# A Comparative Analysis Between Timber Industry and Nontimber Forest Products Industry in Relation to Sustainability and Operators' Proactiveness

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## Abstract

The balance among forest industry development, forest operators' well-being, and environmental conservation has been noted as an emerging concern in forest sustainability strategy. In this study, we innovatively adopted a multidimensional assessment method that integrates economic, environmental, and social dimensions to compare the comprehensive sustainability of roundwood, bamboo, tea products, and fruit industries, which are representative subtypes of the timber industry and the nontimber forest products (NTFP) industry. Additionally, our study examined whether a relationship exists between the forest industry's comprehensive sustainability and operators' proactiveness. We collected data on selected types of forest operators involved in productive loans from 115 villages in southern China between 2008 and 2020. Empirical results indicate that an increase in the comprehensive sustainability rank of the subtype forest industry led to growth in forest operators' financing amount. Specifically, the NTFP industry motivated operators' proactiveness more than did the timber industry, the effect of which was considerably greater in company group than in household group. Our findings reveal the necessity of policy interventions in developing countries to encourage the transition to optimizing forest industrial structure and sustainable forestry operations, which could initiate the socio-economic goal of sustained forest resource use and growth in forest sector output through the natural promotion effect posed by the sustainability advantages.

Forest ecosystems are among the most biologically rich and genetically diverse ecosystems on earth, with a significant contribution to the global carbon cycle (Kohl et al. 2015). Development and future directions of the forest industry have been noted as crucial issues in sustainability strategy, particularly in developing countries where they are considered simultaneously relevant to natural resource use and poverty eradication in rural areas (Baumgartner et al. 2015). Given the chronic land scarcity in densely populated areas of China, the sustainability development of forest industry is a breakthrough in the search for compromise between forest conservation and forest farmers' livelihoods.

China launched a new round of forest tenure reform in 2003, which initially separated forestland ownership and management rights to transfer forestland management rights to individuals. The reform aroused extraordinary enthusiasm for forest product manufacturers in China and became a prominent part of the global trend toward the decentralization of forest management (Siikamaki et al. 2015). According to the National Bureau of Statistics, China's forestry sector output increased 3.81 times from 2003 to 2020 (NBSPRC 2021). Meanwhile, the sustainability of forest production has attracted sustained attention in the context of the reform. The reform boosted forest farmers' awareness of sustainable production methods in addition to environmental protection (Zhang et al. 2015).

Although China's forest industry has been preliminarily on track to sustainable development, this sustainability is still fragile (Yang and Wang 2015). Compared with the industrial sector, the forestry sector is broadly discussed for its social externalities. There have been fast-growing

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debates about future directions of sustainable forest industry development. In the context of the Finnish forest-based industry, the transition to sustainable bioeconomy and diversity of business models plays an essential role in the viability and growth of small and medium-sized enterprises (D'Amato et al. 2020). Concerns about environmental sustainability allow managers to design forest management policies tailored to the peculiarities of each territory, though these may be challenged by the lack of coordination between forest planning and sustainable development (Kohl et al. 2015).

After the forest tenure reform, optimizing forest industrial structure and effectively controlling environmental costs have become goals of China's forest management in the coming decades. In this study, we innovatively adopted a multidimensional assessment method that integrates economic, environmental, and social dimensions to compare the comprehensive sustainability of roundwood, bamboo, tea products, and fruit industries, which are representative subtypes of the timber industry and the nontimber forest products (NTFP) industry. Moreover, we examined whether forest industry comprehensive sustainability has an effect on forest operators' proactiveness.

Our results extend several results in the existing literature. The relationship between sustainable forest resource use and forest industry output has been previously studied, but most have focused on a specific viewpoint (e.g., productivity, ecological costs, job creation; Scarlat et al. 2015, Jena 2020, Kimengsi et al. 2020). This study systematically assessed forest industry sustainability by adopting a broader range of views from the literature and making sustainability between the subtype forest industries comparable. Furthermore, some related studies were based on macro-level analysis, aiming to make improvements in sustainable forest management (SFM; Martinez-Vega et al. 2016, Mederski et al. 2021). This approach can promote the optimization of management concepts; however, the effects of producers on sustainable forest industry development may be overlooked. Therefore, we provided this case using forest operators' data combined with the comparative analysis between the timber industry and the NTFP industry.

For other countries and regions with extensive forest areas, the results of our study could further be used to elucidate the critical question in future forestry development: Do SFM and forestry sector output have the potential to develop in a mutually reinforcing way? Over recent years, the sustainable concept has transferred forest management from timber yield to all products and services provided by the forest. Hence, the main challenge for forest economists is to establish a new economic paradigm to accommodate SFM that is economically viable, socially responsible, and ecologically sound (Kant 2007). Given these objectives, this study aims to provide the theoretical and empirical basis for future forest industry development from a more holistic perspective.

## Sustainable Forest Industry Development

### Timber industry

Typical timber products and their derivatives include logs, wood processing products, and paper products. The timber industry has developed sophisticated production techniques and booming international trade, but the production and trade of wood and its products have been under criticism since the 1970s with the rise of eco-friendly construction materials and worldwide attention to forest carbon sinks (Choong et al. 1993, Huang et al. 2019, Boulton et al. 2022). Deforestation, severe soil erosion, and underpaid forest workers make the development of the timber industry highly controversial (Yang and Wang 2015).

The past two decades have seen the transition of the wood products market; the compression of margins and electronic media have caused this traditional industry to face the challenge of efficiency in using intermediate inputs. When sustainability goals continue to be emphasized, input savings could ease biomass and raw material constraints (Hussain et al. 2016). It has been suggested that the future of intelligent forest production lies in finding the balance among the need for timber production, the conservation of biodiversity, and the provision of other essential ecosystem services (Verkerk et al. 2020).

Another approach to the rational operation of the timber industry is regulation of access to logging and selling qualifications. Harvest quota regulation in China began in 1987 as a response to dramatically declining forest volume, which is set by China's Forestry Administration for each province every 5 years. The scarcity of forest resources makes it prudent for the government to manage this traditional forest operation. The quota limits timber producers' benefits to a range of legal and extralegal mechanisms, which has been roundly criticized for high government administrative costs (Qin and Xu 2013, He 2016). The timber harvest quota system in China has contributed to forestland protection but has inevitably raised the requirements for operators of the timber industry.

### Nontimber forest products industry

Global warming and desertification highlighted the importance of sustainability in forest production. Several countries have begun to focus on NTFP to seek a win–win situation for forest farmers and management departments. NTFP, including roots, stems, leaves, and fruits, are broadly used worldwide as medicines, foods, spices, fibers, and fuel (Laird et al. 2011). NTFP are presently receiving considerable attention from the international society for their contribution to addressing the livelihoods of forest communities with less destruction of the forest. As the demand for NTFP expanded, the enthusiasm for the NTFP industry among indigenous people who depend on forest communities rapidly increased.

Developing countries harvest more NTFP than do developed countries because they rely heavily on forest products for employment (Jena 2020). China is the world's largest exporter of NTFP, followed by India, the United States, and Germany (Yildirim and Kose 2018). Since 2005, China's government has been pursuing the principle that "*Clear waters and green mountains are as good as mountains of gold and silver,*" working to promote a shift from traditional forest production to diversified forest products value-chain construction, including NTFP.

However, there exist limitations and fragility to the contribution of NTFP, one of which is that these products need a solid domestic or global market (Sunderland et al. 2011). Moreover, storage technology and logistics infrastructure also place constraints on current development of the NTFP industry in China. A number of NTFP's production areas, such as those for mushrooms and wild medicinal herbs, are located far from the metropolis or even in poverty-stricken areas. In addition, NTFP industry operators are generally small-scale households. Lack of management capital and labor force make it difficult to guarantee the storage and transportation of NTFP, which poses challenges to the efficiency of the NTFP industry in China and many other developing countries.

## Materials and Methods

### Conceptual background

To determine the comprehensive sustainability of the forest industry, we adopted a multiobjective optimization assessment method (Panwar et al. 2006), which describes the association between forest industry and sustainable development from economic, environmental, and social dimensions. We enriched this multidimensional assessment by taking stock of the above-mentioned literature review. The mechanism of the assessment method is presented in Figure 1. In response to the advanced SFM concept, forest industry has developed a renewed focus on the positive circular feedback relationship among three dimensions concerning nine elements. The comprehensive sustainability of a subtype forest industry is associated with these elements as well as a holistic view of these three dimensions (Figure 1).

Further, to explore the mechanism of how forest industry comprehensive sustainability affects operators' proactiveness, we established the utility function of the forest operators. There are several basic assumptions of this utility function. First, the forest operators aim to maximize their expected utility from the consumption of market goods and leisure under three constraints (the cash budget constraint, the time budget constraint, and the productivity constraint; Morsello et al. 2014). Second, the forest operators have sustained access to forest production loans with yearly repayment of interest on the loan (according to the central bank's forestry loan incentive policy). Finally, total income of the forest operator consists of forest operation income and wage income (Hoang et al. 2020). The utility function and constraints can be represented as follows:

$$\mathrm{Max}(C_{\mathrm{M}}, t_{\mathrm{L}}, t_{\mathrm{FP}}, t)\{E[U(C_{\mathrm{M}}, t_{\mathrm{L}}; H)]\}, s.t.$$

$$P_{\mathrm{M}}C_{\mathrm{M}} + R_{\mathrm{I}} \leq Q_{\mathrm{FP}}P_{\mathrm{FP}} + W(t) \quad (1)$$

$$t_{\mathrm{L}} = T - t_{\mathrm{FP}} - t \quad (2)$$

$$Q_{\mathrm{FP}} = f_{\mathrm{FP}}(t_{\mathrm{FP}}, I) \quad (3)$$

In the utility function, $C_{\mathrm{M}}$ is a vector of market goods consumed, $t_{\mathrm{L}}$ is the time dedicated to leisure, $t_{\mathrm{FP}}$ is the labor time allocated to production and processing of forest products, $t$ is the labor time dedicated to activities concerning wage income, and $H$ is the operator characteristic.

Based on assumption 2, the forest operators can continuously obtain forest production loans to offset previous-period financed capital. Therefore, the cash budget constraint can be expressed such that operators' consumption of market commodities and current period capital cost cannot exceed their acquisition from forest products selling and wage activities. In Equation 1, $P_{\mathrm{M}}$ is the price vector for market goods consumed. $P_{\mathrm{FP}}$ and $Q_{\mathrm{FP}}$ are the price and quantity of forest products produced, respectively, whereas $R_{\mathrm{I}}$ is cost of capital invested in forest production. $W(t)$ is the income generated from wage activities.

Equation 2 presents the time budget constraint of forest operators. The time dedicated to leisure $t_{\mathrm{L}}$ is determined by the total time available $T$, the labor time dedicated to the

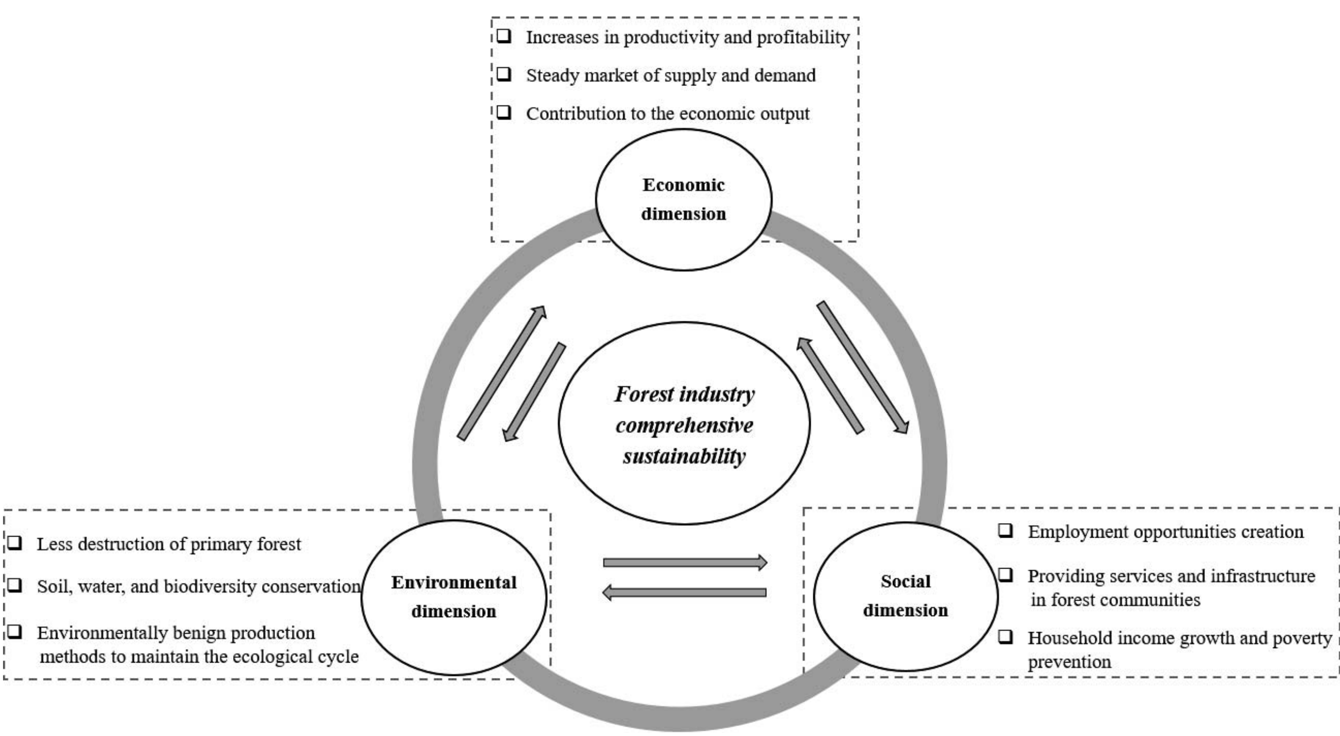


*Figure 1.—Mechanism description of the multidimensional sustainability assessment method.*

production and processing of forest products $t_{FP}$, and labor time dedicated to wage activities $t$. In Equation 3, we adopted the production function of forest products $f_{FP}(\cdot)$. This function demonstrates the mechanism affecting relationships among labor time, invested capital, and productivity of forest products.

It can be concluded from the utility function and three constraints that operators' productive inputs in forest operations $I$ and $t_{FP}$ are related to the following factors: (1) operator's risk expectation; (2) marginal productivity per unit capital or labor and expected supply–demand situation of the forest product; (3) income elasticity of forest operation labor time and wage activities labor time; (4) cost of capital; (5) operator characteristic. Given the definition of multidimensional sustainability in Figure 1, in the long run, (1) is linked to ecological and economic sustainability in addition to the operators' risk appetite, and (2) concerns economic sustainability, while (3) is related to economic and social sustainability. Hence, the multidimensional sustainability of forest industry was adopted as a potentially decisive factor for operators' proactiveness in forest production.

## Study area and sample

Southern China is one of the world's most intensively managed forest areas in the context of the Chinese government's forestland use policy (Tong et al. 2020). Fujian Province, one of the China's four main forest areas, is located close to the Tropic of Cancer with a subtropical monsoon climate. The region supports the highest forest coverage rate (62.96%) at the provincial level in China (FPBS 2021). As a pilot area for forest tenure reform in southern China, Fujian Province has a long history of forest production. Forestry in Fujian Province occupies a leading position in China's domestic market. We selected 115 villages in the government-classified forest-resource concentration area in northern Fujian Province (117°37′E to 118°19′E, 27°27′N to 28°05′N) owing to diversified forest industrial structure and extensive distribution of forest resources in the region.

Roundwood of fir, masson pine (*Pinus massoniana*), and broadleaved tree species belonging to the timber industry, along with bamboo, tea products, and fruit belonging to the NTFP industry, are representative subtype forest industries that account for the majority of forestry sector output in Fujian Province (FPBS 2021). To further explore the situation of forest operations in the region, we conducted a set of comprehensive investigations on forest management departments and forest operators from January 2021 to August 2021. Data on operators of selected subtype forest industries ($n = 1{,}589$) in the 115 villages from 2008 to 2020 was collected and collated using word records provided by local forest-property mortgage registration centers and forest assessment agencies, from which 16 forest operators were excluded because of incomplete information ($n = 1{,}573$). Detailed information on forest operation characteristics was collected from interviews with forest operators. We divided operators into household group and company group to examine the heterogeneity of sustainability on the motivation of forest operators; operators organized as forest farms were excluded when grouping ($n = 3$).

## Estimation model and variables

*Estimation model*.—We performed regression estimations to examine the association between forest industry sustainability and operators' proactiveness in forest production (Angelsen et al. 2014). The general form of the regression model can be expressed in Equation 4:

$$Y = \beta_0 + \beta_1 X + \beta_2 Z + \mu_v + \gamma_t + \varepsilon \qquad (4)$$

where $Y$ represents proactiveness of forest operator $i$, $X$ represents the comprehensive sustainability of the subtype forest industry operated by $i$, $Z$ is a vector of control variables with potential effects on operators' proactiveness, $\mu_v$ captures region fixed effects, $\gamma_t$ captures time fixed effects, and $\varepsilon$ is the error term. Pooled-Ordinary Least Square method was applied in the estimations (Chen 2014), and all continuous variables were winsorized at the 1 percent and 99 percent quartiles to prevent disturbances from extreme values. Additionally, we used heteroskedasticity-consistent standard errors (also known as robust standard errors) to exclude the effect of heteroskedasticity on the estimation results (Hayes and Cai 2007).

*Dependent variable*.—Forest product manufacturers that continually improve their products, make decisions involving risk, and incorporate proactive input into their operation typically outperform those that do not (Elser and Michael 2018). In the production constraint Equation 3, forest products output $Q_{FP}$ is defined as a function of input capital and labor time. We chose capital amount as the dependent variable for two reasons. On one hand, the mechanism linking China's forest tenure reform and the growth of forestry output lies in financing and investment that are encouraged by rights protection (Bai et al. 2014). Furthermore, forest area in northern Fujian province has a vast territory with a sparse population, so the accessibility of capital input is higher than the labor force. Consequently, the amount of capital that the operators financed for their forest production in a natural year (forest production loan released by local banks generally has 1-yr cycle in practice) was used as the proxy capturing operators' proactiveness in the regressions (Qin and Xu 2013), which was deflated using 2008 as the base year to exclude the effect of inflation.

*Explanatory variable*.—Table 1 illustrates the multidimensional analysis results on the subtype forest industries selected in the study. Among them, roundwood production has endured extensive criticism for deforestation and unsustainable use of natural resources, in addition to suffering from poor economic profitability since the 1990s. Bamboo is widely recognized as a new type of NTFP with commercial sustainability. It can be reharvested in $<$10 years and has a higher yield per hectare than that of traditional timber resources (Dixon and Gibson 2014). Although the steady growth of the bamboo industry supports the livelihood of forest farmers, its effect on environmental quality and community well-being remains controversial (Li et al. 2011, Han et al. 2014). As long-lasting commercialized NTFP, tea products and fruit with $<$1 year between harvesting and selling cycles have eco-friendly advantages while considerably contributing to China's forest products export (Laird et al. 2011, Ke et al. 2021, NBSPRC 2021). Nonetheless, there still exists the potential danger that these economic forest products may disadvantage the very poor among local users (Arnold and Perez 2001).

Table 1.—Results of the multidimensional sustainability assessment on forest industry.

| Forest industry | Subtype forest industry | Economic dimension | Environmental dimension | Social dimension | Comprehensive sustainability rank |
|---|---|---|---|---|---|
| Timber industry | Roundwood | Suffered from poor profitability in the 1990s and the same trend has continued in the 21st century; the reduced domestic supply of legally harvested wood and the emergence of rent seeking in forest management under China's harvest quota (Panwar et al. 2006, He 2016) | Has been under criticism since the 1970s for deforestation and severe soil erosion (Choong et al. 1993, Yang and Wang 2015) | Provides limited jobs, services, and infrastructure in rural communities; has potential negative effects in the local region (Panwar et al. 2006, Asanzi et al. 2014) | Low - 1.0 |
| Nontimber forest products industry | Bamboo | Increasing demand and economic returns spur the Chinese bamboo sector to steady growth (FAO 2010) | Has a recovery cycle of <10 yr; the contribution to environmental quality remains controversial (Li et al. 2011, Song et al. 2011, Dixon and Gibson 2014) | Contributes much to rural development and poverty alleviation; has potential long-term consequences within the communities (Song et al. 2011, Han et al. 2014) | Middle - 2.0 |
| | Tea products and fruit | Meet the demand of the domestic market while exporting to the international market for considerable economic value (Ke et al. 2021, NBSPRC 2021) | Have high environmental sustainability under the scientific forest management (Laird et al. 2011, Shen et al. 2021) | Play important roles in rural households' income; still exists the danger that disadvantages the deep poor group (Arnold and Perez 2001, Sunderland et al. 2011) | High - 3.0 |

Figure 2 presents output of the subtype forest industries in Fujian Province from 2008 to 2020 (FPBS 2021). Except for roundwood, remarkable growth trends of productivity could be seen in bamboo (average annual growth rate = 9.08%), tea products (average annual growth rate = 5.86%), and fruit (average annual growth rate = 3.03%). In addition, steady increases in net import of roundwood imply an enormous unmet need, while the growths in net export of bamboo, tea,

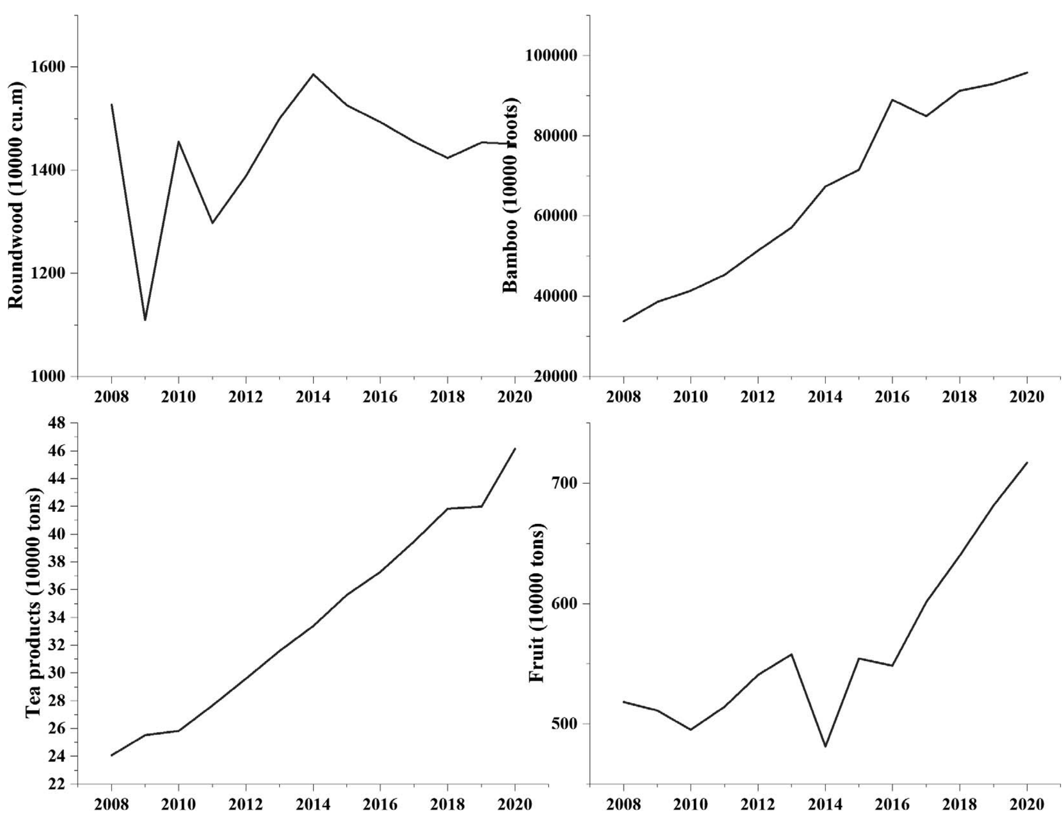


Figure 2.—Productivity of the representative subtype of forest industries in Fujian Province, China. Source: Statistical Yearbook of Fujian Province (FPBS 2021).

and fruit between 2008 and 2020 again verified our analysis in Table 1 (FPBS 2021, NPBS 2021). Referring to the systematic literature analysis presented in Table 1 and statistical data on forestry in the region, the comprehensive sustainability of the subtype forest industries in our study were divided into low level (1.0), medium level (2.0), and high level (3.0).

*Control variables*.—These variables include owned forestland size, financial market environment, and implemented public policy.

Owned forestland size could be a critical operation characteristic (*H*) affecting benefits and costs of forest production (Ren et al. 2018). Compared with small-scale operators, large-scale forestland holders have lower cost per unit of forestland and greater incentive to invest in production (Conrad et al. 2011). Conversely, Xie et al. (2014) found that the intensity of households' investment in forestry is negatively affected by the size of forestland, but positively affected by easiness in obtaining loans. Forestland area with mortgageable function owned by operators was chosen as the control variable concerning operator characteristic in the regression model (Zhang et al. 2014).

The market is another institution that supports forest production methods in addition to households (Wilsey and Nelson 2008). Based on the conceptual function, the financial market environment that responds to coordination of capital supply and demand may have a potential catalytic effect on capital input. We adopted cost of capital (1-yr forest production loan interest rate) as the indicator of market environment (Liu et al. 2017), with data collated from the National Statistical Yearbook of China (NBSPRC 2021).

We established conceptual function in the situation of perfect market competition; however, as a sector with strong social externalities, the government also could act as a contributor to the promotion of forestry. The implementation of public policy on forest industry development in China resulted in substantial increases in forestry sector output (Liu et al. 2017). A representative policy issued by the Chinese government to support the forest production is the *Forestry Infrastructure Subsidy Policy* (described in China's No. 1 central document; Central People's Government of China 2010). The policy aimed to improve the forest subsidy system and to add forest production machines into the scope of subsidy items, which may indirectly boost the productive investment of forest operators.

## Results and Discussion

### Descriptive analysis

In the researched villages, 1,573 forest operators participated in production loans from 2008 to 2020, of which 67.07 percent were NTFP industry operators (Table 2). Timber industry and NTFP industry operators financed an average of 0.953 million Chinese Yuan (CNY) per year (standard deviation [SD] = 1.564) and 1.045 million CNY per year (SD = 1.889), respectively. Concerning owned forestland, timber industry operators (mean = 47.099 ha) were 3.4 times larger than NTFP industry operators (mean = 10.695 ha). The maximum forestland size for the timber industry was 823.580 hectares, while the NTFP industry was 259.733 hectares (Table 2). This result supports the view of Zhang et al. (2005), who found that forestland parcelization takes place when nontimber value far exceeds timber value. The standard deviation of forest production loan interest rate (SD = 0.745) implies slight capital cost fluctuations over the period. Regarding the policy factor, 86.9 percent of forest operators were potentially influenced by the *Forestry Infrastructure Subsidy Policy* when deciding on financing.

### Regression results

Regression estimations in our study were conducted using Stata software (version 13.0). The positive and significant coefficient ($P < 0.01$) of comprehensive sustainability in Table 3, column 1 suggests that an increase in the multidimensional sustainability rank of the subtype forest industry resulted in growth in forest operators' proactiveness of productive financing. Potential explanations are as follows. First, eco-friendly production methods can promote consumer market preference, which increases the attractiveness of internal and external resources. Operators whose production philosophies are consistent with socio-cultural norms contribute to survival and prosperity by ensuring operation legitimacy to reduce associated costs (Panwar et al. 2006). Second, sustainability practices would lead to positive feedback of effective forest operation. Forest industry with short-run business cycle and higher level of environmental commitment requires more sophisticated SFM skills to source information from both industry and public agencies, even though this could be linked to seeking more complex advice (Garay et al. 2017). Finally, trends in economic dimensional sustainability of the subtype forest industries could be easily tracked through the forest products market. Although stable or declining stumpage prices enable timber producers to supply mills at low cost, these signals serve as a poor incentive for forest operators to invest in timber production (Conrad et al. 2010).

Inclusion of time fixed effect and region fixed effect did not change the direction and significance of the coefficient between comprehensive sustainability and operators' proactiveness (Table 3, column 2). Among control variables, the association of owned forestland area with operators' proactiveness was statistically significant and positive ($P < 0.01$). Generally, small-scale operation implies higher unit costs for harvesting, regeneration, and silviculture activities and lower management intensity. Moreover, amount of investment that small-scale forestland holders can afford is limited owing to the imperfection of capital market (Xie et al. 2014). However, the excessive scale-up process may pose risks to the existing multidimensional sustainability of the subtype forest industries. Even though it is endowed with greater comprehensive sustainability, excessive expansion of the NTFP industry may result in decreased density, sparse distribution of species, and depletion of biodiversity (Muraleedharan and Sasidharan 2005), which emphasizes the crucial role of the forest management department in guiding and establishing relevant standards in sustainable forest production.

In both household and company groups, coefficients between comprehensive sustainability and amount of operators' financing were statistically significant ($P < 0.01$) and positive. Nonetheless, the contributions of comprehensive sustainability were notably higher in company group than in household group (Table 3, columns 3 to 6). This might be attributable to disparities in investment management specialization and sensitivity to market fluctuations between forest product manufacturing firms and forest farmers. Compared with individuals, the

Table 2.—Descriptive statistics of variables included in regression estimations. Dependent variable values were deflated using 2008 as the base year to exclude the effect of inflation.

| Variables | Definition | Timber industry (obs. = 518) | | | | Nontimber forest products industry (obs. = 1,055) | | | | All (obs. = 1,573) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | Min. | Max. | Mean | SD | Min. | Max. | Mean | SD | Min. | Max. |
| Dependent variable | | | | | | | | | | | | | |
| Operator's proactiveness | Capital amount that operator *i* financed for the forest production ($1 \times 10^6$ CNY) | 0.953 | 1.564 | 0.015 | 20.017 | 1.045 | 1.889 | 0.010 | 27.753 | 0.982 | 1.790 | 0.010 | 27.753 |
| Explanatory variable | | | | | | | | | | | | | |
| Comprehensive sustainability | Multidimensional sustainability rank of the subtype forest industry operated by *i* (1–3) | 1.000 | 0.000 | 1.000 | 1.000 | 2.929 | 0.257 | 2.000 | 3.000 | 2.294 | 0.931 | 1.000 | 3.000 |
| Control variables | | | | | | | | | | | | | |
| Owned forestland | Total forestland area owned by forest operator *i* (hectare) | 47.099 | 68.321 | 0.400 | 823.580 | 10.695 | 17.062 | 0.253 | 259.733 | 22.684 | 44.980 | 0.253 | 823.580 |
| Forest production loan interest rate | One-year loan interest rate regulated by the central bank (%) | 5.454 | 0.697 | 4.350 | 6.525 | 5.210 | 0.755 | 4.350 | 6.525 | 5.290 | 0.745 | 4.350 | 6.525 |
| Policy initiative | Financed after *China's Forestry Infrastructure Subsidy Policy* = 1; otherwise = 0 | 0.820 | 0.384 | 0.000 | 1.000 | 0.893 | 0.309 | 0.000 | 1.000 | 0.869 | 0.338 | 0.000 | 1.000 |

multifaceted advantages of forest companies include economies of scale, management and control, and risk diversification, as well as awareness of comprehensive assessment (Mechik et al. 2017, D'amato et al. 2020). Additionally, there exists a variation in the effects of policy initiative on operators' proactiveness between these two groups, suggesting that the *Forestry Infrastructure Subsidy Policy* has a larger promotional effect on forest operators organized as enterprises. Forest product manufacturing firms provide basic services and infrastructure in forest communities while having advantages in access to forest products and market opportunities (Asanzi et al. 2014). However, larger market share and better financial performance are frequently accompanied by higher environmental and social aspects of responsibility (Xie et al. 2019, Bian et al. 2021). Furthermore, for small-scale households acting as primary market producers, wage income also plays a pivotal role in their total income (Hoang et al. 2020). These might be the reasons that the coefficients of forest industry comprehensive sustainability and infrastructure subsidy policy initiative were markedly higher in the company group.

## Robustness check

In Table 4, we tested the robustness of our findings in full sample and divided groups. These regressions follow forms of Table 3, except for the changes in rank standard of the explanatory variable. In basic estimations, the comprehensive sustainability was ranked by the subtype forest industry. To examine the robustness, we re-assigned forest industry comprehensive sustainability by adopting comparative results on generalized classification in Table 1 (timber industry comprehensive sustainability = 1.0, NTFP industry comprehensive sustainability = 2.0) to repeat the regressions.

The positive effects and statistical significance of the coefficients for comprehensive sustainability remained unchanged, which strengthened the original interpretation (Table 4). Similarly, positive and significant coefficients of owned forestland and policy initiative could also be found in the robustness checks. Notably, as the rank standard changed, contributions of comprehensive sustainability to operators' proactiveness markedly increased compared with basic estimations. Potential reason for this result is that the

Table 3.—Results of the association between the comprehensive sustainability of the subtype forest industry and forest operator's proactiveness. Robust standard errors are in parentheses; *** $P < 0.01$, ** $P < 0.05$, * $P < 0.1$.

| Variables | Full sample 1 | Full sample 2 | Household 3 | Household 4 | Company 5 | Company 6 |
|---|---|---|---|---|---|---|
| Comprehensive sustainability | 0.557*** (0.049) | 0.495*** (0.042) | 0.313*** (0.027) | 0.296*** (0.028) | 2.193*** (0.265) | 1.940*** (0.215) |
| Owned forestland | 0.024*** (0.002) | 0.024*** (0.002) | 0.019*** (0.002) | 0.019*** (0.002) | 0.025*** (0.003) | 0.025*** (0.004) |
| Forest production loan interest rate | −0.077 (0.057) | −0.187 (0.335) | −0.011 (0.027) | −0.255 (0.267) | −0.253 (0.364) | 0.427 (2.104) |
| Policy initiative | 0.384*** (0.067) | 0.164 (0.576) | 0.340*** (0.042) | 0.204 (0.449) | 0.814** (0.389) | 1.467 (3.591) |
| Constant | −0.770** (0.324) | 0.030 (2.208) | −0.634*** (0.163) | 0.851 (1.756) | −2.005 (2.232) | −6.055 (13.980) |
| Controlling time fixed effect | | Yes | | Yes | | Yes |
| Controlling village fixed effect | | Yes | | Yes | | Yes |
| Observation | 1,573 | 1,573 | 1,408 | 1,408 | 162 | 162 |
| Prob > $F$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| $R^2$ | 0.330 | 0.348 | 0.345 | 0.383 | 0.384 | 0.439 |

Table 4.—Results from additional regressions to check the robustness of the findings. Robust standard errors are in parentheses; *** P < 0.01, ** P < 0.05, * P < 0.1.

| Variables | Full sample | | Household | | Company | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Comprehensive sustainability (changed ranking standard) | 1.003*** (0.096) | 0.885*** (0.083) | 0.539*** (0.057) | 0.503*** (0.054) | 4.385*** (0.531) | 3.880*** (0.430) |
| Owned forestland | 0.024*** (0.002) | 0.024*** (0.002) | 0.018*** (0.002) | 0.019*** (0.002) | 0.025*** (0.003) | 0.025*** (0.004) |
| Forest production loan interest rate | −0.088 (0.058) | −0.206 (0.336) | −0.018 (0.028) | −0.269 (0.268) | −0.253 (0.364) | 0.427 (2.104) |
| Policy initiative | 0.464*** (0.070) | 0.215 (0.579) | 0.392*** (0.043) | 0.238 (0.451) | 0.814** (0.389) | 1.467 (3.591) |
| Constant | −1.172*** (0.344) | −0.347 (2.220) | −0.818*** (0.183) | 0.684 (1.763) | −4.197* (2.312) | −7.995 (14.015) |
| Controlling time fixed effect | | Yes | | Yes | | Yes |
| Controlling region fixed effect | | Yes | | Yes | | Yes |
| Observation | 1,573 | 1,573 | 1,408 | 1,408 | 162 | 162 |
| $R^2$ | 0.319 | 0.341 | 0.325 | 0.368 | 0.384 | 0.439 |

awareness of sustainability among Chinese forest farmers has been in the primary stage; therefore, integrated approaches to assess the effect of forest operation on economic development, ecological protection, and human social behavior should be promoted and widely used in the forest industry in the future (Zhang et al. 2015, Ke et al. 2021). Although the coefficients of comprehensive sustainability on household group and company group have both seen growth, the variation between these two groups has remained considerable (Table 4, columns 3 to 6), which again suggests the robustness of the research findings. Significant difference in comprehensive sustainability incentive effects also provides supporting evidence for individual NTFP industry operators' barriers to finding matching demand markets and the uneven distribution of profits between households and companies (Yildirim and Kose 2018).

## Conclusions

In this study, the high comprehensive sustainability of the NTFP industry has proven to have a positive effect on operators' proactiveness for forest production, thus contributing to dynamic advances in SFM. Given the examination results, what is still required at this stage in China is to work toward decentralization of forest management rights and focus on the promotion of corporatization operation awareness among small-scale forestland holders. In this way, more forest operators could reap dividends from sustainable forestry development while increasing social responsibility. Furthermore, policies regarding sustainable management for different types of forest industry, including timber products and NTFP, should be further differentiated to achieve management precision.

For the timber industry, the life-cycle management of timber products has attracted practical focus for sustainable development. Life-cycle management concept of timber products considers both the ecological and economic costs of wood production to achieve the best social outcomes (Husgafvel et al. 2013, Ramage et al. 2017). Another new direction spurred by ecological constraints is enhancing the efficiency of timber resource use by improving species composition and increment (Mederski et al. 2021). Additionally, sustainability certification was found to be a crucial tool for forest management in practice. Forest loss and fires may continue to occur after sustainability certification, but certified products are associated with a reduction in deforestation and forest fires (Carlson et al. 2018).

The Global Forest Resources Assessment suggested that forest gains were observed in higher latitudes and richer countries while forest losses continued to occur in poorer countries in the tropics (Sloan and Sayer 2015). Hence, it is urgent for developing countries to identify a better path to innovations in the forest management system (Holland and Lansing 2016). By evaluating the forest resources distribution and forest industrial basis, policymakers could encourage reasonable transitions to diversified forest activities, which are not only linked to the well-being of forest communities but also reduce the market risks of unitary traditional forest production (Kimengsi et al. 2020). As the NTFP analyzed in our study, a two-way mutually beneficial development model is established between the government and forest operators through the natural promotion effect posed by the sustainability advantages.

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