on enhancing their knowledge about timber value addition techniques or incentive value addition activities should be introduced at the grower level. (2) Our findings indicate the significance of sapling breeders' control of seedling quantities and influence on the entire *Eucalyptus* timber value chain. This presents an opportunity for the government to establish public–private partnerships to create supportive programs. For example, these programs could include funding and infrastructure development for research and development nurseries, genetic improvement, human capacity building, and regulations to ensure fair distribution of benefits for all actors in the value chain. (3) Considering the absence of policies promoting *Eucalyptus* planting activities and value creation for all actors along the chain, we recommend the development of suitable governmental policies to incentivize responsible *Eucalyptus* planting activities and balanced economic benefits. (4) To enhance the value chain of Eucalyptus products and maximize benefits for all stakeholders, it is recommended that concerned entities prioritize investment in value addition technologies, especially for increasing the efficiency and quality of *Eucalyptus* timber.

Despite the *Eucalyptus* value chain in Thailand being studied, it is recommended that new studies should conducted to capture a comprehensive downstream perspective of the *Eucalyptus* industry. It is necessary to implement a time series for the observation of changes in value chain performance for a dynamic understanding of value-added processes and benefit distribution within the industry.

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