Prospects of Wood-Based Energy Alternatives in Revitalizing the Economy Impacted by Decline in the Pulp and Paper Industry

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Abstract

Recently, the US forest product industry has seen remarkable shifts in market demand for traditional forest products. The displacement of paper demand by new electronic media and communication technology has led to the closure of several pulp and paper–based manufacturing facilities across the nation. The closure of such facilities can have devastating impacts on forest communities in the mills' fiber shed area, particularly forest landowners, loggers, truckers, and others involved in the supply chain. Sustaining forest-dependent communities need viable economic alternatives. Development agencies at the local and regional levels need to fully understand the feasibility of new forest-based alternatives. With a case of 24 counties that made up the hardwood fiber shed for a recently closed pulp mill, this study analyzed the feasibility of three alternatives in revitalizing the affected economy through utilizing the surplus fiber and creating new opportunities for the displaced workforce. Although investment in each business alternative is likely to yield positive return on investment for the region, expected impacts on jobs and industrial output varied considerably. Compared with wood pellet and bioelectricity, the bio-oil industry is likely to generate jobs that will not only offset the current job deficit but also create additional opportunities. Results from a multiregional input–output analysis revealed spillover economic opportunities beyond the impacted areas. Findings will be useful in guiding sustainable business and investment decisions as well as understanding the anticipated community benefits of energy-based industries in revitalizing economies affected by the declining market demand for traditional forest products.

The forest products industry in the United States has experienced a decline in market demand for pulp and paper owing largely to the displacement of paper demands by new electronic information and communication technology (Ince and Nepal 2012). This led to the closure of multiple paper mills nationwide. Brandeis and Guo (2016) presented a list of 17 pulp mills closed during the period 2000 to 2011 in the southeastern United States alone. While the closure of these mills is an outcome of decision making and business choices by the private sector, the closure can have devastating effects on rural economies through lost direct income for forest landowners and jobs for local residents at various stages of the supply chain.

The wood products industry is highly interconnected, beginning with planting and management of sustainable forests to many different uses of wood and end-of-life alternatives. These interconnections may span many stakeholders with varying levels of dependence on a particular commodity. In such a highly interconnected system, the closure of a major supply destination of timber products, such as a pulp mill that uses low-grade logs or pulpwood, will have variable but far-reaching effects on the network of stakeholders that are directly or indirectly connected to the

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This paper was received for publication in January 2017. Article no. 17-00004.

Forest Prod. J. 67(7/8):427–434.
doi:10.13073/FPJ-D-17-00004

industry. Employees of the closed mill will, of course, be most affected. Logging companies, particularly their employees who delivered to the mill, may also be directly affected if they do not have alternatives available for logging operations. The existence of and the distance to alternative markets will also be an important variable. Low-value timber product resources typically supplied for pulpwood production can also be used for producing wood pellets, oriented strand board, or pallets as long as those facilities are within a feasible hauling distance.

While mills may offer severance packages to help their employees in the short term, thousands of people in the supply chain, including landowners, loggers, and truckers, typically receive no such compensation. If the closed mill is large enough to acquire significant volume of wood fiber from a larger geographical region (fiber shed), many landowners, loggers, and truckers are deprived of economic opportunities. Unfortunately, government agencies and private investors are largely unprepared to assist new entrepreneurships that could employ the displaced workforce and utilize the surplus pulpwood. However, emerging literature on bioenergy and bioeconomy suggests that renewable energy can be a reliable economic engine to promote growth and sustainable development in rural areas (Welle-Strand Ball et al. 2012).

The goal of this study was to explore whether and to what extent alternative energy–based forest enterprises could serve as recovery alternatives to create new markets for unutilized fiber (pulpwood, logging residue, and mill chips) and provide employment opportunities for the local community. In particular, the study explored the economic feasibility of wood pellets, bio-oil, and bioelectricity generation in a region impacted by decline in market demand for pulpwood. Although the wood economy has been impacted by numerous other factors, including decline in harvesting on federal forests, this study is more specific, featuring a case of a rural community facing pulp demand decline.

Considering the uncertainty in the long-term economic feasibility and social perception (and to some extent skepticism) of alternative markets, such as advanced biofuels (Hitchner and Schelhas 2012, Radics et al. 2015) and wood pellets, it becomes important to understand the benefits and viability of alternative businesses. Business stakeholders, including financial investors, will need to fully understand the financial feasibility and profitability of new forest-based businesses. Likewise, local and state governments must ensure that any policy adopted to promote such innovative businesses considers the amount of available surplus fiber and employment opportunities for the displaced workforce. While some work has been done to understand market dynamics or economic impacts associated with traditional forest products, such as pulpwood (Ince and Nepal 2012, Kebede at al. 2013, Wear and Greis 2013, Brandeis and Guo 2016), limited literature exists on the possibility of recovery alternatives and associated economic impacts in the context of changing market conditions. In addition, while some work has been conducted to understand economic opportunities coming from wood-based bioenergy alternatives (e.g., Gan and Smith 2007, Perez-Verdin et al. 2008, Joshi et al. 2012), none of these acknowledged the economic contributions beyond the defined area of interest. Further, a recent survey of forest economists published in the *Journal of Forestry* argued in favor of utilizing multiregional input–output (IO) modeling in economic contribution analysis of traditional and nontraditional forestry-related industries (Joshi et al. 2017). Realizing this gap in knowledge in the forest product literature, the study presented in this article uniquely incorporates multiregional IO modeling in economic impact analysis.

Potential of forest-based recovery alternatives

Because paper production, led by structural changes, is expected to further decline in the future (Ince and Nepal 2012), a number of new forest-based businesses offer alternatives to utilize the unused wood. Wood reside from sawmills is being used on-site to generate heat or off-site to use as industrial feedstock (Saud et al. 2015). Using forest biomass for energy production has gained attention recently owing to growing European markets for alternative energy sources (Dwivedi et al. 2014). The European Union has an energy policy target of meeting up to 20 percent of total energy consumption from renewable sources by 2020 (REN21 2010). In the United States, more than 30 states have adopted Renewable Portfolio Standards (RPS) for fuel production, specifying the target share of renewable sources at between 10 and 40 percent (National Conference of State Legislators 2017). The federal renewable fuel standard has been set at 21 billion gallons of annual production of biofuel by 2022 (Yacobucci and Bracmort 2010). In response to these regulations, the business community's interest in investing in energy-based entrepreneurship may grow, particularly if incentives are provided.

Methodology

Study area

An area comprising 24 counties[1] in middle Tennessee was the focus of the research because these counties are believed to have been affected significantly by the closure of a large pulp mill in northern Alabama near the Tennessee border (International Paper's Courtland Mill) (Todd and Livengood 2014). Although the closure directly affected hundreds of mill employees, its impact on middle Tennessee counties is relevant from a forestry and sustainable rural development perspective. The region served as a primary fiber shed for the mill, supplying more than 800 thousand tons of hardwood fiber from 25,000 acres of timberland (Todd and Livengood 2014). Unlike other softwood-dominant counties in Alabama that also supplied the mill, these Tennessee counties contain mostly hardwood fiber, which has relatively few alternatives for product manufacturing.

Brandeis and Guo (2016) estimated that the total impact of this closure on Tennessee included $134 million in lost output and $35.6 million in lost labor income and a total of 648 jobs were affected. Todd and Livengood (2014) reported similar numbers. These statistics demonstrate the enormity of the impact on forest-dependent stakeholders in the supply chain (landowners, loggers, truckers, sawmill owners, and other fiber users) but do not provide insights on

[1] Counties included Benton, Carroll, Chester, Decatur, Dickson, Franklin, Gibson, Giles, Hardeman, Hardin, Henderson, Henry, Hickman, Humphreys, Lawrence, Lewis, Lincoln, Marshall, Maury, McNairy, Perry, Rutherford, Wayne, and Williamson.

what alternatives might be feasible for employing the displaced workforce and utilizing surplus fiber.

Consideration of wood-based alternatives for energy production

Energy generation from forest biomass can be achieved in many ways, including using woody biomass to produce heat and electricity or liquid fuel, such as ethanol. Recently, because of the rising demand from the European Union, wood pellet production has increased in various parts in the United States (Dwivedi et al. 2014). This study will focus on three energy-based industries, including wood pellet production, bio-oil production, and bioelectricity generation as recovery alternatives that could potentially help revitalize the economy of middle Tennessee.

Economic impact analysis

Once a number of energy generation alternatives were identified, a series of economic IO analyses were conducted to characterize the impacts of utilizing woody biomass in different energy facilities. IO analysis was conducted with the IMPLAN program originally developed by the US Department of Agriculture Forest Service and currently marketed by Minnesota IMPLAN LLC (Minnesota IMPLAN Group 2000). IMPLAN employs IO models that mathematically link an array of economic transactions among multiple sectors (e.g., retail, manufacturing, service, and agriculture) of an economy for a given period of time. The models rely on Leontief production functions and are capable of tracing back commodity and service flows from final product (pellet) to industrial inputs (e.g., biomass). The basic assumption behind economic impact analysis is that every dollar generated by new economic activity in a given area ripples through the regional economy and generates further impact. For example, if a new wood pellet facility is established in the region, it will employ several people and generate income for the proprietor (direct impacts). The plant will purchase biomass from backward-linked industries (i.e., local sawmills and forest landowners), thereby creating income and jobs to those entities (indirect impacts). Finally, loggers, truckers, and landowners spend part of their income on goods and services, creating income and jobs in the local area (induced impacts). The total economic impact includes all three types: direct, indirect, and induced. When the transaction associated with indirect or indirect impact goes outside the defined economic region, the cycle stops, causing economic leakage (Schaffer 1999).

Based on the economic linkage among sectors, an IO model allows researchers to analyze how a change in activity or investment in one sector (e.g., wood pellet production) generates impacts (e.g., jobs and wages) on the related sectors (e.g., service). From an economic development and recovery perspective, impacts were established in terms of industry output, jobs, and labor income in the counties affected by the mill closure. Building on previous work (Gan and Smith 2007, Perez-Verdin et al. 2008, Joshi et al. 2012, Little et al. 2013), impacts were estimated for the establishment and operation phase of each facility, both within and beyond the region (remaining counties in the state). The approach was the best fit to meet the goal of assessing whether and to what extent the selected alternatives of bioenergy production would be feasible in generating jobs, income, and other impacts to revitalize the economy impacted by the closure of the pulp mill. Considering that capital investment in construction and establishment are likely to have short-term impacts and operation and maintenance are likely to have longer-term impacts, economic impacts were estimated separately. This approach is commonly practiced in economic impact analysis studies (Miller and Blair 1985, Grover 2009). In addition, given the regional interconnectedness industrial inputs, this analysis is based on the premises of the multiregional IO model (Rúa and Lechón 2016). Therefore, interregional trade flows between impacted and nonimpacted counties within the state of Tennessee were taken into account during model development and analysis.

The IO analysis first needed an approximate estimate of the total woody biomass that might be available from the region to support new biomass processing facilities, such as wood pellets. Our review of literature and secondary information revealed that 800,000 tons of biomass was supplied from the region to the International Paper mill until its closure in 2013 (Todd and Livengood 2014).

On the cost side, the IO analysis also needed reliable estimates of the costs of establishing and/or operating the selected energy production facilities (e.g., wood pellet plant). We assumed costs as used in a similar study recently conducted in Mississippi by Joshi et al. (2012) and originally suggested (with validation from manufacturers) by Pirraglia et al. (2010). For the wood pellet industry, we began by analyzing the impact of a pellet mill with an annual processing capacity of 75,000 dry tons of biomass, which represents the upper capacity of existing wood pellet facilities in the United States (Lu and Rice 2011). The construction (or establishment) and operation costs associated with a wood pellet facility are provided in Table 1.

A range of estimates for the cost of establishment and operation of bio-oil production facilities are available (Table 2). For this study, the estimates of SEH (2009) for mill with a daily capacity of 181 dry tons was selected because of its relative cost efficiency in the long run compared with plants of other capacities (Joshi et al. 2012). In addition to the establishment costs, approximately $10 million was assumed as the operating cost for a bio-oil production plant of this capacity (Joshi et al. 2012). Table 3 provides establishment and operating costs for the bio-oil production plant. Finally, the third alternative considered in this study was energy generation from direct firing of woody biomass in power plants. A review of the literature indicates that cofiring of woody biomass (along with coal or other materials) to produce electric power does not require major modifications to existing handling and storage systems (Tillman 2000, Gan and Smith 2007, Abt et al. 2010). However, a careful analysis of the energy facilities database developed by the US Energy Information Administration (www.eia.gov/state/maps.cfm) did not show any existing power-generating facilities in the project area. Therefore, we analyzed the potential impact of establishing and operating a new biomass-burning electric power facility consuming 1,000 dry tons per day. Considering the total availability of biomass in the region and potential scale of facility operation, we think this is the most appropriate capacity to almost entirely consume the estimated amount of hardwood fiber that remains surplus in the region after mill closure. According to Little et al. (2013), who scaled the assumptions and costs from existing energy plants in North Carolina, a plant of this feedstock capacity could generate

Table 1.—Estimated cost of construction and operation of a wood pellet mill (capacity = 75,000 dry tons annually).[a]

Cost type	Estimated annual cost ($, millions)
Construction	
Site and site preparation	0.21
Building and office space	1.39
Storage warehouse	0.11
Paving, receiving station, loading area	0.08
Front-end loader	0.31
Forklift	0.06
Hammer mill	0.15
Boiler	0.60
Feed hopper	0.18
Pellet mills	1.46
Pellet shaker	0.04
Live bottom bin	3.10
Conveyors	0.31
Dryer, burner, and air system	0.95
Pellet cooler	0.41
Bagging system	0.10
Bagging bin	0.01
Labor	2.77
Total construction	12.25
Operation	
Biomass acquisition	4.05
Power/electricity	2.7
Labor	3.76
Consumables	2.32
Additional costs	0.50
Tax	0.52
Total operation	13.85

[a] Adapted from Pirraglia et al. (2010, p. 2321) and Joshi et al. (2012, p. 531).

445,000 MWh of electricity. Since the recent version of economic impact analysis software (IMPLAN) can accommodate the electricity production from biomass as an industry, the output generated here can be directly used in IO analysis to estimate the expected impact on jobs, industry output, and labor income.

Feasibility analysis for economy recovery and development

Once we estimated the projected economic impacts (jobs, labor income, etc.) associated with a facility of a particular type and capacity, we simulated the total impacts for the region by estimating the number of facilities that could be supported by the available biomass. The projected gain in jobs, labor income, output, and contribution to the region's gross product were compared with the loss in jobs, labor income, output, and gross product reported elsewhere. The comparison allowed us to assess the feasibility of the energy industry as recovery alternatives, that is, whether and to what extent the expected economic impact from alternative bioenergy industries contribute to employ the displaced workforce and utilize the surplus biomass.

Results and Discussion

Results from the IMPLAN analyses are reported in several tables to illustrate the total impact plus the breakdown of direct, indirect, and induced impacts. In addition to impacts, a social accounting matrix (SAM) multiplier is presented to show the ratio of total impact and direct impact. SAM is a measure of the economic multiplier indicating the additional value added by the original stimulus. Table 4 presents the results for the expected impact from construction as well as operation of a wood pellet–processing facility in the region. Construction of a pellet mill of 75,000 annual tons capacity was estimated to create 34 direct jobs and generate $4.07 million of gross output. Another 6 indirect and 27 induced jobs were generated as a result of this new pellet mill. The mill's total value addition, which is a sum of employee compensation, proprietary income, and other indirect business taxes, was estimated as $6.2 million. As shown by the SAM multiplier, every dollar worth of investment in construction of this wood pellet mill resulted in an additional $1.09 of economic return. In addition, the operation-related activities were estimated to contribute a

Table 2.—Review of available estimates of bio-oil production facilities.

Source	Daily capacity (dry tons)	Estimated establishment cost/ investment ($, millions)
Sarkar and Kumar (2010)	500	58
Ringer et al. (2006)	550	48
Badger et al. (2011)	90	6
SEH (2009)	91	19
SEH (2009)	181	29

Table 3.—Estimated cost of construction and operation of a bio-oil production facility (capacity = 66,224 dry tons annually).[a]

Cost type	Estimated annual cost ($, millions)
Construction	
License fee	3.52
Engineering design	4.30
Site development	0.59
Office construction	0.35
Utility connection	0.12
Truck loading/unloading	0.35
Storage	3.28
Front-end loader	2.35
Fire suppression system	0.12
Storage tank system	1.16
Grinding equipment	0.82
Drying equipment	0.59
Pyrolysis system	11.73
Construction total	29.29
Operation	
Biomass acquisition[b]	3.94
Grinding	0.66
Labor	1.30
Administrative cost	0.50
Supplies and service	0.24
Equipment maintenance	2.00
Propane	0.05
Nitrogen and chemical	0.80
Electricity	0.99
Operating total	10.46

[a] Adapted from Joshi et al. (2012, p. 530).
[b] Assumption of $33 per green ton of delivered biomass.

Table 4.—Estimated economic impact of a wood pellet manufacturing facility (capacity = 75,000 tons annually) in 24-county region of middle Tennessee.

Activity	Economic impact ($, millions)				Multiplier	Total impact/ton ($)[a]
	Direct	Indirect	Induced	Total		
Construction						
Output	4.07	0.91	3.56	8.55	2.09	54.27
Value added	3.61	0.49	2.09	6.20	1.71	48.13
Labor income	2.04	0.33	1.20	3.58	1.74	27.20
Jobs (no.)	34.20	6.30	27.20	67.60	1.97	
Operation						
Output	2.85	0.69	3.89	7.44	2.60	38.00
Value added	2.14	0.38	2.28	4.81	2.24	28.53
Labor income	1.48	0.24	1.31	3.04	2.04	19.73
Jobs (no.)	36.4	5.1	29.7	71.2	1.95	

[a] Numbers reported in this column are not in millions.

Table 6.—Estimated economic impact of a bio-oil production facility (capacity = 62,224 dry tons annually) in 24-county region of middle Tennessee.

Activity	Economic impact ($, millions)				Multiplier	Total impact/ton ($)[a]
	Direct	Indirect	Induced	Total		
Construction						
Output	11.43	3.41	2.95	17.79	1.56	183.69
Value added	4.40	1.90	1.73	8.03	1.82	70.71
Labor income	3.43	1.26	0.99	5.69	1.66	55.12
Jobs (no.)	65.1	28.9	22.5	116.5	1.79	
Operation						
Output	8.54	1.82	3.74	14.11	1.65	137.25
Value added	4.71	1.08	2.19	8.00	1.70	75.69
Labor income	3.81	0.78	1.26	5.85	1.54	61.23
Jobs (no.)	92.5	29.3	28.6	150.4	1.63	

[a] Numbers reported in this column are not in millions.

total of $7.4 million of economic impact in the region, including $3.04 million in labor income and 71 full- and part-time jobs. The top five industries benefiting from the construction were wholesale trade, retail, heating equipment, conveying equipment, and limited-service restaurants, whereas those impacted by operation activities were retail, textile bag and canvas mills, wholesale trade, limited-service restaurants, and real estate.

The investment in a wood pellet facility also generated some spillover benefits outside the region (Table 5). Specifically, the total economic impact of construction activities was estimated to be $0.81 million, including five jobs and $0.26 million in labor income, whereas the operation activities were estimated to create $0.6 million in economic output, including four jobs and $0.2 million in labor income. Similarly, the results for the bio-oil processing facility with an annual processing capacity of 66,224 dry tons per year are presented in Table 6. Construction of this biofacility is likely to generate direct output worth $11.43 million, with an estimated 65 direct jobs and $3.43 million in labor income. Adding indirect and induced effects to the direct effect yields a total of $17.79 million in output, $5.69 million in labor income, and 116 full- and part-time jobs. The SAM multiplier for output was estimated to be 1.55, indicating that every dollar invested in construction activities generates an additional return of $0.55 in the region's economy. More than half ($4.4 million of $8 million total) of value added was a direct effect in the region's economy. Sectors benefiting the most from construction activities include construction of new single-family housing, architectural and related services, real estate, machinery manufacturing, and truck transportation.

In addition, activities related to the operation will create an estimated $14 million in economic output, including $5.86 million in labor income and 150 jobs. Further, $4.7 million of the $8.0 million total value added is a direct impact. The SAM multiplier for output (1.65) indicates that every dollar of investment in operating activities will generate an additional $0.65 in return. The top five beneficiary industries of operation-related activities in the region were forestry, forest products and timber tracts, support activities for agriculture and forestry, commercial and industrial machinery, office administrative services, marketing research, and all other services. The spillover effects of a bio-oil facility in the rest of Tennessee counties are listed in Table 7. Construction of a bio-oil facility in the region will help create a total of $1.97 million in direct and indirect economic output in the rest of the state. Even though the construction jobs are short term, it will also generates 13 jobs and $0.65 million in labor income.

Table 5.—Estimated statewide spillover economic impact of a wood pellet manufacturing facility (capacity = 75,000 tons annually) outside the 24-county region of middle Tennessee.

Activity	Direct	Indirect	Induced	Total
Construction				
Output ($, millions)	0	0.42	0.38	0.81
Value added ($, millions)	0	0.20	0.21	0.42
Labor income ($, millions)	0	0.13	0.13	0.26
Jobs (no.)	0	2.3	2.7	5.1
Operation				
Output ($, millions)	0	0.23	0.36	0.59
Value added ($, millions)	0	0.12	0.19	0.32
Labor income ($, millions)	0	0.07	0.12	0.20
Jobs (no.)	0	1.5	2.6	4.1

Table 7.—Estimated statewide spillover economic impact of a bio-oil production facility (capacity = 66,224 tons annually) outside the 24-county region of middle Tennessee.

Activity	Direct	Indirect	Induced	Total
Construction				
Output ($, millions)	0	1.38	0.58	1.97
Value added ($, millions)	0	0.69	0.33	1.02
Labor income ($, millions)	0	0.45	0.20	0.65
Jobs (no.)	0	8.3	4.3	12.6
Operation				
Output ($, millions)	0	0.38	0.39	0.77
Value added ($, millions)	0	0.20	0.21	0.42
Labor income ($, millions)	0	0.13	0.13	0.26
Jobs (no.)	0	3.4	2.8	6.2

Similarly, the operation of the same facility will create six additional jobs and $0.26 million in labor income.

Finally, the estimated economic impact of a biopower plant with a capacity of generating 445,000 MWh of power utilizing 1,000 dry tons of woody biomass per day is provided in Table 8. Because electricity production from biomass is a recognized sector in recent (2014) IMPLAN schemes, we were able to utilize the existing production function relationship to account for direct, indirect, and induced economic impacts. In as much as an analysis could not be specified within impacted counties, these results should provide cumulative impacts within and beyond impacted counties. It is anticipated that construction and operation of this facility will create a total of $56 million in industrial output, yielding $12.4 million in labor income and 226 jobs.

Table 9 depicts the total number of facilities that might be feasible based on the available woody biomass previously supplied to the International Paper pulp mill. Todd and Livengood (2014) estimated that 800,000 tons of green biomass was previously supplied to the mill. The green tons were converted to dry tons using the assumed moisture content of 50 percent, which yielded a total of 533,000 tons as the biomass supply. Considering potential land use changes and a moderate level of support for the bioenergy industry among stakeholders (Radics et al. 2015), we estimated the feasible number of energy facilities and their anticipated impacts under four different scenarios of biomass recovery (i.e., 100%, 75%, 50%, and 25%).

One hundred percent of the hardwood biomass previously supplied to the International Paper mill would support five wood pellet facilities with an annual processing capacity of 75,000 dry tons per mill. In this scenario, the operation of wood pellet industry in the region will help create $37.2 million of economic output along with 356 total jobs and $15.2 million in labor income. There will be further impacts (direct and indirect) in the remaining counties in the state. This does not include the impacts created during the construction phase, which is typically short term. If only half of the previously supplied biomass is recovered, two wood pellet facilities of this capacity could be supported. In this case, a total of $14.88 million in economic output will lead to an additional 142 jobs and $6 million in labor income.

If all the hardwood fiber previously supplied to the International Paper mill were recovered and made available for bio-oil production, six facilities (annual capacity of 66,225 dry tons each) could operate in the region. Extrapolation of IMPLAN results for operation impacts indicates that the bio-oil production industry would lead to $84.66 million in industrial output, adding 1,080 jobs and $35 million in labor income. Simulated economic impacts of this industry in the alternative biomass recovery scenario are presented in Table 9, which shows that even if only a quarter of previously supplied biomass is available, 180 jobs will be created. Similarly, for the biopower production facility, only one facility can be supported in the region even if all biomass is available. Accordingly, the electric power industry will lead to a total of $56.39 million in economic output and add 226 jobs and $12.42 million in labor income.

Discussing the feasibility of these facilities to serve as recovery alternatives required comparing our results (simulated total economic impact of a given new industry) with published estimates of the economic impact of the mill's closure. Brandeis and Guo (2016) estimated that the closure of the International Paper mill led to a loss of $135 million in industrial output, 648 jobs, and $35.6 million in labor income. Another estimate by English et al. 2013 (as cited in Todd and Livengood 2014) calculated a total loss of $126 million in industrial output and 654 jobs. It should be noted, however, that these impacts were estimates for the entire state of Tennessee rather than only the 24 counties directly affected by the closure. The comparison indicates that all industries will create significant economic impacts to help revitalize the region's economy affected by the closure. More important, the bio-oil industry in particular may go well beyond just restoring the affected economy and creating more positive impacts. As can be revealed from comparison of per ton impacts from three industries, the bio-oil industry's economic impacts are the highest, followed by the impacts of wood pellet mills. Conversely, the electric power generation facility appeared less likely to generate enough jobs to help the region recover.

Table 8.—Estimated economic impact of a bio-power generation facility (capacity = 365,000 dry tons annually) in Tennessee.

Activity	Economic impact ($, millions)				Multiplier	Total impact/ton ($)[a]
	Direct	Indirect	Induced	Total		
Construction and operation						
Output	31.50	16.83	8.05	56.39	1.79	86.30
Value added	11.54	8.88	4.66	25.08	2.17	31.62
Labor income	2.90	6.68	2.83	12.42	4.27	7.95
Jobs (no,)	27.2	138.6	60.7	226.5	8.33	

[a] Numbers reported in this column are not in millions.

Table 9.—Simulated economic impact of estimated number of facilities in 24-county region of middle Tennessee under various scenarios of biomass recovery.[a]

	Biomass recovery			
	100%	75%	50%	25%
Wood pellet facilities (annual capacity = 75,000 dry tons)				
No. of facilities possible	5	4	2	1
Total output ($, millions)	37.20	29.76	14.88	7.44
Total value added ($, millions)	24.05	19.24	9.62	4.81
Total labor income $, (millions)	15.20	12.16	6.08	3.04
Total jobs (no.)	356	285	142	71
Bio-oil production facility (annual capacity = 66,225 dry tons)				
No. of facilities possible	6	4	3	1
Total output ($, millions)	84.66	56.44	42.33	14.11
Total value added ($, millions)	48.00	32.00	24.00	8.00
Total labor income ($, millions)	35.10	23.40	17.55	5.85
Total jobs (no.)	902.4	601.6	451.2	150.4
Bioelectric power generation facility (annual capacity = 365,000 dry tons)				
Total output ($, millions)	56.39	NF	NF	NF
Total value added ($, millions)	25.08	NF	NF	NF
Total labor income ($, millions)	12.42	NF	NF	NF
Total jobs (no.)	226	NF	NF	NF

[a] NF = not feasible to sustain the plant of this particular capacity with the available biomass.

Conclusions

Recent changes in market demand, particularly demand shifts from paper-based communication (e.g., mail and print newspaper) to electronic systems (e.g., online billing and banking), has led to the closure of several pulp and paper–based packaging mills throughout the nation. Several recent studies have indicated an overall disinvestment in pulp and paper manufacturing in the region (Wear and Greis 2013) as well as nationally (Ince and Nepal 2012). Closing any wood processing facility can have devastating impacts on rural communities, where it provides employment opportunities to hundreds of workers and purchases wood fiber from landowners within the fiber shed. While we know that the impact of a mill closure is substantial, business stakeholders, including financial investors, need to fully understand the feasibility of new forest-based alternatives to revitalize the economy. Rural development agencies at local or regional levels also must ensure that any policy adopted to promote such innovative businesses consider the amount of available surplus fiber and employment opportunities for the displaced workforce.

The bioenergy market has slowly started to emerge with the introduction of state and federal policies and incentives, but the supply of biomass from other than just the logging and mill residue may be key in sustaining the bioenergy industry (Abt et al. 2010). By analyzing the case of a 24-county region in middle Tennessee impacted by the closure of the International Paper mill in Courtland, Alabama, this study sheds some light on the feasibility of three energy-based forest business alternatives to revitalize the impacted economy: wood pellet manufacturing, bio-oil production, and bio-power generation. Admittedly, several major impediments exist for each of these options. For example, pellets are too far from a port, biomass to electricity faces regulatory (and cultural) resistance, and no significant market for bio-oil currently exists. In addition, there are some sustainability concerns, particularly the unintended consequences of promoting wood resources for energy, such as land use competition, water quality, and biodiversity (Faaij and Domac 2006). Depending on what we consider as biomass (timber harvest vs. logging residue), growing bioenergy economy may affect the pulpwood and timber market. However, recent studies have shown that appropriate government policies and incentive mechanisms may promote intensive management of forest for higher biomass production as well as increased utilization of logging residue (Abt and Abt 2013). However, if the international demand for pellets were to rise at recent rates, the market price will increase, and transportation costs could become trivial. Similarly, anticipated changes in domestic and international regulations will likely lead to policies favoring demand for renewable fuel. Results from our study have several implications for the feasibility of new energy-based forest enterprises in revitalizing the economy and informing investment and public policy decisions. First, all alternatives considered in the analysis were shown to aid in recovery of the regional economy, although expected effects varied considerably. The surplus wood fiber is likely to support as many as five wood pellet facilities or six bio-oil production facilities. Moreover, compared with wood pellet production, the bio-oil industry in the region is likely to generate two and a half times more industrial output and roughly three times more jobs. While the third alternative (electronic power generation) utilized the surplus wood fiber and created significant industrial output, it is not likely to create as many jobs as lost by the closure of the International Paper mill. Second, as shown by the social accounting multipliers from IMPLAN analysis, investment in each business alternative is likely to yield positive returns on investment for the region. Although the market for some products considered in this study (e.g., pellets) is currently in Europe, any future growth in the local market as a result of carbon taxes or costs on fossil carbon emissions may promote local use of pellets. If this is the case, a greater economic impact than reported in our study may be possible. Information like this may guide business and investment decisions in the biomass-based industry in Tennessee and beyond.

Third, the viability of the alternative industries will depend largely on the amount of woody biomass that can be recovered and made available to support the industry. Abt et al. (2010) suggested that meeting the bioenergy demand in the southeastern United States may require biomass beyond just the logging residue. If half of the hardwood fiber previously supplied to recently closed mills were available, only two wood pellet facilities or three bio-oil production facilities could be supported, but a stand-alone bioelectricity-generating facility would not be feasible. Accordingly, the recoverability of woody biomass is critical. Considering the public skepticism of the bio-based energy industry (Hitchner and Schelhas 2012), landowner education is critical.

Fourth, the indirect and induced effects of promoting the alternative energy industry will likely go beyond the fiber shed and benefit the supporting industries in the rest of the state. The significant spillover effect perhaps provides further evidence for state agencies in supporting recovery programs and perhaps making public investments to promote the forest-based energy industry. Demonstrating the spillover benefits may help increase public support and secure resource leverage from neighboring counties to finance recovery plans. Because only a handful of studies have considered interconnectedness of regions in their IO analyses, quantifiable estimates on spillover benefits may help increase public support and secure resource leverage from neighboring counties to finance recovery plans.

Finally, a few limitations of this study should be noted. First, our analysis investigated the estimated economic impacts (jobs, labor income, and output) of energy-based industries with selected processing capacity. Other non–energy-based industries may also offer viable alternatives, but we currently lack the financial and logistic information to conduct parallel analyses. Second, because wood pellet production is driven by the export market, impacts coming from local consumption are relatively low. Since incentives for local bioenergy use will increase the competitiveness of the US market, sensitivity analysis showing impacts of bioenergy industries with and without accounting for subsidies and incentives will shed additional insights. In addition, the economic impact coming from local use versus export is an important future research question. Third, results from IMPLAN analysis may be sensitive to the number and processing capacity of facilities due to associated effects of economies of scale of operation, business competition, etc. However, the particular sizes of facilities were selected primarily owing to a lack of reliable data on construction and operation of facilities for alternative capacities.

Acknowledgments

Authors acknowledge the funding support provided by USDA Rural Development, Tennessee for Rural Business Enterprise Grant 2015.

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