Estimating the Economic Impacts Generated by Small-Scale Wood Pellet Manufacturing in Western North Carolina

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Abstract

In an effort to identify opportunities for regional economic development for western North Carolina, this study investigated the economic impacts generated by collocating a 10,500-ton/yr wood pellet mill alongside a 10-million board foot hardwood sawmill in the Asheville–Brevard combined metropolitan statistical area. Using the analysis-by-parts methodology within the input–output analysis framework, a custom production function was built to describe a small-scale pellet manufacturing facility operating alongside a hardwood sawmill. The additional economic effects generated by a pellet mill collocation are described, along with upper and lower bounds that represent potential variability in the estimates caused by raw material price fluctuation. Last, the impacts generated by the collocated mills are compared with a similar increase in demand distributed among all forest products manufacturing sectors existing within the study area. The study found that wood product firms existing within the region had the opportunity to utilize excess woody biomass for pellet production and could diversify their product lines, create additional jobs, and stimulate value-added economic activity for the region.

The forest products industry has long served as a source of economic activity and employment in the southeastern United States by providing timber, primary products, and secondary wood products for domestic and export markets. In the early 2000s an economic downturn heavily influenced housing starts and resulted in drastic changes in the wood products manufacturing, paper manufacturing, forestry, and logging sectors. As the number of wood product manufacturing facilities operating in the Southeast declined from 2005 to 2009, the forest products sectors' contribution to gross regional product dropped 24 percent, whereas labor income dropped 32 percent (Hodges et al. 2011). North Carolina in particular has experienced drastic changes in its forestry sectors compared with other southern states. From 2005 to 2014, North Carolina saw the number of wood product manufacturing plants drop from 737 to 568 while employment in these mills fell from 29,300 to 20,000 jobs. As of 2014, all forest product–based sectors employed approximately 72,900 people, approximately 66 percent of those employed in 2005 (US Census Bureau 2014). The recession and lack of housing starts not only affected employment and forest products output for the region, but also influenced the timber inventory growing in southern forests. Increases in timber land productivity and steady (or slightly decreased) removals resulted in increased volumes of both hardwood and softwood tree species available on southern forest land (Brandeis et al. 2012). These declines can be attributed to several factors that include technological innovation in wood manufacturing environments, the decline of furniture manufacturing in North Carolina, and the influence of reduced housing starts.

Despite the impact of the recession, forestry-related sectors remain critical to North Carolina's economy, particularly in the western region of the state where forest-based economic development opportunities are being investigated. In western North Carolina, 30,300 jobs were directly supported by forestry, representing 43 percent of the

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state total. Among forest products sectors, sawmills in particular were identified as being key economic drivers for the region, possessing strong forward and backward linkages compared with other industries (Kays et al. 2016). With a growing inventory of small-diameter woody biomass available in western North Carolina forests and strong interindustry relationships existing within the sawmill sector, the integration of wood pellet manufacturing alongside lumber production could serve as an economic growth opportunity for the state.

Wood pellets are a form of lignocellulosic biomass, manufactured using sawdust, bark, wood chips, or roundwood that are burned to create heat or energy. Driven by the Renewable Energy Directive of the European Union, European demand for wood pellets has grown rapidly and spurred Southeast pellet production to approximately 12 million green short tons. The majority of these pellets are sold to the United Kingdom, The Netherlands, and Belgium for residential and district heating and cofired power-plant facilities (Abt et al. 2014). If European pellet demand continues to grow, pellet manufacturing could offer economic development opportunities for regional economies by providing employment and value-added economic activity. As interest in bioenergy production has grown, researchers have attempted to define the market characteristics required for successful pellet manufacturing as well as quantify the economic potential that pellet manufacturing might offer to southern regional economies.

Pirraglia et al. (2010) investigated the conditions that make pellet production advantageous in their technoeconomic feasibility study and found raw material and labor to be the major cost drivers for wood pellet production. The study also found that raw material prices heavily influenced profitability. Their sensitivity analysis concluded that increasing biomass costs by 25 percent resulted in a 4 percent drop in the plant's internal rate of return. Joshi et al. (2012) took this research a step further by adapting construction and operation costs reported by Pirraglia et al. (2010) to input–output accounts in an effort to estimate the economic impact of a pellet mill located in Mississippi. Annual operation of a 75,000-ton/yr facility in Mississippi provided a total of 83 jobs and created $12.4 million in economic output while supporting local forestry, forest product and timber production, food services and drinking places, and electric power–generation sectors. Kebede et al. (2013) estimated that the operation of a 175,000-ton/yr pellet facility in Alabama could support 72 jobs and create $9.7 million in economic output. Little et al. (2013) estimated that the operation of a 1,000-ton/day facility located in Pitt, North Carolina, could support a total of 555 jobs and generate $90.7 million in economic output. Although these studies provided a range of potential economic impacts, they all propose that wood pellet manufacturing resulted in added income to forest property owners and stimulated higher levels of employment than other industries in the region. The estimates presented above are all based on the operation of larger-scale stand-alone pellet manufacturing facilities. However, not all timber market regions in the Southeast provide the right characteristics to support large-scale pellet operations.

Traditional large-scale pellet manufacturing for sale into European markets relies upon a dependable supply of woody biomass and proximity to an established transportation infrastructure. These conditions create favorable regions for pellet manufacturing along the Southeast coast (North Carolina and Georgia) and within the Mississippi Basin (eastern Arkansas, northern Louisiana, northern Mississippi, and eastern Tennessee; Forest2Fuel 2014). In situations where large-scale bulk production may not be advantageous because of raw material feedstock availability or prohibitive distances to ports, smaller-scale pellet production may still offer revenue generation opportunities. Smaller-scale pellet operations could be integrated alongside existing primary wood product manufacturing facilities to produce a higher-quality ''clean'' pellet for sale in bagged quantities to satisfy local heating demand (Wolf et al. 2006). This type of pellet production would utilize sawmill residues and white chips generated from forestry activity as a raw material feedstock to create a potentially higher-quality pellet and could also generate employment and economic impacts in regional economies.

Hunsberger and Mosey (2014) found that small-scale pellet production could be an economically viable enterprise in the state of Maine. In this particular case study, the region provided an available biomass supply, established transportation infrastructure, and a small local market. The return on investment (ROI) for building and operating a 10,500-ton/yr pellet plant built in the region was estimated to be 10 percent. As previously mentioned, varying wood costs and pellet prices heavily influenced the plant's ROI, with worst-to best-case ROI scenarios ranging from 6 to 14 percent. In the context of this region, small-scale pellet production was a more suitable approach for satisfying regional demand, and pellet manufacturing could take place without disrupting existing wood markets (Hunsberger and Mosey 2014).

Pellet production at this scale could also serve as an opportunity for forest products firms to diversify their product mix by utilizing a potential combination of mill processing residues and woody biomass from smaller-diameter timber that has more limited market opportunities. Often, these materials exist in excess in many timber market regions. The gradual decline in pulp and paper manufacturing capacity along with the recent economic downturn has created surpluses of smaller-diameter pine trees in many areas where forest management activities have slowed because of decreased demand. Moreover, the hardwood timber inventory trend for the eastern United States has continued to skew toward smaller-diameter classes (Luppold and Miller 2014). Where local opportunities do not exist for mill residues, facilities often have to pay tipping fees to dispose of slabs, chips, and dust. Manufacturing wood pellets would create both additional sales and purchases for regional forest-based enterprises, but how this would affect a local economy is currently unknown. The financial analysis of Hunsberger and Mosey (2014) coupled with regional input–output accounts provided us a means for quantifying the economic impacts of one potential test case: collocating a small-scale pellet manufacturing facility with a proprietary hardwood lumber mill in western North Carolina.

Objectives

The overall objective of this study was to evaluate the economic impacts resulting from collocating a 10,500-ton/yr pellet manufacturing facility, producing clean bagged pellets, with a 10-million board foot (MMBF) proprietary hardwood sawmill existing within a functional economic area of western North Carolina, the Asheville–Brevard combined metropolitan statistical area (MSA). This was accomplished by constructing a fully integrated sawmill and wood pellet production function for the region, with key purchases that were not likely to be ''new'' sales (at least in the near term) deducted from the gross impacts. Second, the potential change in generated impacts resulting from raw material price fluctuation was described. Last, the impacts generated by the collocated pellet mill were compared with the same level of increased demand across all forest products industries existing within the study region.

Methods

Social accounting matrix

An extension of the input–output model, the social accounting matrix (SAM), was used to estimate economic impacts of the study's scenarios. IMPLAN version 3.0, a software system that combines a general input–output model with regional economic data sets, was used to build a 2014 SAM model representing the Asheville–-Brevard combined statistical area (containing the counties of Buncombe, Hayworth, Henderson, Madison, and Transylvania). Model outputs for logging (16) and forestry, forest product, and timber-tract production (15) sectors were customized to reflect delivered wood values and timber stumpage values available at the time from North Carolina Cooperative Extension (Jeuck and Bardon 2014). Model estimates for regional employee compensation were also updated on the basis of occupational employment statistics provided by the US Bureau of Labor Statistics (Bureau of Labor Statistics 2015).

The SAM created in IMPLAN represented regional interindustry purchases for 536 sectors along with household and other nonmarket income flows taking place within the study area. The structure of the regional SAM matrix is described in Equation 1. Interindustry transactions were outlined in submatrix A and described the industry sector's distribution of outputs in submatrix rows and sector inputs for production in submatrix columns. The SAM also contained submatrices that described nonmarket income flows. Industry payments to employee compensation, proprietor income, property income, and taxes on production and imports were described in the value-added submatrix V. Value-added contributions to household income were described by submatrix Y. Household purchases of goods and services were described in submatrix C. Last, distributions between households by income level were described by submatrix H (Holland and Wyeth 1993, McConnell et al. 2016):

$$\mathrm{SAM} = \begin{bmatrix} A & 0 & C \\ V & 0 & 0 \\ 0 & Y & H \end{bmatrix} \tag{1}$$

$$S = z_{ij}/X_{\cdot j} \tag{2}$$

$$\Delta X = (I - S)^{-1}\Delta F \tag{3}$$

Direct requirements were calculated by dividing industry j's endogenous column elements in the SAM z_{ij}, by its respective column total $X_{\cdot j}$, described in Equation 2, to create the S matrix of normalized expenditure shares. Type SAM multipliers were derived from the total requirements matrix $(I - S)^{-1}$ that described the extent of total economic activity generated by a change in final demand throughout the regional economy, with I being an identity matrix of industry initial requirements (Leontief 1936). Matrix S was closed with respect to labor income flowing to households and their subsequent consumption of goods and services. Economic impact estimates of new levels of output, ΔX, were generated using Equation 3 by multiplying the total requirements matrix by a hypothesized change in final demand represented by vector ΔF (Miller and Blair 2009).

Sawmill characterization

In 2014, the sawmill sector supported 134 jobs in the Asheville–-Brevard combined MSA and generated approximately \$36.6 million in sales. IMPLAN national input–output accounts describe sawmills as producing four products, lumber and mill by-products, preserved wood products, engineered wood members and trusses, and cut-stock, resawn, and planed lumber, with primary products making up 97.5 percent of all sawmill sales. Of the \$36.6 million in output generated by the sawmill sector, 51.3 percent of sales went to meet local demand, 38.4 percent went to customers outside the study area, and 10.3 percent were exported outside the United States. Significant industries operating as sawmill supply-chain members include the logging (16) sector, the sawmill sector itself (134), wholesale trade distribution services (395), and truck transportation services (411; IMPLAN Group LLC 2015).

To estimate the potential economic impacts generated by a hardwood sawmill within the region, it was necessary to define the operating characteristics and output of a typical hardwood sawmill. A mill producing 10 MMBF of lumber annually and operating at 93 percent capacity was modeled. The sawmill's lumber product mix consisted of the following commercial species at their respective percentages of the region's hardwood sawtimber inventory: 8 percent red maple, 26 percent white oak, 23 percent red oak, and 43 percent yellow poplar (US Forest Service 2014b). The mill's bark-free product mix (Fig. 1) was calculated to be 59 percent lumber, 31 percent residue, and 10 percent sawdust using US Forest Service mill conversion data (Hanks 1977). Bark volume was estimated from Koch (1985) to be 18 percent of wood volume and 8 percent of gross volume. Lumber grade mix for the mill, described in Figure 2 was 12 percent First & Seconds (FAS) and FAS 1 Face, 34 percent Selects and No. 1 Common, 38 percent No. 2 Common, and 15 percent No. 3 Common across species, with grade specifications following National Hardwood Lumber Association rules (Hanks et al. 1980). The 53 percent lumber product yield of No. 2 and below was slightly better than the 57 percent average recently reported for eastern US hardwood sawmills (Burbeck 2016). An overall lumber price of \$679 per thousand board foot was derived by weighting lumber production according to lumber grade yield, species availability, and final product prices posted in the *Hardwood Review Weekly* (2014). Model prices for bark, sawdust, and wood residue, presented in Appendix Table 1, were set to \$0.22, \$0.19, and \$0.35 per ft^3, respectively (Settle et al. 2015). Annual sawmill output in 2014 dollars totaled \$6.53 million.

The sawmill employed one proprietary owner and 24 employees in 10 job positions, each receiving fringe benefits equal to 30 percent of their annual salary. Salaries for sawmill operational positions were based on Bureau of Labor occupational employment statistics for Asheville and

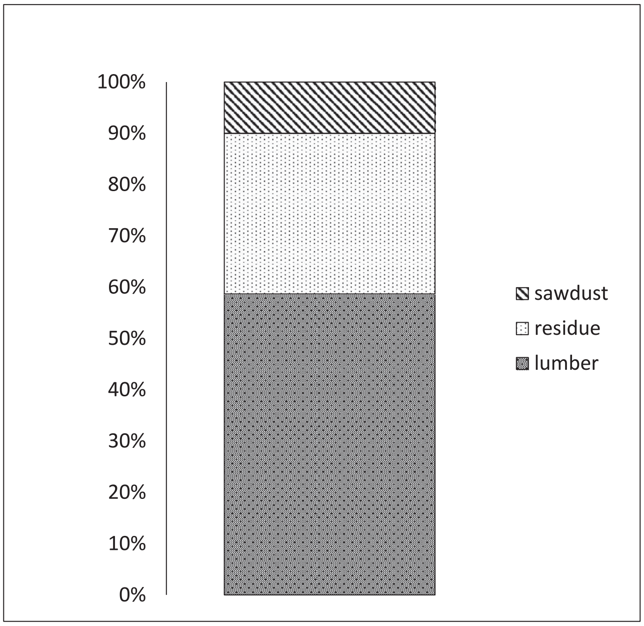

Figure 1.—Bark-free sawmill product breakdown by percentage.

Table 1.—Top five scenario costs along with total output for annual operation of a stand-alone sawmill and collocated sawmill and pellet mill.

IMPLAN sector	IMPLAN cost category/industry	US$/yr
Stand-alone sawmill		
16/134	Wood costs	2,572,000
5001/6001	Employee and proprietor compensation	1,332,000
395	Wholesale trade distribution services	827,000
411	Truck transportation services	228,000
461	Management of companies and enterprises	215,000
Total output		6,532,000
Collocated sawmill and pellet mill		
16/134	Wood costs	3,230,000
5001/6001	Employee and proprietor compensation	1,874,000
395	Wholesale trade distribution services	836,000
49	Electricity	289,000
3433	Monetary authorities and depository credit intermediation	254,000
Total output		9,008,000

were valued at $1.14 million (Bureau of Labor Statistics 2015). The total value of employee and proprietor compensation was $1.33 million.

Pellet mill characterization

A prototype wood pellet manufacturing plant with a nameplate capacity of 10,500 tons and operating at 93 percent capacity was modeled. The size of this pellet mill was advantageous for three reasons: the collocated sawmill provided approximately one-third of pellet mill raw material demand, secondary data pertaining to operational costs had previously been investigated, and a modest pellet operation of this size would have negligible impacts on regional wood supplies. Engineering cost analysis data, derived from Hunsberger and Mosey (2014), were used as a basis for determining annual operating costs, which were regionalized to better reflect local conditions. Annual operating costs are provided in Appendix Table 2. Additional costs associated with grinding wood chips in our pellet mill were accounted for in Hunsberger and Mosey (2014), which included the installation and operation of a pregrinder. The pellet mill's annual raw material input requirement of 19,000 green tons was assumed to consist of 50 percent sawmill residues and 50 percent white chips at an 87 percent hardwood–to–13 percent softwood ratio on the basis of US Forest Service Forest inventory analysis data (US Forest Service 2014a). Because it is likely that chips produced in this region are sold to pulp and paper manufacturers or composite panel mills outside the study area, white chip prices (free on board) paid by our pellet mill reflected the regional market average over the 2014 calendar year (RISI 2015). Annual electricity expenses were obtained for North Carolina from a US Energy Information Administration regional average of $0.085/kWh. All intermediate expenditure prices were margined where appropriate using industry-to-industry margins so that costs reflected producer prices as required by the IMPLAN input–output model. On the basis of a search of wholesale and retail prices across the eastern United States, we assumed a margined pellet price of $268/ton paid to the producer.

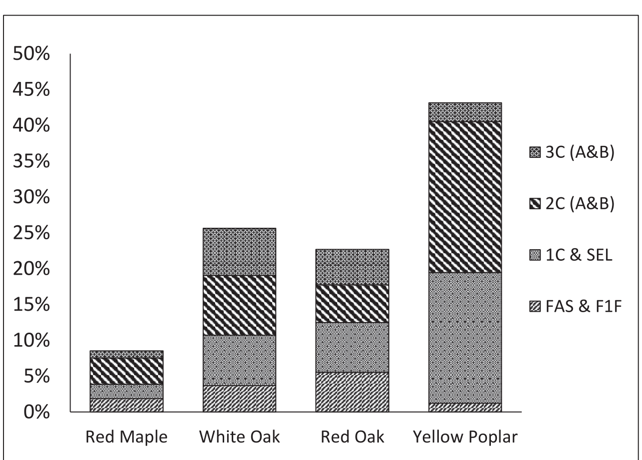

Figure 2.—Sawmill cumulative lumber grade yields by species.

The modeled pellet mill employed one plant supervisor and 12 shift employees in four job positions, each receiving fringe benefits equal to 30 percent of their annual salary. Salaries for pellet mill operational positions were based on Bureau of Labor Statistics occupational employment statistics for Asheville, with total employee compensation valued at $0.54 million (Bureau of Labor Statistics 2015). Pellet mill construction costs, outlined in the 2014 prefeasibility analysis of Hunsberger and Mosey, were accounted for by treating them as a construction loan valued at $2.1 million, paid annually to financial institutions over 10 years at 4 percent interest following Swenson's method (Swenson 2006, Hunsberger and Mosey 2014).

Estimating economic impacts

Economic impacts of sawmill and pellet mill operation were estimated in IMPLAN using an analysis-by-parts (ABP) methodology. The ABP technique allowed us to create scenario-specific industry spending patterns containing interindustry purchases and the labor portion of value added. The technique required defining annual interindustry purchases to arrive at a commodity coefficient, a decimal between 0 and 1, that represented the ratio of commodities purchased per dollar of output. In addition to defining intermediate purchases, scenario labor estimates were defined on the basis of regional wage data and represented a component of value added. With the industry spending pattern defined, it was then scaled according to scenario output and was used to generate economic impact estimates.

Economic impacts resulting from the hardwood sawmill operation were derived using IMPLAN's default sawmill sector (134) production function and were scaled to the previously described output ($6.53 million). Economic impacts resulting from the collocation of a pellet mill with the hardwood sawmill were derived by integrating the individual operation production functions together and scaling them by a total output of $9.01 million; this included the $6.53 million of lumber sales plus $2.62 million of bagged pellets.

Because IMPLAN did not have a sector representing pellet manufacturing, a custom production function was constructed to represent wood pellet manufacturing. The production function was derived by bridging the pellet mill's operational costs (derived from Hunsberger and Mosey [2014] and adapted to western North Carolina) to IMPLAN's input–output accounts (Willis and Holland 1997). This allowed us to create and define the normalized expenditure shares for a pellet manufacturing sector in matrix S. The interindustry and value-added costs, represented in SAM submatrices A and V, were allowed to sum to 95 percent of the total industry spending pattern. The remaining 5 percent was proportionally assigned to the spending pattern of the ''All Other Miscellaneous Wood Products Manufacturing'' (IMPLAN code 145) sector (Lazarus et al. 2002). By incorporating purchases from the miscellaneous wood products manufacturing sector, a more comprehensive production function was created for pellet mill activities. This increased the number of sectors represented in the spending pattern from 18 to 141.

Exogenous constraints were placed on particular sectors in the integrated facility scenario to better reflect economic realities in the region and provide a more accurate representation of regional impacts over simple gross measures. Constraints on the pellet mill's purchase of residual chips from the sawmill sector were instituted because these represent purchases of by-products that existed in excess capacity within the region, as indicated by timber product output surveys (US Forest Service, Forest Inventory Analysis 2016). With constraints applied, chip purchases were not modeled in a way that promoted the production of lumber for the sake of creating chips. In addition, because the IMPLAN database designated 37 percent of logging output as exported from the region, it was reasonable to assume that white chip production would not increase as a result of pellet production (at least in the near term), but instead wood pellet manufacturing would utilize chips previously exported from the region. Constraints on raw material purchases were practically applied by setting these sectors' regional purchase coefficients to zero, which restricted their outputs to remain at existing levels. Last, because the energy sector is a large, declining cost industry based on economies of scale, it is realistic to expect that pellet mill operations would generate only negligible marginal outcomes in the electrical sector (Swenson 2006). This expectation was reasonable as pellet mill energy demand was relatively small, representing only 1.7 percent of the excess electricity capacity existing within the region.

Pellet mill collocation: Sensitivity analysis

Because wood costs were the dominant expenditures of an integrated mill (Table 1), representing 36 percent of all direct requirements, the influence of raw material and final product price fluctuations on economic impacts was analyzed. This provided one set of upper and lower bounds for impact estimates. Price changes for wood fiber and woody biomass were obtained from RISI and were observed to fluctuate approximately 8 percent over the 2014 calendar year (RISI 2015). Therefore, raw material and final wood pellet prices were adjusted by 8 percent to represent upper and lower cost and revenue boundaries for the collocated sawmill and pellet mill. The same ABP methodology described previously was used for each scenario.

Last, the economic impacts generated from lumber–pellet mill collocation were compared with a similar increase in final demand across all wood products manufacturing industries represented within the region. Sectors present in the study area are described in Table 2. To determine economic impacts, an increase in demand of $9.01 million, similar to the direct output of the collocation scenario, was distributed across forest products sectors with final demand weighted by sector output. The resulting impacts were reported and compared with those generated by the collocated sawmill and pellet mill.

Results

Stand-alone sawmill

Impact estimates of a 10-MMBF hardwood sawmill operating at 93 percent capacity in the Ashville–Brevard combined MSA are provided in Table 3. The direct effects generated by annual production level were valued at $6.53 million, including the sale of bark, sawdust, and residues, and required 25 employees including laborers, clerical staff, supervisors, and a chief executive officer. In addition, regional industries involved in the sawmill's supply chain produced indirect sales equivalent to $3.00 million and supported 20 jobs, primarily in the wholesale trade, logging, transportation, and sawmill sectors. If the spending of income generated by employment (induced spending) is considered, an additional $1.64 million in output was generated while supporting 15 jobs in the services, health care, and real estate sectors.

Collocated sawmill and pellet mill

Direct operation of a pellet mill producing about 9,800 tons of pellets annually, in conjunction with a hardwood sawmill, required an additional supervisor, laborers, plant operators, and electricians, resulting in 13 new jobs. Producing pellets in addition to hardwood lumber increased direct economic output of the facilities by 38 percent to $9.01 million. Regional industries associated with the pellet

Table 2.—*Wood product manufacturing sectors present in the Asheville–Brevard combined metropolitan statistical area.*

Sector	Description	Study area output (US$)	Output (%)
134	Sawmills	36,585,000	55.0
137	Engineered wood member and truss manufacturing	4,657,000	7.0
139	Wood windows and door manufacturing	1,897,000	2.8
140	Cut-stock, resawing lumber, and planning	3,644,000	5.5
141	Other millwork, including flooring	3,487,000	5.2
142	Wood container and pallet manufacturing	5,690,000	8.5
144	Prefabricated wood building manufacturing	6,932,000	10.4
145	All other miscellaneous wood product manufacturing	3,729,000	5.6
Total		66,621,000	100.0

mill supply chain experienced an increase in indirect economic output of 11 percent, totaling $3.32 million. Last, induced economic effects created by the additional spending of wages increased 29 percent to $2.11 million (Table 4).

The range of economic impacts created by a collocated sawmill and pellet mill, as influenced by raw material and final product prices, are described in Table 5. Regardless of scenarios, the collocated mills directly supported 38 jobs, whereas the number of spillover employment created through interindustry linkages ranged from 39 to 43 jobs. Product pricing structure influenced the direct impacts generated by the mills by approximately 8 percent, which was expected because of the linear behavior of input–output techniques. Value-added economic activity varied by approximately 10 percent, with value added ranging from $4.72 million to $5.72 million. Last, total economic output, which includes spillover effects, ranged from $13.44 million to $15.45 million. The ranges of effects generated by price changes serve to illustrate the importance of raw material prices on wood product manufacturing profitability (Mani et al. 2006).

A comparison of economic effects generated by two scenarios, collocation and an equal final demand change across all regional wood products sectors, is summarized in Table 6. A demand increase of approximately $9.01 million, distributed across all eight wood products industries, generated 84 total jobs and a total economic output of $14.59 million, a nearly equivalent output to that generated by the collocated mill scenario. Although more jobs were supported by a demand change across all industries, jobs in the collocation scenario appeared to pay higher wages. This point was illustrated by value added being 2.8 percent larger for the collocation scenario. Included within value added was the $193,000 difference in labor income provided by the collocation scenario. It is likely that increased wages also contributed to the value-added increase, as employee compensation is a component of value-added economic activity. The differences in impact generation between the two scenarios were relatively small and we concluded that pellet mill collocation generated levels of employment and economic activity similar to other wood products sectors within the region.

Discussion

Regional economic impacts can be generated using any of three methods: emphasizing export markets to bring new money into the region, substituting imported goods and services with those that are produced locally, and adding value to existing product chains through manufacturing. This study investigated an application of the latter of these methods by modeling a hardwood sawmill that utilizes preexisting wood residues as a raw material source for the production of wood pellets within the context of western North Carolina wood markets. Understanding that the addition of wood pellet manufacturing facilities in this scenario occurs on a smaller scale than that of traditional pellet manufacturing, we illustrate an opportunity for primary wood processors to utilize low-value materials (mill residues along with chips that are largely produced from lower-valued roundwood) to create value-added products resulting in additional revenue for their firms while generating incremental employment and value-added economic activity within the region. We report the economic impacts created using input–output modeling to generate impact estimates. In addition, we estimate how these regional impacts react to raw material and final product price fluctuation.

Traditionally, economic impact estimates for biofuel production created using input–output techniques are overstated. Therefore, we applied constraints to electricity and pellet mill raw material purchases, accounting for 41 percent of the pellet mill spending pattern, to prevent the overestimation of economic impacts generated by the collocation scenario (Swenson 2006). These constraints accounted for preexisting raw material surpluses in the region, opportunities foregone elsewhere (rather than selling residues, the mill held them in storage for use in pellet production), and the likelihood of any impacts truly occurring in a large, declining-cost utility industry. These purchase constraints, practically applied by assigning raw material feedstock purchases a regional purchase coefficient

Table 3.—*Economic contributions of a hardwood sawmill.*

	Employment (no.)	Value added (US$)	Total output (US$)
Direct effect	25	1,435,000	6,532,000
Indirect effect	20	1,357,000	3,003,000
Induced effect	15	909,000	1,645,000
Total effect	60	3,701,000	11,180,000

Table 4,—Economic contributions of a collocated hardwood sawmill and pellet mill.

	Employment (no.)	Value added (US$)	Total output (US$)
Direct effect	38	2,492,000	9,008,000
Indirect effect	21	1,559,000	3,323,000
Induced effect	20	1,168,000	2,113,000
Total effect	79	5,219,000	14,444,000
Multiplier	2.082	2.095	1.603

of zero within IMPLAN software, provided more conservative and realistic descriptions of the economic effects generated by the collocated mills scenario than simple gross measures that provide no offsetting circumstances. An even more cautious assessment could discount all indirect effects emanating across the supply chain owing to wood pellet processing activities and count only the induced impacts from spending of employee wages. The actual impact of the collocated scenario lies somewhere between our estimate and this harsher option.

Collocating a pellet mill alongside a hardwood sawmill in western North Carolina resulted in increases in both direct and spillover economic effects when compared alongside a stand-alone lumber manufacturing facility. Small economic impacts were observed because of the small size associated with the production facility. Thirteen new jobs were supported by the addition of the pellet mill, with the entire collocated operation supporting a total of 81 jobs. In addition, value-added economic activity resulting from pellet mill collocation increased by 41 percent, raising the collocation scenario's contribution to regional gross domestic product (GDP) from $3.70 million to $5.22 million. This value-added regional economic growth represents additional wages paid to regional workers, proprietor income, corporate profits, and indirect business taxes. The modest effects reported here represent the influence of just one collocated facility; if multiple manufacturers were to take advantage of pellet manufacturing opportunities, more substantial regional employment and GDP growth could be realized.

Raw material and final product price changes heavily influenced the economic output generated by the integrated mill scenario as raw material inputs made up a significant proportion of this facility's spending pattern. The influence

Table 5.—Sensitivity analysis impact ranges.

	Direct effect	Total effect	% difference from base
Base case			
Employment (no.)	38	79	
Value added (US$)	2,492,000	5,219,000	
Output (US$)	9,008,000	14,444,000	
Lower bound			
Employment (no.)	38	77	−2.5
Value added (US$)	2,132,000	4,722,000	−9.5
Output (US$)	8,294,000	13,439,000	−7.0
Upper bound			
Employment (no.)	38	81	+2.5
Value added (US$)	2,858,000	5,723,000	+9.6
Output (US$)	9,723,000	15,449,000	+7.0

Table 6.—Collocated sawmill and pellet mill economic effects versus an equal demand change across regional wood product manufacturing sectors.

	All wood product industries	Collocated mills	% difference
Total employment (no.)	84	79	−6.0
Value added (US$)	5,078,000	5,219,000	+2.8
Total economic output (US$)	14,586,000	14,444,000	−1.0

of raw material price changes on impact estimates are shown in Table 5. Raw material price fluctuations changed total sales by approximately $1.0 million, or 7 percent. When higher final product prices are combined with cheaper raw materials, value-added impact generation is maximized. This observation works in the other direction as well. When raw material prices increase and pellet prices drop, mill profitability is squeezed. Although modeled price changes influenced the dollar amounts associated with output, they did not heavily influence the number of jobs supported by the pellet mill operation. Spillover jobs created by the operation of the pellet mill fluctuated by only two jobs.

In addition, the economic impacts generated by the collocated scenario are similar to the economic gains realized from normal wood products industry growth (Table 6), indicating that pellet manufacturing can play a part in developing small-scale regional economic growth in the study area. Whereas employment effects are reduced in the collocation scenario as a result of the application of raw material purchase constraints during modeling, overall economic output and valued-added economic output are similar and larger respectively. These observations suggest that although pellet manufacturing may offer few jobs, these jobs are high paying for the region.

Economic impacts generated by industry sectors are often described using multipliers. Multipliers quantify the change in economic activity resulting from a change in final demand. Derived from employment and output model results, the sawmill sector within the Ashville–-Brevard MSA had SAM employment and output multipliers of 2.40 and 1.68, respectively. These multipliers suggest that for every 1 unit increase in employment and output, an additional 1.4 units of employment and 0.68 unit of output will be created within the region. When the pellet mill was collocated alongside hardwood lumber manufacturing, both the employment and output multipliers dropped to 2.08 and 1.60, respectively. This drop in multipliers is a result of economic effects experiencing greater increases in direct employment and output compared with spillover effects. The generated spillover effects were smaller compared with direct effects because purchase constraints were applied to raw material purchases. These constraints were necessary as pellet raw materials were presumed to already exist within the region and the purchase of these feedstocks would not generate additional spillover economic activity.

However, the collocation scenario still provided an employment multiplier greater than other wood products manufacturing sectors within the region, which range from 1.55 to 1.95 (IMPLAN Group LLC 2015). The collocated scenario output multiplier of 1.60 is also on the top end of output multipliers generated by wood products manufacturing, with these multipliers ranging from 1.50 to 1.62

(IMPLAN Group LLC 2015). These multipliers help to describe a regional wood products industry with a strong regional supply chain. Because of these strong interindustry relationships, collocation of pellet manufacturing serves as an advantageous way to generate employment and economic output within western North Carolina.

Conclusions

This study examined the economic impacts created by operating a small-scale pellet mill in western North Carolina, a location where large-scale pellet manufacturing may not be feasible because of raw material supply constraints or excessive transportation costs. We found that collocating a small-scale pellet mill operation alongside existing lumber manufacturing operations resulted in incremental increases in employment and value-added economic output for the study area. The added economic activity generated by the pellet mill collocation is comparable to that generated by a similar increase in growth across all wood product sectors existing within the region, indicating that pellet manufacturing generates similar value-added economic activity to that of wood product manufacturers in western North Carolina.

Throughout the modeling of this study, thorough efforts were made to address the overestimation that typically takes place when reporting economic impacts associated with input–output modeling. However, typical input–output assumptions existing within the mathematical framework of the model hold true in our application of the technique and should be considered when interpreting results. These include constant returns to scale, zero factor substitution, unlimited availability of inputs, and fixed technological improvements. In addition, this study is an attempt to quantify the economic impacts generated for a region as a result of pellet mill operation; it is not a thorough attempt to define the true profitability of such an operation. However, creating our own unique industry spending pattern for this scenario did shed light on operational parameters integral to the success of a pellet mill.

This particular study focused heavily on the regional economic effects that could be generated by pellet mill collocation and could benefit by further research into regional woody biomass markets. Because the pellet mill model assumes a small demand for white chips at an average fixed market price, the influence of pellet mill demand on white chip prices is ignored. It would be beneficial to determine the degree of regional pellet manufacturing required to instigate competitive price changes in wood residue markets and how those changes might affect pulping industries in the surrounding area. In addition, it would be beneficial to investigate the influence of raw material and final product prices on the collocated facility's lumber and pellet product mix, with the understanding that lumber manufacturers have the ability to adjust lumber recovery to respond to increased demand in wood residue markets. Last, it may be of interest to energy policy researchers to augment this study by investigating the potential offsets in home energy consumption resulting from the use of pellets for residential heat in western North Carolina.

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Appendix Table 1. —Sawmill products produced and respective prices.[a]

Sawmill products	Production	Price (US$)	Total cost (US$)
Lumber	9,300 MBF	679/MBF	6,310,217
Sawdust	132,255 ft^3	0.19/ft^3	24,492
Residue (chips)	413,376 ft^3	0.35/ft^3	143,855
Bark	240,622 ft^3	0.22/ft^3	53,472
Total			6,532,036

[a] MBF = thousand board feet.

Appendix Table 2.—Pellet mill annual spending pattern.

Operational requirements	Cost (US$)	Margin (if appropriate)	Total cost (US$)
Raw material, sawmill chips			245,478
Raw material, chip mill chips			412,995
Die costs			20,000
Roller shell costs			4,800
Roller bearing costs			3,600
Bag costs			127,006
Pallet costs (no recycling)			50,000
Electricity costs			137,646
Other industrial machinery manufacturing	49,932	0.823	41,076
Wholesale trade business	49,932	0.165	8,241
Transport by air	49,932	0.001	70
Transport by truck	49,932	0.011	545
Plastics packaging materials and unlaminated film and sheet manufacturing	7,500	0.936	7,024
Wholesale trade business	7,500	0.037	281
Retail stores—miscellaneous	7,500	0.008	61
Transport by air	7,500	0.001	5
Transport by rail	7,500	0.001	8
Transport by truck	7,500	0.016	122
Petroleum refineries	5,367	0.852	4,573
Wholesale trade business	5,367	0.083	445
Retail stores—gasoline stations	5,367	0.027	144
Transport by air	5,367	0.000	0
Transport by rail	5,367	0.003	14
Transport by water	5,367	0.005	28
Transport by truck	5,367	0.019	104
Transport by pipeline	5,367	0.011	59
Working capital			3,775
Bank payments			219,917
Real estate services			168
All other sectors			130,998
Labor			541,697
Taxes			108,170
Other components of value added			550,915
Total			2,619,963