Curr Forestry Rep (2016) 2:177–188
DOI 10.1007/s40725-016-0042-z

Forest Products Markets under Change: Review and Research Implications

Lauri Hetemäki[1,2] · **Elias Hurmekoski**[1]

Published online: 20 August 2016

Abstract
Background In terms of global forest product market developments, the twenty-first century has been in many ways very different from the twentieth century—striking structural changes have taken place. The global forest sector can be interpreted to be in a phase of creative destruction—an era characterized by a major decline of a number of established products and businesses, and simultaneous emergence of new products and businesses.
Main Findings The forest product research field appears to be lacking the tools for formally assessing the significance and extent of the changing production and consumption patterns. That is, the mainstream of quantitative forest product market research has relied to a large extent on forest sector modelling, focusing on questions related to the impacts of policies, sufficiency of wood resources, trends in the production of primary wood products, and international competitiveness. In doing so, they have paid less emphasis on some of the equally important questions, such as value added development, employment issues, structural changes, the diffusion of new products and services, and the realistic contribution of the forest-based sector to the global sustainability challenges. When considering the importance of global forest product markets to the economy, employment and forests, and the changes taking place in the markets, the scale of research on forest product markets is alarmingly low.
Conclusions This review clearly points to a need to significantly increase the volume of academic research and education on the global and regional forest-based product markets.

Keywords Bioeconomy · Econometrics · Forest products markets · Long-term outlook · Modelling · Structural change

This article is part of the Topical Collection on *Forest Policy, Economics and Social Research*

✉ Lauri Hetemäki
lauri.hetemaki@efi.int

Elias Hurmekoski
elias.hurmekoski@efi.int

[1] European Forest Institute (EFI), Yliopistokatu 6, 80100 Joensuu, Finland

[2] University of Eastern Finland (UEF), School of Forest Sciences, Yliopistokatu 7, 80111 Joensuu, Finland

Introduction

A number of recent studies have indicated major structural changes taking place in the global forest products markets ([1, 2, 3, 4•, 5••, 6, 7, 8•, 9, 10]). The forest-based sector, particularly in North America and Western Europe, are facing perhaps the largest structural changes for more than a century, due to the combined effect of:

- the changing global competitive advantages, with a remarkable share of forest industry investments going to fast-growing markets in Asia and low-cost production regions such as South America[1]
- the declining demand for communication paper products and stagnating demand for a number of other forest products in many OECD countries
- record long economic downturn, particularly in Western Europe, and its impacts on the structure of the forest products industries

[1] The share of inward foreign direct investment flows for the developed countries have diminished from 89 % in 1989–1991 to 16.5 % in 2004–2006 [11].

- the emerging bioeconomy and new products and services that are expected to provide new opportunities and diversify the industry

Given these trends, the forest-based sector can be said to be in a phase of *'creative destruction'* [5••]. The term was coined in the 1940s by Joseph Schumpeter, who used it to describe the evolution of economy. By creative destruction Schumpeter refers to a continuous process that serves to maintain the vitality of market economy. It points out that some economic activities or sectors will decline and eventually vanish, while at the same time, new technologies, products and business models are emerging. These types of changes may take place constantly, yet the scale and intensity of the forest sector trends in the 2000s seem exceptional, when compared to the trends of the past century.

Comprehensive market analyses related to the trends in the global forest products industry come in a surprisingly short supply [5••, 12••]. The forest products markets long-term outlook studies are rarely published in scientific journals. They tend to be published regularly by consulting companies (e.g., RISI, International Wood Markets Group Inc., and Poyry Inc), international organizations (FAO and UNECE, typically every 5 years or so), or commissioned by governments [13–16]. Otherwise, research on the forest industry market outlook takes place less systematically and typically focuses on one particular product category or region [3, 5••, 8•, 9, 10, 17, 18].

The purpose of this review is to help to fill the gap in academic research by providing an overview on how the global forest products markets are changing. The short review is not exhaustive, but rather highlights selected ongoing and expected changes. In addition, the review analyses the implications of the ongoing structural changes on research, by comparing the needs for further research efforts and to which direction current research is headed. The discussion takes the perspective of a long-run demand determination, with an emphasis on structural issues rather than on business cycles, as this is seen to be a largely neglected topic within the field.

Global Forest Products Markets

The forest products markets can be defined in a number of ways, depending on to what extent the further processing (value added) industries are included or excluded (printing, furniture, carpentry, wood construction). For example, the European Commission tends to use the more extensive definition, whereas FAO uses the more restricted one. According to estimates based on FAOSTAT trade and production data, the value of global forest products production exceeded 800 billion USD in 2014 (Table 1). The global employment of these industries is estimated to have been almost 10 million employees in 2011. If one was to include also the forest biomass based printing, carpentry, wood construction, bioenergy, and chemicals industries, one should expect the scale of production value and employment to be at least doubled. There are no consistent statistics on this, but already the joinery and furniture sectors in the EU constitute another 120 billion € of production value (Eurostat). Furthermore, the industrial roundwood utilization of the forest products industries was 1.8 billion cubic meters in 2014 (FAOSTAT). Thus, the sector has also a major impact on the condition and structure of forests, forest owner revenues, and rural employment.

The pulp and paper products markets and their end uses differ in many significant ways from wood products markets. Therefore, also the major drivers for the operating environment of the product categories differ. Consequently, the markets are analysed separately.

Pulp and Paper Markets

The global and the European Union pulp and paper markets are undergoing more significant structural changes than in decades. First, for the past 7–15 years, in many OECD countries the paper and paperboard production and consumption has been either stagnating or declining. The reasons behind the regressive development are both cyclical ones related to economic downturn, and structural ones related to digital media replacing the need for communication or graphics papers.[2] In addition, there has been major movement of production capacity from West (mainly OECD-countries) to East (mainly non-OECD countries). This change is illustrated in Fig. 1.

Of the major graphics paper production and consuming regions, the markets in in North America, the EU and Japan have been declining in the past 10–15 years. North American production (and consumption) has almost been cut by a half from the record high level of 45 million tons in 2000 to 25 million tons in 2014. The EU graphics paper production was record high in 2006 (48 mil. t.), from which the production fell by one fifth by 2014 (36 mil.t.). The pulp production has declined somewhat less - by 13 % from 2006 to 2014. In line with the stagnating or diminishing consumption and production levels, the real prices of paper products have continued to decline. The structural changes are exacerbating this trend [3]. However, the significant exception to this in the twenty-first century has been the softwood pulp prices, for which the long

[2] Paper grades used for communication purposes are called *communication papers* or *graphics papers*. They consist of two main paper grade types, *printing and writing papers* and *newsprint*. Printing and writing papers is often disaggregated into four major grades: coated woodfree (freesheet), uncoated woodfree (freesheet), coated mechanical and uncoated mechanical papers. In terms of world consumption of graphics papers, the most significant grade is the uncoated woodfree, accounting for over 37 % of the total graphics paper consumption, followed by newsprint (23 %) in 2012.

Table 1 Production volume and value and employment of the global forest products industries in 2014 *(based on FAOSTAT and* [19]*)*

	Paper and Paperboard	Wood Pulp	Sawnwood	Wood-Based Panels
Weighted average price	962 $/ton	656 $/ton	298 $/m^3	453 $/m^3
Production volume	400 tons	173 tons	439 m^3	388 m^3
Production value	385 billion $	113 billion $	131 billion $	176 billion $
Employment in 2011	4.3 million employees		5.4 million employees	

run decrease has stopped, and even started slightly to increase in recent years [7]. This reflects to a large extent the increase in demand in China.

Outlook studies seem not to have satisfactorily captured the changes in the global forest products markets. For example, the extensively cited recent projections in the European forest sector outlook study (EFSOS II) [20], the EUwood study [21], and the North American outlook study (NAFSOS) [16] suggest increasing consumption and production of paper products in North America and Western Europe to 2030 or even 2060. In essence, the past trends are projected to continue, with no structural changes expected [3, 8•]. However, a few experts and studies have in fact projected structural changes and stagnating or declining graphics paper markets as early as in the late 1990s [1, 3, 14, 22–25].

The structural changes have not only impacted the graphics paper sector, but also the packaging and paperboard market growth has been stagnating in the USA and Western Europe in the twenty-first century, due to the economic downturn and structural factors. The latter ones relate to the development of consumer and industrial goods manufacturing increasingly moving to emerging economies, such as China. As the production has moved there, so has the packaging of the goods.

Changes occur not only in high-income countries. For example, the annual growth rate of consumption in world's largest of graphics paper market, China, has clearly started to decline. Figure 2 shows the growth rate of graphics paper consumption in China using a 3-year moving average, which helps to dampen cyclical effects. From about 2004 onwards, the growth rates have started clearly to decline for printing and writing paper and newsprint. For the latter, it is currently even negative, i.e. the consumption has started to decline. Thus, the structural changes due to digital media observed already in high-income countries, have started to impact markets also in China.

It makes a significant difference for the market outlook, whether we assume pulp and paper markets in the above regions will follow the trends of the twenty-first century or the twentieth century. Choosing one or the other time period in effect determines whether the outlook for the production and consumption appears to be increasing or declining. The outlook would not only have impacts on production and consumption, but also for the income, employment, and industrial roundwood consumption, as well as for the wood products and bioenergy markets. The latter relate e.g. to changes in roundwood and sawnwood chips demand and supply, pulp mill energy generation, and possibilities to integrate new biorefineries to pulp and paper mills.

Hetemäki et al. [3] and Hänninen et al. [2] analyse the global pulp and paper markets long-term outlook in more detail. The studies indicate that the main patterns observed in twenty-first century in global pulp and paper markets could continue up to 2030. Accordingly, the graphics paper consumption and production would decline in all regions, but more rapidly in the mature markets of North America, Western Europe and Japan. On the other hand, according to a consulting company outlook [7], packaging and tissue paper consumption will increase, but the production is increasing mainly in emerging countries, and the growth is very slow in Western Europe and declining in North America.

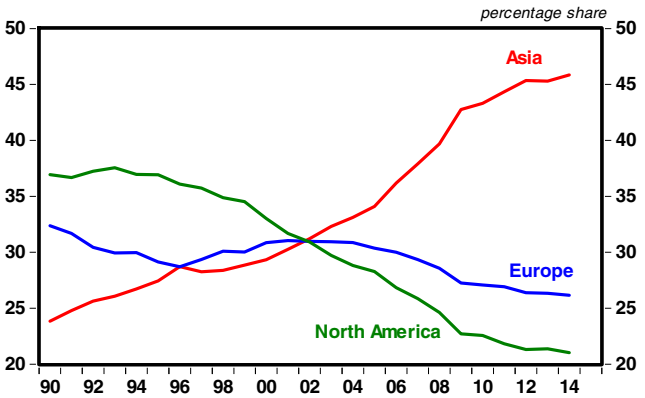

Fig. 1 Shares of world paper and paperboard production in the three main producer regions 1990–2014 (FAOSTAT)

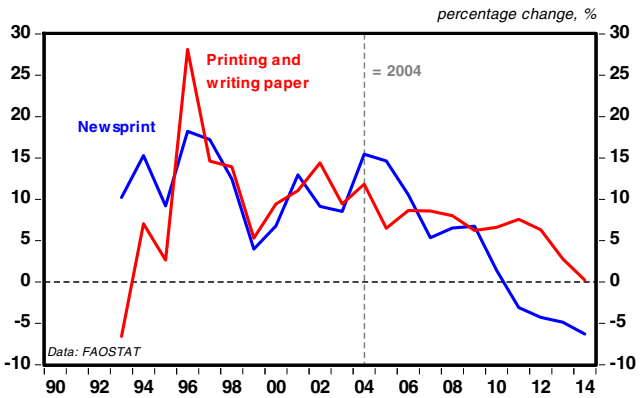

Fig. 2 The 3-year moving average annual growth rate of newsprint and printing and writing paper consumption in China 1990–2014 (FAOSTAT)

Hänninen et al. ([2], Tables 3.6–3.8) provide a summary of some recent projections of European pulp and paper production and consumption up to 2030, and compared these to trend projections using data from 2005 to 2012. The results show that trend projections, i.e., recent market patterns, imply significantly lower consumption and production levels than the outlook studies. If the trend forecasts were updated to include the more recent data (2013–2015), the difference would be even more significant. According to Poyry [7], the world paper production is projected to increase from 2014 to 2030 by 60 %, i.e., from 220 to 356 million tons (see Table 2). This is the result of growth in Asia and emerging economies, whereas the production in North America and Europe is projected to decline. Similar trends are projected also by other consulting companies, such as RISI. Consequently, the patterns that have been observed in the past decade are projected to continue. Thus, these outlook studies give very different projections than some of the often cited outlook studies [16, 20]. The trends in paper markets are also reflected in the pulp markets (Table 2).

Wood Products Markets

The three wood products industry sub-sectors, i.e., sawnwood, panels and joinery, differ largely from each other in terms of production volume and value creation. For example, in the European Union sawnwood is clearly most important in terms of the production volumes, whereas joinery generates most of the value added (Table 3, see also [27]).

The global wood products markets have been growing significantly in the 2000s, yet almost exclusively due to the growth in Asia. Asia's growth is most evident in the wood-based panel sector, in which the share of Asia from the global production has increased from 25 % to 60 % during the past two decades [26]. In China alone, the production of plywood has increased from 11 million m^3 in 2000 to 104 million m^3 in 2014 [26]. The primary cause for the significant growth seems to be the rapidly increased construction activity in China, as the total investments in construction have increased in the twenty-first century by an annual rate of 20–30 % [28]. China has also become the world's largest producer, consumer and exporter of value-added wood products [29], thus forcing the European panel and furniture producers to move the production eastward [30, 31].

Table 2 Paper and paperboard production in 2000 and 2014 [26] and outlook for 2030 [7] (*million tons*)

	2000	2014	2030
Paper and paperboard			
Asia	95	183	236
Eastern Europe	11	18	26
Western Europe	89	85	77
North America	107	84	77
World	325	400	467
Wood pulp *(excl. Recycled pulp)*			
Asia	21	29	39
Eastern Europe	9	10	14
Western Europe	37	33	32
North America	84	65	58
World	167	167	185

The markets in most OECD countries have been severely affected by the economic downturn after 2007. For example, the EU sawnwood production has experienced an eight-year period of negative or slow growth since the peak level of 2007 [26, 32]. Despite the low level of capital intensity in sawnwood production, some of the lost capacity might not return, when the period of low construction activity ends, due to a possible shift towards the production of value added wood products [33].

The few existing global long-term outlook studies for the wood products markets seem to be outdated [16, 34], due to the combined effect of the decline in construction activity since 2007 in most OECD countries, and the rapidly increasing production in Asia (see Table 4 and [2], Figs. 3.16–3.19). Moreover, in the absence of more systematic analysis of the wood products markets, the understanding of the factors affecting the outlook remains poor.

The global coniferous sawnwood production in 2014 was 30 million m^3 less than in 1989, when it peaked at 342 million m^3 [26]. The decline and stagnation of the sawnwood markets can to a large extent be explained by the lack of growth in Asia, besides the USSR exiting the markets in the early 1990s, and the global economic downturn after 2007 [35]. Moreover, Buongiorno [36] found that unlike with most forest products, the level of sawnwood consumption is not converging between regions. The underlying cause for the stagnating markets seems to be the dependence of the wood products markets on the construction sector [8•, 37, 38], which is characterized by numerous path dependencies [8•, 39, 40].

The issue may be better explained by converting the absolute market volumes into per capita volumes. That is, the global sawnwood consumption per capita trend has declined for decades [26], despite the continued growth of the global GDP [41]. Globally, the relative decline may originate from the global population growth, along with the substitution of sawnwood for alternative construction materials, including light weight wood-based panels and engineered wood products [42].

Cultural and socio-economic factors seem to explain why the market share of wood construction varies from above 80 % in the Nordic countries to near zero in many Southern European countries (below 10 % on average in Europe, [43]) [44]. As shown in Fig. 3, the sawnwood consumption per capita remains considerably higher in Europe and North

Table 3 Production and value added of the EU27 wood products industry (average values for 2008–2011)

	Production volume *(FAOSTAT)*		Value added *(EUROSTAT)*	
	million m³	*% of total*	*billion €*	*% of total*
Sawnwood *(NACE C16.1)*	98.6	59 %	6.9	27 %
Wood-based panels *(NACE C16.21)*	58.3	35 %	4.7	19 %
Joinery *(NACE C16.23)*	10●	6 %	13.5	54 %

●*Estimate, due to the non-comparable measurement units*

America compared to Asia, despite the severe decline in construction activity after 2007, most likely because of the higher level of GDP per capita [41] and the higher market share of wood construction [35]. Thus, also for the coming decade, wood construction may be expected to have significant importance mainly in regions where the forest-based sector has a significant role for the economy and the society. Nonetheless, even a small change in market share in a large enough market, such as China or India, could result in a significant increase in demand for wood products.

Despite the stagnating sawnwood consumption, certain niches may offer positive market prospects for wood products, such as bridges, industrial halls, sport centres, multi-storey residential buildings, facade renovations, additional storeys, windmills, etc. [42, 45]. For example, the production of cross laminated timber (CLT) in Europe has grown at an average annual rate of 15 % since 2007, despite the economic downturn [45, 46]. It is also expected to continue growing in double digits [47], possibly reaching 3 million m^3 by 2030 [48]. The index depicted in Fig. 4 shows how the CLT production growth rate compares to sawnwood production growth rate and the GDP growth rate in the EU. The figure does not give a completely appropriate view, as it scales off the market volume, yet it does provide a clear indication of the different life cycle stages of these two products.

New Products and Services

The concept of "new forest-based products" has in the past typically referred to old products with incremental improvements [49], which may result in lighter weight, reduction of costs, and substituting non-renewable materials with biodegradable ones [50]. The largest markets by volume in this category are paper and packaging, textiles, construction products and car parts [51]. The other major class of "new" products are the old products that have new and increasing demand due to changes in the operating environment. For example, dissolving pulp for the textile industry due to the need to substitute for cotton, which takes land from agriculture and consumes scarce water resources; or forest-based biofuels and chemicals that substitute for fossil fuels or agri-based biofuels and chemicals [49].

A range of novel products are also under development, such as nanocellulose or lignin based products. When wood fibres are broken down to the smallest of scales, they may begin to exhibit unique and novel properties, such as superior strength, liquid crystal behaviour, transparency, low thermal expansion, capacity to absorb water and piezoelectric and electric behaviour [52]. These properties may be utilized, for example, for construction products, aerospace materials, sensors, food additives, cosmetics, medical and pharmaceutical applications, paper applications, car parts, flexible displays, electronic actuators, battery membranes, separation membranes, barrier membranes and paints and coatings [51, 52].

With the new applications, the forest-based sector is gradually expanding to cover a wide range of economic sectors and end uses. Or, reversely, other sectors are expanding their resource base to cover forest-based biomass. If the twentieth century forest sector was dominated by two major product categories, pulp and paper and wood products, the key word for the twenty-first century forest-based bioeconomy sector

Table 4 EFSOS II reference scenarios for the wood products markets in Europe (excl. Russia) (Jonsson 2012) and trend projections based on more recent data (updated from [33])

	Sawnwood production (Mm^3)				***Sawnwood consumption (Mm^3)***			
	2007	**2010**	**2020**	**2030**	**2007**	**2010**	**2020**	**2030**
EFSOS II reference	132	127	135	143	126	121	127	133
Trend 1990–2014			121	136			95	98
Trend 2000–2014			113	112			88	74
	Wood-based panel production (Mm^3)				***Wood-based panel consumption (Mm^3)***			
	2007	**2010**	**2020**	**2030**	**2007**	**2010**	**2020**	**2030**
EFSOS II reference	79	75	83	91	78	73	81	90
Trend 1990–2014			71	85			69	81
Trend 2000–2014			66	69			65	68

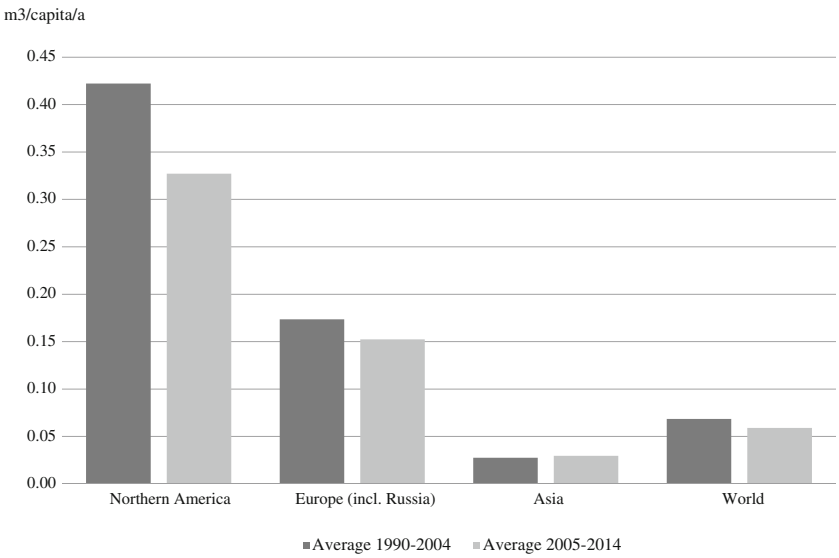

Fig. 3 Sawnwood consumption per capita (Based on [26])

seems to be *diversification*. There will most likely be a large number of product categories, none of which dominates the sector to the extent that paper and wood products did in the past century, particularly in terms of value added.

Yet, it is still difficult to assess the possible scale of new forest products even towards 2030. So far the research and expert literature on new forest based products have been dominated by the engineering and technological analysis and visions. This literature has focused on what is technically possible to manufacture from wood. The conclusion seems to be that wood could substitute for fossil based raw materials to an almost unlimited extent. Partly driven by the significant technical potential, the stakeholders and decision-makers have envisioned doubling the value added of the industry in Europe by 2030 compared to 2010 [53].

However, as far as we are aware, there are no studies that have provided systematic economic and market analysis or scenarios of the scale of the demand and supply of these products in the coming decades, nor where and in what scale the production would take place. *In summary, the critical question does not appear to be what can be made of forest biomass, but rather what will be made, on what scale, where, and driven by what?*

The State of Forest Products Markets Research

The above discussion has demonstrated the following essential points. First, the global forest products markets have significant economic importance. Second, they are in a stage of

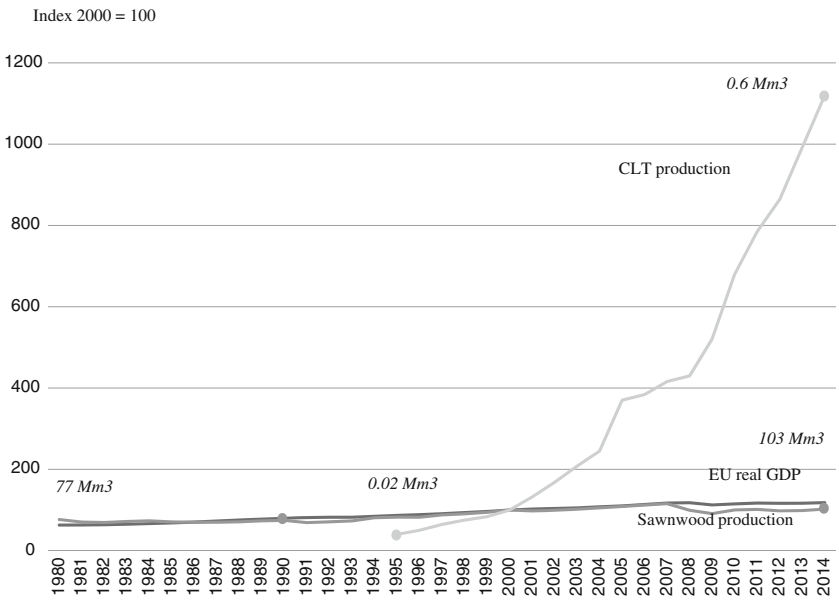

Fig. 4 Indices for the production of sawnwood and CLT in the EU, compared to the GDP (Based on [26, 41, 47])

many fundamental structural changes. Thirdly, the past major outlook studies carried out by forest products market researchers have to a significant degree failed to capture these structural changes. Finally, the emerging forest-based bioeconomy markets are showing signs of great diversification, and many new innovative products are entering the markets in the near future, or over coming decades. How do these trends appear in academic research?

Two major findings emerge. First, the volume of academic research in this field needs urgent and significant upscaling, given the current economic importance of forest based products, the expectations for the future bioeconomy development, and the global implications of these for forests. Second, there is a need to supplement the traditional models and methods with new ones that better capture the structural changes, and provide more relevant information for understanding the changing forest product market patterns.

Indeed, in some respects, the forest products markets fall into a *no-man's-land* in research. It is not the traditional fare of the global forest research community, which is to a great extent focused on forest resources (e.g., *forest management and inventory, biodiversity, climate change, non-wood products*). This is clearly reflected also in the academic journals. Neither are the non-sector-specific academic institutes producing studies on forest products markets to any significant degree.

Globally, the number of active academic researchers who regularly publish in the main scientific journals on the forest industry and forest products markets, seems to be very low, probably less than twenty. Moreover, the number of those researchers that are actively engaged in providing work on the outlook for forest products markets is even significantly smaller. Indeed, the analyses of the markets for current and new forest-based products seem to rest largely on studies produced by consulting companies. These studies may be beyond the reach of most academics due to their high costs (typically several thousand euros or USD). In addition, they are not transparent in the academic sense, since their methods and data sets may not be fully described, and they are not subject to peer-review [54]. Thus, it is difficult to assess the robustness of the analyses and the information they provide. Yet, they are often the only source for systematic and detailed information about the market developments of the global forest-based industry and markets.

Consequently, we argue that there is an urgent need to significantly increase the volume of academic research in this field. The issue is not only the volume of the research, but also the quality of the research, although there might be a correlation between them. While updated projections with more recent data can to some extent consider the recent major fluctuations of the global economy, new models and approaches are needed to explain the structural changes, as well as to capture the diffusion of emerging forest products [2, 4•, 9, 44].

Modelling Implications

The forest products market studies that are used for analysing current or future demand (consumption) and supply (production) of forest products are typically based on an equation similar to the one below [4•]:

$$\ln D_t = \alpha + \beta_1 \ln(p_t) + \beta_2 \ln(GDP_t) + \beta_3 \ln(D_{t-1}) + \varepsilon \quad (1)$$

where D = demand, p = price, GDP = income growth, α = constant, β_1, β_2, β_3 = coefficients, and ε = residual. According to economic theory, the price elasticity of demand should be negative and the income (GDP) elasticity positive for *normal goods* [55, 56].[3] To guarantee that the parameters (elasticities) will get the "correct" signs and magnitudes, they can also be restricted or directed in empirical estimation to fulfil this objective. For example, the Stein-rule shrinkage estimator has been used for this purpose [56].

Equation (1) is central to all of the partial equilibrium forest sector simulation models used frequently to analyse the impacts of, for example, subsidies, taxes, and bioenergy and climate policies. The same model has also been used for forest product outlook projections. However, as a number of studies [4•, 9, 25, 44, 57] have shown, equation (1) fails to capture the structural changes discussed above in the global paper markets and the European sawnwood markets. Even though the structural changes in communication paper markets have increasingly been acknowledged, it has not led to changes in the demand equation specification and its interpretations in the forest sector outlook studies [16, 20].

Although the partial equilibrium forest sector models are primarily used for "what if" simulation to analyse, e.g., the impacts of policy changes rather than for long term projections of market demand as such, the problem of being unable to capture the structural changes or emergence of new forest products remains. This is due to the numerous interdependencies and feed-back effects in the forest sector models (and the forest sector itself) between the different forest products and raw material markets. Failing to capture the changes in one product market may distort the feed-back effects between the different parts of the sector, a feature that is considered as one of the core motivations for the use of the simulation models. Thus, the robustness of policy simulations may be questioned with a projection period of several decades,

[3] The income elasticity of demand is the relative response of demand to changes in income (here GDP), or the percentage change in demand due to a percentage change in income. See also [55], p. 284–285.

even though the points raised in this review mainly concern the use of the models for long run demand projections.

The forest products markets research field appears to be lacking the tools for making quantitative assessments of the changing market patterns, as the only frequently used tools – the econometric equations and forest sector models – have not been subject to systematic effort for capturing these changes. Revising the equation is not straightforward, as it would require finding the missing omitted variables causing the structural changes, i.e., developing new models that are capable of explaining the changes based on sound theory. The knowledge gaps on the market-driven changes in the above context deserve much wider attention in future research [9, 25].

The following points highlight the type of issues that ought to be considered in further forest products markets research:

- Citing Toppinen & Kuuluvainen ([58•], p.7): "*Do the empirical work and outlook studies respond to the questions that decision-makers are interested in, or are they focusing on those markets and research problems, for which established methods and data sources exist?*"
- If choosing the conventional econometrics approach, does it pass the "fitness checks" for robustness, i.e., are the variables in the conventional forest products demand and supply equations likely to capture and explain the long-run structural changes in the markets? Do the GDP and price variables capture the essential features, or are other type of models and variables needed?
- To what extent the quantitative approaches are useful for analysing emerging new forest-based products (biofuels, chemicals, etc.), for which very little or no data exist?

Improving Econometric Applications for Forest Sector Modelling

The econometric applications will remain useful, despite the need for broader analysis identified above. Therefore, we identify in particular three major issues that need to be paid more attention in econometric applications. They are all in one way or another related to the lack of sufficient data analysis and knowledge about the markets studied, which can have severe implications to the robustness of the results and conclusions drawn from them.

First, there is a need to pay more attention to problems of estimating regression equations using long time-series data which contain different market structures [6]. As pointed out above, the market structures and driving forces in the twenty-first century are often in many ways different compared to the twentieth century. Yet the regression equations or forest sector simulation model parameters continue to be typically estimated using observations that rely heavily on the twentieth century data, and do not give more weight for the twenty-first century, when making projections to 2020, 2030 or 2050 [9, 16]. For example, if one fits equations to data from 1970 to 2012, the parameter estimates more heavily weight the period before 2000, which may come from different market structure than the post 2000 data. The earlier period data may even indicate opposite parameter signs than the latter period (e.g., typically in graphics paper markets). A few studies point to the importance of this type of data screening before estimating parameter values [3, 6, 25, 57].

As a possible solution for potential structural changes, the researcher can first use simple ANOVA, Chow-tests, and CUSUM analysis to see whether there are structural changes within the sample, and then try to adjust the estimation sample accordingly [59, 60]. Also the use of panel data and shorter time series can be partial solutions. In the latter case, the degrees of freedom in the estimation are reduced, which in turn requires parsimonious model specifications. Another simple and useful approach to test the robustness of the model and results, but rarely used in forest products market research, would be to apply out-of-sample forecasting tests. Forecasters generally agree that forecasting methods should be assessed for accuracy using out-of-sample tests rather than goodness of fit to past data or in-sample tests [59, 61]. The test can also be as an insurance against in-sample over-fitting. Yet, models used for forest products outlook studies rarely carry out such tests (except for, e.g., [54]). Indeed, had the recent outlook studies carried out such tests, they probably would have revealed the problems of not being able to project the data in the twenty-first century.

Secondly, literature does not seem to pay enough attention to potential aggregation problems. For example, [6] and [9] are valuable studies in pointing the structural breaks over time, but fail to acknowledge the problems in aggregating countries to non-homogeneous regions. It is not unusual to see the aggregation of country groups or regions to large groups, such as OECD and non-OECD countries [9], or high-income and low-income countries [6]. However, for many products the market developments for some countries within these groups may have been almost opposite during the twenty-first century. In this case, parameters estimated for the aggregate group should not be used for individual countries within the group.

Consider the recently published projections to 2065 (see [6]) for the three major forest products consuming countries in Asia, Europe and North America: China, the UK and the USA (Table 5). The parameters used for projecting China's consumption are based on the estimation results for all the low-income countries, and similarly in the case of UK and USA by using all the high-income countries. Table 5, and information from [1–3, 7], leads one to expect that the projections for the three countries are very unlikely. Indeed, even the trend is likely to be opposite in each of the cases compared to

Table 5 Newsprint and printing and writing paper consumption *(million tons, FAOSTAT)*

	1992	2003	2008	2013	Projection to 2065 [6]
Newsprint					
China	1.0	3.2	5.0	4.1	12.7–13.1
UK	1.9	2.3	2.3	1.4	2.3–2.4
US	12.1	10.9	6.9	3.8	6.4–6.6
Printing and writing paper					
China	6.6	14.8	21.3	26.6	97.9–70.2
UK	3.2	4.8	4.2	3.1	4.9–5.5
US	22.2	26.3	24.4	18.7	30.3–34.7

what [6] projects. Therefore, the utility of the projections for practical purposes is questionable.

The above case shows the importance of the detailed analysis of both the time series and aggregation issues when making projections. Moreover, it stresses the importance of running out-of-sample forecasting tests for each case, as well as comparing the results, for example, with the results of the consulting studies. It may be added, that good knowledge about the markets, and comparing the results to industry experts' projections, is likely to help to minimize the risks of unrealistic projections.

It is also surprising how rare it is in econometric applications on forest products markets to analyse *multicollinearity.* This is in particularly worrying since often the specifications include variables that have very similar patterns, such as GDP, time trend, lagged dependent or independent variables, or economic activity variables highly correlated with GDP. If one was only interested in using the equation for prediction, then multicollinearity is not a problem, as it does not reduce the predictive power or reliability of the model as a whole. But if one is interested in the impact of individual variables, or using the elasticities for example in forest sector simulation models, then it would be a severe problem. If multicollinearity is present, the parameter estimates of the regression equation may change erratically in response to small changes in the model or the data, which makes it impossible to produce precise and robust estimates. However, the issue needs to be checked separately for each sample, as for example the construction activity and the GDP have been found not to be collinear in all samples [44]. One possible solution to multicollinearity would be to use data in difference format (as in [6]), but the drawback would be the loss of long-run information of the data. Some of the further technical issues with panel econometrics on forest products markets, which have received only limited attention despite their significant impact on the reliability of conclusions, include the endogeneity of the independent variables, serial correlation and non-stationarity.

The positive lesson from the above discussion is that there are a number of straightforward and rather simple ways of trying to improve the forest products market analyses. With these simple steps, market researchers should be able to provide more robust, meaningful and informative analysis for decision makers and stakeholders, and avoid some of the past pitfalls. However, providing meaningful analysis for the new emerging forest products, for which there is yet none or very little data, is more challenging. Also, factors that are often not easily quantifiable, such as cultural and institutional differences and innovations, remain a challenge for the empirical analysis. Most likely, capturing them will require the uptake of complementary qualitative and expert analysis, along with alternative modelling frameworks.

New Approaches

Given the messages from the previous sections, at least the following observations can be made. Firstly, the factors causing long-run structural changes or substitution in the end use markets, can be independent from economic activity (GDP) and the short term price of the product, i.e., the two main variables – if not the sole variables – in the demand equations. GDP and price may still work well for short-run analysis trying to capture the business cycle changes. But for long-run projections, structural factors such as ageing, urbanization, digital information technology, and institutional environment, may be more important. Therefore, it may be necessary to use separate models for long-term structural factors (using cross section or panel data) and short-term business cycle factors (using time series data, often with high frequency) (see also [44]).

There are cases for which the traditional econometric models do not fit well, such as analysing emerging markets or niche markets for which there are none or very little data, or markets for current products which have shifted to a new structure. The CLT market volume growth compared to the GDP growth (see Fig. 3) shows, how spurious it would be to analyse the niche markets with the same model as the established sawnwood markets: The GDP elasticity would be multiple orders higher for the CLT markets. Yet the correct interpretation would probably be that the model is omitting important variables related to substitution patterns, and that the GDP barely has an impact on the level and growth rate of CLT in the time period of 1990–2015.

The problem of unstable market share in the beginning of the product life cycle is similar to the problem of declining markets, in that the theoretical expectation between the GDP growth and consumption does not conform to theoretical expectations. Some examples of potential qualitative and quantitative approaches to complement the traditional econometric analysis for the purpose of examining the emerging or changing markets have been suggested [4•, 8•], including participative and descriptive approaches.

Conclusions

In terms of global forest products market developments, the twenty-first century has been in many ways very different from the twentieth century – striking structural changes have taken place. For example, in 2000–2014 the global production (and consumption) of graphics paper, wood pulp and wood fuel show opposite patterns to the period of 1985–1999. Yet, the traditional major drivers of forest products consumption and production, i.e., economic growth (GDP) and population growth, have continued to follow the past patterns globally. Moreover, new innovative forest biomass based products, such as second generation biodiesel, nanopulp and lignin derivative products, and new wood-based construction systems, have been introduced to markets. Also, the global picture hides the regional and country level patterns, which have in many cases experienced even more striking structural changes.

Given the above developments, the global forest sector can be interpreted to be in a phase of *creative destruction* — an era characterized by a major decline of a number of established products and businesses, and simultaneous emergence of new products and businesses. Many of the traditional forest industry countries are suffering from a decline of production in traditional forest products, while new production opportunities have emerged, for example, in bioenergy, biochemicals and prefabricated wood products. The emerging economies have faced a different situation in the 2000s, characterized by a rapid growth of traditional forest products markets. Due to the global competition, the forest products production is moving to least cost regions and resources. On the other hand, the strategy and policy responses for the global sustainability challenges (climate change, population growth, resource scarcity), and technological development, will continue to shape the sector in the coming decades. These trends will result in a more complex, more diverse and more interlinked forest-based sector, with the pulp and paper sector diversifying towards integrated biorefineries, and the wood products industry diversifying towards a broad range of niche construction market products.

The standardized industry classification used by statistical offices is giving an increasingly biased picture of the diversifying forest-based sector, in that it does not capture all of the emerging products and services. On the other hand, in the absence of coherent data, the expectations created by vision documents and bioeconomy strategies may also exaggerate the scale and pace of changes.

The changing operating environment necessitates further research efforts to obtain better data and understand the interlinkages and competitive advantages of the sector (e.g., [62]). On the other hand, there is a need for more specific and disaggregated market analysis for improved relevance for decision-making (e.g., [63, 64•]). It would also be important to focus research on how to connect the analysis of the emerging small volume, high value added markets to the analysis of the large volume, established markets. So far, there have been few efforts towards this [4•, 8•, 65, 66].

When considering the importance of global forest products markets to the economy, employment and forests, and the changes taking place in the markets, the scale of research on forest products markets is alarmingly low. For example, in Europe and North, there appears to be less than 20 professorships on forest products markets. Moreover, most of them focus on marketing research, while practically none focus on market analysis or long-term market outlook or employment patterns. Indeed, giving the importance of jobs, it is worrying that there is hardly any research on forest sector labour markets.

The current situation would not necessarily be a matter of great concern, if this type of research was carried out in other disciplines, such as in business schools and economics departments. But this seems not to be the case. Academic literature on forest products or forest bioeconomy markets and employment, and especially their long-term outlook, is nearly non-existent. The field is currently almost completely covered by consulting company studies (e.g. [67]), which cannot substitute for academic research, despite their great value, due to the non-transparent data sources and method description, and the lack of peer-review.

Current research has relied to a large extent on traditional theory-driven market modelling, focusing on questions related to the sufficiency of wood resources, trends in the production of primary wood products and international competitiveness. In doing so they have paid less emphasis on some of the equally important questions, which the modelling frameworks have difficulties in capturing, such as value added development, employment issues, structural changes, and the diffusion of new products and services. Indeed, the changing demand patterns for forest-based products constitute a significant research gap, which the research orientations in forest economics and forest products market analysis ought to address for improved relevance for industries, other stakeholders and for policy-making [4•, 5••, 8•, 68, 69].

Forest products markets research clearly falls into the realm of applied science. For such a research orientation, the practical relevance and the ability to capture and explain market developments is essential. The research should also provide information and foresight analysis on forest products market outlook that decision makers and stakeholders find informative and useful, and cannot find in other sources, such as in consulting studies. If forest products research does not succeed to improve, and also address more widely the societally important questions, it is in danger of making itself irrelevant for the decision makers and stakeholders.

This review clearly points to a need for significantly increasing the volume of academic research and education on the global and regional forest based products markets. With the increased volume of research, also the quality and societal relevance issues pointed in this study could be addressed.

Compliance with Ethical Standards

Conflict of Interest Drs Hetemäki & Hurmekoski wish to acknowledge financial support from the Strategic Research Council at the Academy of Finland through the FORBIO (Sustainable, climate-neutral, and resource-efficient forest-based bioeconomy) project.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by the author.

References

Papers of Particular Interest, Published recently, Have Been Highlighted as:
- • Of Importance
- •• Of Major Importance

1. RISI. European Graphic Paper 15-Year Forecast. 2013;13:(3).
2. R. Hänninen, L. Hetemäki, E. Hurmekoski, A. Mutanen, A. Näyhä, J. Forsström, et al.. European forest industry and forest bioenergy outlook up to 2050: a synthesis, Cleen/Fibic research report no D 1.1. 1. Helsinki, Finland; 2014.
3. Hetemäki L, Hänninen R, Moiseyev A. Markets and market forces for pulp and paper products. In: Hansen E, Vlosky R, Panwar R, editors. Global Forest products: trends, management, and sustainability. USA: Taylor and Francis Publishers; 2013.
4.• Hurmekoski E, Hetemäki L. Studying the future of the forest sector: review and implications for long-term outlook studies. Forest Policy Econ. 2013;34:17–29. **Gives an overview of long-term outlook studies**.
5.•• L. Hetemäki. Future of the European Forest-Based Sector. Structural Changes Towards Bioeconomy, What Science Can Tell Us 6, European Forest Institute, 2014. **Gives an overview of the ongoing and expected changes in the forest products markets particularly from a European perspective, with a focus on structural changes and open questions**.
6. Buongiorno J. Income and time dependence of forest product demand elasticities and implications for forecasting. Silva Fennica. 2015;49(5):1–17.
7. Poyry Inc. World fibre outlook up to 2030. Vantaa, Finland; 2015.
8.• E. Hurmekoski. Long-term outlook for wood construction in Europe. Dissertationes Forestales 211. Finnish Soc For Sci. 2016. **Gives an overview of long-term outlook studies**.
9. G.S. Latta, A.J. Plantinga, M.R. Sloggy. The effects of internet use on global demand for paper products. J For. 2016.
10. D. Wear, J. Prestemon, M.O. Foster. US forest products in the global economy. J For. 2015.
11. Toppinen A, Zhang Y, Geng W, Laaksonen Craig S, Lahtinen K, Li N, et al. Changes in global markets for forest products and timberlands. Forests and society: responding to global drivers of change. Helsinski (Finlandia): IUFRO-WFSE; 2010.
12.•• E. Hansen, R. Panwar, R. Vlosky. The global forest sector: changes, practices, and prospects. CRC Press; 2013. **Provides a uniquely comprehensive overview and outlook of the global forest products industry**.
13. R.W. Haynes, An analysis of the timber situation in the United States: 1952 to 2050, Technical Report, US Department of Agriculture, Forest Service, Portland, Oregon; 2003.
14. L. Hetemäki, S. Nilsson. Information technology and the forest sector, IUFRO World Series Vol. 18. Vienna; 2005.
15. L. Hetemäki, R. Hänninen. Arvio Suomen puunjalostuksen tuotannosta ja puunkäytöstä vuosina 2015 ja 2020. Working papers of the Finnish Forest Research Institute 122, 2009.
16. J. Buongiorno, S. Zhu, R. Raunikar, J.P. Prestemon. Outlook to 2060 for world forests and forest industries: a technical document supporting the Forest Service 2010 RPA assessment, U.S. Department of Agriculture Forest Service, Southern Research Station, Techical Report SRS-151, Asheville, NC; 2012.
17. Jonsson R. How to cope with changing demand conditions - the Swedish forest sector as a case study: an analysis of major drivers of change in the use of wood resources. Can J For Res. 2013;43:405–18.
18. FAO. The Russian Federation forest sector outlook study to 2030. Rome: FAO; 2012.
19. A. Lebedys, Y. Li, Contribution of the forestry sector to national economies, 1990–2011, Forest Economics, Policy and Products Division, Forestry Department, Food and Agriculture Organization of the United Nations; 2014.
20. UNECE/FAO. The European forest sector outlook study II 2010–2030. Geneva: UNECE/FAO; 2011a. p. 107.
21. U. Mantau, U. Saal, K. Prins, F. Steierer, M. Lindner, H. Verkerk, et al.. EUwood–real potential for changes in growth and use of EU forests, Final report. Hamburg/Germany; 2010.
22. Boston Consulting Group. Paper and the electronic media: creating value from uncertainty; 1999.
23. Boston Consulting Group. The prospect for graphic paper. The impact of substitution, the Outlook for Demand; 2007.
24. L. Hetemäki. Information technology and paper demand scenarios, world forests, society and environment. Springer; 1999. p. 31–40.
25. L. Hetemäki, M. Obersteiner, US newsprint demand forecasts to 2020, International Institute for Applied Systems Analysis (IIASA), Interim Report IR-01-070; 2001.
26. F FAOSTAT. Forestry production and trade database. Available at: http://faostat3.fao.org/browse/F [Accessed 13/01/2016].
27. Sandberg D, Vasiri M, Trischler J, Öhman M. The role of wood mechanical industry in the Swedish forest industry cluster. Scand J For Res. 2014;29(4):352–9.
28. National Bureau of Statistics of China. Statistical database, http://www.stats.gov.cn/english/statisticaldata/ [Accessed 28/01/2016].
29. Wan M, Lähtinen K, Toppinen A. Strategic transformation in the value-added wood products companies: case study evidence from China. Int J Emerg Mark. 2015;10(2):224–42.
30. A. Wahl. Wood market trends in Europe, FPInnovations, Special Publication SP-49; 2008.
31. Poyry Inc., The future of the wood-based panel industry in Europe. Markets, industry trends and profitability – Europe 2020; 2013.
32. R. Taylor, A. Koskinen, F. Maplesden, I. Novoselov. Sawn Softwood. In: UNECE/FAO, editor. Forest products annual market review 2014–2015, Geneva, Switzerland; 2015.
33. E. Hurmekoski, Wood Products Markets. In: Hänninen R, editor. European Forest Industry and Forest Bioenergy Outlook Up to 2050: A Synthesis, Cleen/Fibic Research Report no D 1.1. 1, Helsinki, Finland; 2014. p. 48–68.
34. UNECE/FAO. The north American forest sector outlook study 2006–2030. Geneva: UNECE/FAO; 2012.

35. Baumgardner M, Johnson S, Luppold W, Maplesden F, Pepke E. Markets and market forces for lumber. In: Hansen E, Panwar R, Vlosky R, editors. The global Forest sector. Changes, practices, and prospects. Boca Raton, FL: CRC Press; 2013. p. 41–76.
36. Buongiorno J. International trends in forest products consumption: is there convergence? Int For Rev. 2009;11(4):490–500.
37. A. Baudin, Modeling and forecasting the demand for sawnwood in Western Europe from an end-use perspective; 2003. 246.
38. Schuler A, Adair C. Demographics, the housing market, and demand for building materials. For Prod J. 2003;53:8–17.
39. Mahapatra K, Gustavsson L. Multi-storey timber buildings: breaking industry path dependency. Build Res Inf. 2008;36(6):638–48.
40. Arora SK, Foley RW, Youtie J, Shapira P, Wiek A. Drivers of technology adoption—the case of nanomaterials in building construction. Technol Forecast Soc Chang. 2014;87:232–44.
41. World Bank. World development indicators database, http://databank.worldbank.org/data [Accessed 27/01/2016]
42. U. Bühlmann, A. Schuler. Markets and market forces for secondary wood products. In: Hansen E., Panwar R., Vlovsky R, editors. The global forest sector. Changes, practices, and prospects. CRC Press; 2013.
43. D. Alderman. Housing and construction markets. In: UNECE/FAO, editors. Forest products annual market review 2012–2013. Geneva Timber and Forest Study Paper 33, Forestry and timber section. Geneva, Switzerland; 2013. p. 115–122.
44. Hurmekoski E, Hetemäki L, Linden M. Factors affecting sawnwood consumption in Europe. Forest Policy Econ. 2015;50: 236–48.
45. T. Pahkasalo, P. Aurenhammer, O. Bartlomé, C. Gaston. Value-added wood products. In: UNECE/FAO, editor. Forest products annual market Rreview 2013–2014. Geneva, Switzerland; 2014. p. 99–110.
46. H. Manninen. Long-term outlook for engineered wood products in Europe. European Forest Institute, Technical Report 91, 2014.
47. T. Pahkasalo, C. Gaston, G. Schickhofer.Value-added wood products. In: UNECE/FAO, editor. Forest products annual market review 2014–2015. Geneva, Switzerland; 2015. p. 105–114.
48. Espinoza O, Trujillo VR, Mallo MFL, Buehlmann U. Cross-laminated timber: status and research needs in Europe. Bioresources. 2015;11(1):281–95.
49. A. Näyhä, L. Hetemäki, T. Stern. New products outlook. In: Hetemäki L, editor. Future of the European forest-based sector: structural changes towards bioeconomy, EFI what science can tell us –report Vol. 6; 2014. p. 15–32.
50. Wegner TH, Jones EP. A fundamental review of the relationships between nanotechnology and lignocellulosic biomass. In: Lucia LA, Rojas OJ, editors. The nanoscience and Technology of Renewable Biomaterials. Hoboken, NJ: John Wiley & Sons Ltd; 2009. p. 1–41.
51. Shatkin JA, Wegner TH, BILEK E, Cowie J. Market projections of cellulose nanomaterial-enabled products − Part 1: applications. TAPPI J. 2014;13(5):9–16.
52. Cai Z, Rudie AW, Stark NM, Sabo RC, Ralph SA. New products and product categories in the global Forest sector. In: Hansen E, Panwar R, Vlosky R, editors. The global Forest sector. Changes, practices, and prospects. Boca Raton, FL: CRC Press; 2013. p. 129–50.
53. FTP. Horizons - revised vision 2030 for the European forest-based sector, the European forest-based sector technology platform; 2012.
54. Hetemäki L, Mikkola J. Forecasting Germany's printing and writing paper imports. For Sci. 2005;51(5):483–97.
55. Varian H. Intermediate microeconomics. 8th ed. New York: W. W. Norton & Company, Inc.; 2010.
56. Simangunsong BCH, Buongiorno J. International demand equations for forest products: a comparison of methods. Scand J For Res. 2001;16(2):155–72.
57. Hetemäki L. ICT and communication paper markets, information technology and the Forest sector. IUFRO World Ser. 2005;18:76–104.
58.• Toppinen A, Kuuluvainen J. Forest sector modelling in Europe - the state of the art and future research directions. Forest Policy Econ. 2010;12(1):2–8. **Discusses the state of the art and future research directions on forest section modeling**.
59. M.P. Clements, D.F. Hendry. The Oxford handbook of economic forecasting. Oxford University Press; 2011.
60. Hansen BE. The new econometrics of structural change: dating breaks in US labor productivity. J Econ Perspect. 2001;15(4): 117–28.
61. Giacomini R, Rossi B. Forecast comparisons in unstable environments. J Appl Econometrics. 2010;25(4):595–620.
62. Stern T, Ledl C, Braun M, Hesser F, Schwarzbauer P. Biorefineries' impacts on the Austrian forest sector: a system dynamics approach. Technol Forecast Soc Chang. 2015;91:311–26.
63. Stern T, Haas R, Meixner O. Consumer acceptance of wood-based food additives. Br Food J. 2009;111(2):179–95.
64.• Hurmekoski E, Jonsson R, Nord T. Context, drivers, and future potential for wood-frame multi-story construction in Europe. Technol Forecast Soc Chang. 2015;99:181–96. **Discusses future potential for wood-frame constructions**.
65. A. Näyhä. Towards bioeconomy: a three-phase Delphi study on forest biorefinery diffusion in Scandinavia and North America; 2012.
66. H.K. Sjølie, Use of backcasting in forest sector models, presentation at the SSAFR conference, Uppsala, Sweden, 20 August 2015; 2015.
67. Indufor. Study on the wood raw material supply and demand for the EU wood-processing industries. Final report, commissioned by European commission, enterprise and industry directorate general; 2013.
68. Näyhä A, Pelli P, Hetemäki L. Services in the forest-based sector – unexplored futures. Foresight. 2015;17(4):378–98.
69. B. Solberg, L. Hetemäki, A.M.I. Kallio, A. Moiseyev, H.K. Sjølie. Impacts of Forest Bioenergy and Policies on the Forest Sector Markets in Europe-what do we Know? In: Pelkonen P, Mustonen M, Asikainen A, Egnell G, Kant P, Leduc S, et al, editors. Forest Bioenergy for Europe, EFI Technical Report 89; 2014.