Input–Output Modeling of Wood-Based Bioenergy Industries in Mississippi

Omkar Joshi Donald L. Grebner James E. Henderson
Stephen C. Grado Ian A. Munn

Abstract

The southern region of the United States, which includes Mississippi, has abundant forest resources that provide an opportunity to establish a wood-based bioenergy industry in the region. This study estimated the direct, indirect, and induced economic impacts associated with establishment of wood-based bioenergy facilities in Mississippi. Three potential wood-based bioenergy facilities, wood pellets, bio-oil, and methanol-based gasoline, were considered. The requisite cost information pertaining to the construction and operation of selected wood-based bioenergy facilities were obtained from various secondary sources. Construction activities would impact the economy for a shorter period of time. Results showed operation of a wood pellet facility, having an annual production capacity of 75,000 dry tonnes, would contribute 8,282 full- and part-time jobs and US$12 million worth of economic output to the state economy. Likewise, operation of a bio-oil facility, having an annual production capacity of 66,224.5 dry tonnes, would provide 112 new full- and part-time jobs and an economic output of US$13 million. Similarly, an economic output of US$96 million and 795 more full- and part-time jobs would be added to the Mississippi economy by establishing a methanol-based gasoline facility. Clearly, these impacts are likely to draw the attention of policy makers and investors toward developing wood-based bioenergy opportunities in Mississippi.

The southern United States has abundant forest resources, covering approximately 29 percent of its area with productive forest lands, which are largely dominated by private landownership (Smith et al. 2004). Cox and Munn (2001) indicated that total economic impacts associated with the forest products industry in the southern United States were significantly larger than those in the Pacific Northwest region. Owing to such an important contribution, economic impacts associated with forest resources and the forest product industries have been periodically analyzed in this region (e.g., Cox and Munn 2001, Munn and Henderson 2003, Henderson et al. 2008). In particular, forest resources provide an important economic base in Mississippi because their annual contribution in terms of economic output is over US$17.4 billion (Henderson et al. 2011).

Four important sectors of the forest product industry, characterized in existing input–output literature are logging, solid wood products, pulp and paper, and wood furniture manufacturing (Munn and Henderson 2003). Undoubtedly, these are sectors in which the woody biomass obtained from forest resources is conventionally used. However, availability of unused forest biomass coupled with increased energy demand in the southern region provide an opportunity to establish wood-based bioenergy as a new market for forest resources in the southern United States (Henderson et al. 2008, Perez-Verdin et al. 2008). Given the use of otherwise unused woody biomass such as logging, thinning, and mill residues, feedstocks used in wood-based bioenergy may not compete with other forest product industries at least in the near future (Guo et al. 2007, Henderson et al. 2008).

Because existing energy production in Mississippi is far less than consumption (Energy Information Administration [EIA] 2012), facilities generating alternative energy are needed to meet the state's renewable energy needs. The forestry sector is poised to meet these energy needs with the establishment of various types of wood-based bioenergy facilities such as co-firing electricity, biofuel, bio-oil, wood pellets, and methanol-based gasoline in Mississippi, which would also greatly enhance the sector's contribution to the state's economy.

The authors are, respectively, Graduate Research Assistant, Professor, Assistant Extension Professor, Professor, and Professor, College of Forest Resources, Mississippi State Univ., Mississippi State (ojoshi@cfr.msstate.edu, dgrebner@cfr.msstate.edu [corresponding author], jamesh@ext.msstate.edu, sgrado@cfr.msstate.edu, imunn@cfr.msstate.edu). This paper was received for publication December 2012. Article no. 12-00116.

Forest Prod. J. 62(7/8):528–537.

Literature concerning economic impacts associated with wood-based bioenergy is limited because it is such a new opportunity. Gan and Smith (2007) evaluated the possibility of generating electricity by using logging residues in East Texas along with the coinciding socioeconomic and environmental benefits. Their study used input–output models to understand the total economic impacts of logging residue utilization on socioeconomic indicators. The authors estimated 2.4 million tons of CO_2 displacement by replacing logging residues for coal in power generation. Other socioeconomic benefits reported were the reduction of US$7.3 million to US$9.1 million in site preparation costs and the creation of 1,340 new job opportunities in East Texas (Gan and Smith 2007). In their effort to account for the economic benefits of woody biomass utilization in Mississippi, Perez-Verdin et al. (2008) determined that the logging and thinning residue recovery would generate 585 direct jobs, contributing US$152 million of gross domestic output. Similarly, logging operations would create 481 indirect jobs and 646 induced jobs in Mississippi (Perez-Verdin et al. 2008). The report further stated that woody biomass use for electrical generation was likely to contribute 281 direct jobs and a direct gross output worth US$64.5 million annually to the state economy. Moreover, results indicated that some 1,756 direct employment opportunities with a total gross output of US$242.7 million per year would be created through the establishment of biofuel facilities in Mississippi. Other studies (Faaji et al. 1998, Timmons et al. 2007, Hodges et al. 2010) also analyzed the economic impacts associated with wood-based bioenergy. In the literature, it is observed that three sectors, logging and thinning residue recovery, creating biopower from co-firing systems, and bioethanol production, have been analyzed to account for the economic impacts of woody biomass utilization for bioenergy.

New methods of utilizing woody biomass in the form of wood pellets, bio-oil, and methanol-based gasoline have also received considerable interest in recent years. Accurate estimates of economic impacts will acknowledge the contribution of new bioenergy industries through employment opportunities, economic outputs, and taxes to state economies. It is worth mentioning that existing provisions of the 2008 Farm Bill required anticipated impacts of a bioenergy industry on local economies as a prerequisite for federal assistance (Bailey et al. 2011). Given such provisions, an accounting of economic impacts will help these industries benefit from new federal programs.

Because the region contains a large amount of unused woody biomass, there is increasing interest among North American entrepreneurs for wood pellets (Spelter and Toth 2009), a compact wood fuel currently popular in Europe. Production and marketing of wood pellets have continuously increased since 2002, and North American production was expected to reach 6.2 million tonnes in 2009 (Spelter and Toth 2009). Not surprisingly, wood pellet processing facilities have already started production in Mississippi (Indeck Energy Services [IES] 2008, Coblentz 2010). Similarly, given its excessive handling cost, the conversion of solid woody biomass into liquid bio-oil has been recently identified as a cost-effective alternative with a greater energy density that can be used as a fuel oil in many industrial applications (Badger and Fransham 2006). Therefore, this technique has been pilot tested and even commercialized in many places in the United States (Badger and Fransham 2006, Guo et al. 2007). Likewise, in recent years converting woody biomass into biomethanol has emerged as a new opportunity (Demirbas 2008). Given that ligno-cellulosic biomethanol can be produced from renewable sources and has potential economic and environmental benefits, it can be considered as another future source of biofuel (Demirbas 2008).

The use of woody biomass for wood pellets, bio-oil, and methanol-based gasoline are new developments that have started receiving added attention from entrepreneurs and policy makers lately. Possibly because of this reason, none of the research related to economic impact analysis of woody biomass utilization has included wood pellets, bio-oil, and methanol-based gasoline production. In an attempt to fill this research gap, we conducted an economic impact analysis on the construction and operation of methanol to gasoline (MTG) technology, of a bio-oil facility, and of a wood pellet facility.

Input–Output Modeling

Impacts based on input–output analysis are characterized as direct, indirect, and induced effects. While the technical coefficients inherent in the input–output model specify the direct effects, power series approximations of the Leontief inverse matrix provide an estimation of total effects of change in demand (Miller and Blair 1985, Karkacier and Goktolga 2005). In this model, changes in outputs due to changes in final demand are characterized in the form of direct, indirect, and induced impacts (Miller and Blair 1985, Karkacier and Goktolga 2005, Perez-Verdin et al. 2008).

While direct impacts explain the immediate changes in the production of an economic activity, indirect impacts report on the cumulated impacts attributed to interindustry spending in an economy of interest (Miller and Blair 1985, Perez-Verdin et al. 2008). Finally, ripple impacts in different sectors of an economy, due to changes in household spending patterns, are called induced impacts (Miller and Blair 1985, Perez-Verdin et al. 2008).

The Impact Analysis for Planning (IMPLAN) model, based on input–output analysis, has national matrices and estimates for activities including final demand, payments, and outputs (Minnesota IMPLAN Group [MIG] 2000). The IMPLAN database, which currently includes 440 sectors, is developed annually using data from the US Census Bureau (MIG 2000). IMPLAN separates out total impacts into direct, indirect, and induced impacts (MIG 2000). Similarly, flexibility in deflating or inflating model results with time and data customization abilities are some of the other benefits of using IMPLAN (MIG 2000).

Methods

Methods used to analyze direct, indirect, and induced economic impacts of establishing new wood-based bioenergy industries in Mississippi largely followed the existing literature on economic impact analysis of wood-based bioenergy industries (Gan and Smith 2007, Perez-Verdin et al. 2008). Requisite cost information pertaining to wood pellets, bio-oil, and the methanol-based gasoline industry was obtained from secondary sources. The input–output model of the Mississippi economy was developed using the IMPLAN 2010 data set.

The North American wood pellet industry generally relies on primary wood processing facilities for biomass feedstock, and annual plant capacity of the firms varies from 30,000 to 100,000 tonnes (Spelter and Toth 2009, Pirraglia et al. 2010). Therefore, to account for a realistic industry situation in the United States, a wood pellet firm having a 75,000 tonnes[1] per year processing plant was considered for analysis. Information pertaining to construction and operational costs of a wood pellet plant was obtained from recently published literature on the techno-economic analysis of emerging wood pellet markets in the United States (Pirraglia et al. 2010). Pirraglia et al. reported that the total construction and installation cost of a 75,000 tonnes per year plant was approximately US$12.25 million with an additional US$6.5 million to operate the facility annually. Detailed information on construction and operational costs of a wood pellet industrial plant is reported in Table 1. Pirraglia et al. (2010) made a cost comparison between a wood pellet facility producing 75,000 tonnes per year and one producing 125,000 tonnes per year. The authors noted that the per unit selling price of wood pellets was lower for a plant having an annual production capacity of 125,000 tonnes per year. Construction and operation costs reported by Pirraglia et al. (2010) were modified to bridge them in the IMPLAN model and were used to account for an economic impact of a wood pellet facility with 125,000 tonnes per year production capacity. As a note, despite larger facilities having smaller wood pellet production costs (Pirraglia et al. 2010), the majority of the existing wood pellet firms in the United States are smaller in size (Lu and Rice 2011).

Despite its US commercial production, market and technologies available for bio-oil production are currently in a state of infancy (Ringer et al. 2006). Perhaps, given this situation, the capital and operation-related costs of bio-oil plants reported in the literature have been highly variable. For instance, Sarkar and Kumar (2010) reported that total capital costs incurred for the establishment of a bio-oil facility with a capacity of processing 500 dry tonnes of biomass per day was about US$58 million. Ringer et al. (2006) estimated total capital costs of US$48.29 million for the establishment of a 550 dry tonnes per day bio-oil facility. Similar variations were reported in midsize bio-oil facilities. Badger et al. (2011) reported a total investment need of US$6.03 million for establishment of a 90.71 dry tonnes per day facility. In contrast, a report submitted by Short Elliott Hendrickson (SEH 2009) to the Bios Forte Band of Chippewa provided a business plan with detailed construction and operating costs needed for establishment of small to midsize bio-oil facilities. Total investment needed for establishment of a 90.71 dry tonnes per day facility was estimated at about US$19 million. The report revealed that a bio-oil facility having a plant capacity of 181.44 dry tonnes per day (66,224.5 dry tonnes/y) of feedstock input seemed to be the most economically feasible for long-run operations. Total construction cost of such bio-oil facilities was estimated to be US$29.22 million. Likewise, total operating costs of bio-oil facilities, assuming delivered feedstock costs at US$33.06 per green tonne, was US$10.46 million. SEH (2009) provided the most explicit cost information on the total construction and annual operating costs associated with a bio-oil plant with a biomass feedstock input of 181.44 dry tonnes per day. Therefore, this data was used to develop the IMPLAN model used in the current analysis. A detailed breakdown of construction and operational costs of a 181.44 dry tonnes per day bio-oil facility is reported in Table 2. Similarly, a bio-oil facility having a plant capacity of 90.71 dry tonnes per day (33,112.25 dry tonnes/y) was also considered for an economic impact analysis. Similar to a wood pellet facility, the production cost of bio-oil decreases with increase in capacity of a processing facility (Sarkar and Kumar 2010).

Table 1.—Modified operation and capital costs (2008 US$) for a bio-oil manufacturing facility in Mississippi reported by Short Elliott Hendrickson (2009).

IMPLAN sector[a]	Cost category/industry	Million US$/y
Capital costs		
36	Site development	0.59
389	Utility connection	0.12
207	Drying equipment	0.59
218	Grinding equipment	0.82
189	Fast pyrolysis system	11.73
189	Storage tank system	1.16
335	Truck loading/unloading	0.35
387	Fire suppression system	0.12
205	Front-end loader	2.35
37	Storage	3.28
34	Office construction	0.35
369	Engineering design	4.30
Other	Licensing fee	3.52
Total capital costs		29.29
Operation costs		
15	Biomass cost	3.94
19	Biomass grinding cost	0.66
31	Electricity cost	0.99
121	Nitrogen and chemical	0.80
260	Propane	0.05
380	Miscellaneous supplies and service	0.24
417	Equipment maintenance	2.00
384	Administration cost	0.50
Employee compensation	Labor cost	1.30
Total operation costs		10.46

[a] IMPLAN = Impact Analysis for Planning.

The third category considered for economic impact analysis was a methanol-based gasoline facility. The National Renewable Energy Laboratory has conducted an assessment of producing gasoline from methanol by way of a thermo-chemical process (Philips et al. 2011). This facility requires 2,000.34 dry tonnes of biomass per day (730,000 dry tonnes/y), which by the process of gasification is converted into methanol via a syngas route. Finally, gasoline is produced from methanol through the MTG process. Total estimated construction and annual operating costs of this facility were US$199 million and US$84 million, respectively (Table 3).

Of note, any economic impact analysis of new construction activity requires a critical examination on how to proceed. The literature regarding methods used for conducting an economic impact analysis of construction activity has varied. For instance, Perez-Verdin et al. (2008) annualized the construction cost impacts using a capital recovery factor and accounted for construction-related economic impacts for an economic lifetime of a

[1] Information available in US tons are converted into tonnes (SI unit) by a conversion factor of 1 tonne = 1.102311 tons.

Table 2.—Modified operation and capital costs (2007 US$) for a 75,000 dry tonnes per year wood pellet manufacturing facility in the United States based on a techno-economic analysis study by Pirraglia et al. (2010).

IMPLAN sector[a]	Cost category/industry	Million US$/y
Capital costs		
188	Pellet cooler	0.41
205	Front-end loader	0.31
205	Hammer mill	0.15
205	Paving, receiving station, load area	0.08
206	Pellet mills	1.46
206	Pellet shaker	0.04
220	Feed hopper	0.18
228	Conveyors and misc. equipment	0.31
228	Fork lift	0.06
228	Dryer, burner, and air system	0.95
319	Live bottom bin	3.10
215	Boiler	0.60
319	Bagging bin	0.01
319	Bagging system	0.10
36	Building and office space	1.39
36	Site and site preparation	0.21
36	Storage warehouse	0.11
Employee compensation	Labor cost	2.77
Total construction costs		12.25
Operation costs		
84	Consumables	2.32
228	Additional costs	0.50
15	Biomass cost	4.05
31	Electricity cost	2.70
Employee compensation	Labor	3.76
Tax	Tax	0.52
Total operation costs		13.85

[a] IMPLAN = Impact Analysis for Planning.

Table 3.—Modified operation and capital costs (2007 US$) for a methanol-based gasoline manufacturing facility based on a techno-economic analysis study by Philips et al. (2011).

IMPLAN sector[a]	Cost category/industry	Million US$/y
Capital costs		
207	Feed handling and drying	25.51
121	Gasification	14.90
127	Tar reforming, quench, and compression	27.96
319	Acid gas and sulfur removal	12.35
227	Alcohol synthesis-compression	10.61
319	Alcohol degassing	4.90
319	Methanol to gasoline process	22.04
267	Steam system and power generation	23.57
216	Cooling water and other utilities	6.02
369	Construction	19.95
367	Legal and contractor fees	13.84
369	Engineering	17.91
Total construction costs		199.60
Operation costs		
15	Feedstock	39.10
126	Catalysts	0.20
26	Olivine	0.50
319	Other raw material cost	0.60
390	Waste disposal	0.60
E.C.	A. Labor cost and overhead	6.98
388	B. Maintenance	3.99
359	C. Insurance and taxes	3.99
V.A.	Average income tax	7.20
Proprietor income	Average return on investment	20.90
Total operation costs		84.06

[a] IMPLAN = Impact Analysis for Planning; E.C. = employee compensation; V.A. = value added .

biofuel facility. On the other hand, Grover (2009) estimated the economic impacts of ocean wave energy assuming that all the construction work would be completed in a year. In contrast, Bailey et al. (2011) argued that economic impacts associated with construction of a bioenergy facility were to be estimated separately outside the framework of an input–output model.

Recent updates in the literature on IMPLAN modeling literature revealed that impacts of short-term and temporary construction activity should be isolated from operation- and management-related activities, which are continuous and long run in nature (Day 2012). The rationale is that IMPLAN, being a snapshot model of an economy, cannot estimate economic impacts over a long time span (Day 2012). In our case, whereas wood pellet and bio-oil facilities were expected to be constructed within a year, secondary literature revealed that the construction activity of a methanol-based gasoline plant would need 2.5 years to complete (Philips et al. 2011). Therefore, the best approach in this case, following Day (2012), would be an independent examination of economic activities on a yearly basis for the entire construction duration. This approach best adheres with the IMPLAN model assumptions, which require no supply restrictions, similar production costs, and constant technology within an industry (Miller and Blair 1985) and analyzes the construction impacts as a ‘‘snapshot’’ of the economy.

Given that there were several methods being used or suggested for an economic impact analysis of construction activity (Perez-Verdin et al. 2008, Grover 2009, Day 2012), we were interested in examining whether these methodological differences would have an effect on this study's IMPLAN results. Therefore, the impacts of construction activities on a methanol-based gasoline facility, without a year-wise breakdown, were also estimated in the IMPLAN model. Such a comparison, however, was possible only for the methanol-based gasoline facility because construction of the other two facilities was assumed to be completed within a year.

Overall economic impacts of all three facility types and their contributions to the Mississippi gross regional product (GRP) were also estimated. A wood pellet facility having an annual production capacity of 75,000 tonnes, a bio-oil facility having an annual production capacity of 66,224.5 dry tonnes, and a methanol facility having an annual capacity of 730,000 dry tonnes were considered for this analysis. Because a wood pellet facility primarily relies on mill residues (Spelter and Toth 2009), total available volumes of mill residues reported by Joshi (2013) were used for extrapolation concerning economic impacts of wood pellet facilities. Of note, Grebner et al. (2009) reported that approximately 3.6 million dry tonnes of woody biomass is available for additional use in the state of Mississippi. While 3 percent of the available woody biomass was contributed by mill residues, 97 percent was obtained from other sources including logging residues, thinning residues, small diameter trees, and urban wood waste (Grebner et al. 2009). Available woody biomass sources reported by Grebner et al. (2009), net mill residues, were used for simulating overall economic impacts associated with bio-oil and methanol facilities in Mississippi. Information available in the IMPLAN 2010 database was used for these estimates.

Results

IMPLAN results related to economic impacts of bioenergy industries in Mississippi are reported in Tables 4, 5, and 6. As suggested in the literature (Grover 2009, Day 2012), construction- and operation-related activities were separately simulated for economic impact analysis. Construction-related activities in the wood pellet facility would create 15 full- and part-time jobs and generate US$2.34 million of gross output directly. These construction activities would create an additional 32 full- and part-time jobs due to the indirect and induced impacts. The industries benefiting the most from construction activities included wholesale trade businesses (12), construction of other new nonresidential structures (4), and food services (3), among others. Total value added, obtained as a sum of employee compensation, proprietor income, and other taxes, was US$2.94 million. The social accounting matrix (SAM) multiplier, which is the total impacts (i.e., direct, indirect, induced) divided by direct impacts, indicated that unit dollar worth of stimulus in wood pellet construction-related activities resulted in an additional US$2.09 of value-added economic return. Of note, construction-related economic impacts would be short term and would not persist after the completion of the construction period. Similarly, operation- and management-related activities in the wood pellet facility were expected to contribute US$12.37 million in economic output in Mississippi, including US$3.74 million in wages and 83 full- and part-time jobs. Of the total output, the value-added component had US$8.45 million or 68 percent share. In terms of employment, the industries that benefited the most from the operation of a wood pellet plant were support activities for forestry or timber production (16); forestry, forest product, and timber production (9); food services and drinking places (6); and electric power generation (5). As a note, the economic impacts of a wood pellet facility producing 125,000 dry tonnes per year were markedly larger. Table 4 shows the economic impacts of construction and operation of both wood pellet facilities in Mississippi.

The economic impacts of constructing a bio-oil facility having a production capacity of 66,224.5 dry tonnes per year are greater than a wood pellet facility having an annual production capacity of 75,000 dry tonnes (Table 5). The construction-related activity of such a bio-oil facility was estimated to create 122 new full- and part-time jobs and US$15.50 million of economic output. Of these, 67 new full- and part-time jobs and US$9.71 million of economic output came from direct economic impacts in Mississippi. The SAM multiplier of the economic output of construction-related activity for a bio-oil facility was 1.60, indicating that for every dollar spent in construction of a bio-oil facility, there was an additional economic return of US$0.60 in Mississippi, after taking out-of-state leakages into account. Total estimated value-added economic impacts were US$7.38 million, of which US$4.09 million was direct effects. Based on output, the most positively affected sectors by the construction of a bio-oil facility were architectural, engineering, and related activities (25); construction of new

Table 4.—Economic impacts of wood pellet facilities having annual production capacities of 75,000 dry tonnes per year and 125,000 dry tonnes per year in Mississippi based on the Impact Analysis for Planning (IMPLAN) 2010 database.

Activity	Direct	Indirect	Induced	Total	Type SAM[a]
Economic impact of 75,000 dry tonnes per year facility					
Construction					
Employment	15.3	5.4	26.8	47.4	3.09
Labor income (M$)[b]	0.70	0.24	0.89	1.83	2.61
Total value added (M$)	0.95	0.34	1.65	2.94	3.09
Output (M$)	2.34	0.65	2.75	5.75	2.45
Operation					
Employment	19.1	20.2	43.4	82.7	4.32
Labor income (M$)	1.63	0.66	1.44	3.74	2.29
Total value added (M$)	4.99	0.78	2.66	8.45	1.69
Output (M$)	6.64	1.27	4.46	12.37	1.86
Economic impact of 125,000 dry tonnes per year facility					
Construction					
Employment	44.9	11.5	50.4	106.8	2.37
Labor income (M$)	2.20	0.49	1.68	4.38	1.99
Total value added (M$)	3.39	0.73	3.09	7.22	2.13
Output (M$)	5.90	1.34	5.19	12.43	2.10
Operation					
Employment	47.6	34.6	59.2	141.4	2.97
Labor income (M$)	3.48	1.15	1.98	6.60	1.89
Total value added (M$)	8.81	1.36	3.64	13.81	1.56
Output (M$)	12.59	2.23	6.10	20.91	1.66

[a] SAM = social accounting matrix.
[b] M$ = millions of US dollars.

Table 5.—Economic impacts of two bio-oil facilities having annual production capacities of 66,224.5 dry tonnes and 33,112.25 dry tonnes in Mississippi based on Impact Analysis for Planning (IMPLAN) 2010 database.

Activity	Direct	Indirect	Induced	Total	Type SAM[a]
Economic impacts of 66,224.5 dry tonnes per year bio-oil facility					
Construction					
Employment	67.04	25.52	29.78	122.34	1.82
Labor income (M$)[b]	3.39	0.97	0.99	5.35	1.58
Total value added (M$)	4.09	1.46	1.83	7.38	1.81
Output (M$)	9.71	2.73	3.06	15.50	1.60
Operation					
Employment	53.3	23.8	35.4	112.5	22.11
Labor income (M$)	3.07	0.80	1.18	5.05	1.65
Total value added (M$)	55.51	1.02	2.18	8.75	1.59
Output (M$)	7.92	1.72	3.64	13.27	1.68
Economic impacts of 33,112.25 dry tonnes per year bio-oil facility					
Construction					
Employment	53.3	17.5	21.8	92.6	1.74
Labor income (M$)	2.53	0.66	0.73	3.92	1.55
Total value added (M$)	2.98	0.99	1.34	5.32	1.79
Output (M$)	6.74	1.85	2.24	10.83	1.61
Operation					
Employment	33.2	12.8	21.9	67.9	2.05
Labor income (M$)	1.80	0.43	0.73	2.97	1.65
Total value added (M$)	3.01	0.56	1.35	4.91	1.63
Output (M$)	4.57	0.95	2.25	7.76	1.70

[a] SAM = social accounting matrix.
[b] M$ = millions of US dollars.

Table 6.—Economic impacts of a methanol-based gasoline facility having an annual production capacity of 730,000 dry tonnes in Mississippi based on Impact Analysis for Planning (IMPLAN) 2010 database.

Activity	Direct	Indirect	Induced	Total	Type SAM[a]
1st year of construction					
Employment	67	9	32	107	1.60
Labor income (M$)[b]	4.33	0.26	1.05	5.64	1.30
Total value added (M$)	6.58	0.48	1.94	9.00	1.37
Output (M$)	8.36	0.80	3.24	12.40	1.48
2nd year of construction					
Employment	448.50	126.45	188.57	763.52	1.70
Labor income (M$)	22.21	5.44	6.28	33.94	1.53
Total value added (M$)	32.12	8.52	11.59	52.23	1.63
Output (M$)	61.49	15.67	19.38	96.54	1.57
3rd year of construction					
Employment	157.1	44.04	73.41	274.57	1.75
Labor income (M$)	9.24	1.48	2.44	13.16	1.42
Total value added (M$)	9.69	2.29	4.51	16.49	1.70
Output (M$)	17.89	4.01	7.54	29.44	1.65
Operation					
Employment	243.41	205.28	346.31	795.00	3.27
Labor income (M$)	12.94	6.65	11.48	31.07	2.40
Total value added (M$)	29.69	7.93	21.28	58.90	1.98
Output (M$)	47.48	13.44	35.48	96.40	2.03

[a] SAM = social accounting matrix.
[b] M$ = millions of US dollars.

nonresidential structures (20); and metal tank manufacturing (11). Similarly, operation-related expenses in the bio-oil facility, which were simulated separately for impact analysis, were estimated to create a total of 112 new full- and part-time employment opportunities and US$13.27 million of economic output in Mississippi. The SAM output multiplier for a bio-oil facility operation was 1.68 and its total value-added contribution was US$8.75 million. Sectors most affected by the operation of a bio-oil facility were support activities for forestry and related activities (30); commercial machinery repair and maintenance (21); and forestry, forest product, and timber tract (9). As a note, economic impacts of a bio-oil facility having 33,112.25 dry tonnes per year, reported in Table 5, were markedly smaller.

Economic impacts associated with the construction and operations of a methanol-based gasoline facility are reported in Table 6. Since construction activity was assumed to be completed in 2.5 years, each year's construction impacts were estimated separately, following Day (2012). The construction of this facility was estimated to create 107 full- and part-time jobs and US$12.40 million of economic output in the first year. There would be 763 new full- and part-time jobs and US$96.54 million of economic output in the second year. Finally, a total of 275 new full- and part-time construction-related jobs would be created in the final year of construction. Similarly, the annual operation of a methanol-based gasoline facility supported 243 direct full- and part-time jobs and US$47.48 million of economic contributions in Mississippi. In total, the operation would contribute an economic value of US$96 million and 795 full- and part-time jobs, annually. The SAM employment multiplier for methanol-based gasoline operations was 3.27, indicating a strong ripple effect in this facility. The largest sector impacted was forestry support activities (131), with the next two largest sectors being forestry and forest products (87) and building and dwelling services (82).

Results contrasted widely, in terms of jobs, value added, and economic output, when economic impacts were analyzed using the different methods described earlier. For instance, total number of employment opportunities generated through the construction of a methanol-based gasoline plant, when construction activity was assumed to be completed in a year, were higher than the sum of all construction activities when they were examined as annual expenditures during the entire construction phase of 2.5 years (Tables 7 and 8). Available mill residues would be sufficient for establishing 37 hypothesized wood pellet facilities having an annual production capacity of 75,000 dry tonnes, should the entire potentially available mill residues be used for generating wood pellets within the state. The wood pellet industry, in such a case, would generate 3,129 full- and part-time jobs with US$457 million of economic output in Mississippi. Likewise, 60 percent use of the potentially available mill residues in wood pellet facilities would generate 1,877 full- and part-time jobs with US$274 million of economic output in Mississippi (Table 9). It is worth noting that we could not segregate how many of these job types were full time or part time, which is one limitation of this IMPLAN-based study.

Utilizing all potentially available woody biomass reported by Grebner et al. (2009), except mill residues, would be sufficient to establish 53 bio-oil facilities with a capacity of 66,224.5 dry tonnes per year or four methanol facilities having a capacity of 730,000 dry tonnes per year. Given that both facility types are likely to compete for the same source of biomass feedstock (SEH 2009, Philips et al. 2011), total economic impacts in the Mississippi economy, similar to that suggested by Perez-Verdin et al. (2008), would depend upon the proportion of available woody biomass for an individual facility type. For example, 100 percent distribution of available woody biomass for bio-oil facilities would generate 5,932 full- and part-time jobs with US$700 million of economic output. Likewise, 40 percent distribution of available biomass in bio-oil facilities and the remaining 60 percent used in methanol facilities would generate 4,654 full- and part-time jobs with US$557 million of economic output (Table 10). Results indicated that three facility types would roughly contribute 1.27 percent of the Mississippi GRP, should all the potentially available biomass be used for generating bioenergy (Tables 9 and 10). Of note, even with a 60 percent use of potentially available biomass, combined economic impacts of three facility types, in terms of total economic output, would be slightly lower than 1 percent of the Mississippi GRP.

Discussion

These results provide an estimate of the economic impacts of some selected wood-based bioenergy facilities in Mississippi. These impacts depict the prospect of wood-based bioenergy industries in Mississippi, and they are not trivial. IMPLAN results from this study are comparable to other employment-related information available in the region. For instance, Pirraglia et al. (2010) revealed that operation of a typical wood pellet facility would create 30

Table 7.—Variations in economic impacts of a methanol-based gasoline facility in Mississippi based on the assumption of 1-year construction impact using Impact Analysis for Planning (IMPLAN) 2010 database.

Construction	Economic impacts			Total	Type SAM[a]
	Direct	Indirect	Induced		
Employment	885.65	243.32	392.76	1,521.73	1.72
Labor income (M$)[b]	47.63	9.90	13.08	70.61	1.48
Total value added(M$)	65.64	15.53	24.15	105.31	1.60
Output (M$)	129.68	28.53	40.36	198.57	1.53

[a] SAM = social accounting matrix.
[b] M$ = millions of US dollars.

Table 8.—Economic impacts of all three industries on Mississippi economy based on per unit tonne of biomass use by using Impact Analysis for Planning (IMPLAN) 2010 database.

Industry	Total (M$)[a]	Per unit (US$)
Wood pellet	12.37	164.93
Bio-oil	13.27	200.38
Methanol	96.4	132.03

[a] M$ = millions of US dollars.

Table 9.—Simulated economic impact of 75,000 dry tonnes per year wood pellet facilities on overall Mississippi economy based on contributions to growth regional product (GRP) by using Impact Analysis for Planning (IMPLAN) 2010 database.

Biomass use (%)	No. of facilities	Employment	Output (M$)[a]	Contribution to GRP (%)
100	37.83	3,129	456.99	0.50
80	30.27	2,503	365.60	0.40
60	22.70	1,877	274.20	0.30
40	15.13	1,251	182.80	0.20
20	7.57	626	91.40	0.10
0	0.00	0.00	0.00	0.00

[a] M$ = millions of US dollars.

Table 10.—Simulated economic impacts of 66,224.5 dry tonnes per year bio-oil and 730,000 dry tonnes per year methanol facilities on overall Mississippi economy based on their contributions to growth regional product (GRP) by using Impact Analysis for Planning (IMPLAN) 2010 database.

Biomass use distribution (%)		No. of potential facilities		Total employment		Total output (M$)[a]		Combined contribution to GRP (%)	
Bio-oil	Methanol	Bio-oil	Methanol	Bio-oil	Methanol	Bio-oil	Methanol	Employment	Output
100	0	52.73	0.00	5,932	0	699.93	0.00	0.40	0.77
80	20	42.18	0.96	4,746	760	559.94	92.21	0.32	0.72
60	40	31.64	1.91	3,559	1,521	419.96	184.43	0.24	0.66
40	60	21.09	2.87	2,373	2,281	279.97	276.64	0.16	0.61
20	80	10.55	3.83	1,186	3,042	139.99	368.86	0.08	0.56
0	100	0.00	4.78	0	3,802	0.00	461.07	0.00	0.51

[a] M$ = millions of US dollars.

new jobs in the United States, and Lu and Rice (2011) reported that the total number of jobs created by a majority (66%) of US wood pellet mills were below 20 employees. Similarly, Dunlap (2010) presented that Piney Wood-Pellets, a 52,000 tons per year facility located in Wiggins, Mississippi, has direct economic impacts of about US$6.8 million in the Mississippi economy and generates 26 employment opportunities in the local economy. Given that wood pellet facilities are largely automated and are less labor intensive (Lu and Rice 2011), our direct and total employment impacts based on the IMPLAN model were generally comparable to these estimates (Dunlap 2010, Pirraglia et al. 2010, Lu and Rice 2011) and make intuitive sense.

The small economic impacts derived from wood pellet and bio-oil industries are attributed to the small size of their production facilities. Generally, because comparatively small construction and operation costs are needed for establishing such facilities, relatively small economic impacts are generated compared with investment-intensive methanol-based gasoline facilities. However, it is possible that these facilities could be created in greater numbers and actually exceed the economic impacts of a large facility, which may be harder to duplicate. Evidently, the large employment multiplier for a wood pellet facility indicates that this industry, which is already in operation in Mississippi, is likely to have significant impacts on the economic trajectory of Mississippi. IES (2008) indicated that establishing one pellet mill with a production capacity of 63,503 dry tonnes could replace the 5 percent of annual fuel requirements in a 250-MW electricity generating plant. Following the logic forwarded by Grado et al. (2011) in their waterfowl hunting study, localized production/utilization and an established market within Mississippi might have been the reasons behind a higher multiplier effect and lower dollar outflows in the case of a wood pellet facility.

Pirraglia et al. (2010) suggested that a wood pellet facility in the United States having an annual wood pellet production capacity of 75,000 dry tonnes becomes profitable if the price of wood pellets is higher than US$221 per tonne. Based on the average estimates of prices for wood pellets in the United States, it can be a profitable business (Bourque 2012). Similar to the wood pellet facility, a medium-sized bio-oil facility would not require large amounts of biomass feedstock. Because a wood pellet firm mostly relies on feedstocks from primary wood processing facilities, competition for biomass feedstock between the wood pellet industry and the bio-oil industry will likely be minimal in the short run. The bio-oil industry is still improving in terms of technical efficiency; it will become a more resource-efficient industry in the future. Bio-oil is an important chemical product that has multiple uses (Badger et al. 2011). Bio-oil and char are important ingredients in producing industrial natural gas, propane, and other fuel oils (Badger et al. 2011). Therefore, establishing this industry would also contribute to other industries in the region as well.

Among all industry types, the methanol-based gasoline plant, which requires 2,000 tonnes of biomass to operate on a daily basis, had the highest impact on the economy of Mississippi. Given that the investment required to build a methanol-based gasoline facility was the greatest of the three types of facilities considered, having markedly higher impacts makes intuitive sense. In addition, the unit cost incurred for gasoline and liquefied petroleum gas produced from state-of-the-art gasoline via methanol technology is relatively cost competitive with other fuels (Philips et al. 2011). However, given its higher input requirements, the methanol-based gasoline industry might have to compete with other bioenergy and/or conventional forest product industries for feedstocks. Similarly, while a methanol-based gasoline facility had the highest multiplier effects in terms of economic output, its economic impact based on per tonne biomass use was the least among all three industries (Table 8). In other words, a methanol-based gasoline facility, all else being equal, would use the greatest volumes of woody biomass for the same amount of economic output in the state economy.

Of note, because the construction period of a methanol-based gasoline plant is assumed to be 2.5 years, economic impacts will be spread out across that period. Recent IMPLAN manual updates have explicitly suggested the need for an annual examination of construction impacts and oversimplified assumptions, if any, related to construction impacts of an industry should be avoided. Oversimplified assumptions, as we have seen in Tables 6 and 7, might inflate or at least provide unrealistic information related to the economic impact of an industry.

While economic impacts of the three facility types are impressive, all these facility types and the overall bioenergy industry sector itself need to overcome some challenges. For example, bioenergy still has an incipient market (Guo et al. 2007), and volatility in market demand has been identified as one of the impediments for development of wood pellet facilities in the United States (Lu and Rice 2011). For instance, the demand for wood pellets relies on fossil fuel prices (Lu and Rice 2011), which have fluctuated in the United States in last few years. Other generally agreed concerns are the larger capital costs, the differences in quality standards between the United States and Europe, and the availability of biomass for bioenergy feedstock use among others (SEH 2009, Dunlap 2010, Lu and Rice 2011).

Conclusions

Given Mississippi's large forest resource base, it has potential for establishing and supporting a wood-based bioenergy industry. This study examined the economic impacts of some potential wood-based bioenergy facilities in the state. The wood pellet industry, which is already in operation in Mississippi, has contributed to the economy by creating a significant number of jobs in the region. While construction-related jobs are temporary and short term, operations related to wood pellet industries provide permanent job opportunities in the state. There is also the possibility that construction may crop up again in the future through renovation projects and plant expansions. The bio-oil and methanol-based gasoline industries, however, have yet to be established in the state. As our study results reveal, the establishment of a bio-oil industry would contribute to the state economy by providing markets for logging residue and by creating jobs for Mississippians and any state in which it is feasible for them to operate.

A new methanol-based gasoline industry would help contribute to the economy by creating the highest number of job opportunities among all three bioenergy industries considered in this economic analysis. However, because this industry would require a significant volume of woody biomass as a feedstock, it might have to compete with other bioenergy or forest product industries for raw materials in the long run. Likewise, excessive use of woody biomass can have a negative impact on wildlife and environment. Therefore, financial burdens in minimizing environmental hurdles, given excessive uses of woody biomass in these industries, also need to be examined.

This study is not free from limitations. Despite our efforts, information on operation- and construction-related costs could not be obtained from local facilities. Therefore, this economic impact analysis study relied on secondary data. Likewise, some adjustments or mathematical extrapolations were needed in construction and operational costs because available information was not sufficient enough for cost bridging with appropriate IMPLAN sector numbers. Similarly, the economic impact analysis could not be expanded for the entire southern region due to the higher cost of IMPLAN data. Results from this study, however, are applicable in other southern states because biomass availability and construction and operation costs of facility types would be similar within this region. Nevertheless, these establishments would not only create jobs and other economic opportunities, but the state would also contribute to the goal of making the United States an energy-independent nation.

Acknowledgments

The authors would like to thank the Mississippi State University Sustainable Energy Research Center, USDA CSREES Wood Utilization Research Special Grant, and Forest and Wildlife Research Center at Mississippi State University for funding this project.

Literature Cited

Badger, P., S. Badger, M. Puettmann, P. Steele, and J. Cooper. 2011. Techno-economic analysis: Preliminary assessment of pyrolysis oil production costs and material energy balance associated with a transportable fast pyrolysis system. *Bioresources* 6(1):34–47.

Badger, P. C. and P. Fransham. 2006. Use of mobile fast pyrolysis plants to densify biomass and reduce biomass hauling costs—A preliminary assessment. *Biomass Bioenergy* 30:321–325.

Bailey, C., J. F. Dyer, and L. Teeter. 2011. Assessing the rural development potential of lignocellulosic biofuels in Alabama. *Biomass Bioenergy* 35(4):1408–1417.

Bourque, A. 2012. Wood pellet basics. Media kit 2012. http://www.woodpellets.com/downloads/WoodPellets.com-MediaKit_Basics2012.pdf. Accessed November 28, 2012.

Coblentz, B. 2010. Wood pellet production has potential for state. Mississippi State University Extension Service news. http://msucares.com/news/print/fwnews/fw10. Accessed November 18, 2012.

Cox, B. M. and I. A. Munn. 2001. A comparison of two input-output based approaches for investigating regional economic impacts of the forest products industry in the PNW and South. *Forest Prod. J.* 51(6):39–46.

Day, F. 2012. Principles of impact analysis and IMPLAN applications. MIG Group, Stillwater, Minnesota. 338 pp.

Demirbas, A. 2008. Biomethanol production from organic waste materials. *Energy Sources Part A* 30(6):565–572.

Dunlap, T. 2010. Wood pellets: Mississippi, renewable energy and the economy. Presented at the 9th Annual Southern Bioproducts and Renewable Energy Conference. http://www.ms-biomass.org/conference/2010/presentations/dunlap.pdf. Accessed February 28, 2013.

Energy Information Administration (EIA). 2012. Official energy statistics from the U.S. government. http://www.eia.doe.gov. Accessed March 3, 2012.

Faaji, A., B. Meuleman, W. Turkenburg, A. Wijk, A. Bauen, F. Rosillo-Calle, and D. Hall. 1998. Externalities of biomass based electricity production compared with power generation from coal in the Netherlands. *Biomass Bioenergy* 14(2):125–147.

Gan, J. and T. Smith. 2007. Co-benefits of utilizing logging residues for bioenergy production: The case for East Texas, USA. *Biomass Bioenergy* 31(9):623–630.

Grado, S. C., K. M. Hunt, C. P. Hutt, X. T. Santos, and R. M. Kaminski. 2011. Economic impacts of waterfowl hunting in Mississippi derived from a state-based mail survey. *Hum. Dimen. Wildl.* 16:100–113.

Grebner, D. L., G. Perez-Verdin, C. Sun, I. A. Munn, E. B. Schultz, and T. G. Matney. 2009. Woody biomass feedstock availability, production costs and implications for bioenergy conversion in Mississippi, chap. 12. *In:* Renewable Energy from Forest Resources in the United States. B. Solomon and V. A. Luzadis (Eds.). Routledge, London. 330 pp.

Grover, S. 2009. Economic impacts of wave energy to Oregon's economy. A report to Oregon Wave Energy Trust. ECONorthwest, Portland, Oregon. 37 pp.

Guo, Z., S. Sun, and D. L. Grebner. 2007. Utilization of forest derived biomass for energy production in the U.S.A.: Status, challenges and public policies. *Int. Forestry Rev.* 9(3):748–758.

Henderson, J. E., J. B. Auel, and I. A. Munn. 2011. Logging is important to the Mississippi economy. Research Note. Forest and Wildlife Research Center, Mississippi State University. 2 pp.

Henderson, J. E., I. A. Munn, G. Perez-Verdin, and D. L. Grebner. 2008. Forestry in Mississippi: The impact of the forest products industry on the post-Katrina Mississippi economy—An input-output analysis. Research Bulletin FO374. Forest and Wildlife Research Center, Mississippi State University. 31 pp.

Hodges, A. W., T. J. Stevens, and M. Rahmani. 2010. Economic impacts of extended woody biomass utilization on the bioenergy and forest products industries in Florida. Research Report. Florida Department of Agriculture and Consumer Services, Tallahassee. 36 pp. http://https://www.gru.com/Pdf/futurePower/TestimonialsExhibits/Schroeder/RMS-7%20Div%20of%20Forestry%202-23-10.pdf. Accessed May 15, 2013.

Indeck Energy Services (IES). 2008. Mississippi wood pellets. Clean renewable energy for generations. Mississippi Wood Pellet Primer. http://www.indeckenergy.com/biofuels.php. Accessed October 11, 2012.

Joshi, O. 2013. Opportunities, issues and economic potential of wood based bioenergy in Mississippi. PhD dissertation. Mississippi State University, Starkville. 118 pp.

Karkacier, O. and Z. G. Goktolga. 2005. Input-output analysis of energy use in agriculture. *Energy Convers. Manag*. 46:1513–1521.

Lu, N. and R. W. Rice. 2011. Characteristics of wood manufactures and markets in the United States, 2010. *Forest Prod. J*. 61(4):310–315.

Miller, R. E. and P. D. Blair. 1985. Input-Output Analysis Foundations and Extensions. Prentice-Hall, Englewood Cliffs, New Jersey. 464 pp.

Minnesota IMPLAN Group (MIG). 2000. IMPLAN Professional Version 2.0 User's Guide, Analysis Guide, Data Guide, 3rd ed. MIG, Stillwater, Minnesota.

Munn, I. A. and J. E. Henderson. 2003. Forestry in Mississippi: The impact of the forest products industry on the Mississippi economy: An input-output analysis. Research Bulletin FO 216. Forest and Wildlife Research Center, Mississippi State University. 22 pp.

Perez-Verdin, G., D. L. Grebner, C. Sun, I. A. Munn, and S. C. Grado. 2008. Economic impact of woody biomass utilization for bioenergy in Mississippi. *Forest Prod. J*. 58(11):75–83.

Philips, S. D., J. K. Traud, M. J. Biddy, and A. Dutta. 2011. Gasoline from wood via integrated gasification, synthesis, and methanol to gasoline technology. National Renewable Energy Laboratory, Golden, Colorado. 108 pp.

Pirraglia, A., R. Gonzalez, and D. Saloni. 2010. Techno-economical analysis of wood pellets production for U.S. manufacturers. *Bioresources* 5(4):2374–2390.

Ringer, M., V. Putsche, and J. Scahil. 2006. Large scale pyrolysis oil production: A technology assessment and economic analysis. Technical Report NREL/TP-510-37779. National Renewable Energy Laboratory, Golden, Colorado. 93 pp.

Sarkar, S. and A. Kumar. 2010. Large-scale bio-hydrogen production from bio-oil. *Bioresour. Technol*. 7350–7361.

Short Elliott Hendrickson (SEH). 2009. Biofuel feasibility study. Bios Forte Band of Chippewa. SEH No. A-BOISF0702.00. Nett Lake, Minnesota. www.boisforte.com/documents/Feasibility_Study_Final-1-30-09.pdf. Accessed May 15, 2012.

Smith, W. B., P. D. Miles, J. S. Vissage, and S. A. Pugh. 2004. Forest resources of the United States, 2002. General Technical Report NC-241. USDA Forest Service, North Central Research Station, St. Paul, Minnesota. 37 pp.

Spelter, H. and D. Toth. 2009. North America's wood pellet sector. Research Paper FPL-RP-656. USDA Forest Service, Forest Products Laboratory, Madison, Wisconsin. 21 pp.

Timmons, D., D. Damery, and G. Allen. 2007. Energy from forest biomass: Potential economic impacts in Massachusetts. Research Report. Prepared for Massachusetts Division of Energy Resources and Massachusetts Department of Conservation and Recreation, Boston. 30 pp.