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Fast-growing broadleaf trees in niche configurations: A business model approach to economization and socio-technical transitions

Derek Garfield, [a*] Vilis Brukas. [a]

a: Southern Swedish Forest Research Centre, Swedish University of Agricultural Sciences, Alnarp, Sweden.

[*]Corresponding author: E-mail: derek.bradley.garfield@slu.se

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ABSTRACT

Ecological pressures, increasing forest damages, and declining forest biodiversity in Sweden have led to policy changes that seek to diversify practices beyond coniferous rotation forest management and improve the resilience of forests. Increasing the proportion of fast-growing species, such as birch and aspen, is a key alternative to address the challenges faced by the conifer-based system while increasing biomass to support the transition to a sustainable bioeconomy. Our study applies a business model and value chain approach to a niche configuration perspective to understand how firms use fast-growing broadleaf species to create value and develop pathways toward more broadleaf forestry. Firms create value with these species in six identified configurations combining innovation and niche protection measures. These range from small rural businesses creating birch beverages to industrial-scale production of hardwood textile pulp. We conclude that forest certification has been the most influential form of niche protection, enabling a fit-and-conform transition pathway. Thus, the certification raised broadleaf values without transforming the regime practices. Some configurations demonstrate a stretch-and-transform alternative, building on the material attributes of fast-growing broadleaf species and instigating innovation with potential for a deeper change.

BACKGROUND

Societal concerns about the effects of climate change and the need to develop away from fossil fuels as the basis for much of the world's economy have led to the reevaluation of the societal role and value of forestry (Fischer et al. 2020). A forest-based bioeconomy is seen as a viable approach to reducing greenhouse gas emissions via the sequestration of carbon in trees and long-lasting wood products, as well as the replacement of non-renewable fossil carbon with carbon-neutral biomass. Climate change, directly and indirectly, creates pressures and shocks by exacerbating abiotic and biotic damages via inter alia storms, droughts, pest infestations and diseases, that destabilize the forestry regime and, in boreal climates, are likely to lead to adverse outcomes for Norway spruce (*Picea abies* L.) (Kellomäki et al. 2007). The actual damages and loss of forest biomass volume resulting from the current regime-preferred species conflict are incompatible with the increasing demand for biomass to support the transition to a bioeconomy (Dubois et al. 2020). This conflict necessitates a diversification of forest types, tree species, and management practices to enhance the resilience and productivity of Swedish forests (Bergh et al. 2010, Hahn et al. 2021, Hemery 2008, Messier et al. 2019, Roberts et al. 2020). Broadleaf species also play a crucial role in maintaining and creating the biodiversity necessary for achieving national environmental protection goals (Felton et al. 2011, 2010) and may have advantages under projected climate change conditions (Hemery et al. 2010).

Forestry and forest-based industries are an important socio-economic sector in Sweden. Approximately 10% of jobs, exports, and value-added production can be attributed to the activities of this sector, and nearly 70% of the country's land use (Swedish Forest Industries Federation 2024). Contemporary forestry activities and industrial production primarily focus on the two most common boreal species in Sweden and Norway, Norway spruce (*Picea abies (L.) H.Karst)* and Scots pine (*Pinus sylvestris L.*). Roughly 82% of biomass volume on productive forestland consists of these two coniferous species. Among broadleaf species, also known as hardwoods, birch (*Betula spp*.) is the third most common species in Sweden, accounting for 12.8% of the growing stock (SLU 2022). These proportions have a strong regional variation with increasing diversity of species and proportions of broadleaf trees in southern latitudes towards the nemoral vegetation zone. As a forest type, broadleaf-dominated forests, where at least 50% of biomass volume is of broadleaf species, have seen a positive development from roughly 6% of forestland in the 1980s to just over 9% as of 2022 (ibid.).

Increasing the volume of hardwood within forests undoubtedly has an impact on forest industries' value-seeking and creation activities, necessitating innovative ways to adapt to changes in the composition and structure of more diverse forests. In this study, we examine the use of fast-growing broadleaf species (FGBs) encompassing birch and poplar (*Populus* spp.) species, that form a niche configuration in relation to the dominant paradigm of coniferous rotation forestry in Sweden. We investigate the following questions: 1) How do firms produce FGBs as valuable through processes of economization and the mobilization of niche protection mechanisms? 2) How do these configurations contribute to the development of the FGB niche and changes within the forest sector?

THEORETICAL FRAMEWORK

In order to explore the potential implications of a shift towards FGBs in Swedish forestry, we base our study on systems transition theories, particularly the *multi-level perspective* and the recently developed *niche configurations* approach (Lazarevic and Valve 2020). We elaborate and develop the niche configurations approach by introducing two additional concepts to enable the operationalization of this approach: business models and value chains. We introduce the underlying theory that informs the niche configurations approach before explaining niche configurations and elaborating on our reasoning for introducing value chains, which serve to advance our understanding of niche configurations and provide a basis for analysis.

Socio-technical systems theory

When exploring the dynamics of change within complex systems, such as *socio-technical systems (STS),* analysis is often framed within a multi-level perspective that seeks to capture the interactions of enmeshed and co-evolving trajectories of structuration across several social and technical domains at three analytical levels: the *regime, landscape,* and niche (Geels 2002). At the heart of the multi-level perspective is the concept of STS. In the broadest sense, STS are heterogeneous arrangements of social, institutional, and material components that are intended to produce important societal functions (Geels 2004, 2002). Often, they are described in terms of sectors such as transportation, energy, agriculture, or, as in our case, forestry, which produce benefits in the form of goods or services for society. A key concept that animates STS is that of the *regime*, which can be described as a dominant paradigm serving as the status quo framework that underpins the operation and functionality of an STS. As stated in the introduction, coniferous rotation forest management is the dominant paradigm that underpins the functionality of the forest sector in Sweden. The STS *landscape* refers to exogenous factors that shape the development of the regime as a selection environment (Smith et al. 2005). These factors consist of a plethora of ecological and social drivers that originate beyond the STS's internal dynamics yet largely shape a regime's trajectory by forcing actors to respond to this dynamic environment.

Within the multi-level perspective, *niches* are theorized to play a key role in enabling change within regimes by introducing novelty and difference through innovation. Niches are viewed as spaces of experimentation that are protected from mainstream selection environments, such as markets, via passive or active mechanisms, or both, that can shield, nurture, and empower incipient, emerging socio-technical arrangements providing alternatives to the societal functions, goods and services, offered by the regime (Smith and Raven 2012). Actors who are engaged in the development of niches are system builders who draw on resources from multiple domains, e.g., political, cultural, economic, and combine these in new ways to produce innovation. Social and individual learning processes for knowledge production about material artifacts-in-use take place within niches. Knowledge and expectations about an innovation’s functionality are derived from local experiments, often conducted within firms or collaborative projects (Geels and Raven 2006). Analyses using the multi-level perspective have tended to focus on the interactions between a single niche innovation, often a technology, and a single regime, though some recent developments in the literature emphasize that a pluralistic view of multiple interacting niches and regimes more holistically addresses complex transition dynamics (Geels 2019). Lazarevic and Valve (2020) argue for a heterogeneous and complex view of niches, in contrast to the predominant approach in the field of niches as constituted of singular technologies (See also Berkhout et al. 2004). Instead, niches represent a multiplicity of differing modes of valuation with a flexible technological core that interacts and co-evolves with multiple regimes providing societal functions.

Niche configurations

The *niche configurations* approach has recently been developed by Lazarevic and Valve (2020) to address the connection between 1) the production of value and 2) the mobilization of mechanisms for niche protection as co-constitutive. The configurations contribute to changes in regimes through their interactions with STS regimes, in ways that may reinforce existing regime structures or contest and challenge them.

To examine the processes of value production within diversified niches, Lazarevic and Valve (2020) draw on the work by Çalışkan and Callon (2009), who developed a field of inquiry termed economization by building on theoretical developments from sociological and anthropological studies of the production of economic subjects and objects. They argue that economic values are produced in "the intersection between the materialities of things and people's skills and competencies" (ibid. 2009, p. 338). Lazarevic and Valve (2020) connect this idea to the concept of business models. A business model is a conceptual framework that outlines a firm's activities and strategies for creating value for its customers (Teece 2010). They describe what things are valued, for what purposes, and for whom, as well as how the firm conducts itself to create and capture value for its owners and various stakeholders. They describe how a business operates to achieve multiple values, not least the economic, but increasingly includes the identification, creation, and capture of ecological and social values as key aspects of a firm's value-creation activities (Bocken et al. 2014, Neesham et al. 2023). Values are produced relationally through firms' interactions with suppliers and customers (Freudenreich et al. 2020, Zott and Amit 2008).

This relational view of value creation is another important parallel between the concept of business models and valuation from an economization perspective. Following Çalışkan and Callon (2009), valuations change as valued materials circulate between economic actors and come into contact with new competencies and networks. With reference to Appadurai (1986), they call for attention to the 'careers' of things in moments of market exchange. These exchanges highlight the role of differing value definitions in enacting and realizing values. Differing valuations are created in particular times and spaces, comprising the circumstances enveloping the exchange of goods between valuing agents. Here, we suggest that it is helpful to mobilize *value chains* explicitly to further operationalize a valuation and economization perspective within the niche configurations framework. To achieve this, we drew on the work of Mo et al. (2024) to develop a simplified framework for the composition of wood-based value chains and descriptions of key activities. Forest value chains begin in a land-use segment with activities centered around the management of trees to produce a variety of forest-based raw material goods. These activities are generally referred to as on-site operations and include activities such as silvicultural programs, seedling production, extraction of non-timber forest products, and logging. The primary activity is to produce a variety of roundwood qualities for markets. The next segment can be summarized as industrial processing, where roundwood is refined into intermediate and final products via technological systems. Mo et al. (ibid.) identify four major technological systems: sawmills, veneer mills, reconstituted wood manufacturing, pulp and paper mills. It is essential to note that the flow of raw materials to these systems often occurs between them, as by-products produced through production in one system complement raw materials in another. For example, wood chips from saw or veneer mills are used as inputs with pulp-quality roundwood in pulp and paper processes. This pattern of raw material exchange is often referred to as cascading use (Mantau 2015).

The second aspect of niche configurations relates to Smith and Raven's (2012) conceptualization of niche protection, which encompasses both active and passive forms. Passive protection arises from general conditions within the regime and landscape, preceding the mobilization of resources in support of specific innovations. Active protection is defined as the “deliberate and strategic” creation of space to shield specific innovations from the regime’s selection pressures (ibid.). Publicly funded subsidy programs are a classic example of active protection mechanisms that are intended to create space and build support for alternatives to standard arrangements produced by the regime. We think that both passive and active forms of protection are likely to be recognized within the business models of firms as integral to their value creation activities.

Application to the case of FGBs in Sweden

The forestry sector fits well within the niche configurations framework, as regime activities support the production of heterogeneous kinds of societally important functions, including food, fiber, material, energy, etc., that are shaped through social, institutional, and material interactions between interconnected regimes, for example, transportation, construction, and energy systems. The value of tree species within the forestry sector is dependent on forest-resource-based value chains for their production into value-added products via the business models of participating firms. Tree species can have differing relations to such value chains and potential end uses. The use of FGBs represents only a relatively small portion of the total activity of the forestry-industrial regime and the production of biomass and other ecosystem services as societal functions. Therefore, we argue that active value production utilizing FGBs constitutes niche activity.

Our ambition with this study is to describe how “creative, imaginative, and calculative people” engage in processes of value production (Çalışkan and Callon 2009, p. 387) using FGBs, including the mobilization of niche protection mechanisms. Based on this, we hypothesize about their potential to instigate wider market (re)formations. We attempt to show how attention to the materiality of FGBs and the creativity, skills, and competencies of actors in mobilizing conditions created by various niche protection mechanisms and technologies are combined to produce FGBs as valuable in a variety of ‘configurations that work’ (Berkhout et al. 2004, Geels and Raven 2006). We do this by following FGBs in their various “careers” along value chains as their materialities and ascribed values are transformed in moments of exchange, bringing them into contact with new socio-technical arrangements, described within the business models of the participating firms, that further their careers towards valuable products to be consumed in wider markets. This process is visualized in Figure 1.

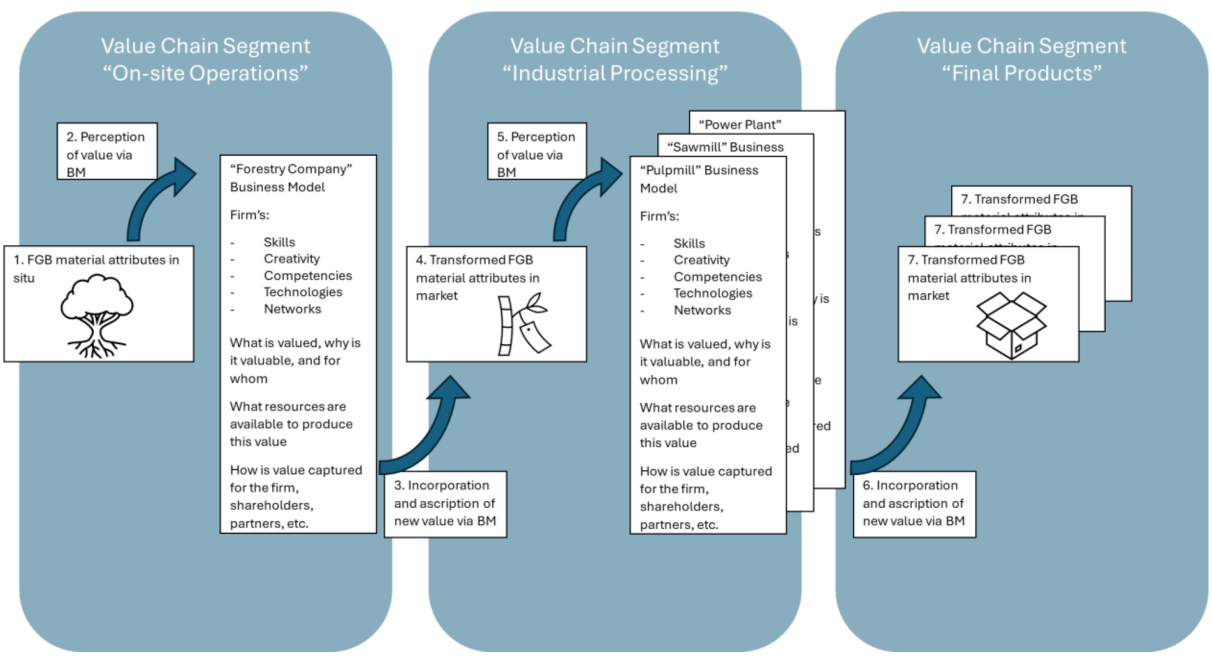

Figure 1. Visualization of economization in the study.

METHODS

Qualitative interviews

Lazarevic and Valve (2020) call for engaging qualitatively with bottom-up approaches that follow actors involved in processes of economic production. Aiming to attain a thorough, contextualized understanding of the phenomenon, we also adopt a qualitative approach that seeks to engage with heterogeneous economic processes in which our focal niche, FGBs, are located.

Interview methods are among the most commonly applied data collection methods in the social sciences and include a variety of approaches (Trainor and Graue 2012). Semi-structured interviews are one broad classification of interview approaches that seek to balance a researcher’s motivation to answer research questions while providing some flexibility and sensitivity to the agency of participating informants in the co-production of data by following more conversational or deliberative approaches (Kvale 2007). In semi-structured interviews, an interview guide, composed of questions that are intended to engage with the research topic and study questions via theoretical and conceptual lenses, is used to focus the conversation between the participants towards the aims of the researcher, but also allow participants the opportunity to address emergent knowledge and respond to unforeseen or novel information that could serve to forward understandings of the research subject (Roulston 2010). Semi-structured interviews are therefore researcher-directed while allowing for greater active co-production of knowledge with informants than what more structured questionnaires or surveys would allow.

With a desire to engage with a variety of ways in which FGBs could be brought into contact with value chains, we adopted purposeful sampling of interview informants, as described further within this section. According to Maxwell (2009), purposeful sampling is useful to capture and represent heterogeneity and the range of variation, and can be used to enable comparisons and explain differences within a study. As such, this strategy of informant selection meets the needs of our study.

Identification and selection of relevant firms

Our strategy for identifying relevant firms for this study began by establishing two basic criteria for participation. Since we are interested in the processes of economic valuation and production using FGBs, the first criterion for inclusion was that participants needed to offer products or services that depended on the use of these species. Therefore, we excluded research and interest organizations from this study, although we recognize the fundamentally important role that such organizations play in shaping the underlying framings and knowledge on which economic valuations depend. Second, we are interested in the STS of the Swedish forestry sector and its particular dynamics and stabilities that contribute to possible valuations for FGBs. Therefore, the sourcing of FGB material or the creation of FGB products entirely or primarily in Sweden served as the second criterion.

We then conducted a review of business collaborators within the Trees For Me project, a research center focused on producing knowledge about FGBs, as a primary source of potential interviewees. We reviewed available information on corresponding websites to identify specific mentions of FGBs by using species names, e.g. "birch" and "aspen", "Betula" and "Populus", as well as more general descriptors such as "broadleaf" and "hardwood" in keyword searches, both in Swedish and in English. We also used internet search engines using a similar keyword approach to identify additional actors outside of the Trees For Me center who could be relevant to the study. We supplemented these searches using "Sweden" as an additional search term. The possible participants identified through internet searches were subjected to the same selection process described previously. The identified firms from the combined searches produced our initial pool of potential informants.

In line with our ambition to engage with the multiple and heterogeneous forms in which FGBs are involved in processes of production and value generation, we applied the value chain concept to refine our pool of potential firm informants further, aiming to capture the diversity and range of forms in which FGBs are made valuable. Therefore, we sought out interviewees who could give insight into how FGBs interact with the four main processing technologies of forest-based value chains. The final group of participants is described in Table 1, and the companies are categorized by their location within FGB value chains and primary activities that contribute to FGB value creation.

Table 1. Interviewed companies

Value chain segment	Company name (and number of employees)	Core business activities
On-site Operations		
	Södra (3400)	Silviculture: planning and management
	Sveaskog (800)	Silviculture: planning and management
	Stora Enso (22000)	Silviculture: planning and management
	Trolleholms Gods (20)	Silviculture: planning and management
	SydVed (115)	Silviculture: planning and management
	Kopparfors Skogar (28)	Silviculture: planning and management
	Ängabackens Björksoda (3)	Non-timber product: birch beverages
	Savhuset Åre (5)	Non-timber product: birch beverages
	Sydplantor (5)	Tree nursery
	Swetree Technologies (18)	Plant breeding technology developer
Sawmills		
	Special Trä (5)	Small sawmiller economic association
	Munka-Ljungby Såg & Hyvleri (2)	Small hardwood sawmill
Pulp mills		
	Tree to Textile (30)	Man-made regenerated cellulosic fibers
	Södra (3400)	Hardwood dissolving pulp
Veneer mills		
	Riga Wood "Latvijas Finieris" (2400)	Birch veneer plywood products
Energy producer		
	Cortus Energy (36)	Biomass gasification plant

Data collection and analysis strategy

Our interview guide was based on D’Amato et al. (2020), who used business model analysis to investigate how business model innovations within forest-based biomaterials industries in Finland. We were inspired to use business models as articulations of the valuations of FGBs in use and the transformation of these values through material exchanges occurring in value chains from primary production, forestry, to secondary production within forest-based biomaterials industries. We adapted the D’Amato et al. (2020) interview guide to better align with our focus on the role of FGBs in firms’ value creation activities, as well as how policies, interpreted broadly, contribute to the protection of activities associated with the use of FGBs. We also questioned interviewees about how they perceived FGBs in relation to the forestry regime now and in the future. We reviewed the information available on actors' websites about related products and services, as well as searched these websites for additional documents that mentioned FGBs to prepare for interviews and to supplement information co-produced through the interviews. Accordingly, we centered the analysis of each of our interviewees’ business models on the observed attentions and values that were constructed from the firm’s recognition of the material attributes of FGBs and the skills, competencies, and infrastructures of that firm. These also pertain to suppliers and customers in the value chain, marshaled to actualize those values. We analyzed interviewees’ descriptions of the interactions between their value production activities with FGBs and multiple regimes to conceptualize expectations of reformist or transformative change in the forestry sector, our target regime, and other STS. The interviews were conducted in English and Swedish by the lead author, and transcripts were created based on recorded audio. Atlas.ti software was used to facilitate the analysis.

As instructed by Lazarevic and Valve’s (2020), niche configurations are, in the first place, variations of value production using a flexible “technological core”. However, with our shift of attention to the role of particular tree species within the forest-industrial regime, we look to identify variants from *multiple technological cores* in which FGBs could appear within value chains, including FGBs’ roles in production systems within the land-use segment. Another indicator is the presence of active protection mechanisms that contribute to creating or enhancing the value of niche technologies and practices (Smith and Raven 2012).

RESULTS: FGBs IN NICHE CONFIGURATIONS

We conducted semi-structured interviews with fifteen firms operating in different areas of the Swedish forest sector and contributing to a variety of value chains (see Table 1). The results of the interview analysis, summarized in Table 2, reveal six configurations in which values using FGBs were created. These configurations suggest that large incumbent firms and small entrepreneurial start-ups have contributed to developing new values for FGBs and mobilized active and passive protection measures to support this development. Furthermore, these firms have created a range of products that span from specialty goods to commodities, providing value to diverse consumers and users.

Table 2. Six niche configurations, their valuations and protections.

Configurations	Valuations		Protections	
	Key	*Supporting*	*Active*	*Passive*
Energy Forests	Rapid accumulation of biomass	Optimized land use, carbon-neutral energy, and improved ecological impact compared to agriculture	'Energy Forest' subsidies from the Board of Agriculture	Carbon markets and taxes on fossil fuels, national goals to increase renewables, research grants
Biodiversity Initiatives	Ecological diversity	Increased availability of ecosystem services and resilience of forests	Forest certification standards, conversion to broadleaf-dominated forests, breeding programs and new plant schools	National environmental quality goals
Hardwood Textile Pulps	Short-fiber cellulose	FGB wood structure more accessible to solvents, large market potential replacing environmentally harmful alternatives	None identified. (Pulp production is regime practice; production of staple fibers is not.)	EU Green Deal, forest certification standards, research grants
Hardwood Veneers	Functionality of FGB hardwood	Long-lasting engineered wood products can be used in a wide variety of specialized applications	None identified	Foreign production centers in neighboring countries with mature industries
Small-Scale Hardwood Sawmills	Aesthetics and functionality of FGB hardwood	Locality as exclusivity, craftsmanship	None identified	Regulations protecting noble broadleaf forests, forest certification standards, heritage preservation programs
Birch Sap Beverages	Birch ability birch produce large quantities of sweet sap	Non-consumptive use of trees, reinvigoration of traditional practices, more sustainable beverages	None identified	Rural development grants

Energy forests

Primary informants: Cortus Energy, Trolleholms Gods

Hybrid aspen and poplar share this niche configuration with willow (*Salix* spp.) and are actively protected by subsidies from the Swedish Board of Agriculture, specifically for the establishment of "energy forests" on marginal, abandoned, or otherwise non-intensively managed arable land agricultural lands. The driving valuation for this configuration is the rapid production of woody biomass for energy through short-rotation forestry. Contribution to a more diverse landscape and biodiversity was not discussed as a major motivation driving engagement with this configuration. The configuration has been in decline for several decades and there are less than 3,000 hectares of hybrid aspen and poplar on arable land in Sweden (Jordbruksverkets Statistikenheten 2025). This is despite the existence of a large area of disused agricultural land and recently afforested arable land that would be suitable for hybrid aspen and poplar (Anander et al. 2024, Böhlenius et al. 2023).

Interviewed firms describe how energy forests are used to support other broadleaf forestry systems, often by larger land-owning companies, such as Trolleholms Gods, that have properties with multiple land uses and diversified holdings. Longer rotation ages for slower-growing, high-value broadleaf species, such as beech and oak, are complemented by FGBs in energy forests to provide an additional revenue stream with consistent demand. Energy forests have been used as an effective means to bridge the gap between short-term income from agricultural crops and long-term forestry products, which often take around a century to produce.

Most forest biomass used for energy receives little to no refinement, as the majority is sourced from waste products of sawmilling, such as bark and sawdust, or from forestry residuals, including tree branches and tops. Fuelwood harvested during thinnings or low-quality roundwood is chipped and directly incinerated in heating and power plants. In contrast, gasification and other biorefinery processes can produce biodiesel, methanol, and hydrogen to support other energy demands. *Cortus Energy* reported that they have used energy forest biomass previously, but that their current source is woodchip residuals, approximately 25% of which are from broadleaf species. They found that the declining availability of energy forest biomass meant that shifting to a more consistent supply of woodchips made operations less complex and more economically efficient. Biomass from energy forests may be included in the sourced woodchips, but it is not known for certain.

Consistency in raw material inputs in aggregate was key to achieving value by limiting the need to make adjustments at various stages of biomaterial processing, such as removal of foreign materials, additional drying of biomass, treatments to remove pollutants after combustion, etc. Therefore, any potentially advantageous material attributes of poplars and hybrid aspens are unrealized in favor of achieving this overall consistency.

In the energy forests configuration, we find several challenges for its diffusion and transformation of the forestry regime under current conditions. We base this on the fact that the primary active protection mechanism supporting this configuration is aimed towards the optimization of agricultural land use, rather than forestlands, and their ability to more effectively produce biomass for the energy sector. This configuration faces strong competition from the regime, due to the high availability of waste product streams as a source of biomass for energy from normal forest-industrial operations. This undermines the key valuation of this configuration, as the regime tends to produce this demanded function, i.e., combustible biomass waste from sawmilling, while also creating other social and ecological values, i.e., ecosystem services, that are not strongly valued or realized within this configuration. The type of forest-owning business best positioned to successfully mobilize this configuration appears to be land-owning companies with large properties that span multiple land-use types.

As a counterpoint, our interviewed firms have found that this configuration can also be used to support the hardwood veneers and textile pulps configurations, suggesting alternative higher-value end uses for the biomass produced in this configuration. However, these depend on the landowner’s choice of silvicultural program, as these have important effects on the qualities of FGB biomass produced during a rotation. When employed by firms engaged in other forms of broadleaf forestry, this configuration indirectly supports the small-scale broadleaf sawmilling configurations by underpinning the economic stability of their hardwood timber suppliers. In such a way, energy forests can contribute to the creation of other values more strongly associated with broadleaf forestry through their combined use.

Biodiversity initiatives

Key informants: Stora Enso, Sveaskog, Södra, Syd Ved, Kopparfors Skogar, Sydplantor

Within this configuration, the primary valuation of FGBs centers on the production of ecosystem services beyond provisioning services, particularly in sustaining ecological biodiversity, and is primarily structured by forest certification standards as an active form of protection. Through forest certification standards (FCSs), broadleaf species in general became strongly associated with the actualization of biodiversity values enshrined in forest and environmental protection laws. Within this valuation, broadleaf trees are organized and managed according to chiefly non-productive logics and prioritized into sites for the specialization and intensification of environmental values in service of production values for coniferous forestry. Though FCSs are part of regime practice as a mechanism to support more diverse value creation and capture for societal stakeholders, their current demand for at least 10% broadleaf ingrowth within coniferous production forests functions as an active niche protection mechanism. It thus contributes to the availability of hardwoods, particularly birch, for timber, pulp, and fuelwood. Both major FCSs promote retaining broadleaf species in buffer zones and on moist or wet soils. Branchy, old, and large trees should be preserved as biological retention trees during harvesting. Before the introduction of FCSs, standard silvicultural practice was to remove all hardwood ingrowth to promote coniferous monocultures.

From the 1940s to the 1960s, birch and other broadleaf species across forests in northern Sweden were sprayed with Agent Orange in an attempt to stem their reproduction and eliminate them from conifer stands. For many decades, birch in particular was considered by many foresters as only a weed to be eliminated by mechanical or chemical interventions. Increased biodiversity valuation of broadleaf species reinforced the non-productive use of these species and intensified material forms that promoted biological rather than productive values, establishing a positive feedback loop that inhibits their exploitation for productive uses. On the other hand, this has contributed to the current conditions where, despite an increased volume of broadleaf species, particularly birch, the flow of hardwood material into productive uses is restricted, and what does come into resource streams is often ill-suited for processing into valuable sawn wood products, imposing additional costs on producers.

There are several examples of active protection for FGBs that are being implemented within large forest-owning companies. *Sveaskog* and *Stora Enso*, two of Sweden’s largest forest-owning companies, plan to convert some conifer forests into birch-dominated broadleaf forests. The former identified conifer forests within two of their Ecopark management areas for conversion to broadleaf-dominated forests. The latter set targets within its biodiversity program to plant birch-dominant and mixed-broadleaf stands, increasing the total share of broadleaf forests from 2.3% to

5% by 2050, which means creating 1000 hectares of broadleaf forests per year until that year. Additionally, these two companies have also made strategic investments in the breeding program for improved birch led by Skogforsk, the Swedish Forest Research Institute. These programs create prerequisites for a considerable expansion of available FGB volumes in the future for both production and conservation uses. This strategic planning can be contrasted with other strategies discussed, such as birch and aspen-dominated stands created where their natural regeneration was strong enough to challenge regeneration with conifers or where artificial regeneration failed. These two strategies would seem to more closely resemble a regime approach to FGBs regeneration, where these species are mobilized as a backup plan to comply with legal requirements for ensuring forest regeneration after harvests.

The forest owner association *Södra* incentivizes the protection of broadleaf species and biodiversity by building on FCSs. They offer price premiums (labeled nature conservation premiums) for delivered roundwood that scale to the number of conservation set-asides on a forest owner-member's property, exceeding the requirements of FCSs. Such set-asides are not restricted to broadleaf species, but there is a considerable overlap. Here, as with FCS generally, the development and protection of relational non-consumptive use values of broadleaf species are made to directly contribute to the instrumental use values of managed stands through a redistribution scheme. The added value received for certified timber products is redistributed to forest owner-members who set aside forests to levels at or above those that are required by certification schemes.

FCSs as a niche protection mechanism have actively shaped forests and the availability of FGBs within them. These standards were enacted as a form of regime optimization, ensuring that a greater degree of ecological sustainability would be achieved within the coniferous rotation forest management system. FCSs can be considered as strengthening the value of the regime; however, they also function as a niche protection mechanism since they have actively contributed to the maintenance of a relatively large supply of hardwood volumes within production forests. This availability has, in turn, stimulated forest owners and companies to find and create additional value from this material resource, but it seems to be most often considered a byproduct of the regime.

Hardwood pulps for textile fibers

Key informants: Södra, Tree to Textile

Wood pulping for paper and packaging products is a well-established and profitable industry in Sweden. Wood pulps have diversified, with companies offering different pulps with varying qualities for distinct purposes. Softwood, hardwood, and softwood-hardwood blend pulps for paper and packaging have been in use for over a century and can be considered part of established practice. However, the production of dissolving pulps for use as textile fibers of regenerated cellulose is a relatively new focus for only a few producers in Sweden. The demand for bio-based textile fibers is expected to increase as the textile market transitions away from petroleum-derived fibers, such as polyester and nylon, which currently account for approximately 60% of the global textile fiber market. Cotton, which accounts for approximately 25% of the global fiber consumption, is increasingly viewed as problematic due to its negative environmental and social impacts (Frazier et al. 2024).

Södra has produced dissolving pulps with hardwood species, a blend of birch (60%), aspen (30%), and beech (10%), since 2012. This proportion is primarily based on the historical availability of broadleaf species in the region of southern Sweden and neighboring Baltic countries. In recent years, small amounts of poplar and hybrid aspen from energy forests have been included in their textile pulps to supplement the limited availability of European aspen in the region. Consequently, this firm has set an annual production target of 80,000 m^3 of aspen to meet its raw material demand for textile pulps. To achieve this, Södra advises its forest-owning members with appropriate site conditions to plant hybrid aspen or poplars and participate in the energy forest configuration. Pulp production is the most profitable branch of this firm's business, and they have made large investments in innovations, developing textile production, including a new process to recycle textile waste and mix it with their forest-based regenerated cellulosic fibers.

Tree to Textile is focused on commercializing a new process for the production of a man-made regenerated cellulosic staple fiber for use in woven and non-woven textile manufacture. The motivating value proposition was to create a textile fiber with as low a climate impact as possible. This is achieved through the development of a new process using salts for the extraction of cellulose from forest-based biomaterial and refinement into staple fiber. The circular use of forest material waste streams within wood processing in Sweden, combined with the effectiveness of the new pulping processes, means that the production of this regenerated cellulosic fiber has a lower climate impact than lyocell and viscose competitors produced in other regions. They have tested a variety of hardwood-based pulps within their processes, including several fast-growing species, such as eucalyptus. Cellulose extracted from hardwood species has shorter fibers than that produced from softwoods. The fibers produced from different hardwood species are largely indistinguishable in this process; however, the behavior of the biomaterial in the production process does vary due to the wood's structure and molecular composition. This can represent an important source of value in achieving favorable ratios of process inputs to product yields. FGBs seem to perform well in this regard.

This configuration has several strengths that would tend to positively develop the FGB niche. Hardwood-based pulps combine forestry industry know-how and infrastructure to exploit market demands and selection pressures within another sector, that of textile manufacturing. The textile regime is experiencing a significant amount of pressure from civil society at a global level, and the European Union is making efforts to transition this industry into the circular bioeconomy. Global demand for biobased textiles is expected to rise as synthetic fibers derived from petroleum, such as polyester, are replaced in a variety of applications. Additionally, the production of hardwood-based textile pulps in Sweden requires a significant volume of FGBs, and scaling up production will require increasing FGB biomass availability within forests.

Hardwood veneers

Key informants: Riga Wood, Södra

Several of the firms we interviewed supply or use rotary veneer technologies in processing FGBs. One of the advantages of working with veneers when compared to more traditional sawmilling is the wider range of workable timber qualities. Lower-quality sawlogs and even some high-quality, larger-dimensional pulpwood can be used to produce veneers for laminated products. This means that larger quantities of birch timber currently found within Swedish forests, i.e., self-regenerated individual trees with little to no interventions to improve hardwood timber quality sourced from stands managed for coniferous timber, could be used to create long-lasting engineered wood products for several consumer segments, from light construction to transportation to furniture.

We were unable to identify specific active protection mechanisms that support this configuration in Sweden. However, the production of birch plywood and veneer itself constitutes a well-established industry in the Baltic Sea region, particularly in Finland and Latvia. The use of veneers for plywood and engineered wood products is able to reach diverse markets and customer uses, from specialist applications to consumer goods. These countries have forestry regimes and industries that have relied more heavily on birch to create valuable products. The supply of FGB wood into these production streams has been subjected to a major shock stemming from the Russian-Ukrainian war, as Russia has historically been the largest supplier of birch and aspen roundwood, as well as birch plywood and veneer. We might consider this shock as a form of passive protection arising at the EU level in the form of trade embargos that stimulate demand for FGBs in Sweden. These conditions suggest that the development of this configuration would have strong positive impacts on incentivizing the increase of FGB volumes.

The major challenge for developing this configuration lies within the logistical difficulties of harvesting and delivering sufficient amounts of suitable quality birch when this timber is dispersed geographically and there is strong competing demand from the regime and other niche configurations for hardwood-based pulps.

Small-scale broadleaf sawmills

Key informants: Munka-Ljunby Såg och Hyvleri, Special Trä

This niche configuration primarily connects to domestic markets for interior furnishings, including flooring, light construction (e.g., trim and paneling), and furniture. Small-scale sawmills are often operated by forest owners who fell and process trees from their forests or from surrounding properties. Sawmilling itself is often not the sole economic activity of such firms but merely one part of small vertically integrated value chains in which primary production, raw material processing, production of value-added products, and skilled labor services utilizing the owner-operator’s own products are offered to local consumers. These small, integrated value chains often harvest and produce just enough to conduct the company’s business, but not infrequently sell byproducts or material excesses in local or regional markets, e.g., to timber buyers for roundwood or local furniture makers.

A major value proposition of small-scale hardwood sawmills is the production of locally sourced and produced sawn wood products, often created to order, and not otherwise available through large-scale industrial value chains. The aesthetic and relational values of these products are at the fore in this mode of valuation. The connection to locality and the aesthetics of hardwood grains sets them apart from other, more common species, such as pine.

Beech and oak are the primary species valued in this configuration. Noble broadleaf species in production forests are conserved in the landscape through regulations that require regeneration with noble broadleaves after the final harvest of noble broadleaf-dominated stands. Thus, the total forest area with these species should not decrease, though the species composition could change. There are high costs for maintaining standard assortments, meaning that only the most frequently demanded and high-value products are retained. Birch and aspen are somewhat marginal species in this configuration, but historically there have been periods of comparatively large demand within interior furnishings, for birch in particular, as furniture and flooring, but even aspen for saunas.

These local sawmills are often the only source of hardwood timber products available for the preservation and restoration of culturally important historical buildings. Such preservation projects strongly value the use of building materials similar to those available historically within the local area, creating a dynamic that depends on highly specialized, local production knowledge to create tailor-made products for specific projects. We consider this a passive protection mechanism that indirectly supports this niche configuration through laws and programs supporting heritage preservation.

Birch sap beverages

Key Informants: Savhuset, Ängabackens Björksoda

An unexpected configuration of birch comes in the form of beverages produced entirely from its sap. The production of non-timber forest products is a relatively underdeveloped area for business in Sweden, and the creation of birch sap-based drinks represents a novel and potentially transformative development within the FGB niche. This configuration relies on the birch's capacity to produce large amounts of water-like sap in the early spring, as the tree prepares to flush its leaves. Social and cultural values are fundamental to realizing economic value in this configuration. Producers utilize a sense of place and the aesthetic appeal of birch trees to enhance the value of their products.

For *Ängabackens Björksoda*, the use of the surrounding landscape and birch's place within it is central to achieving customer value. A tasting room and farmhouse store on the property, where the birch trees from which the sap is harvested, use the landscape to create an experience and give a sense of place for customers to connect with. The business owner is also the forest owner in this case, and the valuing of birch in this way has influenced the forest management practices to enhance the accessibility and visibility of birch in the landscape. For both of our interviewed beverage producers, the cultural and historical use of birch sap in Sweden was seen as part of achieving value in this configuration. Through this configuration, cultural practices are revived and made available for modern consumers through innovative products that have not been previously available in the Swedish beverage market. They position themselves as offering alternatives to less sustainable specialty beverages commonly available, such as imported wines that entail high carbon emissions and water costs. The sustainability of the production processes and their products is a key value proposition, as all sourcing and production of birch-sap beverages occur within close geographical proximity, reducing the need for transportation during production.

Non-timber forest products in the birch sap beverage configuration receive no active protection. Rather, actors have had to mobilize additional sources of value, such as cultural heritage and local knowledge, and forms of passive protection, such as rural development grants, to support their value-creation activities. This configuration offers possibilities for forest commercialization with additional social and environmental benefits when compared to conventional forestry and may support a deepening of non-economic values available from forests. However, this configuration can operate within the regime of coniferous rotation forest management by moving sap harvesting to new forest stands as timber harvesting occurs. Nevertheless, scaling up this configuration could also support diversification to other silvicultural systems, such as continuous cover or agroforestry, since harvesting trees is not necessary to create the products. In any case, businesses engaging in this configuration would likely benefit from an increase in birch-dominated stands within geographical proximity to their production facilities, though this was not identified as a limiting factor at present or in the near future. A major challenge for these products is their novelty in well-saturated and often traditional beverage markets. Key intermediaries within food and beverage industries, such as sommeliers or chefs, have little to no exposure to such products, and thus expectations about their use are non-existent and must rely on an individual's interest in novelty itself. Current levels of production do not require large amounts of birch from which to source sap.

Scaling up this configuration may not induce significant demand for additional birch trees but could help to improve the economic returns of forest owners engaging with these producers, as harvesting sap is a non-consumptive use and does not preclude the harvesting of trees and their use in other value chains.

DISCUSSION

The methodology we developed for this study combines concepts from several different fields of inquiry to produce a qualitative analysis of a complex subject in a novel and approachable way. There is likely a greater amount of variation and diversity in value creation than what has been captured in this study, but we are confident that the identified configurations describe an instructive variety of ways in which FGBs' materialities are combined with the skills, knowledge, and creativity of actors in the forest-based industries.

Using business models and engagement with firms to explore the dynamics of systems transitions and niche development through economization has facilitated a unique, actor-centered view of value creation with FGBs in Sweden. Using business models as a data source to identify and describe the functioning and structures of niche configurations can give a holistic, if somewhat generalized, view of how firms create value. Details about particulars, such as processes, products, or technological specifications, might escape the view of informants from large companies whose knowledge and practice do not directly depend on such details. Conducting analysis at a more detailed, fine-grained level could reveal other types of structures and behaviors within the STS not captured by a business model approach to processes of economization and their contribution to complex systems change.

The explicit use of the forest value chains (Mo et al. 2024) enabled us to widen our view of the FGB niche and examine relationships between niche uses as well as interactions with multiple sectors beyond our target regime. This provided insight into important niche-regime and niche-niche dynamics, as well as the potential influence of other sector regimes within the STS landscape selection environment. The identified niche configurations and the interactions between the niche and regime as described in this study may not be immediately transferable to other forestry systems, but may find some similar expressions in a wider European context due to similarities in governance structures. The European Union's Common Agricultural Policy and international forest certification standards are pertinent examples of niche protection mechanisms, although national implementation can influence the extent to which these are deployed.

From our investigation of niche configurations, it is clear that FGBs are made valuable in a variety of distinct ways and that valuations of their materialities shift within value chains, where actors with differing resources, material and immaterial, are able to create different types of value. The view of the configurations described in the results develops a value chain approach to understanding modes of valuation within the forest sector. Firms engaging in value-creation activities within these configurations do not do so exclusively; often, they engage with several configurations as well as with practices that can be identified with the regime. This challenges traditional ideas within the transitions literature that have assumed that outsiders with external resources are the primary sources of radical change within STS (Kemp et al. 1998) and supports more recent views of heterogeneity in incumbent actors' strategies in transitions towards greater sustainability (Saleh et al. 2025). The Swedish forestry sector seems to express a relatively high degree of collaboration, with competing firms often pooling resources to address common challenges. Many firms operate at both the niche and regime levels, leveraging regime infrastructures while developing niche innovations. Some of the firms interviewed are partially owned by incumbent actors or collaborate across sectors to develop new products based on FGBs. The general expectations for FGBs by the interviewed actors are positive, despite the identified challenges. FGBs, and birch in particular, are expected to play a greater role in forestry and forest-based industries in the future. Their contributions to biological diversity, role in climate change adaptation and mitigation strategies, and potential to increase wood volumes were widely viewed as incentives to support this niche. Demand for improved birch seedlings has increased over the past few years and outstripped supply; yet, infertility within the breeding stock is currently a major bottleneck for establishing improved birch stands. Susceptibility to browsing, intermittent supply of high-quality timber, and drought intolerance are challenges for FGBs in meeting expectations for productive use. We suggest the following simplified process model (Figure 2) based on the dynamics of niche trajectories, developed in Geels and Raven (2006), for the positive development of the FGB niche. We argue that our interviews largely support this model, and that the businesses interviewed have followed a development cycle that is broadly applicable, regardless of where within the forest sector innovation is happening.

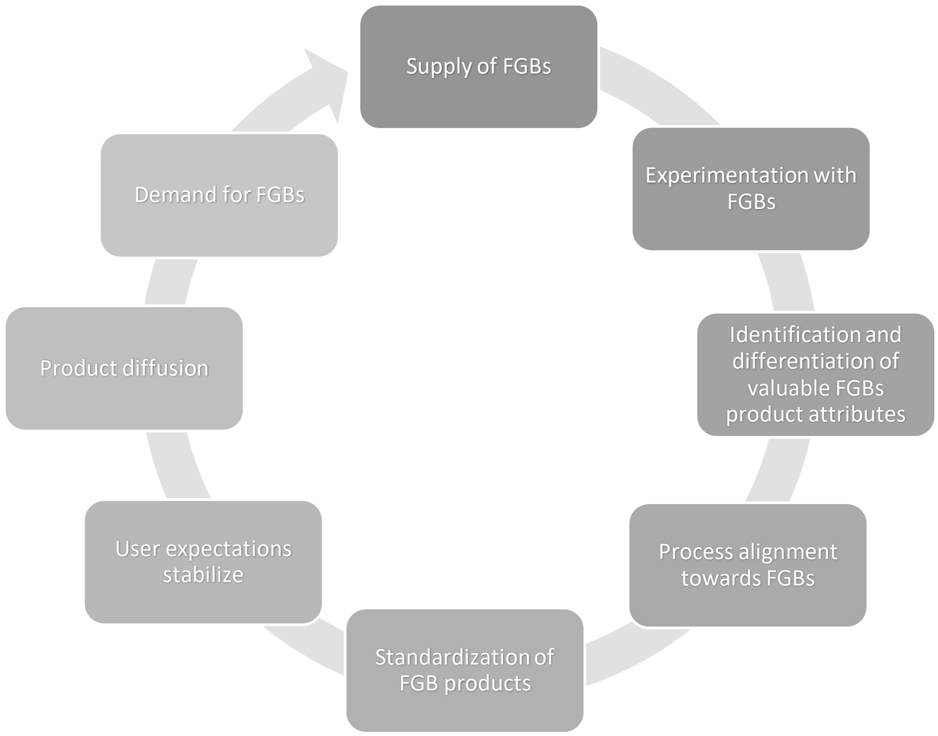

Figure 2. Theoretical development cycle for the FGB Niche.

A key difference between niche and regime approaches to FGBs is that, in general, the niche configurations seek to find and create value by relying on the particular materialities of FGBs, rather than basing their value on a reduction to component parts shared in common with regime-preferred species. This distinction might be best understood as enacting two archetypical transition pathways conceptualized by Smith and Raven (2012): fit-and-conform versus stretch-and-transform, with the reduction and homogenization approach of the regime following the former and the distinction and particularity approach characteristic of the latter.

The regime approach to FGBs historically has been to reduce them in two important ways. Firstly, the reduction of their volume within forests. Regime praxis is to establish new forests after harvesting through artificial regeneration, i.e., planting, with regime-preferred softwood species. The costs of planting softwood and higher prices for their timber lead to their prioritization during silvicultural interventions, resulting in the elimination of FGBs in production stands. Through the implementation of FCSs since the 1990s, FGBs' role in fulfilling the biodiversity values demanded by society in the wake of burgeoning environmental and sustainability movements has become the dominant valuation for FGBs, setting expectations for the potential value of these species. This implementation has been an incremental process, along with the gradual strengthening of certification standards to support an increase in broadleaf volumes. FCS requirements to maintain five, now ten, percent broadleaf ingrowth in coniferous stands have likely contributed to maintaining an incidental and sporadic distribution of FGBs trees. This distribution creates logistical challenges for the production, harvesting, and transportation of higher-quality hardwood timber for sawn wood products, which have a consistently higher market value than pulp and fuelwood qualities. Each of the forestry companies we interviewed cited this as a major barrier to achieving higher values with FGBs. The demand for FGB pulpwood and the intermittency of the high-quality FGB timber supply create a dilemma for forestry companies in balancing the highest use value for available resources against logistical constraints in planning harvesting operations and transporting harvested material (Woxblom and Nylinder 2010). Several forest-owning companies have found that identifying, harvesting, and transporting small volumes of high-quality FGB timber to local small hardwood sawmills is simply too economically inefficient. Selling this material as pulpwood often generates a greater value for forest owners and timber buyers. This barrier might be overcome if this proportion of hardwood ingrowth continues to increase and the total volume of FGBs reaches a critical threshold for logistical efficiency within a given region.

The second form of reduction within the regime approach to FGBs is that of species into their component parts, such as cellulose and lignin, as is done in pulping and biorefining. Within these processes, FGBs, treated as forestry byproducts, can be reduced into basic molecular components shared in common with the regime-preferred softwood species. Once successfully reduced and their components extracted, they can be brought into processes with more economically valuable conifers. On the one hand, this enables value creation with FGBs by bringing them into economically productive resource streams, but it may also undercut the achievement of higher values that might be possible when the material attributes of FGBs are centered. When treated as byproducts or waste streams, available volume and consistency of resource inputs are determining factors of economic efficiency, and the potential benefits that FGBs may have in terms of favorable ratios between valuable molecular structures, e.g., cellulose to lignin, or superior rates of biomass volume production, lose their relative competitive advantage to economies of scale.

CONCLUSIONS

Regime strategies of cascading use (Mantau 2015) and seeking the highest use-value have, to some degree, induced the diversification of value chains for FGBs. FCSs have been the most impactful form of niche protection for FGBs, yet predominantly enabling a fit-and-conform transition pathway, where these species are often reduced and homogenized through industrial processes centered on generating value with regime-preferred conifer species.

A more transformative pathway can be discerned within some of the niche configurations explored here, where actors generate value with FGBs by focusing attention and centering value-creation activities on their particular materialities. These actors produce a range of products from specialty beverages and sawn wood products unavailable in wider markets to commodities, such as birch veneers and hardwood pulps, in which the particular attributes of the FGBs are made to compete against conifer-based regime alternatives. Firms that have innovated these FGBs products have often developed connections to other economic sectors, e.g., beverages and textiles, through which additional resources and pressures from the wider STS landscape can be mobilized and incentivize the adaptation of the forestry regime.

Discovering advantageous differences between FGBs and traditional softwood products and developing new products to promote these advantages could create a positive feedback loop in the supply-demand dynamic by improving supplier, producer, and consumer expectations for those products. Within products where the functionality and role of FGBs are key but their visibility is concealed, greater transparency of their particular contributions could build positive expectations for this niche and a wider understanding of the value of these species, which in turn can attract additional resources to the niche.

CONFLICTS OF INTEREST

The authors confirm there are no conflicts of interest.

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APPENDIX: INTERVIEW GUIDE.

1. What is your role in the company?
2. What were the initial motivations for starting the company?
3. When was the company established?
4. What is the size of the company? Employees? Turnover?

<u>Open questions:</u>

5. What kind of products/services does your company provide?
    - How is the use of FGBs related to these?
    - How did the decision to include FGB come about?
    - What species are used? What are the qualities that make it useful? Other species?
    - What is the relative importance of FGB products/services in relation to the totality of your business offerings?
6. What are the innovative/revolutionary aspects of your company's products/services?
    - How did these come to be?
    - What needs to change within the current business as usual to enable your success?
7. What are the competing or alternative products/services?
    - Are there other emerging innovations that you see as supporting your goals?
    - Do you see any synergies or conflicts between other uses for FGBs?
8. What does your company do differently in manufacturing processes and/or other operations?
9. How do your key partners support/enable your value creation? E.g. shareholders, employees, suppliers, contractors, customers, local communities and other stakeholders.
    - Who shares your vision of using FGBs for bio-resources?
    - Do you participate in any networks that you see as supporting FGB products/services?
    - Do you have any downstream or upstream collaborations?
    - What policies (including industry standards, laws, taxes, subsidies, grants, etc.) hinder or facilitate your success? Any that concern FGBs specifically?
10. Can you describe in what way your business model could lead to cost reduction/profit increase compared to dominant business logic (directly or indirectly)?
11. How does your company make a positive contribution to environmental and social development?
    - What role do FGBs play in this contribution, if any?
    - How are such contributions measured and evaluated?
    - I am interested in how to increase the proportion of FGBs in the Swedish landscape. In what ways do you think your business supports such efforts? To what extent?
12. Where will your company be in 5 to 10 years and what business opportunities and challenges do you foresee arising for your company?
    - How will future markets impact your product/process offerings?
    - How do you see the future of FGB-based products and services in Sweden and beyond?

14. Any other comments/ideas/opinions?