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Forest market outlook in the Southern United States

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ABSTRACT

The forest products market in the U.S. South is poised to undergo significant changes in the coming decades as a result of an evolution of social, economic, and environmental factors. To better understand these changes, this paper utilizes a forest sector partial equilibrium model to examine the market and trade impacts of the U.S. forest sector under various Shared Socioeconomic Pathways (SSPs) and alternative projections of climate from 2020 to 2070. Our results indicate that U.S. production and consumption of forest products will grow in most scenarios. The U.S. South is projected to remain the leading timber-producing region of the nation. Our results also highlight the complex dynamics within the forest sector in response to trade restrictions and changing market demands. One of six scenarios reported shows how higher trade barriers significantly affect southern U.S. hardwood markets, causing a reduction in net exports to outside the region and slowing hardwood price growth. On the other hand, such barriers simultaneously create more favorable conditions for domestic softwood producers, especially in the U.S. South, to supply the U.S. construction sector. A scenario focused on mass timber demonstrates that rising demand for softwood lumber used in mass timber products could lead to considerably higher production and prices, compared to a benchmark scenario.

1. Introduction

The forest industry has experienced significant changes in the past decade, both globally and in the United States. In the South, nationwide, and globally, the emergence of real estate investment trusts and timber management investment organizations has restructured ownership and altered incentives and management practices of timber-focused management (Zhang et al., 2012). In more recent years, regional, national, and global forest products production, consumption, prices, and trade have steadily risen from the deep contraction experienced in the real estate investment market-driven severe recession of 2007 to 2009 (Brandeis and Hodges, 2015). And while economic growth in emerging as well as most wealthy economies has fostered overall growth in demand for major final products, ongoing competitive pressures by electronic media has acted to maintain an uninterrupted trend downward in the consumption and production of graphics paper and its fiber inputs. Simultaneously, the U.S. South has experienced an erosion in its dominant role as an exporter of wood building products but emerged as the dominant exporter of wood pellets for energy. In other paper (e.g., sanitary and wrapping) and paperboard markets, its import-dependence has receded along with demands for graphics paper (Brandeis et al., 2021). With respect to wood pellets, the U.S. South has attracted significant attention regionally, with its expanding capacity and wood pellet production. Specific aspects of the changes in the forest product markets, both short-run and long-run, have been the subject of many research efforts. Buongiorno and Johnston (2018) quantified the effects of hypothetical trade barriers in the US and globally. Nepal et al. (2019) focused on the emerging wood pellet sector. Prestemon et al. (2018, 2022) outlined prospects for the residential housing sector to 2070. Buongiorno (2021) and Prestemon and Guo (2022) examined the effects of the global pandemic. Nepal et al. (2022) outlined the possible effects of rising seas on domestic and international global markets.

The U.S. Department of Agriculture (USDA) Forest Service recently released a report, the 2020 Resources Planning Act Assessment (RPA), quantifying how socioeconomic and climate changes may affect forest resources and markets in different regions of the country over the next 50 years (USDA Forest Service, 2023). While the 2020 RPA provided a high-level overview of possible future forest products sector dynamics under four multifaceted scenarios by region, it gave less attention to regional differences. The 2020 RPA built upon past scenario-based

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efforts to describe the prospective future of the U.S. forest sector. For example, the Subregional Timber Supply Model (SRTS), developed to describe timber inventory and roundwood production futures at substate spatial scales in the U.S. South, has supported past regional assessments and special analyses of the South's future (e.g., Prestemon and Abt, 2002a, 2002b; Galik et al., 2015; Galik and Abt, 2016). The Southern Forest Futures Project (Wear and Greis, 2013) reviewed the recent history of the sector in the South and described national-level projections under a variety of future scenarios. Each of these previous studies prior to the 2020 RPA Assessment utilized different modeling systems and projected the future under different scenarios and assumptions regarding national and global markets. The present study builds on past studies by applying a new global forest sector market model (Johnston et al., 2021), contains a wider range of processed forest products, includes the effects of climate change on forest productivity nationally and globally, and starts its projections with the most up-to-date information on current sector conditions regionally, nationally, and globally. Finally, unlike previous studies, our models apply statistical downscaling methods to generate projected futures of product markets and employment at the state level, enabling a richer description of intraregional market dynamics and the South's future.

Sector-wide analyses of the U.S. forest sector have updated some of what we learned in the Southern Forests Future Project (SFFP) (Wear and Greis, 2013). Brandeis and Hodges (2015) focused on short-run changes following the 2007–2009 recession, documenting some growth but noted labor demand shrinkage. Prestemon et al. (2015) and Wear et al. (2016) examined long-term trends in the sector, including its receding yet still dominant stature in global markets. Brandeis et al. (2021) documented the key market variables of interest through the second decade of the 2000s, including a focus on its continued reliance on imports for many categories of wood building products but balanced trade in pulp and paper. Despite significant market changes, research in this area has not fully kept pace with these changes, especially on the regional level. As Wear et al. (2016) point out, long-term trends in the U. S. forest sector are revealed not just in markets for forest products but also in its demands for inputs, including labor, capital, and wood. However, little attention has been given to the employment trajectory of the wood products or paper sectors.

Understanding the future of forest product markets is vital for the sustainable use and management of forest resources, economic growth, and environmental conservation. However, the future of forest product markets is challenging to forecast since it is influenced by social, economic, and environmental developments that are highly unpredictable. A novel scenario framework has been constructed by the climate change research community. This framework, referred to as the Shared Socioeconomic Pathways (SSPs), outlines the trajectory of population, urbanization, and economic growth up to 2100 (Van Vuuren et al., 2011; Riahi et al., 2017). Since its development, the SSP framework has been extensively employed to investigate the effects of socio-economic and climate development. Daigneault et al. (2019) developed detailed narratives for how the global forest sector could vary across the five different SSPs, through the development of Forest Sector Pathways (FSPs). However, the impacts of these FSPs on regional forest product markets are still unclear. Since the U.S. South is the world's largest timber and wood pellets producing region, there is growing interest in addressing the impact of expanded global wood energy demand on the U.S. regional forest product markets.

This paper uses a partial equilibrium model of the forest sector to project future wood energy market trends under six different socio-economic-climate scenarios. It places emphasis on the regional woody biomass harvest volumes and final product markets across the different scenarios. This paper extends the current literature in two directions. First, it details the analysis at the regional level. Second, it provides estimates about the current extent of total employment on a regional and state scale and describes its projected trends over time. For a sensitivity analysis, we consider two other scenarios of changing trade conditions and mass timber demand based on a "business as usual" scenario. The rest of the paper is organized as follows. Section 2 introduces the model and methodology employed in the analysis. Section 3 presents the results of the model, while Section 4 discusses the findings and concludes the paper. A detailed description of the empirical model is provided in the supplementary material.

2. Methodology

2.1. The FOrest resource outlook model

The Forest Resource Outlook Model (FOROM) is used in this analysis to advance the understanding of long-term trends of relevance for southern forest markets from 2020 through 2070. FOROM is a partial equilibrium model of global forest sector. It comprises forest resources, timber supply, demand for intermediate and final products, and international trade, as described in Johnston et al. (2021). The current version of the FOROM includes 20 distinct interconnected products (Fig. 1) across 55 countries and regions of the world and explicitly recognizes the United States as six distinct RPA regions, separating the RPA South region into southeast and south central. The model's framework allows for analyses of the impact of external shocks and changes in future socio-economic conditions on the production, consumption, trade, and prices of raw materials, intermediates, and final products, while also accounting for changes in forest land area and forest standing stock.

The FOROM integrates a series of static equilibria with dynamic exogenous assumptions. In the static phase, the model focuses on maximizing economic welfare for all products in all countries as shown in Eq. (1):

$$W = \sum_k \left\{ \sum_j \int_0^{Q_j^k} P_j^k\left(Q_j^k\right) dQ_j^k - \sum_i \int_0^{Y_i^k} C_i^k\left(Y_i^k\right) dY_i^k - \sum_i \sum_j \left(t_{ij}^k + \tau_{ij}^k\right) x_{ij}^k \right\} \tag{1}$$

where P_j^k and Q_j^k refer to the price and quantity of wood product k consumed by country/region j, while C_i^k and Y_j^k refer to the manufacturing cost and production in region i. The cost of moving product k from region i to j, x_{ij}^k, is a function of the shipping and handling cost, t_{ij}^k, and the associated tariffs, τ_{ij}^k.

This optimization process aligns with the spatial price equilibrium framework. Equilibrium prices, quantities, and net trade levels are determined in the static phase. Once a solution for the current period is determined, the model will enter the dynamic phase, in which the parameters of the model are updated based on exogenous drivers (e.g., gross domestic product growth, population growth, changes in productivity, carbon dioxide fertilization, policy shocks, etc.) and endogenous variables (e.g., harvest levels, standing stock levels, etc.) in preparation for the next iteration cycle. More specifically, Demand is assumed to change over time through exogenous shifts to GDP per capita, $\dot{y}_t$, and translated through the growth rate of per capita GDP, $g_j^{\dot{y}_t}$, and the elasticity of demand with respect to the growth rate of per capita GDP, δ_j^k:

$$\overline{Q}_j^k = Q_j^k\left(1 + \delta_j^k g_j^{\dot{y}_t}\right) \forall k \in f \tag{2}$$

where symbols embellished with a bar indicate benchmark levels. Supply of harvestable (roundwood) inputs (i.e., industrial roundwood, fuelwood, other roundwood) are assumed to change over time through exogenous shifts to forest area and forest stock:

$$\overline{Y}_i^k = Y_i^k\left(1 + \varepsilon_i^k g_{i,t}^A + \nu_i^k g_{i,t}^I\right) \forall k \in h \tag{3}$$

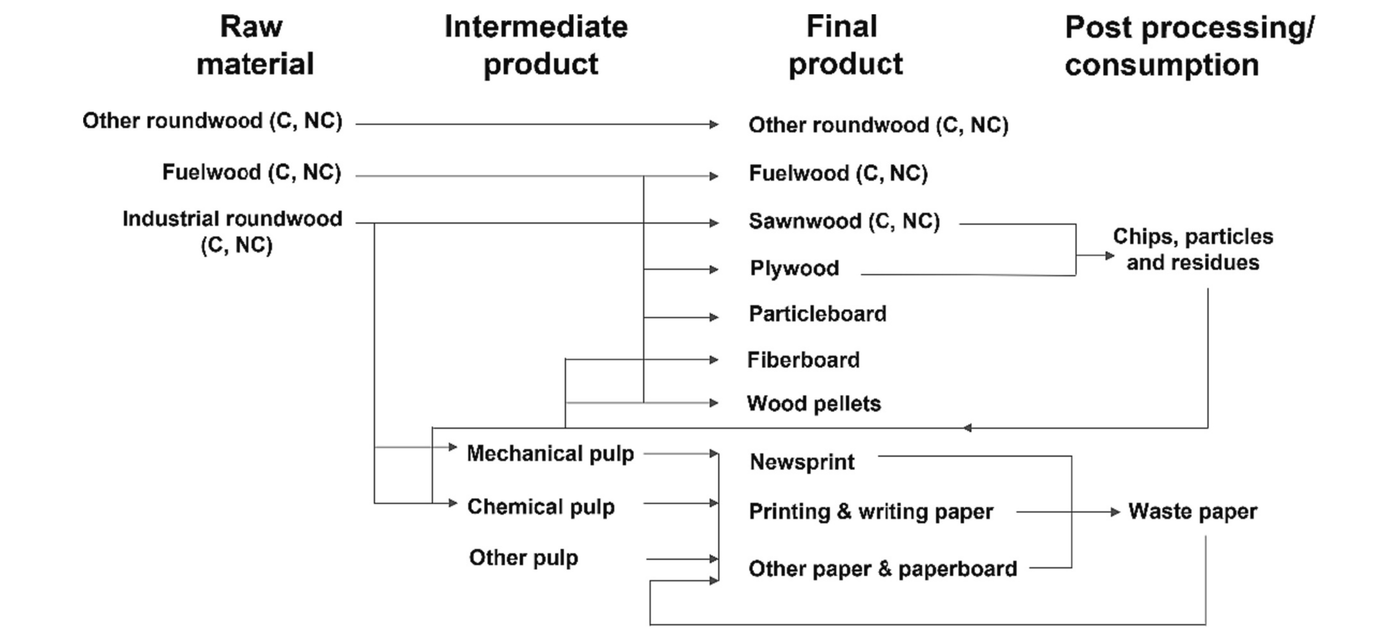

Fig. 1. Forest product flow chart in FOROM.

where $g_{i,t}^{A}$ is an exogenous change in the growth rate of forest area at time t, $g_{i,t}^{I}$ is an endogenously determined growth rate of forest inventory, which changes over time based on the specified nonlinear negative relationship between forest growth and stocking density, and ε_i^k and ν_i^k are elasticities associated with forest area and inventory, respectively.

The supply of other fiber pulp, which is derived from recovered paper or from fibrous vegetable materials other than wood (i.e., outside forest) is assumed to change over time through exogenous shifts to per capita GDP, and translated through the elasticity of supply with respect to per capita GDP, ω_i^k:

$$\overline{Y}_i^k = Y_i^k\left(1+\omega_i^k g_i^{y_i}\right)\forall k \in e \tag{4}$$

A comprehensive overview of the broader modeling framework can be found in Johnston et al. (2021). Initially, FOROM was developed to provide an outlook on the global and U.S. forest sector for the U.S. Forest Service 2020 Resource Planning Act (RPA) Assessment. Since then, the model has been updated periodically and been used to tackle a variety of forest-related research questions (e.g., Nepal et al., 2021; Johnston et al., 2022).

Table 1
Key exogenous drivers of global trends in the RPA scenarios.

	RPA scenarios			
Exogenous driver	LM	HM	HL	HH
Socioeconomic				
GDP	High in LICs, MICs; moderate in HICs	Moderate	Low	High
Population	Relatively low	Moderate	Low in OECD, high in other countries	High in OECD, low in other countries
Technological change	High	Moderate	Low	High
Trade openness	Moderate	Moderate	Low	High
Bioenergy preferences	High	Moderate	Low	High
Climatic				
Atmospheric warming	Low	High	High	High
Motivated by the following IPCC scenarios				
SSP	SSP1	SSP2	SSP3	SSP5
RCP	RCP 4.5	RCP 8.5	RCP 8.5	RCP 8.5

LIC = low income country; MIC = middle income country; HIC = high income country.

2.2. Scenarios

The RPA Assessment scenarios were operationalized within the dynamic phases of FOROM. These scenarios encompass a range of interconnected future climate, population, and socioeconomic changes by pairing two alternative climate futures (Representative Concentration Pathways or RCPs) with four alternative socioeconomic futures (Shared Socioeconomic Pathways or SSPs). The RPA scenarios pair two alternative climate futures (Representative Concentration Pathways or RCPs) with four alternative socioeconomic futures (Shared Socioeconomic Pathways or SSPs) in the following combinations: RCP 4.5 and SSP1 (lower warming—moderate U.S. socioeconomic growth, LM), RCP 8.5 and SSP3 (high warming—low U.S. socioeconomic growth, HL), RCP 8.5 and SSP2 (high warming—moderate U.S. socioeconomic growth, HM), and RCP 8.5 and SSP5 (high warming—high U.S. socioeconomic growth, HH) (Table 1). The four 2020 RPA Assessment scenarios (Johnston et al., 2023) encompass the projected range of climate change from the RCPs and projected quantitative and qualitative range of socioeconomic change from the SSPs, resulting in four distinct futures that vary across a multitude of characteristics and providing a unifying framework that organizes the RPA Assessment natural resource sector analyses around a consistent set of possible world views. Table 1 shows the key exogenous drivers of global trends in the RPA scenarios. A description of how these scenarios were selected and paired is available in the Scenarios Chapter, and more extensively in Langner et al. (2020).

To evaluate forest sector climate change impacts, the FOROM model incorporated exogenous net primary productivity (NPP) projections to adjust supply costs for non-U.S. countries. NPP through 2070 was projected by the global dynamic vegetation model MC2 (Kim et al., 2017) using climate and CO_2 inputs from IGSM-CAM under RCP 4.5 (LM scenario) and RCP 8.5 (HL, HM, HH). For the United States (only), MC2 projections of forest growth changes affecting supply costs were replaced with the RPA Forest Dynamics Model (FDM), averaged across climate scenarios. The FOROM-FDM framework jointly modeled the U.S. forest sector, harmonizing inventory and removals. In each 5-year time step of FOROM, the FDM was used to calibrate inventory growth rates across the RPA regions and were an exogenous input into FOROM. Then, FOROM projected forward an endogenous path of removals and roundwood prices. The roundwood prices were then used in the FDM harvest choice and timber supply models to project removals. The projected removals from FOROM and the FDM were then compared to ensure alignment.

In FOROM, the demand for bioenergy from fuelwood and wood pellets is driven not just by economic development assumptions, but also by consumer preferences and policies underlying the IPCC's shared socioeconomic pathways (SSPs). For fuelwood demand, FOROM incorporates trends in global primary biomass energy use consistent with the SSPs. Similarly, wood pellet consumption growth is constrained by global secondary biomass energy production trends from the SSPs, beyond just GDP changes. This captures SSP-related preference and policy differences. Recent regional wood pellet demand growth rates were scaled using the global secondary biomass energy growth rates (Johnston et al., 2022). There are two additional scenarios that deviate from the HM scenario described earlier. The first is the HM-Mass Timber scenario, which maintains the assumptions of the HM scenario but introduces a hypothetical rapid expansion in the consumption of mass timber products not only in the United States but also in countries such as Brazil, Argentina, Chile, Spain, Italy, France, Germany, the United Kingdom, Poland, the Netherlands, and Austria. The HM-Mass Timber scenario is calibrated to the "Optimistic Estimate" scenario described by Ganguly (2021) and modeled by Nepal et al. (2021). In this scenario, the total consumption of mass timber in these countries is projected to rise from 0.656 million mbf (1.553 million cubic meters) in 2025 to 10.5 million mbf (24.816 million cubic meters) by 2060; the consumption level is projected to remain constant beyond 2060. For the United States, consumption is assumed to rise from 0.017 million mbf (0.037 million cubic meters) in 2025 to 1.298 million mbf (3.064 million cubic meters) by 2060. For context, under the HM scenario, U.S. consumption of softwood lumber, the input to mass timber products, is projected to be 40.661 million mbf (98.584 million cubic meters) in 2060. The second scenario is the HM-Restricted Trade scenario, which retains the assumptions of the HM scenario but simulates an increase in trade costs on U.S. imports and exports of forest products. In this scenario, trade costs are assumed to rise by 25% in 2020, effectively modeling the impact of increased barriers against U.S. exports to all other countries by 20% and increased barriers against U.S. imports from all other countries by about 30%. The purpose of this scenario is to examine how trade barriers or a "trade war" involving the United States would influence several market variables across all product categories. The effects of such a broad increase in trade costs would imply a reduction in trade volumes across the U.S. border but have uncertain effects on intraregional trade (i.e., across regions of the United States, including the RPA South Central and Southeast regions).

The four main 2020 RPA Assessment projection scenarios and the two additional scenarios on mass timber and increased trade costs generate results from 2020 to 2070 at the RPA Region level. The region-level projections can be downscaled to the state level for some product categories by combining statistical models with region-level projections. Such statistical approaches can be used to generate projections of forest sector jobs at the state level. In our analysis, the forest product output of all four RPA scenarios and two additional policy variants are summarized by using states' historical production share. Employment in the forest sector is downscaled to the state level using the fixed effects regression estimates of jobs per unit of forest product output and time trends by state, based on the U.S. Bureau of Labor Statistics' (2022) Quarterly Census of Employment and Wages (see Appendix).

3. Results

3.1. Industrial roundwood markets

Our results (Table 2 and Table 3) indicate that both softwood and hardwood industrial roundwood production in the South will increase over time. However, the scenario with the weakest economic growth, HL, predicts the least softwood production increase from 2020 to 2070. In terms of hardwood industrial roundwood, all scenarios indicate a rise in production, with the highest growth projected in the Southeast. Under the HM-Mass Timber scenario, which demands more wood for the construction of multifamily residential and nonresidential structures, projections show minimal change in softwood production (a 0.1% increase in the South Central and a 0.2% increase in the Southeast by 2070 compared to the HM scenario in 2070). On the other hand, hardwood production is projected to decrease (by 1.3% in the South Central and 1.3% in the Southeast by 2070, relative to the HM scenario in 2070).

In the HM-Restricted Trade scenario, softwood industrial roundwood production is 0.2% lower in both southern regions. Additionally, hardwood industrial roundwood production is projected to be lower by 1.3% in the South Central and 5.6% in the Southeast by 2070, compared to the HM scenario in 2070. This reduction is primarily due to higher tariffs imposed on hardwood log exports. It is worth noting that the United States has historically been and is projected to continue being a net exporter of hardwood. Restricted trade does not affect softwood industrial roundwood output significantly because of the higher domestic demand for manufacturing softwood lumber and plywood, which offsets the reduced export demand caused by higher tariffs imposed by foreign buyers.

Over the past two decades, prices for softwood industrial roundwood have generally declined due to the increased availability of softwood standing timber in the South. However, projections indicate a reversal of this trend from 2030 until 2070 in most scenarios (Table 2 and Table 3). The shift in prices reflects the growing influence of rising global prices on southern pine prices, as global markets for softwood expand (Johnston et al., 2023). Regarding hardwood, historical data also demonstrate an upward price trend, although trends vary significantly across regions. Export markets for hardwood roundwood and hardwood lumber are projected to exert upward pressure on prices until 2070.

The impact of rising mass timber demand becomes apparent in the price of softwood industrial roundwood under the HM-Mass Timber scenario. By 2070, prices are projected to be 0.2% higher compared to prices in the same year under the HM scenario. Despite the additional wood demand for mass timber production, the effect on both production and prices of softwood industrial roundwood is not substantial. While production and prices would generally increase to accommodate the greater wood requirements of mass timber manufacturing facilities, the influence of mass timber demand is limited. For hardwoods under the HM-Mass Timber scenario, prices are estimated to be 1.5% lower in the South Central region and 1.3% lower in the Southeast region by 2070 compared to the HM scenario in the same year. Under the HM-Restricted Trade scenario, softwood industrial roundwood prices in 2070 are 0.1% lower in the southern region relative to the HM scenario. Similarly, hardwood prices in 2070 are projected to be 1.2% lower in the South Central region and 2.4% lower in the Southeast region compared to prices in those regions under the HM scenario in 2070.

3.2. Lumber markets

Softwood lumber production is projected to experience growth in both the South Central and Southeast regions over the next 50 years across all scenarios (Table 4 and Table 5). Particularly, under the HM-Mass Timber scenario, the expanding market for softwood lumber, driven by the demand for mass timber manufacturing, leads to an increased demand for southern pine. By 2070, softwood lumber production is projected to be, on average, 7% higher in the states of the

Table 2
Projected differences in coniferous industrial roundwood production and price in 2030, 2050 and 2070.

Region	Scenario	Production: (thousand cubic feet)				Price: ($/cubic foot)			
		2015	2030	2050	2070	2015	2030	2050	2070
South Central	LM	3095.1	12.9%	30.4%	47.3%	2.0	2.9%	24.5%	43.8%
	HM	3095.1	7.3%	15.6%	22.7%	2.0	−2.4%	10.3%	19.7%
	HM-Mass Timber	3095.1	7.3%	15.8%	22.8%	2.0	−2.4%	10.4%	19.9%
	HM-Restricted Trade	3095.1	7.2%	15.5%	22.5%	2.0	−2.5%	10.3%	19.7%
	HL	3095.1	2.4%	4.9%	7.5%	2.0	−7.1%	0.0%	4.9%
	HH	3095.1	14.0%	35.5%	59.4%	2.0	3.9%	29.6%	55.6%
Southeast	LM	2982.7	14.7%	32.1%	48.8%	1.9	3.8%	24.2%	44.7%
	HM	2982.7	8.8%	16.8%	23.7%	1.9	−1.8%	9.7%	20.3%
	HM-Mass Timber	2982.7	8.8%	16.9%	23.9%	1.9	−1.8%	9.7%	20.5%
	HM-Restricted Trade	2982.7	8.6%	16.7%	23.6%	1.9	−1.9%	9.6%	20.2%
	HL	2982.7	4.0%	6.5%	9.0%	1.9	−6.3%	−0.2%	5.9%
	HH	2982.7	15.5%	36.8%	59.8%	1.9	4.6%	28.8%	55.5%

Note: 2015 is the benchmark level, 2030, 2050, 2070 are the projected percentage differences in coniferous industrial roundwood production and price compared to the benchmark level. Prices are approximated in FOROM using net trade information from FAO (FAO, 2021) and may differ from the real transaction prices.

Table 3
Projected differences in non-coniferous industrial roundwood production and price in 2030, 2050 and 2070.

		Production: (thousand cubic feet)				Price: ($/cubic foot)			
		2015	2030	2050	2070	2015	2030	2050	2070
South Central	LM	1133.1	11.9%	30.6%	48.9%	3.8	5.3%	25.4%	45.4%
	HM	1133.1	8.0%	18.6%	27.7%	3.8	1.5%	13.8%	24.6%
	HM-Mass Timber	1133.1	7.9%	17.4%	26.1%	3.8	1.4%	12.6%	23.1%
	HM-Restricted Trade	1133.1	7.8%	18.2%	26.4%	3.8	1.4%	13.4%	23.4%
	HL	1133.1	2.1%	4.5%	8.4%	3.8	−4.2%	0.1%	5.7%
	HH	1133.1	14.5%	39.8%	66.4%	3.8	7.8%	34.3%	62.5%
Southeast	LM	756.8	22.8%	47.6%	72.3%	3.6	15.6%	42.6%	68.8%
	HM	756.8	17.5%	34.5%	45.7%	3.6	10.5%	29.9%	42.6%
	HM-Mass Timber	756.8	17.4%	33.8%	44.4%	3.6	10.4%	29.2%	41.3%
	HM-Restricted Trade	756.8	15.0%	28.9%	40.1%	3.6	8.4%	27.5%	40.2%
	HL	756.8	10.0%	13.3%	19.0%	3.6	3.2%	9.2%	16.4%
	HH	756.8	26.5%	65.3%	111%	3.6	19.3%	59.9%	107%

Note: 2015 is the benchmark level, 2030, 2050, 2070 are the projected percentage differences in non-coniferous industrial roundwood production and price compared to the benchmark level. Prices are approximated in FOROM using net trade information from FAO (FAO, 2021) and may differ from the real transaction prices.

Table 4
Projected differences in softwood lumber production and price in 2030, 2050 and 2070.

		Production: (million bf)				Price: ($/mbf)			
		2015	2030	2050	2070	2015	2030	2050	2070
South Central	LM	5307.4	13.6%	33.2%	54.7%	486.7	28.4%	59.4%	86.1%
	HM	5307.4	6.9%	19.6%	34.4%	486.7	39.6%	83.7%	118.1%
	HM-Mass Timber	5307.4	7.5%	25.4%	41.4%	486.7	42.0%	96.7%	135.0%
	HM-Restricted Trade	5307.4	10.4%	23.3%	35.9%	486.7	34.7%	77.8%	118.1%
	HL	5307.4	3.1%	9.1%	15.4%	486.7	20.7%	37.1%	51.2%
	HH	5307.4	13.1%	38.1%	74.2%	486.7	50.7%	136.0%	237.8%
Southeast	LM	4983.8	14.9%	38.8%	60.1%	486.7	21.6%	48.8%	77.4%
	HM	4983.8	12.3%	29.7%	44.3%	486.7	26.5%	54.6%	89.0%
	HM-Mass Timber	4983.8	10.4%	31.1%	49.9%	486.7	28.4%	68.2%	117.1%
	HM-Restricted Trade	4983.8	9.1%	26.4%	41.5%	486.7	37.1%	68.2%	99.7%
	HL	4983.8	9.6%	11.8%	21.6%	486.7	−3.1%	30.4%	33.7%
	HH	4983.8	15.5%	38.9%	77.1%	486.7	45.4%	134.5%	227.1%

Note: 2015 is the benchmark level, 2030, 2050, 2070 are the projected percentage differences in softwood lumber production and price compared to the benchmark level. Prices are approximated in FOROM using net trade information from FAO (FAO, 2021) and may differ from the real transaction prices.

South Central region and 5.6% higher in the states of the Southeast region compared to the HM scenario. In contrast, the HM-Restricted Trade scenario results in different outcomes across the two regions. In the states of the South Central region, softwood lumber production is projected to be, on average, 1.5% higher in 2070 relative to the HM scenario. However, in the states of the Southeast region, production is projected to be lower by 2.8% in 2070 compared to production under the comparison HM scenario. These regional variations suggest that reduced softwood imports into the United States from Canada and other trading partners have a more favorable impact on South Central producers, while the Southeast region is more heavily connected to export markets, which affects its results differently.

Projections indicate that softwood lumber prices will rise across all scenarios, both in the South Central and Southeast regions. The extent of the price increases varies, with moderate rises under the weakest economic growth scenario (HL) and higher increases under the strongest growth scenario (HH). This trend aligns with the findings regarding production under the HM-Mass Timber scenario, as increased lumber demand for mass timber production drives the prices upward. Since the United States relies on softwood lumber imports, and the South is a net

Table 5
Projected differences in hardwood lumber production and price in 2030, 2050 and 2070.

		Production: (million bf)				Price: ($/mbf)			
		2015	2030	2050	2070	2015	2030	2050	2070
South Central	LM	2813.3	8.0%	19.0%	29.3%	1100.4	4.2%	11.9%	15.3%
	HM	2813.3	7.3%	17.4%	25.3%	1100.4	5.7%	9.9%	19.2%
	HM-Mass Timber	2813.3	7.3%	17.4%	25.4%	1100.4	5.7%	9.7%	18.5%
	HM-Restricted Trade	2813.3	7.4%	17.4%	25.4%	1100.4	5.0%	10.2%	19.0%
	HL	2813.3	2.8%	7.3%	12.3%	1100.4	6.1%	9.7%	6.9%
	HH	2813.3	11.1%	29.0%	48.2%	1100.4	5.7%	13.8%	24.1%
Southeast	LM	1679.0	25.7%	58.4%	95.8%	1132.7	11.2%	41.6%	81.1%
	HM	1679.0	23.9%	53.4%	68.2%	1132.7	19.5%	49.7%	69.5%
	HM-Mass Timber	1679.0	23.7%	53.4%	69.4%	1132.7	21.2%	50.3%	70.5%
	HM-Restricted Trade	1679.0	23.7%	44.8%	61.4%	1132.7	21.8%	36.0%	56.2%
	HL	1679.0	14.3%	21.3%	32.6%	1132.7	16.6%	31.6%	33.3%
	HH	1679.0	33.0%	91.1%	175.7%	1132.7	11.8%	55.7%	149.6%

Note: 2015 is the benchmark level, 2030, 2050, 2070 are the projected percentage differences in hardwood lumber production and price compared to the benchmark level. Prices are approximated in FOROM using net trade information from FAO (FAO, 2021) and may differ from the real transaction prices.

exporter, restricted imports into the United States tend to benefit southern producers, particularly in the states of the Southeast region. In this region, softwood lumber prices are projected to average 22.6% higher in 2070 compared to prices projected for the same year under the comparison HM scenario.

The production of hardwood lumber is projected to increase across all scenarios and states. Specifically, under the HM-Mass Timber scenario, production is projected to rise by 0.1% in the states of the South Central region and by 1.2% in the Southeast region compared to production in 2070 under the comparison HM scenario. On the other hand, under the HM-Restricted Trade scenario, the average production remains unchanged in the states of the South Central region, but it is projected to be 6.8% lower than the levels anticipated in 2070 under the HM scenario.

As for hardwood lumber prices (Table 5), they are anticipated to increase in both the South Central and Southeast regions under all scenarios from 2020 to 2070. The weakest growth in prices is projected under the HL scenario, while the strongest growth is projected under the HH scenario. In the HM-Mass Timber scenario, in comparison to the HM scenario, prices are estimated to be 0.7% lower in the South Central region, but 1% higher in the Southeast region. Overall, this results in a relatively balanced effect on prices region-wide, as reduced external exports are mostly compensated by higher domestic demand. Under the HM-Restricted Trade scenario, the reduced export opportunities lead to a slower rate of price growth for hardwood lumber compared to the HM scenario.

Projections for net exports of softwood lumber reveal varying trends across different scenarios (Fig. 2). Initially, net exports tend to increase until around 2030 or 2040 before declining in all scenarios except for the HM-Mass Timber scenario. In the scenario with the strongest economic growth, HH, net exports are projected to decrease from the 2020s to 2070. This decline can be attributed to robust economic growth, which leads to faster consumption growth compared to production. However, under the HM-Mass Timber scenario, net exports are projected to rise until around 2050 before stabilizing. In the HM-Restricted Trade scenario, due to the South's status as an exporting region, net exports are higher in all years compared to the benchmark HM scenario. The higher net exports imply growth in the South's domestic market share, as imports shrink more than exports.

Similarly, net exports of hardwood lumber are anticipated to

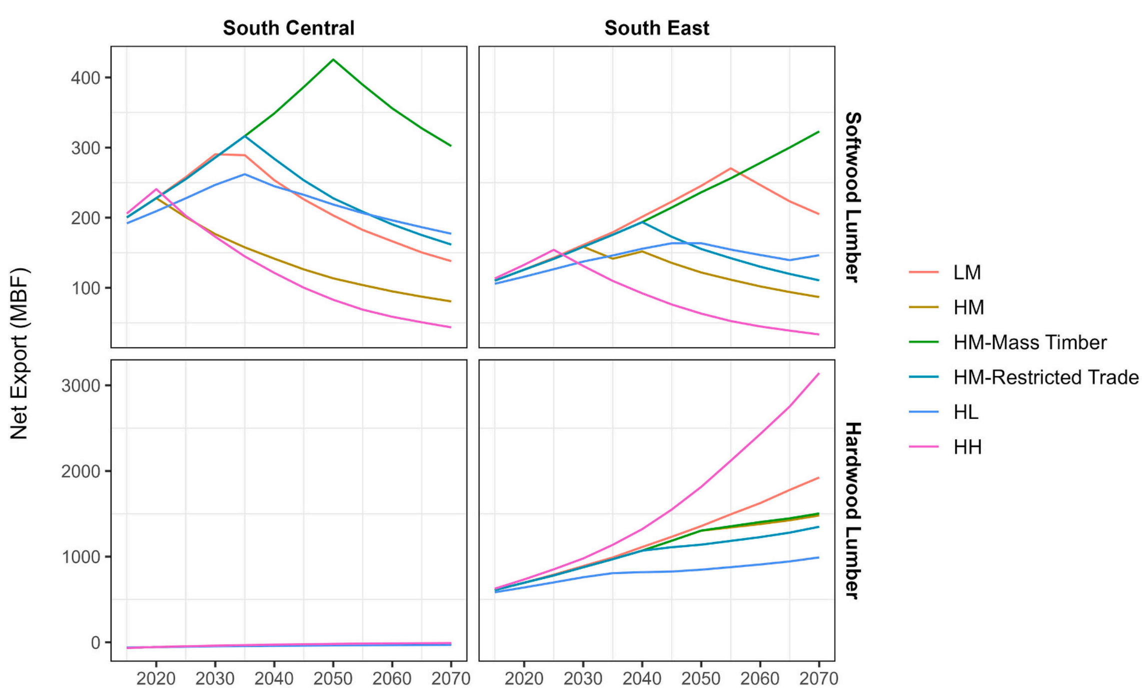

Fig. 2. Net export of softwood and hardwood lumber by regions by projected year by scenario.

increase across all scenarios. Notably, the Southeast region is the only region with significant net exports of hardwood lumber. As with softwood lumber, net exports follow a similar pattern of initially rising until approximately 2030 or 2040, and then declining in all scenarios except for the HM-Mass Timber scenario. In the HH scenario, characterized by strong economic growth, net exports are projected to decrease from the 2020s to 2070, reflecting the higher consumption growth compared to production. Under the HM-Mass Timber scenario, states in the Southeast region experience a rise in net exports until around 2050 before stabilizing. In both the HM-Restricted Trade and HM-Restricted Trade scenarios, exports in the Southeast region remain relatively unchanged, as external exports are discouraged while internal exports to other parts of the United States are encouraged.

3.3. Wood pellets markets

Wood pellet production in the southern states is projected to increase across all scenarios, except for the HL scenario. The LM and HH scenarios, in particular, demonstrate a significant rise in wood pellet production, as domestic producers cater to the growing demand for energy production in Europe. By 2070, output is projected to more than triple compared to 2015, with the exception of the HL scenario. In the South Central region, production is projected to increase from approximately 2.05 million tons in 2015 to as high as 8.8 million tons under the LM scenario by 2070. Similarly, in the Southeast, which already has higher production levels than the South Central region, wood pellet production is projected to rise from around 5.08 million tons to approximately 14.2 million tons by 2070. However, under the HM-Restricted Trade scenario, although production still experiences substantial growth compared to 2020, the increases are significantly smaller compared to the baseline HM scenario. In the South Central region, production rises are lower by 47%, while in the Southeast, they are 2% higher. Southwide, there is a projected net drop of 5% in wood pellet production under the HM-Restricted scenario compared to the HM scenario. On the other hand, the HM-Mass Timber scenario shows slightly higher production levels across states compared to the benchmark HM scenario. This increase is primarily driven by a higher production of residues that serve as feedstock for pellet manufacturers.

The rising output and high export demand for wood pellets have an impact on prices and production (Table 6). Except for the HL scenario, prices are projected to increase between 2020 and 2070 across all scenarios. However, under the HM-Restricted Trade scenario, simulated higher tariffs lead to a decrease in prices throughout the South. Specifically, prices are projected to be 44% lower in the South Central region and 41% lower in the Southeast region by 2070, relative to the HM scenario. While net exports remain positive under the HM-Restricted Trade scenario, they are smaller by 22% in the South Central region and 2.6% in the Southeast region in 2070, compared to the HM scenario. In contrast, the HM-Mass Timber scenario, driven by the increased residues from mills, results in higher wood pellet output and net exports. Net exports (Fig. 3) are estimated to be 3% higher across the entire South and 8.6% higher in the Southeast region, although net exports from the South Central region may experience a decrease. Additionally, prices are projected to be lower under the HM-Mass Timber scenario, with a decrease of 4.3% in the South Central region and 5.2% in the Southeast region by 2070. The price result is primarily due to the lower wood input costs associated with the scenario, in comparison to the baseline HM scenario.

3.4. Employment

All scenarios predict a decrease in jobs in the forest sector, as shown in Table 7. The differences in projected job numbers are not significant compared to the differences in projected production and price variations discussed earlier. The impact of either a rapidly growing mass timber subsector of wood products (HM-Mass Timber) or tighter trade restrictions (HM-Restricted Trade) on the three sectors is also quite small when compared to the baseline (HM). Therefore, our study focuses on providing detailed projections at the state level under the HM scenario (Fig. 4).

Within the forestry and logging sector (Table 7), a sharp decline has been observed, continuing a trend that has persisted for the past two decades. The pulp and paper sector follows historical patterns in all 13 states, but the decline is more pronounced due to rapid technological changes. Contrary to the trends observed since the 2007–2009 recession, the wood products sector shows a decline in projected jobs, aligning with a long-standing negative trend. Although most states experienced job growth in the wood products sector since 2009, this growth appears to have plateaued by 2020. Additionally, data from the U.S. Bureau of Labor Statistics (2022) indicate a slowdown or even a reversal in job growth since 2019. The paper sector demonstrates diverse job dynamics across states, despite overall projected declines in all scenarios. Two main factors contribute to the observed and projected long-term decline in the paper sector: the implementation of labor-saving technologies, and reduced demand for newsprint and printing/writing paper. While the production of other paper and paperboard may see modest growth or remain stable until 2070, the shrinking graphics paper market leads to an overall decrease in jobs within the sector. This trend is projected for every southern state by 2070.

4. Discussion

In this paper, we carried out a long-run market analysis using FOROM to project a range of hypothetical futures for forest product

Table 6
Projected differences in wood pellets production and price in 2030, 2050 and 2070.

		Production (1000 tons)				Price ($/ton)			
		2015	2030	2050	2070	2015	2030	2050	2070
South Central	LM	2053.1	93%	199%	329%	150.8	41%	133%	238%
	HM	2053.1	88%	157%	244%	150.8	42%	80%	141%
	HM-Mass Timber	2053.1	88%	158%	241%	150.8	40%	74%	131%
	HM-Restricted Trade	2053.1	65%	123%	197%	150.8	29%	58%	97%
	HL	2053.1	65%	−2%	−26%	150.8	34%	4%	−46%
	HH	2053.1	99%	222%	317%	150.8	50%	164%	263%
Southeast	LM	5088.9	32%	94%	186%	150.8	76%	153%	214%
	HM	5088.9	28%	46%	88%	150.8	69%	102%	139%
	HM-Mass Timber	5088.9	28%	49%	96%	150.8	64%	94%	127%
	HM-Restricted Trade	5088.9	28%	49%	90%	150.8	29%	61%	98%
	HL	5088.9	26%	−38%	−56%	150.8	62%	05%	−46%
	HH	5088.9	21%	75%	171%	150.8	80%	161%	224%

Note: 2015 is the benchmark level, 2030, 2050, 2070 are the projected percentage differences in wood pellets production and price compared to the benchmark level. Prices are approximated in FOROM using net trade information from FAO (FAO, 2021) and may differ from the real transaction prices.

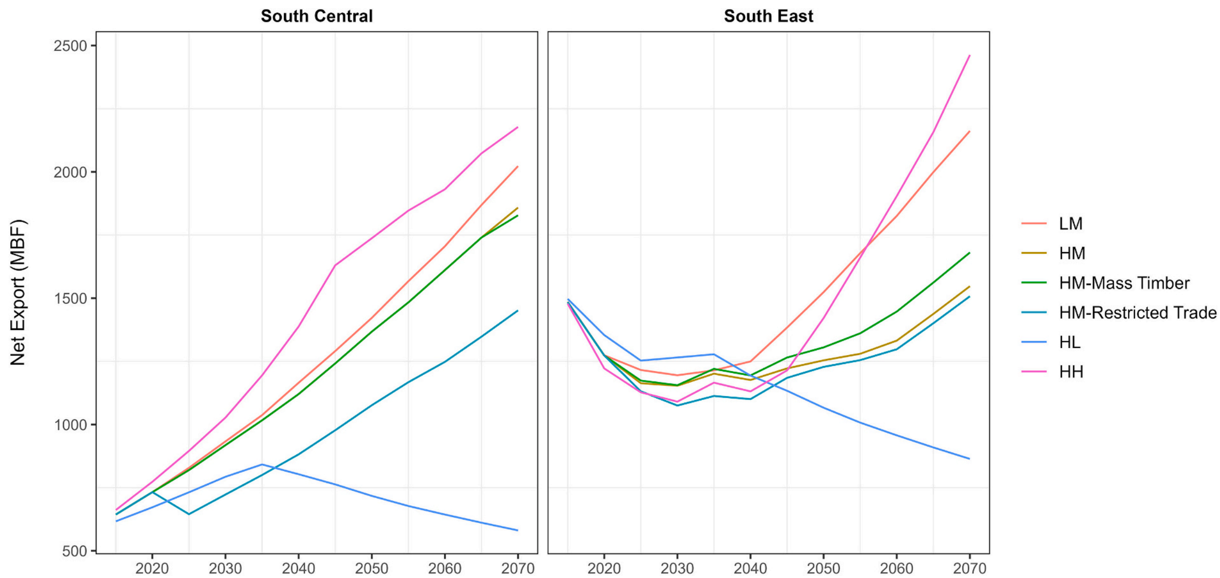

Fig. 3. Net export of wood pellets by regions by projected year by scenario.

Table 7
Projected differences in employment in 2030 and 2070 by sectors.

		Sector 113			Sector 321			Sector 322		
		2015	2030	2070	2015	2030	2070	2015	2030	2070
South Central	LM	16,745	−21%	−54%	85,349	−4%	−39%	74,704	−25%	−74%
	HM	16,745	−25%	−61%	85,349	−7%	−47%	74,704	−28%	−77%
	HM-Mass Timber	16,745	−25%	−61%	85,349	−7%	−47%	74,704	−28%	−77%
	HM-Restricted Trade	16,745	−25%	−61%	85,349	−6%	−48%	74,704	−31%	−77%
	HL	16,745	−28%	−66%	85,349	−13%	−57%	74,704	−29%	−78%
	HH	16,745	−20%	−50%	85,349	−1%	−30%	74,704	−25%	−73%
Southeast	LM	15,636	−19%	−53%	69,067	−4%	−39%	64,502	−23%	−73%
	HM	15,636	−23%	−60%	69,067	−7%	−45%	64,502	−25%	−76%
	HM-Mass Timber	15,636	−23%	−60%	69,067	−8%	−45%	64,502	−25%	−76%
	HM-Restricted Trade	15,636	−23%	−61%	69,067	−10%	−46%	64,502	−28%	−76%
	HL	15,636	−26%	−65%	69,067	−12%	−57%	64,502	−27%	−77%
	HH	15,636	−18%	−48%	69,067	−1%	−29%	64,502	−23%	−71%

Note: 2015 is the benchmark level, 2030, 2070 are the projected percentage differences in employment compared to the benchmark level. Note: Sectors 113, 321 and 322 represent Forestry and Logging (NAICS 113), Wood Product Manufacturing (NAICS 321), and Paper Manufacturing (NAICS 322), respectively. The same note applies to Fig. 4 and appendix.

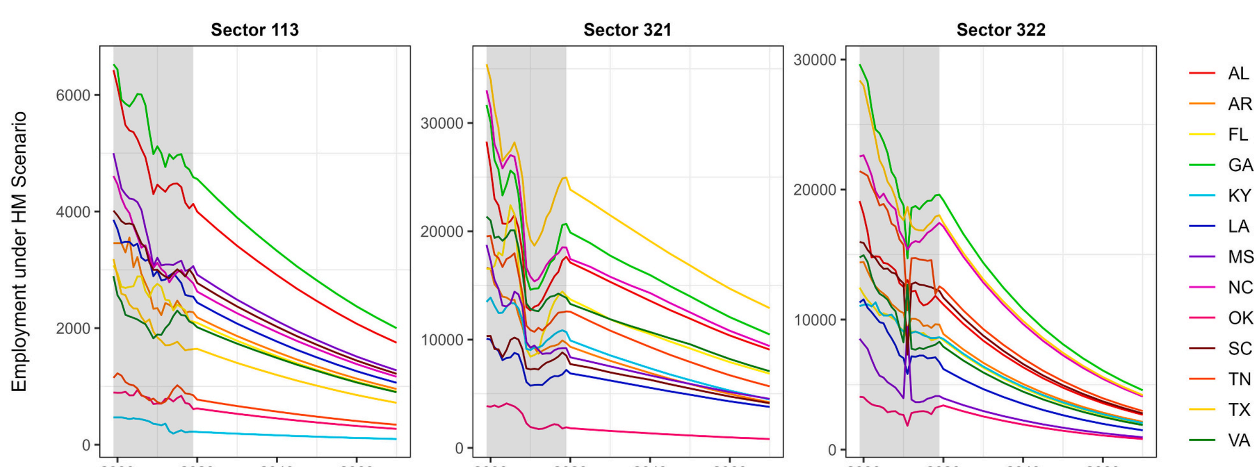

Fig. 4. Employment by States by projected year under the HM Scenario.

prices, production, consumption, and trade for the South. We deepened the modeling results by downscaling production of selected products and generated projections of employment in the three main parts of forest industry of the U.S. South. Broadly speaking, our findings are in line with previous scenario-based projections of the sector for the South, finding that timber production, under most scenarios, has the potential to expand substantially in the South. And like those other studies, we revealed that future markets prospects are significantly determined by rates of change in wood and paper product demand growth (Wear and Greis, 2013).

Unique to this outlook for the region, we were able to project changes in wood pellet production and exports. Our projections indicate an expanding wood pellet market, with wood pellet output and prices rising in nearly all scenarios. The main driver of these projected trends overseas demand for wood pellets. Galik et al. (2015) analyzed a hypothetical Renewable Portfolio Standard policy that created similar bioenergy demand in the southeastern U.S. and found that, due to competition for roundwood, the growing demand for roundwood input could lead to an increase in sawtimber prices by 15% in 2040, as compared to the levels observed in 200. While it is difficult to directly compare our results to those of Galik et al. (2015), these findings together suggest that our different modeling approaches result in similar outcomes, although the magnitude of price changes differ between the studies (and across the scenarios we evaluated). Likewise, consistent with both Galik and Abt (2016) and Galik et al. (2015), the scale of wood pellet production increases projected for the South amount to a small share of total roundwood input.

Jonsson et al. (2021) is among the few studies that have analyzed the prospective future of forest sector employment. Using the Global Forest Trade Model (GFTM), the authors found that boosting wood-based construction in the European Union (EU) would be the most effective way to increase EU production and employment, including in logging and solid wood-products manufacturing, as well as in sectors that use sawmilling byproducts as feedstock. This finding contradicts our analysis, which projected a decreasing forest sector employment under all scenarios despite rising pellet demand. One major reason for this difference is that Jonsson et al. (2021) did not account for the increased labor productivity that has been observed in the United States over the past several decades and that is expected to continue through 2070. As a result, their estimates of employment changes may be appropriately considered as modeling short-run trends.

5. Conclusions

The forest sector in the South has experienced various transitions, including the growth of industrial-style forestry and a decline in hardwood harvests due to overseas competition. These changes have led to an increase in both coniferous and non-coniferous timber stocks, which are projected to triple between 2020 and 2070. Consistent with a growing abundance of forest stocks, recent history has seen declining roundwood prices. Nevertheless, our projections suggest a reversal, wherein increasing global demand for roundwood drives domestic U.S. prices upward in the future. Softwood lumber production and prices are projected to increase, especially under the HM-Mass Timber scenario. Wood pellet production and prices are projected to rise in nearly all scenarios, primarily driven by increasing overseas demand. However, wood pellets are projected to remain a small component of overall wood consumption across all scenarios. Employment in the forest sector is projected to decline, although differences across scenarios are minimal. Nevertheless, declining employment does not necessarily indicate declining labor income, as rising capital intensification could lead to higher wages due to productivity growth (although we did not project either labor income or wages). Finally, we emphasize that projection results for several other product categories not described in this article are available, including for product categories such as nonindustrial roundwood, fiberboard, chemical pulp, and fuelwood (see Johnston et al., 2021).

Our analysis presented projections across multiple scenarios of the future without making definitive claims about their likelihoods. Likewise, it is important to note that our projections did not consider the specific impacts of changes in demand for different wood products by particular forest product consuming sectors, including those driven by the residential and nonresidential construction industries. While studies have projected the future of residential new construction, less is known about the potential effects of nonresidential construction, repair and remodeling activities, and other uses of wood products in the US economy. Further research could examine these specific demand components and assess the impacts of policies affecting wood product demand, including those related to mass timber, on overall timber product output. Similarly, in the paper sector, declining demand for graphics paper could create opportunities for other fiber-consuming products, as investors seek out new profit earning opportunities arising from more abundant fiber. Models that can account for these new fiber products separately would enable credible simulations of the effects of technology change and supporting policies on timber product outputs. Expanding our knowledge in these areas would enhance our understanding of the forest products market dynamics and support informed decision-making. Another research direction is to understand the complex interplay between climate change and timber growth. While rising temperatures and CO_2 levels can enhance growth, precipitation changes, increased disturbances, reduced CO_2 absorption capacity of trees may offset these positive effects, potentially affecting timber stocks and production capacity. By considering the potential impacts of changing demand, policy interventions and climate change, future analyses could provide more comprehensive insights into the effects of technology advancements, trade policies, and market dynamics on timber product outputs. This information is crucial for industry stakeholders, policymakers, and researchers seeking to navigate the evolving landscape of the forest products market in the South.

Disclaimer

The findings and conclusions in this publication are those of the authors and should not be construed to represent any official USDA or U. S. Government determination or policy.

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Declaration of Competing Interest

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.forpol.2023.103091.

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