Comparing forest sector modelling and qualitative foresight analysis: Cases on wood products industry

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Abstract

Scenario analyses are widely used in forest sector foresight studies, being typically based on either qualitative or quantitative approaches. As scenario analyses are used for informing decision-makers, it is of interest to contrast the similarities and differences between the scenario processes and outcomes using quantitative and qualitative approaches and to explore the underlying causes of differences. This paper uses the output from a qualitative scenario study to design forest sector model (FSM) scenarios and compares the results from the two approaches. We analyse two cases on wood products markets in Norway: i) Wood products suppliers establish a developer firm specializing on wood construction to boost demand, and ii) Levying a carbon tax while reducing CO_2 emissions in cement production. Comparing the qualitative studies (innovation diffusion analysis, backcasting and Delphi) and FSM analyses (NorFor model), the results resemble for case ii) but deviate strongly for case i). Notably, the strategy aiming to boost the demand for domestic wood products leads in NorFor mainly to an increase in imports with limited impact on Norwegian sawnwood production. Causes of the discrepancies are discussed. Despite the challenges of combining the two frameworks, we believe that the method where assumptions based on stakeholder input or other qualitative research approaches are elaborated in a FSM and compared, should be more explored. Importantly, applying various methods and frameworks allows for complementing and diversifying the picture, and thus improving the knowledge base.

Keywords: foresight; partial equilibrium modelling; NorFor; wood products

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1 Introduction

Various techniques and approaches exist for the study of the future. It makes sense to pursue diverse approaches in forward-looking studies to gain a holistic view of the problem (For-learn 2016). Further, as noted by Gordon & Glenn (2009), diverse methods can identify affecting factors which any of the techniques alone might have missed. The simultaneous use and comparison of alternative research approaches, methods and data in the study of the same phenomenon can be referred to with the term “triangulation”. This form of triangulation remains rare in forest sector outlook literature (Hurmekoski & Hetemäki 2013).

Despite the clear motives, joint undertakings between qualitative and quantitative research are not the norm in practice (Varho & Tapio 2013). According to Lüdeke (2013), researchers tend to take one of the two following positions: Either that only quantitative methods are regarded as truly scientific or that quantitative methods tend to obscure the reality of the phenomena under study, because they underestimate or neglect the non-measurable factors. As further argued by Lüdeke (2013), quantitative approaches allow for handling the information in consistent and reproducible ways, combining figures, comparing data, and examining rates of change, which allows for much greater precision than simply talking about increases or decreases. Yet the operational range of any model, including quantitative models, is restricted by the data. The intangible nature of some of the affecting factors of which we have very limited data or knowledge, implies that qualitative approaches may be equally useful, for example in bringing forward information that can be incorporated into quantitative models.

There are very few studies in the forest sector literature explicitly comparing or combining forest sector modelling and qualitative foresight methods (e.g., Sjølie et al. 2016, see also Hurmekoski & Hetemäki 2013). The objective of the paper is to compare the research outcomes obtained by qualitative foresight analysis and forest sector modelling through selected case studies on wood products markets. The findings from the empirical cases are used to identify needs for further method development and possible directions towards combining different lines of research. In the next section, we will put forward the methods and data used for the study, while section 3 describes the two case studies that form the basis for the scenarios. The results are described in section 4, followed by conclusive remarks.

2 Methods and data

The research design follows the framework set by Fortes et al. (2015) for combining and comparing qualitative and quantitative approaches (see Fig. 1), in which the results of the qualitative studies are used to focus and set up the scenarios for the quantitative study. Moreover, the framework suggests exploring, whether the conclusions from the different lines of research conflict each other, and whether some results are exclusive to one of the approaches.

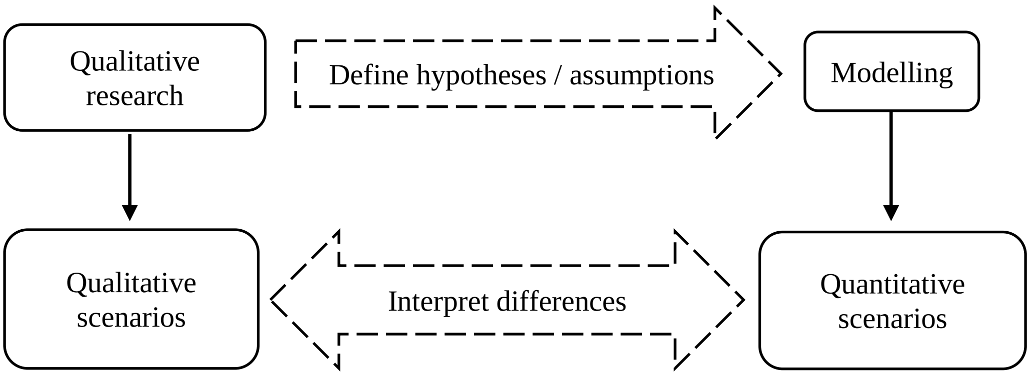

Figure 1. Process for linking qualitative foresight approaches and quantitative methods and comparing the outcomes (based on Fortes et al. 2015).

The research process consisted of three stages: First, the existing literature on the factors affecting the markets of sawnwood used for construction – the single most significant end use category of wood products – were identified and analysed. These data convey numerous factors affecting the wood construction market that could feed into a modelling exercise as variables. Second, scenarios were developed for two case studies, chosen based on the ability of the forest sector models (FSM) (see, e.g., Kallio et al. 1987, Latta et al. 2013) to quantify the affecting factors, and on the novelty of the perspectives given the existing literature. Third, the scenarios of the two cases were run with a FSM, and the results were compared to the results from the qualitative studies.

The qualitative data are based on a state-of-the-art literature review and an expert survey (Hurmekoski 2016), building on innovation diffusion analysis (Rogers 2003), participative backcasting (Dreborg 1996) and Delphi (Linstone and Turoff 2002). The innovation diffusion framework identifies a variety of complex and interrelated factors related to the attributes of a given product or technology, the perceptions towards it and the context structure (Roos et al. 2014), and explores the possible rate of market diffusion based on the total of these factors. Backcasting entails looking back from a preferred future typically set by stakeholders and identifying the steps that need to be taken to achieve it. Empirical data for the backcasting exercise were collected by performing a Delphi survey, employing a web-based questionnaire and semi-structured interviews. The combined results of these approaches were used to guide the scenario analysis for the two case studies.

The scenarios were run with the partial equilibrium forest sector model NorFor (Sjølie et al. 2011a), that has been applied for several studies of economic and greenhouse gas mitigation potentials in the Norwegian forest sector (Sjølie et al. 2011b, 2013a, 2013b, 2016). The NorFor model maximises the discounted social welfare in the Norwegian forest sector (i.e., producer surplus plus consumer surplus net of transport and investment costs) by simulating the behaviour of three groups of agents: forest owners, forest industry and consumers of wood products. Forest owners are assumed to maximize the profit from selling timber and harvest residues and the utility from owning old-growth forest, industry to maximize the profit from producing and selling wood products and consumers to maximize the utility from consuming wood products. The model simulates how these groups of agents adapt to changes in economic and policy frames ('what if' scenarios), based on perfect foresight (intertemporal optimization) in 5-year periods to year 2100.

The growth and management of almost 9,000 plots covering all productive forest in Norway are simulated, with management and harvest timing (including never harvest) being endogenous to the model. The optimal management regime and harvest timing for all forest land is found as part of the optimal solution. Harvest residual supply costs are given on the county level, with supply in each period being capped by the county harvest level.

There are only about 20 pulp, paper and board mills in Norway, each specified in the model with input-output coefficients and capacities. These parameters are modelled on the county level for the sawnwood and bioenergy industries. Sawnwood products include spruce, pine and birch sawnwood. The pulp, paper, board and bioenergy industries consume sawmill chips and pulpwood, and the bioenergy sector also harvest residuals. Bio-heat options include stoves in homes burning wood or pellets and water-borne heating systems fed by chips or pellets for consumers and industry.

Demand for wood products is given on the county level and changes with price and GDP growth, the latter being influenced by population growth. The assumed GDP growth rate is 1.5% p.a. in Norway and 1.0% p.a. in other counties. Two foreign regions ensure balance in the markets; trade with foreign markets or between some of the nineteen domestic regions takes place as long as the price difference between two regions exceeds transportation costs.

Carbon is accounted for in the major components in the model: carbon sequestered as trees grow and stored in stem, branches, tips and roots as well as in the soil, based on the Marklund (1988) functions. Greenhouse gas emission rates from silviculture, the use of machinery, transportation and processing are added based on life-cycle analyses; a full account of these numbers are given in Trømborg and Sjølie (2011). Carbon stored in wood products are included, as well as the products' expected life span and substitution rates, based on Petersen and Solberg (2005). All wood products are assumed to be combusted at the end of their life cycle, and to replace domestic heating oil.

Given the degrees of economic sectoral details that few other quantitative models can match, combined with the carbon fluxes and possibilities for pricing carbon, we found the NorFor model being very suitable for carrying out this analysis.

3 Case studies

3.1 Case one: Moving downstream in the construction value chain

A recent backcasting study (Hurmekoski et al. 2017) identified two major pathways for increasing the market share of wood construction and the value added of the industries by 2030. One is based on gradual process change and standardisation. The other is based on firms moving downstream in the construction value chain, for example, by wood products suppliers establishing a joint developer firm that would specialize on wood construction. The latter pathway was by the interviewed experts regarded to be markedly more efficient in pursuing the targets of higher market share and value added. Several measures for reaching these targets were identified, such as industrial prefabrication, standardisation, and shifts in the value chain. Some of the measures could potentially lead to simultaneously meeting both targets.

In reference to the above, the first case explores the consequences for the forest sector, if the market share of wood construction was to considerably increase by 2030. The scenario assumes a 15% increase in sawnwood demand per 5-year interval for the period 2010–2030 and a 5% increase per 5-year interval for the period 2030–2050. This results in roughly doubling the demand between 2014 and 2050 which is in the scale what the qualitative studies indicate being possible (Hurmekoski et al. 2017).

3.2 Case two: Advanced construction technologies under more stringent environmental regulation

The qualitative studies showed that wood construction markets are critically dependent on the regulatory and cultural acceptance for wood construction and on the competition with other construction products (Hurmekoski 2016). The latter point has not received enough attention in wood construction outlook literature – wood-based construction practices tend to be compared to conventional construction methods based on Portland cement also in long-term outlook studies (Hurmekoski et al. 2015b). Yet it makes a significant difference for both economic and environmental competitiveness, what the wood-based practices are being compared to. Notably, it appears that the greenhouse gas emissions of modern cement manufacturing could be reduced by 20–70 % compared to conventional Portland cement (e.g. Hasanbeigi et al. 2012). The issue is even more important as more stringent environmental policies are typically considered to lend a competitive advantage for wood construction exclusively.

The case consists of two scenarios. The first examines the consequences of addressing the market failure of environmental externalities by introducing a carbon tax of 100 €/ton CO_2eq for the industrial and usage part of the forest sector, i.e., industrial processing, wood product storage and substitution, while forests and forestry are excluded. For each period, taxes are levied if greenhouse gas emissions are above baseline levels. On the other side, subsidies are paid if emissions are below baseline levels. Subsidies are granted for wood product carbon storage if the change of stock is larger in a given period than in the base scenario. Analogously, if substitution of fossil-based products is higher and thus leads to more avoided emissions than in the base, subsidies are granted. The carbon tax is set on a high level, compared to the long-term level of the EU emissions trading system (ETS) price per permit (around 7 €/ton), since the socially optimal level for CO_2 emissions has been suggested to be as high as 140 $/ton in the industrialized countries to reflect the true societal costs of the emissions (OECD & IEA 2014).

The second scenario for this case additionally assumes that the displacement factor of concrete, i.e. the impact on greenhouse gas emission when wood substitutes concrete and steel in construction, is diminished by 50 %, i.e., from 431 to 215.5 kg CO_2eq/m^3.

Table 1 summarizes the assumptions for a total of four scenarios for the two cases. The emphasis of the analysis is on value creation, trade balance and carbon flows.

Table 1. Case study assumptions.

	Scenario	Demand for sawnwood	CO_2 tax	Sawnwood-concrete carbon substitution coefficient
	1) Reference	Business as usual – follows a 1.5% p.a. GDP growth	-	431 kg CO_2eq/m^3
Case I	2) Moving downstream in the construction value chain: Establishing a developer firm owned by wood products suppliers	15 % per 5-year interval 2010-2030; 5 % per 5 year interval 2030-2050; 2050- no additional demand growth	-	431 kg CO_2eq/m^3
Case II	3a) Levying a CO_2 tax for the production of construction products	Business as usual – follows a 1.5% p.a. GDP growth	100 €/ton of carbon	431 kg CO_2eq/m^3
	3b) Levying a CO_2 tax, and reducing the cement production emissions through the uptake of advanced technologies	Business as usual – follows a 1.5% p.a. GDP growth	100 €/ton of carbon	215.5 kg CO_2eq/m^3

4 Results and discussion

Figures 2–5 show the results of the two cases for the sawnwood demand, sawnwood net exports, sawnwood and sawlog prices, and greenhouse gas flows under the four scenarios up to 2050. In the case of increasing the market share of wood construction (case 1), one of the most significant findings from the NorFor runs is that the notable demand increase for sawnwood leads the domestic production of sawnwood to grow by only 0.5 million m^3, while the rest of the 2 million m^3 demand growth is satisfied by imports, as shown in Fig. 3. This is in contrast with the strategy of the wood products firms and the ambition to increase the demand for own sawnwood products. The import growth spurred by higher demand can be explained by imports being more elastic than domestic supply in the model in the short run. However, if sawnwood markets are highly competitive and price sensitive, a strategy for wood product firms could indeed be to shift from a supplier position to a developer or main contractor position, if the resources and the organisational culture of the firm allow it.

The model runs suggest that doubling the demand of sawnwood would trigger an increase of 27% in the sawnwood producer surplus. This finding would question the view obtained from qualitative analysis regarding a simultaneous and similar scale increase in value added and in market share. However, one needs to remember that the model does not include products refined from sawnwood, so the impact on the entire wood products sector remains unclear.

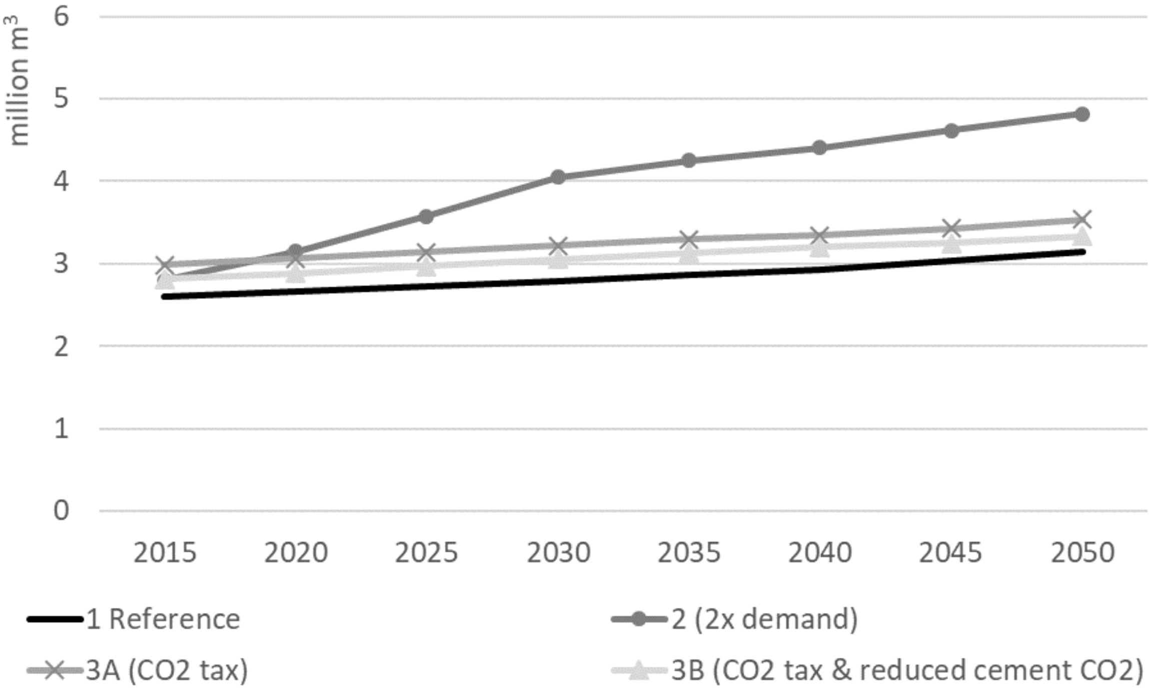

Figure 2. Scenario impacts on domestic sawnwood consumption.

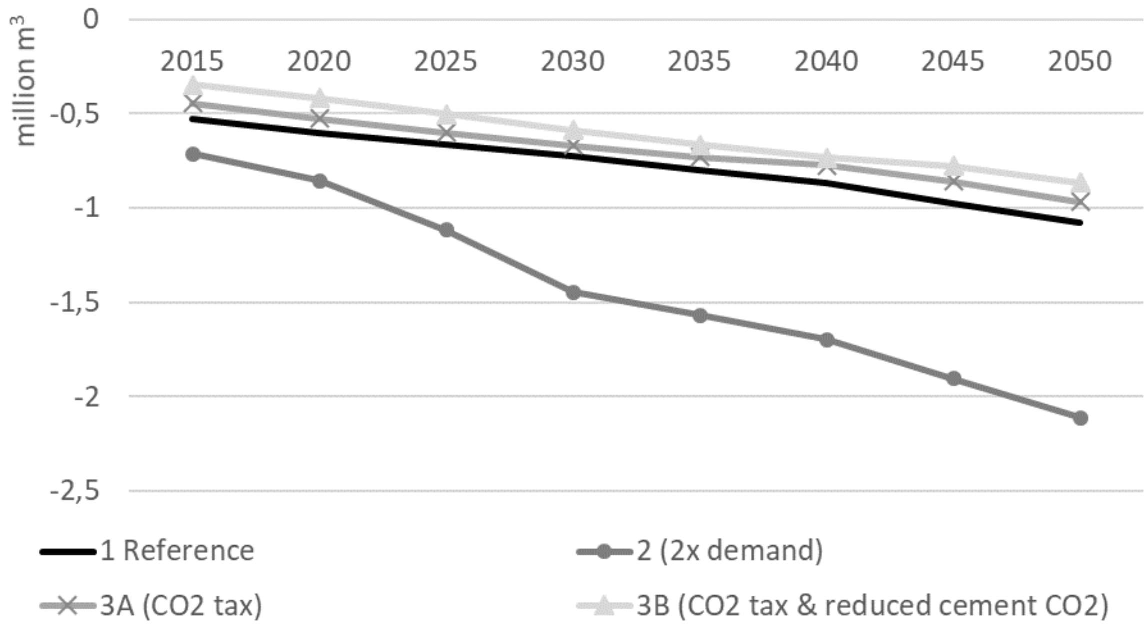

Figure 3. Scenario impacts on sawnwood net exports.

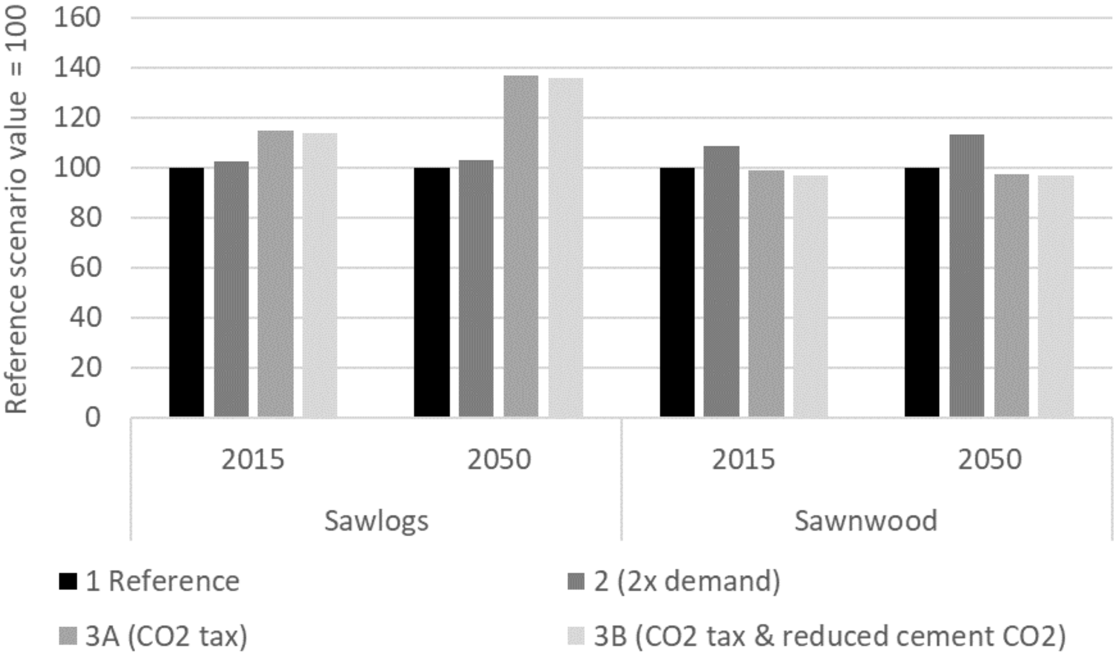

Figure 4. Scenario impacts on sawnwood and sawlog prices.

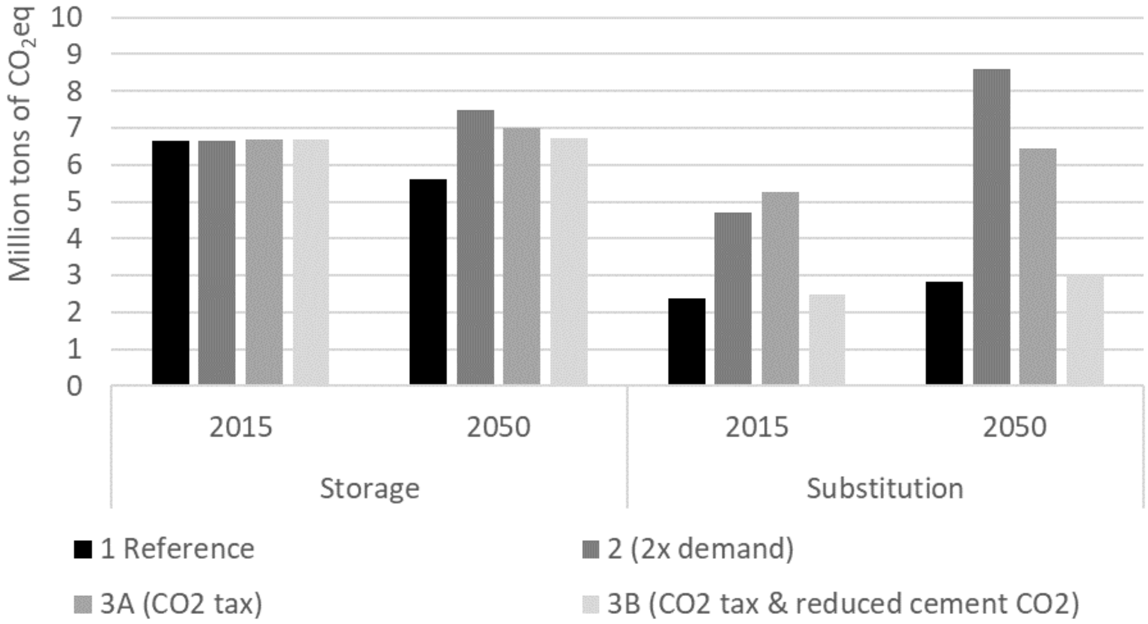

Figure 5. Scenario impacts on greenhouse gas flows in the forest sector.

Regarding the case of introducing a carbon tax and a consequent uptake of cement production processes with considerably lower emissions (Scenario 3b), one of the most significant findings is that the scenario with market-driven elevated demand for sawnwood would seem to result in larger potential for climate change mitigation compared to the introduction of a carbon tax. Furthermore, the substitution effect (avoided emissions) under the carbon tax is close to the reference scenario, in the case of advanced concrete products in the model (3b). However, again one needs to note that the results can only be held as indicative, as the competition in the construction sector in this model is represented exclusively by the CO_2eq displacement factor for sawnwood.

The introduction of the carbon tax increases only the price of sawlog in the domestic market and not sawnwood. Sawnwood is a more global good than sawlogs, with higher import price elasticity, more stable prices and lower transportation costs. However, with carbon taxes that apply to all industrial and end use segments, including bioenergy, the prices of sawnwood by-products rise significantly which improves the competitiveness of sawmills. The carbon tax benefits both forest owners with higher timber prices, and sawmills who improve the producer surplus.

Table 2 summarizes the similarities and differences of the qualitative and quantitative approaches for the selected cases. The scenario outcomes may look different, if the secondary processed products or even an entire construction end use module was integrated to the model. One could also try to include a stochastic component to the model (e.g., Kallio 2010) or compute marginal cost curves at certain intervals as a form of sensitivity analysis.

Table 2. Comparisons of qualitative study findings and NorFor outcomes.

	Findings from qualitative studies	**NorFor outcomes**	**Similar**
Supply and demand	Wood product suppliers ought to establish a common developer firm to boost demand for their products	Demand increase increases production by 0.5 Mm^3 and imports by 2 Mm^3 by 2050	No
Market share and value added	The means and impacts of pursuing increased market share and value added are very similar	Doubling the demand for sawnwood results in 27 % growth in producer surplus	No
Carbon flow	The uptake of competing green construction products could severely affect the market prospects of wood construction	The demand (and CO_2 reduction potential) of wood construction is close to the reference even when a carbon tax is introduced. if emissions from concrete production are halved	Yes

However, each of these directions pose further challenges. Firstly, the inclusion of, for example, engineered wood products or construction elements would possibly require expanding and re-estimating the demand equation. This is highly relevant, because explaining the demand of substitute products exclusively by the GDP and prices creates model bias due to omitted variables, leading to issues with serial correlation in the absence of relevant data (see also Hurmekoski et al. 2015a). So far this challenge has been successfully addressed only for newsprint (Hetemäki & Obersteiner 2001, Johnston 2016). However, it is possible to address the issue also by relying on Bayesian econometrics (e.g., Hetemäki & Obersteiner 2001, Bolkesjø et al. 2003), so that one would at least indirectly capture the omitted variables for the products in other phases of their life cycle than maturity. Alternatively, the demand for such products would need to be addressed by exogenous S-curve projections or similar extrapolation techniques (Kucharavy & De Guio 2011), or, for example, agent-based modelling (e.g., Zhang et al. 2011).

Related to this, introducing a construction sector end use module with a formal presentation of the competition between sawnwood, concrete, bricks, etc. would be needed to shed further light on the possible impacts of environmental policies (cf. Moiseyev et al. 2013). However, for the case of construction, this might be more demanding compared to for example an energy module, as the drivers of demand in construction are not homogeneous between regions and market segments. Moreover, some of the decisive affecting factors appear elusive, such as the risk perceptions of the CEO's of main contractor firms making the final decisions, or the culture and traditions of using different materials (Hurmekoski 2016). Under the influence of such diverse decision criteria and heterogeneity of products, costs may be a secondary decision criteria when it comes to substitution between different construction techniques. It might only be in the long run that the markets become established and standardised so that costs begin to play a decisive role.

Moreover, of the two possible ways of affecting value added (reducing costs versus increasing value), one may argue that the latter option appears to be more valid in the Western economies. This would translate to developing new products and increasing the role of product-related services (Näyhä et al. 2015).

This discussion points to several challenges in coupling a qualitative study and FSM. An advantage of the FSM is the economic consistency modelled across the sector, where the main agents are formally specified with a theoretically based behaviour. However, as most FSM, NorFor does not include downstream products, such as industrially prefabricated construction elements. While addressing this issue in satisfactory precision would require extensive work, such products could be introduced by adding a new product layer, with their own cost structure, demand functions and capacities. Another option could be to modify the demand functions for sawnwood given the changes in the prefabrication segment.

Finally, generalising the discussion for the study of the forest products markets one may argue that the most suitable method depends on the life cycle stage in which the given product is – i.e., introduction, growth, maturity, or decline (see e.g. Routley et al., 2013). That is, as the market characteristics and the subsequent driving forces differ significantly between the different life cycle stages, a more holistic picture of the forest product market developments could be gained by addressing each of the product life cycle categories separately, with the most suitable methods and data for each respective category. Table 3 presents an attempt to characterise the different market segments by life cycle stage and suggests suitable research approaches for each segment. Here, it should be emphasised that a framework for building bridges across the markets in different life cycle stages would be desirable, given that the developments in different markets influence each other. Kallio et al. (2015) is a recent example where different types of demand functions were applied for various forest products, highlighting that this can be relatively effortlessly be done in most present FSMs. Regarding utilizing qualitative study results in FSM, the main challenge is to translate the qualitative results into forms which are applicable in the FSM in question.

Table 3. Characterization of markets and relevant methods at different life cycle stages for forest products.

	Introduction	**Growth**	**Maturity**	**Decline**	**Renewal**
Exemplary products	Wood-based bioplastics	Engineered wood products, pellets, second generation biofuels	Sawnwood, pulp, graphic papers	Newsprint	Wood-based textiles
Market characteristics & affecting factors	Technical and economic barriers; uncertainty; hype	Growth mostly determined by other factors than GDP	Business cycle dependency; stable or small growth rate	Decline in demand, due to substitution for superior products	Rebound in demand due to new drivers; cf. growth phase products
Methods	Qualitative scenario analysis	Agent-based modelling, S-curves, substitution models, qualitative scenario analysis	Econometrics, forest sector modelling	Substitution models, Bayesian econometrics, forest sector modelling	Substitution models, Bayesian econometrics, forest sector modelling

5 Conclusions

The paper uses the output from qualitative futures studies to form forest sector modelling (FSM) scenarios and compares the output through two cases on wood products markets: i) Wood products suppliers establish a developer firm specializing on wood construction to boost demand for their products, and ii) Introduction of a carbon tax and reducing CO_2 emissions in cement production. Regarding case i), the FSM model results suggest that it may be very difficult for the sector to meet their goals for the market share of wood construction (demand for sawnwood) and the value added of the wood products industries. Regarding case ii), the market diffusion of advanced concrete products could diminish the possible positive impact of levying a carbon tax on construction products, from the point of view of the wood construction sector. These aspects conform to the majority of expert views in a backcasting study (Hurmekoski et al. 2017) and the qualitative analysis in an innovation diffusion study (Hurmekoski et al. 2015b), respectively.

FSM could be a coherent framework for assessing and monitoring the balance of stagnating or declining mature intermediate product markets and the growing niche markets in the interfaces of other sectors, if the demand for existing and emerging forest products can be specified. However, the means of accurately capturing the factors affecting the demand, particularly for new products for which little data exists, are to a large extent missing within the current framework. Despite these challenges, this study shows that it can be of interest to create assumptions based on stakeholder input or other qualitative research approaches to be elaborated within FSM. Applying quantitative models can be a way to put the realism of the stakeholder views and targets to test (see Sjølie et al. 2016). Perhaps most importantly, applying various methods and frameworks allows for complementing and diversifying the picture, and thus improving the knowledge base.

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