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Opportunities, Issues, and Economic Potential of Wood-Based Bioenergy in Mississippi

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By

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While the southeastern United States, including the state of Mississippi, has a strong natural resource base, woody biomass is not fully utilized to produce bioenergy in this region. This study intended to explore opportunities, issues, and the economic potential of wood-based bioenergy in the state of Mississippi. Realizing the importance of private forest landowner decisions in sustaining a bioenergy feedstock supply, one aim of this study was to understand their choices for preferred harvesting methods of supplying woody biomass for wood-based bioenergy industries. Study results indicated that landowners were interested in optimizing revenue from woody biomass utilization while minimizing damage to the surrounding environment and facilitating less site preparation. Similarly, by administering a survey instrument, total and unused volumes of residues in primary and secondary mill operations were also estimated. Availability of woody residue was higher in the primary wood processing industry. Similarly, the likelihood of getting feedstock would be higher if a wood-based bioenergy generating facility could be located near a larger, year round operational forest product industry. This study further accounted for the potential direct, indirect, and induced economic impacts of a state wood-based bioenergy industry. Three potential wood-based bioenergy industries namely wood-pellet, bio-oil and methanol-based gasoline facilities were considered for an economic analysis. Study results revealed that operation of a wood-pellet industry would contribute 82 full- and part-time jobs to the economy with $12 million worth of economic output to the Mississippi economy. Likewise, the operation of a bio-oil industry would generate 165 new full- and part-time jobs and provide an economic output of $17 million. Also, $96 million in economic output and 795 full- and part-time more jobs would be added by establishing a methanol-based gasoline industry. Clearly, these impacts are substantial and are likely to draw the attention of policy makers and investors towards wood-based bioenergy in Mississippi.

Key words: Choice Experiment, mill residues, woody biomass, bioenergy industry, economic analysis, landowners

DEDICATION

I would like to dedicate this work to my late father Janak Raj Joshi, who is the source of inspiration for honor, ethics, and integrity in my personal and professional life. I miss you!!!

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CHAPTER I

GENERAL INTRODUCTION

1.1 Introduction

Wood-based bioenergy, a renewable source of energy, has received attention in the United States due to its numerous socioeconomic and environmental benefits (Mayfield et al. 2007, Gan and Smith 2006, Domac et al. 2005). It can be derived from various woody sources such as logging/thinning residues, mill residues, urban and suburban waste, and perennial herbaceous crops (Guo et al. 2007, Perlack et al. 2005). Currently, agricultural and forest biomass are two major contributors as a feedstock for bioenergy in the United States (Perlack et al. 2005). However, use of agricultural inputs in bioenergy production often conflicts with national food security and environmental health (GC and Mehmood 2010, Skipper et al. 2009). Therefore, bioenergy production from forest-based biomass, comprising of logging residues, coarse and fine woody debris, and mill residues among other sources seems a viable option for reducing the United States dependence of foreign sources of energy, without compromising the existing food supply chain (Burton 2008). Perhaps realizing this fact, existing provisions in the Energy Independence and Security Act (2007) cap the production of corn-based ethanol and require 21 billion gallons of renewable fuel to be generated from cellulosic sources by 2022 in the US (Sissine 2007). Likewise, to promote the production of feedstocks for wood-based bioenergy, the biomass crop assistance program (BCAP) mandated by the

2008 Farm Bill provides various incentives to biomass producers (USDA 2012). Pu et al. (2008) indicated that approximately 30% of the total biomass to be used in bioenergy could be obtained from the forestry sector. Among these feedstock types, logging and thinning residues are obtained during commercial timber harvesting (Perez-Verdin et al. 2009, Perlack et al. 2005). Similarly, mill residues are obtained as a by-product in the primary and secondary wood processing facilities (Perlack et al. 2005).

Nonindustrial private forest (NIPF) landowners are one of the dominant landownership types in the nation (Smith et al. 2004). For instance, 55% of the forest land in the northern region, 59% in the southern region and 12% in the western region is owned by this group (Butler and Leatherberry 2004). Therefore, their decision to harvest or not to harvest is critical for any form of woody biomass supply (Gruchy et al. 2012, Joshi and Mehmood 2011). Perhaps that is the reason why NIPF landowner timber harvesting behavior, in general, was a widely documented area of forest research in the past and continues to be so in North American forestry (Joshi and Arano 2009, Kuuluvainen et al. 1996). However, feedstocks used in bioenergy are not typical forest products and landowner motivations for supplying them are likely to be different than those for conventional timber products (Joshi and Mehmood 2011). Given the growing interest in alternative energy sources including, bioenergy in the United States, studies in the recent past have analyzed issues concerning woody biomass harvesting behavior of landowners (e.g., Gruchy et al. 2012, Susaeta et al. 2012, Joshi and Mehmood 2011, GC and Mehmood 2010, Paula 2009).

Review of the literature indicated that earlier research analyzed the willingness of NIPF landowners to supply woody biomass without explicitly explaining the possible interconnection among the attributes that guide their motivations (Gruchy et al. 2012, Susaeta et al. 2012, Joshi and Mehmood 2011, GC and Mehmood 2010, Paula 2009). Also, existing literature does not explicitly acknowledge the issue of bioenergy feedstock sustainability. For instance, excessive and unsustainable harvesting of biomass could have detrimental environmental impacts such as, loss of site productivity, loss of biodiversity, and nutrient leaching among others (Perlack 2005). All of these factors would have a pronounced effect on regeneration and tree growth, not to mention wildlife and fisheries habitats. These factors, therefore, magnify the scope and need for research concerning woody biomass harvesting behavior of landowners. To address this knowledge gap, the second chapter of this dissertation explains how NIPF landowners might respond to utilizing logging residues for bioenergy, when they have to make decisions after a careful examination of the opportunities and negative aspects associated with wood-based bioenergy. A choice experiment has been designed for an empirical examination of this issue.

Another category of feedstock commonly used in bioenergy industries are mill residues obtained from primary and secondary wood processing facilities. Mill residues obtained from wood processing facilities can be utilized to generate bioenergy (Guo et al. 2007). Despite their widespread internal use in energy generation, the literature suggests that some volumes can still be available for sale (GC and Potter-Witter 2011, Indiana Department of Natural Resources 2011). Importantly, mill residues are relatively clean and more condensed than other sources of bioenergy feedstock such as logging and thinning residues (Foster et al. 2005). Therefore, transportation and refinement costs involved in utilizing mill residues to generate wood-based bioenergy are relatively lower than others (Foster et al. 2005). Out of the total mill residues, internally unused volumes include the amount of mill residues sold, given away, or disposed of by a wood processing facility. Even though mill residues are considered to be a high quality feedstock for wood-based bioenergy (Perlack et al. 2005), only a handful of literature in the past (GC and Potter-Witter 2011, Carter 2010) has analyzed issues pertaining to their use in the wood-based bioenergy industry. Realizing this information gap in the literature, the third chapter of this dissertation contains an econometric analysis pertaining to factors affecting availability of mill residues in the state of Mississippi.

Obviously, wood-based bioenergy presents a new opportunity and it certainly brings some economic prospects in Mississippi. For instance, Gan and Smith (2007) noted that electricity generated by using logging residues contributed to the regional economy in East Texas by creating 1,340 new job opportunities. Perez-Verdin et al. (2008) also analyzed the economic impacts of logging residue recovery and ethanol production in Mississippi. The authors reported that the logging and thinning residue recovery would generate 585 direct jobs, contributing 152 million dollars of gross domestic output. Similarly, logging operations would create 481 indirect jobs and 646 induced jobs in Mississippi (Perez-Verdin et al. 2008). A review of the literature indicated that economic impacts of new forms of bioenergy industries such as: wood-pellet, bio-oil, and methanol are yet to be analyzed. Therefore, the fourth chapter of this dissertation has explored the economic impacts of the wood-pellet, methanol, and bio-oil industries on the major economic sectors such as manufacturing, construction, distribution, and employment within Mississippi.

The dissertation is organized as follows. Chapter II contains the first article, entitled *"Determinants of landowner choices of preferred harvesting methods for supplying woody biomass."* Chapter III contains the second article, entitled "An analysis of utilizing unused woody biomass from wood processing facilities in Mississippi". Chapter IV contains the third article, entitled "Input-Output modeling of some wood-based bioenergy Industries in Mississippi". Finally, Chapter V summarizes the conclusions for this dissertation.

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CHAPTER II

DETERMINANTS OF LANDOWNERS' CHOICE OF PREFERRED HARVESTING METHODS FOR SUPPLYING WOODY BIOMASS[1]

2.1 Abstract

Understanding nonindustrial private forest landowner preferences for harvesting woody biomass is an important issue for feedstock sustainability of wood-based bioenergy industries. Given their diverse ownership objectives, an assessment of attributes influencing biomass harvesting activity is likely to help design a landowner's preferred timber harvesting plans. Conducting a choice experiment (CE), landowner's preferences for hypothetical timber harvesting plans and willingness to accept (WTA) for attributes that guide their harvesting behavior were analyzed. The nested logit model employed in the analysis included alternative-specific (e.g., wood biomass utilization, environmental impacts, site preparation cost savings, price per acre) and person-specific attributes (e.g., age, education, income). Landowners were interested in optimizing revenue from woody biomass utilization while minimizing damage to the surrounding environment and creating a need for less site preparation. While landowner propensity to harvest woody biomass declined with age, more formally educated landowners and those having higher annual household incomes were interested in supplying woody biomass for

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[1] Chapter II is accepted for publication in Forest Science.

wood-based bioenergy industries. Findings indicated that landowners were in favor of supplying woody biomass for wood-based bioenergy. This study results reveal a need for raising awareness and providing training to increase landowner awareness about issues related to timber harvesting, woody biomass utilization, and ecological sustainability.

Keywords. Choice experiment, nested logit, nonindustrial private forest landowners, woody biomass utilization

2.2 Introduction

About 71% of the total forest area in the southern United States is owned by nonindustrial private forest (NIPF) landowners (Smith et al. 2004), making them an important ownership type category for supplying woody biomass. Earlier research on NIPF landowners has identified them as a diverse group having management objectives that vary from timber production to wildlife management and recreation (Majumdar et al. 2008, Arano and Munn 2006, Butler and Leatherberry 2004). Forest management decisions of landowners are difficult to predict due, in large part, to inherent heterogeneity among their management objectives (Majumdar et al. 2008, Butler and Leatherberry 2004) and their subjective preferences in timber harvesting (Amacher et al. 2003, Kuuluvainen et al. 1996). On the other hand, from a resource accessibility stand point, NIPFs are an important source for wood-based bioenergy feedstock (GC and Mehmood 2010), as large amounts of logging residues and harvesting by-products are readily available in these forests. Hence, NIPF landowner harvesting decisions are important factors in determining the amount of sustainable woody biomass for wood-based bioenergy generation facilities (Joshi and Mehmood 2011).

While the timber harvesting behavior of NIPF landowners is a widely documented topic, an empirical study of landowner preferences for timber harvesting continues to be an important topic in North American forestry due to the diverse and dynamic nature of NIPF management objectives (Joshi and Arano 2009, Amacher et al. 2003, Conway et al. 2003, Kuuluvainen et al. 1996). For example, forest management objectives, biophysical characteristics of the forest, and socio-demographic variables have influenced landowner timber harvesting decisions (Joshi and Arano 2009, Amacher et al. 2003, Kuuluvainen et al. 1996). Most of previous research, however, has focused on issues such as nonmarket valuation and timber harvesting, timber bequest motives of landowners, and relationships between landowner preferences and timber harvesting (Amacher et al. 2003). It is worth noting that feedstocks needed for bioenergy are not the conventional forest products and many landowners are not well familiar with this opportunity. Therefore, landowner motivations for biomass harvesting are likely be different than typical forest products such as sawlogs, chip-and-saw, and pulpwood. Moreover, public interest in meeting national energy security needs, and economic, and environmental benefits associated with wood-based bioenergy necessitate research specifically focusing on the woody biomass harvesting behavior of NIPF landowners.

Despite an extensive body of literature on timber harvesting behavior of NIPF landowners (e.g., Joshi and Arano 2009, Amacher et al. 2003, Conway et al. 2003, Kuuluvainen et al. 1996, Newman and Wear 1993), studies in recent past (Markowski-Lindsay et al. 2012, Gruchy et al. 2012, Joshi and Mehmood 2011, GC and Mehmood 2010) have highlighted their harvesting behavior, particularly, in the context of supplying forest-based biomass for wood-based bioenergy. The reason, to a large extent, is because assessing NIPF landowner willingness to participate in wood-based bioenergy markets is a relatively new topic in forest economics and policy research. Recent studies conducted by Gruchy et al. (2012), Joshi and Mehmood (2011), and GC and Mehmood (2010) have primarily highlighted factors affecting NIPF landowner willingness for participating in wood-based bioenergy programs.

Earlier studies, in general, have provided some insights into forest biomass harvesting behavior of NIPF landowners. None, however, explored why or how their harvesting behavior changes when multiple harvesting options are available. Moreover, earlier research analyzed the willingness of NIPF landowners to supply woody biomass holistically, without explicitly explaining their willingness to accept for the attributes that guided their motivations. Therefore, this study's objective is to identify this gap in knowledge by designing a choice experiment to explore NIPF landowner preferences for harvesting woody biomass and the attributes that affect their harvesting decisions. Similarly, socio-demographic attributes are also included in the choice experiment as variations in age, education, and income would likely make significant differences in landowner motivations for harvesting (e.g., Joshi and Mehmood 2011, Joshi and Arano 2009, Amacher et al. 2003, Conway et al. 2003, Kuuluvainen et al. 1996). Specifically, landowner preferred attributes, based on hypothetical biomass harvesting plans, are analyzed in this study. Since attributes associated with woody biomass harvesting influence feedstock sustainability, it is believed that their thorough understanding of this issue would likely help design bioenergy policies that best match the needs and aspirations of landowners in the US.

2.3 Choice Experiment and Harvesting Decisions

Stated preference methods are becoming more common in environmental research as a way to explain the preferred alternatives of respondents. These studies present alternatives, based on a specific combinations of attributes, from multiple choices offered to them (Horne et al. 2005, Boxall et al. 2003, Adamowicz et al. 1998, Hanley et al. 1998). One commonly used stated preference method is the CE.

This method uses a survey instrument where respondents are asked to choose their preferred alternative from two or more options available to them (Horne et al. 2005). Alternatives offered to respondents, most often, are characterized by different levels of qualitative or quantitative attributes (Horne et al. 2005). Another approach, the Contingent Valuation Method (CVM), explores the hypothetical willingness of a respondent to pay or accept compensation for a change in environmental goods and services that are not traded in a real marketplace (Hanley et al. 1998, McFadden 1994). Through an experimental inquiry, Bateman et al. (1997) explained that since different parts (divisions) associated with a complete project are evaluated independently in CVM, their sum, which should be equal to the independent valuation of the whole project, in fact exceeds it. This issue, raised by an observer's inability to make an accurate judgment during experimentation, is generally known as part-whole bias (Bateman et al. 1997). While both methods are theoretically grounded in the concept of stated preferences, CE is generally considered to be a superior approach (Hanley et al. 1998). CE is usually free from the part-whole valuation effect (Hanley et al. 1998) because different components of an attribute of interest can be experimentally evaluated in the same research setting (Hanley et al. 1998). Consistent with this result, Adamowicz et al.

(1998) found that results based on the CE method better incorporated the issue of status quo bias and endowment effect ─ the human tendency to "overestimate the value of goods that they own" (Thaler 1980).

While attribute based methods have been widely used in environmental research (Horne et al. 2005, Boxall et al. 2003, Hanley et al. 1998, Holmes et al. 1998, Garrod and Wills 1997), limited literature is available when it comes to their use in NIPF landowner timber harvesting behavior. Holmes and Adamowicz (2003) analyzed timber harvesting preferences among NIPF in Maine and found that they were not in favor of existing harvesting practices that allowed clear-cutting. Apart from their choice for a particular harvesting option, the study further identified landowner levels of satisfaction (or dissatisfaction) of harvest attributes such as the removal of live trees, dead trees, and percent of forest left from harvesting. Dennis and Twery (2007) used a choice modeling approach to understand the expectations of general public towards private forest land. Their study indicated that the general public was more interested in enhancing existing wildlife habitat related activities in the surrounding private forest land.

Past research (Mayfield et al. 2007, Perlack et al. 2005, Burger 2002) indicates that excessive woody biomass utilization can result in negative impacts on soil and the environment through organic matter depletion, nutrient leaching, wind and water erosion of the soil, and soil compaction. Therefore, attributes such as biomass utilization, effect of timber harvesting on environmental quality, site preparation expenses, and feedstock prices are important factors in biomass harvesting activity (Mayfield et al. 2007, Perlack et al. 2005). Consistent with choice experiment research, it can be argued that questions related to landowner preferences for biomass harvesting cannot be answered completely, unless issues such as: how much woody biomass can be removed for bioenergy, whether or not to allow for losses in environmental quality, whether or not to invest in site preparation, and minimal acceptable price per acre, are properly addressed in the analysis. Therefore, in this choice experiment study, respondents were asked to choose among different woody biomass harvesting alternatives, which were characterized by multiple attributes pertaining to the effects of biomass harvesting.

2.4 Methods

2.4.1 Random Utility Theory

The theoretical base for using the choice experiment method follows from the random utility framework. Accordingly, landowners (n=*1,.....N*) maximize utility from forest land by comparing *J* unique timber harvesting alternatives (j=*1,....j*) in choice set A on the *k*th occasion, and choosing the alternative that provides the greatest level of satisfaction or utility given budget and time constraints (Hussain et al. 2010, Holmes and Adamowicz 2003). In mathematical notation, let U_{njk} be the *n*th landowner utility index for alternative j $(j \in A)$ on the *k*th occasion (Hussain et al. 2010, Holmes and Adamowicz 2003). Economic rationality dictates that a landowner will prefer a particular harvesting alternative *i* if it increases his or her indirect utility more than other available alternatives,

$$U_{nik} > U_{njk} \tag{2.1}$$

In accordance with random utility theory, let's assume that the total utility index can be written as the sum of a deterministic (V_{njk}) and a random component (ε_{njk}). While the choices made by respondents are deterministic in the random utility theory, there exists some stochasticity in efforts made by researchers to correctly predict them (Ben-

Akiva and Lerman 1985, Manski 1977). The deterministic component (V_{njk}) in a random utility model is characterized by a vector of attributes; and the prevalent uncertainty is represented by random component (Greene 2008, Ben-Akiva and Lerman 1985, Manski 1977). This relationship can be expressed as:

$$U_{njt} = V_{njk} + \varepsilon_{njk} \tag{2.2}$$

The deterministic component (V_{njk}) is assumed to be linear in weights α = ($\alpha_1 \ldots \alpha_t$) and additive in attributes Y=($Y_1 \ldots Y_t$). The systematic component of utility into non-cost and cost attributes can be partitioned such as:

$$V_{njk} = \alpha_{0j} + \alpha_1 Y_{1njk} + \ldots\ldots\ldots \alpha_{t-1} Y_{t-1njk} + \alpha_t Y_{tnjk} \tag{2.3}$$

where,

V_{njk} = deterministic component of random utility index

$Y_{1njk} \ldots\ldots Y_{t-1njk}$= the non-cost attributes of alternative *j,*

Y_{tnjk}= the cost attribute of alternative *j,*

α_{0j}= the constant showing mean impact of unobservable component on total utility index

$\alpha_1 \ldots \alpha_{t-1}$= coefficient for the non-cost attributes of alternative *j,*

α_t= coefficient for the cost attributes of alternative *j,*

Implied marginal willingness to pay (mWTP) for small changes in a particular attribute (say Y_1) is given by the expression (Hole 2007),

$$\frac{\partial Y_{tnjk}}{\partial Y_{1njk}} = -\frac{\alpha_1}{\alpha_t} \tag{2.4}$$

While there is ongoing debate over interchangeable use of WTP and WTA estimates in nonmarket valuation research from last three decades (Haab and McConnell 2003), following Holmes and Adaniwicz (2003), no differences between WTP and WTA estimates were assumed. The interpretations are made accordingly.[2]

2.4.2 Econometric Model

Socio-economic variables such as age, income, and education are important determinants of NIPF landowner timber harvesting behavior (Conway et al. 2003, Kuuluvainen et al. 1996). Consistent with random utility theory, as explained in Section 2.4.1, different attributes associated with woody biomass harvesting and socio-demographic characteristics of the landowner were included as independent variables in the econometric model to account for the deterministic component (V_{njk}) of equation 2.2. Since the study's intent was to understand timber harvesting behavior, socio-demographic variables were included. A standard conditional logit model with socio-economic variables such as age, education, and income, cannot be employed because these variables (X) are person-specific and do not vary across the *J* alternatives (Holmes and Adamowicz 2003).

Therefore, the general conditional logit model, in which person-specific attributes (X) were interacted with dummies for *J-1* alternative specific constants (ASC), can be

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[2]Economic theory suggests that divergence between WTP and WTA is minimal for the goods which are close substitutes (Hanemann 1991).

considered for the econometric analysis. A limitation of the conditional logit model is that it assumes independence of irrelevant alternatives (IIA). That is, the relative odds of choosing alternative A over B the same no matter what other alternatives are available or what attributes they contain (Holmes and Adamowicz 2003, McFadden 1974). Following the intuition of McFadden (1974), this assumption may not be appropriate in analyzing a landowner's preferred harvesting option(s) because there is a potential for shared unobserved attributes between harvest plan A and B (*harvest*) versus harvest plan C (*no harvest*).

The nested logit model, which partially relaxes the IIA assumption, may be appropriate. According to this model, errors corresponding to alternatives in a given nest are assumed to be correlated whereas errors across nests are considered to be independent (Greene 2008). According to the nested logit model, the unconditional probability of alternative l in branch t may be written as the product of conditional and marginal probabilities (Meyerhoff et al. 2009):

$$P_{lt} = P(l/t)\ P(t), \tag{2.5}$$

$$P_{lt} = \left[\frac{\exp(V_{lt}/\lambda_t)}{\exp(I_t)}\right]\left[\frac{\exp(\lambda_t I_t)}{\sum_{K=1}^{R}\exp(\lambda_k I_k)}\right] \tag{2.6}$$

$$I_t = \log\left[\sum_{i=1}^{l_r}\exp(V_{lt}/\lambda_t)\right] \tag{2.7}$$

where,

$P_t =$ marginal probability of choosing branch t,

$P(l/t) =$ conditional probability of choosing alternative l conditional on branch t,

$V_{lt} =$ indirect utility of alternative l,

$I_{t=}$ inclusive value, and

$\lambda_{t\,=}$ coefficient of inclusive value

Random utility theory restricts the value of λ_t to lie between zero and one; values outside this range, while mathematically possible, are inconsistent with random utility theory (Train 2002). A value of unity for this parameter suggests a conditional logit model without a nested structure whereas a value of zero suggests that the levels are perfectly correlated (Train 2002). Interestingly, a negative value for this parameter indicates that more of an attribute, all else being equal, can diminish its chances of being preferred (Train 2002). Clearly, such results are not consistent with the premises of utility maximization theory (Train 2002). Finally, when the value of λ_t is greater than 1, consistency of utility maximizing behavior is limited within a particular range of independent variables (Train 2002).

2.4.3 Survey Design and Administration

A survey of NIPF landowner willingness to harvest woody biomass was conducted to understand their preferences for harvesting methods to supply biomass for wood-based bioenergy industries in Mississippi. The questionnaire used for the survey consisted of six sections. The first three sections contained general questions such as biophysical characteristics of the respondent's forest, forest management objectives, and willingness to supply woody biomass. Section four contained the choice experiment, in which landowners were asked to choose their preferred harvesting plan given different attributes. The fifth section of the survey asked respondents to rate four hypothetical timber harvesting scenarios. In the last section, respondents were asked for their socio-demographic information. A detailed version of the survey instrument can be found in Gruchy (2011).

Random samples of 2,560 landowners, owning more than 100 acres of forest land, were selected for the survey from a list of NIPF landowners in Mississippi. Following past survey research in Mississippi (Munn and Hussain 2010, Hussain et al. 2007, Jones et al. 2001), the rationale behind imposing a lower limit of 100 acres was to obtain the biomass harvesting opinion from landowners who would most likely have the capabilities to contribute toward supplying feedstocks for wood-based bioenergy. The mail survey was conducted from December 2009 to February 2010. The survey followed the Tailored Design Method recommended by Dillman (2000).

2.4.4 Construction of Choice Set

The questionnaire and attributes used in the choice experiment were developed after review of the available literature pertaining to woody biomass utilization, consultation with the university researchers, and a pilot survey of three NIPF landowners in Mississippi. After discussion with stakeholders, four attributes - woody biomass utilization, environmental quality effect, site preparation required, and price per acre - were designated for the choice experiment survey in a 100 acre hypothetical pine forest stand. Attributes and their levels are presented in Table 2.1.

In the survey questionnaire, landowners were informed about three hypothetical harvesting plans and current fair market values for timber in Mississippi. The fair market value of timber was obtained from Timber Mart South average prices for 2009 (Timber Mart South 2009). Similarly, the attributes characterizing each harvesting alternative were explained in the survey. Among different attributes, ‘woody biomass utilization’ was expected to increase landowner willingness to harvest timber. An example of a set of alternative timber harvesting scenarios is provided in Table 2.2. Perlack et al. (2005) highlighted that, with an integrated recovery system, more than 90% of the woody biomass can be recovered during harvesting operations. Any form of biomass harvesting that recovers more than 85% of the recovered woody biomass, however, may reduce soil quality, water quality, and species richness or biodiversity (Perlack et al. 2005). Perlack et al. (2005) also highlighted that 70% of the available forest biomass in the United States is utilized in conventional forest product industries. While biomass harvesting reduces site preparation costs (Gan and Smith 2007), given the higher costs associated with soil productivity loss, volumes of the available biomass will likely be less than the actual biological potential for forest lands (Gan and Smith 2010). Since the long-run supply of feedstock material is likely to depend upon the ecological sustainability of forest resources, it would be interesting to see how landowners valued the economic opportunities obtained from excessive biomass harvesting relative to the associated likely ecological concerns. To account for these issues, the amount of logging residues and non-merchantable trees to be removed from site for creating bioenergy was categorized into three levels: 95%, 70%, and 0% respectively.

Utilizing 70% and 95% of logging residues were both expected to increase landowner preference for timber harvesting compared to over the base case of ‘0%’ utilization. On the other hand, landowners were expected to favor ‘no change’ in environmental quality over ‘slight or substantial decreases’. Since site preparation is a cost to landowners, the attribute ‘no site preparation required’ was expected to be favored over other alternatives that require site preparation. Finally, the price per acre attribute was expected to impact a landowner's choice of timber harvesting alternatives positively. The bid set in survey ranged from $2,800 per acre to $3,200 per acre whereas the fair market value was $3,000 per acre.

Among socio-demographic variables, 'age' was expected to be negatively related with landowner willingness to conduct harvest timber. Moreover, to capture the change in the level of landowner willingness with increases in age, the square of age was also included as an explanatory variable in the model. Use of squared explanatory variables, to capture the nonlinear effect of an attribute over time, is not uncommon in resource management literature (e.g., Poudyal and Hodges 2009, Stevenson 2004, and Mehmood and Zhang 2001). Therefore, it was decided to include both variables in the model to understand the effect of varying ages on timber harvesting behavior of NIPF landowners. Education was expected to have a positive association with landowner preferences for selecting timber harvesting alternatives over a status quo option. Finally, a positive relationship between landowner choice for timber harvesting and annual household income was expected, because it is likely that people in a higher income category would participate more in timber harvesting activities (Joshi and Arano 2009).

A total of 20 orthogonal choice sets, based on the fractional factorial design, were created using the Optex procedure in SAS (SAS Institute 1999). Of note, similar allocations can also be performed by using asymptotic variance covariance approach (Bliemer et al. 2009). Since it would be inconvenient for a respondent to answer all 20 choice sets during a survey, total choice sets were blocked into four versions each containing five choice sets. Each choice set contained two harvesting alternatives and a status quo alternative representing the option 'no harvest'. The inclusion of 'no harvest' as an alternative resembles a real market situation for respondents and allows a choice set model to derive measures of WTP (Hussain et al. 2010, Holmes and Adamowicz 2003, Roe et al. 1996). Since the status quo is not included in the model, using a dummy code attribute causes perfect collinearity between the status quo option and the intercept in a choice experiment model (Bech and Gyrd-Hansen 2005, Holmes and Adamowicz 2003). Therefore, effect coding, in which parameter estimates of a status quo option cancel out the average effect of alternatives, was used to make the intercept independent with other parameter estimates (Louviere et al. 2000). Similarly, an alternative-specific constant (ASC) was included to capture characteristics of timber harvesting behavior not explained by attributes specified in the model (Boxall et al. 2003).

2.5 Results

One hundred and twenty-two questionnaires were returned as either undeliverable or with the respondent being deceased, leaving a remaining sample of 2,438. Respondents returned 703 questionnaires for an adjusted response rate of 28.8%. Only 520 among those returning the survey had complete answers for the choice experiment section of the survey. In the choice experiment, 85.7% of the respondents selected an option that involved timber harvesting (selected harvesting option A or B), whereas 14.3% selected the non-harvest option (Option C).

Summary statistics of all returned questionnaires indicated that average age of respondents was 65 years. The average landownership size was approximately 462 acres. Few landowners reported that they owned less than 100 acres at the time when they received the survey. Average gross income per household was $87,000, which was well above the state median income of $ 38,718 for year 2007-2011 (United States Census

Bureau 2012). Consistent with the southern (Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia) and national averages provided by Butler et al. 2011, landowners most frequently reported an annual income within the $50,000-99,999 range. The majority of respondents (55%) had a university degree. The most frequently reported level of education was a bachelor's degree, which is consistent with the southern average (Butler et al. 2011). Selected descriptive statistics of important variables are presented in Table 2.3.

Given a low usable response rate, telephone calls were made to a random sample of 50 non-respondents to inquire as to why they were not interested in filling out survey. Their reasoning included: 1) do not own forest land any more, 2) do not have time to fill out survey, and 3) prefer not to answer any survey questions. It was felt that these answers did not reveal any potential systematic bias with these findings. Similarly, there was statistical insignificance between respondents and non-respondents in terms of their age. Likewise, differences among early and late respondents, based on a two sample t-test of important variables such as income, age, and parcel size were also statistically insignificant. In short, follow-up telephone calls to non-respondents, comparison of data with southern and national landowner survey data, and statistical non-significance between early and late respondents did not indicate non-response bias in this study which was consistent with other similar studies (Curtin et al. 2000, Visser et al. 1996). Likewise, consistent with Curtin et al. (2000), the overall effect of a low response rate on study results would likely be minimal, as non-respondents were not willing to answer the survey questionnaire even with multiple requests. Nonetheless, theoretical possibility of nonresponse bias cannot be negated completely in regard to a low response rate. Therefore, a cautious interpretation of study results is recommended.

2.5.1 Choice Experiment Results

Results based on conditional and nested logit models were consistent. The likelihood ratio test, however, indicated that the nested logit model was superior to conditional logit model. In addition, since the inclusive value (0.23) was significantly different than one and the study was based on underpinnings of a random utility model, the nested logit model was finally selected for further analysis. Results based on nested logit model are reported in Table 2.4. Positive and significant explanatory variables included 95% logging residue utilization, slight decreases in environmental quality, minimal site preparation requirements, price, and age. All of these variables were significant at 1% level. Similarly, negative and significant explanatory variables included substantial decreases in environmental quality, intensive site preparation required, age-squared, education, and income. While the variable education was significant at 5% level, all other attributes were significant at a 1% level.

The 95% confidence intervals for WTA estimates based on the delta method and are reported in Table 2.5. As Hole (2007) suggested, since the coefficient associated with the price variable was precisely estimated and the sample size was relatively large, therefore the delta method which underpins the assumption of a normally distributed WTA estimate would provide accurate interval estimates.

2.6 Discussion

The negative sign of the ASC for the no harvesting alternative indicated landowner aversion to the status quo (*no harvest*) alternative and preference for harvest alternatives. Similarly, econometric results indicated that harvesting, which utilized 95% of the logging residues and non-merchantable trees, while clear-cutting the site for commercial wood products was preferred over no utilization. Based on the odds ratio, alternatives that provided 95% of logging residue utilization were 15% more likely to be preferred over alternatives that did not utilize logging residues. Thus, landowners are likely to require $141.70 less per acre for alternatives that utilize 95% of logging residues than alternatives that do not utilize logging residues. Since utilization of biomass for wood-based bioenergy would reduce site preparation costs (Gan and Smith 2007), landowner WTA a lesser price for clearing 95% of logging residues seems reasonable. This observation resonates with an explanation that many landowners, as of now, are not aware of market opportunities associated with logging residues as potential feedstock for wood-based bioenergy (Gruchy et al. 2012, Joshi and Mehmood 2011) and do not consider it of any economic value. Therefore, landowners are, perhaps, accepting less revenue for more biomass being removed from their forest land. Although the coefficient related to 70% logging residue utilization had the expected sign, it was not significantly different from the reference category of 0% logging residue utilization. The coefficient corresponding to the reference level of the logging residue utilization attribute was not estimated directly. This can, however, be obtained as a negative sum (-0.16) of the other two attribute levels (Boxall et al. 2003). The reduced preference expressed by landowners for utilizing 70% of logging residues is quite intuitive because landowners might have less interest in harvesting if almost one-third of their logging residues are not utilized for producing wood-based bioenergy. This result suggests that landowners are either unaware of, or ignore, Perlack et al. (2005)'s insights that leaving some volumes of logging residues would be important to maintain productivity and soil fertility in the forest.

As expected, landowners required $116.16 per acre more compared to the base category of no change in environmental quality for a timber harvesting plan that would adversely affect the environment. Since the majority of landowners in the United States value wildlife management and recreation as important forest management objectives (Butler and Leatherberry 2004), a landowner preference against harvesting alternatives that could adversely impact the environment in terms of soil and water quality and biodiversity was not surprising. Interestingly, landowners had a positive preference for utilizing 95% of logging residues, but they were not in favor of any harvesting that might result in a substantial decrease in environmental quality. These seemingly conflicting interests perhaps indicate that while landowners do not prefer to diminish the environmental quality of their forest land, they do not know how much the removal of logging residues from residue harvesting could cause in the loss of site quality and biodiversity. Of note, landowner participation in carbon credit or forest certification program, which was not explicitly analyzed in this survey, could also be a potential reasoning behind their concern with environmental quality of the forestland.

The positive sign of the coefficient associated with a slight decrease in environmental quality indicated that landowners prefer harvesting plans that provide them an optimum premium with a minimal loss of environmental quality. Characterizing the management behavior of landowners, Butler and Leatherberry (2004) indicated that wildlife management, recreation, land management, and timber production are common forest management objectives of NIPF landowners in the United States. Since most, if not all, forest management objectives may not significantly affect environmental quality; landowners may prefer to generate revenue from the utilization of logging residues, if the negative impacts of logging residue recovery are site specific, short-term, and minimal. Since more than 80% of landowners chose a timber harvesting alternative, they accept that some minimal loss of environmental quality, a concern noted by Nyland (2002), may occur with clear-cutting.

Harvesting in any form brings changes to the physical environment (Nyland 2002, Smith et al. 1997). As expected, a negative coefficient associated with intensive site preparation indicated that landowners received significantly less utility from harvesting plans which required intensive site preparation relative to those that required no site preparation. As suggested by the WTA estimates, landowners are likely to require $150.08 less for timber harvesting alternatives that require no site preparation. Given the substantial financial investment associated with intensive site preparation activities, landowner dislike for options requiring substantial site preparation seems justifiable.

The positive coefficient associated with the attribute describing minimal site preparation requirements indicates that in comparison to a no site preparation option, landowners are 5% more likely to prefer harvesting plans that require minimal site preparation to attain similar re-planting results. This result did not meet a priori expectations. One possible explanation of this result could be that since minimal site preparation provides a better environment for forest reestablishment for such a relatively small monetary investment, landowners might have preferred such an option.

Consistent with a priori expectations, the positive coefficient on price indicated that landowners prefer options generating more revenue. Landowners' preference for harvesting plans generating higher revenue is not surprising. This indicates that bioenergy industries might need to pay competitive price to ensure feedstock availability.

Among person-specific socio-demographic variables, age, education, and income had a significant impact on landowner choices for harvest specific alternatives. Consistent with earlier results (Joshi and Arano 2009, Arano et al. 2004, Kuuluvainen et al. 1996, Romm et al. 1987), the positive sign of age indicated that elderly landowners preferred the 'no harvest' alternative. Kuuluvainen et al. (1996) indicated that elderly landowners, all else being equal, preferred to bequest their forest to future generations. Similarly, Poudyal and Hodges (2009) indicated that older age landowners preferred wildlife and avian habitat management. Further, the authors concluded a diminishing level of landowner interest in any active land management activity that increases with one's age. Since woody biomass harvesting and re-planting are active forest management activities that need considerable time and effort, older landowner preferences for the status quo are reasonable. As a note, while the coefficient associated with age-squared was significant and negative, the net effect of the non-linear relationship was positive. This finding needs to be carefully interpreted because insights gained do not contradict the impact of age on a landowner's choice of harvesting alternatives; rather it indicates that elderly landowners have a preference for the status quo and that this tendency increases at a decreasing rate eventually declining with age.

An important note about choice experiment survey is that the status quo alternative did not necessarily rule out the possibility of landowners managing forest land for non-harvesting activities such as wildlife management and/or recreation. Therefore, this result suggests that landowner preferences for all forms of forest management objectives, holding all else constant, diminishes with an increase in age.

The negative sign for education suggests that more formally educated landowners favor harvesting over the status quo option of no harvesting. Since formally educated people are usually more aware of the relative benefits and risks associated with management activities, their participation in active forest management is consistent with previous timber harvesting research (Gruchy et al. 2012, Joshi and Mehmood 2011, Joshi and Arano 2009, Nagubadi et al. 1996, Bell et al. 1994).

Finally, results indicated that increasing incomes decreased the preference for the ‘no harvest’ alternative; landowners having higher annual income were more likely to favor timber harvesting. It is possible that wealthier landowners have better access to resources such as land, contractors, loggers, and consulting foresters (Joshi and Arano 2009). Therefore, landowners in higher income categories, if they decide to harvest timber, would generate additional revenues from harvested woody biomass due to benefits associated with their accessibility to technology and resources. A positive relationship between income and timber harvesting activities has been documented in previous research (Joshi and Arano 2009, Romm et al. 1987), and seems justifiable.

2.7 Conclusion

The research results provide important insights into the harvesting behavior of NIPF on issues such as landowner propensity for logging residue utilization, concerns regarding potential adverse environmental impacts, and willingness to invest in site preparation activities. From a logging residue utilization standpoint, these are important attributes that dictate the amount of logging residue potentially recoverable from a site. Results revealed that while landowners preferred to sell most of the available logging residue, they were equally concerned about the potential negative impact of timber harvesting on the environment. An important cautionary note is that landowners may not know at what point utilizing more logging residue will result in a loss of environmental quality. While study results on one hand revealed the need to raise awareness, they further indicated that timber harvesting plans should involve an integrated recovery system to ensure optimum levels of logging residue utilization without jeopardizing the ecosystem of which their forest lands are a part.

A national goal of replacing fossil fuels with an alternative source of energy is ambitious and hence requires active support from the public, irrespective of their age and education. Study results resonate with earlier findings (GC and Mehmood 2010, Butler and Leatherberry 2004) that NIPF landowners, as a group, are predominantly elderly people. Since elderly landowners are relatively less receptive to timber harvesting, a full range of awareness training and outreach programs may be needed to help motivate older landowners to supply woody biomass for wood-based bioenergy. Likewise, given the negative preference of low income landowners toward harvesting, bioenergy policies providing assistance, in the form of cost share and tax support, may help motivate this group to harvest logging residue.

In general, study indicated that harvesting plans that involve utilization of logging residues with minimal damage to the environment and that require relatively little site preparation was favored by Mississippi landowners. Given that bioenergy is growing in international significance and the socio-demographic attributes of respondent population generally resemble those landowners from other parts of the country, these results certainly have regional and national implications. Likewise, as earlier reported, there is little research evaluating landowner timber harvesting behavior using attribute-based methods such as choice experiments (Beach et al. 2005) and it is believed that this study will contribute to the existing body of literature.

Since this study hypothesized a pine stand for the choice experiment, it is worth noting that pine forests nationwide have enormous potential as raw material sources for wood-based bioenergy facilities. This is because most landowners with pine plantations preferred some form of biomass harvesting in this study. Of note, this study did not provide an option of partial-cutting as a timber harvesting alternative, which perhaps landowners might prefer, given their motivation for wildlife management and concerns over the ecological health of the forest. Landowner interest in forest certification or carbon credit program might influence their biomass harvesting motivations, which was not also analyzed in this study.

Despite the fact that socio-demographics of the survey respondents followed the general trend characterized by NIPF landowners in the U.S., it was realized that sampling across the nation would best represent the common opinion of US NIPF landowners regarding wood-based bioenergy. However, this was not done, due to resource and time constraints. Future research involving more harvesting alternatives, a wider geographical extent, socio-demographic issues, and other attributes such as accessibility to the forest would definitely shed more light on issues associated with biomass harvesting behavior of NIPF landowners across the nation.

Table 2.1 Attributes and level of harvesting plans designed for determining nonindustrial, private forest landowner choices of preferred harvesting methods for supplying woody biomass from hypothetical planted pine stands (>100acres) in Mississippi, United States.

Attribute	Unit	Levels	Landowner hypothesized response
Woody biomass utilization	Percentage	95% 70% 0%	Landowners are more willing to harvest when they expect that a higher percent of the biomass would be utilized
Environmental quality effect	Type	Substantial Slight decrease No change	Landowners are less willing to harvest when they expect that environmental quality will deteriorate
Site preparation required	Type	Intensive Minimal No	Landowners are less willing to harvest when intensive site preparation is required
Prices	$/acre	$3,200 $3,000 $2,800	Increase in price per acre induces landowners to increase harvest

Table 2.2 Alternative timber harvesting plans designed for determining landowner choice of preferred harvesting method for supplying woody biomass from hypothetical planted pine stands (>100acres) in Mississippi, United States.

Harvest Attributes	Harvest plan A	Harvest plan B	Harvest plan C
Woody biomass utilization	70%	95%	
Environmental quality effect	Slight decrease	Slight decrease	
Site preparation/cleanliness of site	Minimal site prep required	No site prep required	
Price received per acre	$2,800/ac	$3,200/ac	
Choose one	A	B	No harvest

Table 2.3 Descriptive statistics of variables used in econometric analysis pertaining to landowners' choice of preferred harvesting methods for supplying woody biomass from hypothetical planted pine stands (>100acres) in Mississippi, United States.

Variable	Mean	Std. Dev	Min	Max
Age (years)	64.90	12.53	28	78
Education	4.32	1.85	1	8
Income	86.84	43.10	30	150
Alternative 1 (%)	43.38			
Alternative 2 (%)	42.31			
Status Quo (%)	14.31			

(1 = Did not complete high school, 2 = High school graduate or GED, 3= Some college, 4 = Associate degree, 5= Bachelor's degree, 6= Master's degree, 7= Doctoral degree, 8= Professional degree). Alternative 1 or 2 mean some form of biomass harvesting.

Table 2.4 Nested logit model based parameter estimates of landowner choices of preferred harvesting from hypothetical planted pine stands (>100 acres Mississippi, United States.

Variable	Coef.	Std. Err.	P>|z|	Odds Ratio	%	*Implied mWTA*
Woody biomass utilization						
95%	0.142	0.042	<0.001	1.152	15.29	-141.70
70%	0.015	0.014	0.285	1.015	1.52	-14.99
Environmental quality effect	-0.116	0.036	0.001	0.880	-11.02	116.16
Substantial						
Slight	0.060	0.021	0.004	1.060	6.18	-59.71
Site preparation required						
Intensive	-0.151	0.045	<0.001	0.860	-13.99	150.08
Minimal	0.051	0.019	0.007	1.052	5.28	-51.18
Price	0.001	2.93E-4	<0.001	1.000	0.101	
ASC_{sq}	-1.910	19.852	0.92			
Socio-economic variables						
Age* ASC_{sq}	0.192	0.043	<0.001	1.210	21.17	
Age-square* ASC_{sq}	-0.001	3.23E-4	<0.001	0.938	-6.228	
Education*ASC_{sq}	-0.064	0.031	0.038	0.990	-0.67	
Income*ASC_{sq}	-0.007	0.002	<0.001	0.990	-0.138	
Summary statistics						
Inclusive values		*Harvest*	0.230			
		No harvest	1(fixed)			
Log-likelihood	-2282					
Wald-chi square(11)	73.139					
R Squared	0.120					
Number of observations	7800.00					

* Base categories for woody biomass utilization, environmental quality effect, site preparation required are zero percent, no change, and no site prep required respectively.
**ASCsq – Alternative Specific Constant corresponding to the status quo option. Two level nested logit model with a degenerate branch having tree Harvest (1, 2) and No (status quo) was estimated using the random utility model 2 (RU2) specification.

Table 2.5 Implied willingness to accept (WTA) estimates pertaining to the attributes of preferred harvesting methods for supplying woody biomass from hypothetical planted pine stand (>100 acres) in Mississippi, United States and their 95% confidence intervals based on delta method.

Attribute	Nested logit model		
	WTA	Upper limit	Lower limit
Woody biomass utilization			
95%	-141.70	-164.12	-119.28
70%	- 14.99	- 41.44	11.47
Environmental quality effect			
Substantial	116.16	88.93	143.40
Slight	- 59.71	-85.00	- 34.42
Site preparation required			
Intensive	150.08	117.72	182.45
Minimal	- 51.18	- 75.20	- 27.15

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CHAPTER III

UTILIZING MILL RESIDUES FROM WOOD PROCESSING FACILITIES IN MISSISSIPPI

3.1 Abstract

Mill residues obtained from wood processing industries are potentially important feedstocks for the wood-based bioenergy industry. Although a considerable percentage of residues generated in mills are internally utilized for energy production, recent literature revealed that significant volumes of mill residues are still available for sale in United States. This study analyzed factors that could possibly affect the availability of residues from mills in Mississippi. Information pertaining to available residues from forest product industries in Mississippi was obtained by administering a mail survey instrument. Generalized least square and Tobit models were used for the analysis. Results indicated that availability of woody residues was higher in primary wood processing manufacturers than secondary manufacturers. Similarly, the likelihood of obtaining feedstocks would be higher if wood-based bioenergy could be located near larger, year round, forest product industry operations. The study revealed the need for increased awareness regarding market opportunities for products such as bioenergy, in particular for less formally educated entrepreneurs in Mississippi.

Key words: Generalized Least Square model, Tobit model, mill residues

3.2 Introduction

In recent years, wood-based bioenergy has received an unprecedented amount of attention in national policy and research, as its numerous benefits pertaining to energy security, the environment, and rural economies are widely recognized (Gruchy et al. 2012, Joshi and Mehmood 2011, Gan and Smith 2007, Guo et al. 2007). As the terminology wood-based bioenergy implies, different sources of woody biomass such as logging and thinning residues, woody urban wastes, mill residues, fuel treatment residues, among others, are used as feedstocks to generate this form of energy (Foster et al. 2005). While private forest lands in the United States are considered to be key contributors in supplying unused logging and thinning residues (e.g., Gruchy et al. 2012, Joshi and Mehmood 2011), mill residues, on the other hand, are obtained from primary and secondary wood processing facilities (Perlack et al. 2005). Perlack et al. (2005) reported that 50% of the existing biomass energy consumption in the United States, highest among all sources, has been contributed by woody residues obtained from primary and secondary wood processing facilities. Of importance, a substantial amount of the wood residues obtained from mills are currently utilized to generate energy in United States (Guo et al. 2007).

Although a considerable percentage of residues generated in mills are internally utilized for energy production, recent literature revealed that substantial volumes of mill residues are still available for sale in United States. For instance, GC and Potter-Witter (2011) reported that while 59% of the woody residues obtained as a by-product from primary wood processing facilities were reused to generate energy either in their own facilities or some other industries, 38% was sold to other manufacturing facilities.

Similarly, 3% of the total woody residues available in Michigan were either disposed of, or given away. Consistent with these findings, a study conducted by the Indiana Department of Natural Resources (2011) indicated that 47% of woody residues obtained from primary wood processing facilities in Indiana were used for miscellaneous purposes including livestock bedding and mulch. Likewise, in their effort to estimate the amount of wood waste produced from wood product companies, Garrard and Leightley (2005) found that 61% of the total wood waste produced in northern Mississippi was sold. The authors, however, noted that given a declining interest in wood waste purchases and problems associated with its disposal, many millowners in northern Mississippi were willing to collaborate with other companies to find a better way of utilizing wood waste (Garrard and Leightley 2005). Given these results, it can be argued that even though the use of woody residues for energy generation is an established practice in forest product industry (Foster et al. 2005), some volumes of internally unused woody residues could still be better utilized to generate wood-based bioenergy. More explicitly, following the argument forwarded by Walsh (2008), currently utilized volumes of residues would also be available for bioenergy, should a reasonable price be paid to feedstock suppliers.

Since woody residues generated in forest product industries such as sawdust and chips are clean and free from dirt particles, they can be efficiently used as feedstock to generate wood-based bioenergy (Foster et al. 2005). In particular, when it comes to their use in wood-based bioenergy, transportation and operational costs associated with clean woody residues from mills are relatively lower than those associated with logging and thinning residues (Foster et al. 2005). More importantly, if wood-based bioenergy facilities could be integrated with, or located near, forest product facilities, transportation cost for feedstocks, which plays an important role in economic viability of wood-based bioenergy industry (Grebner et al. 2009), would be minimal (Foster et al. 2005). Given that some quantity of woody biomass is currently disposed of, or given away by forest product firms and, therefore, are freely available for use, energy generated from mill waste would also be less expensive and cost competitive when compared to fossil fuel alternatives. Similarly, despite its existing use, since alternative sources of mulch are already available in the market (Liang et al. 2002), it can be argued that the agriculture is likely to suffer little in the long run due to mill residue use in a wood-based bioenergy industry.

As Heiningen (2006) reported, the concept of integrating with a new industry, such as wood-based bioenergy, is important for North American forest product industries as these firms are facing increased competition from their international counterparts for their product lines. For example, competition is increased due to globalization, as tropical nations can produce better value added production, at lower costs partially due to a readily available and significantly inexpensive labor market (Heiningen 2006, Schuler and Buehlmann 2003). As Hagadone and Grala (2012) noted, clustering would help forest product industries compete in the global marketplace, as firms can benefit from each other by sharing inputs, technology, and labor required for an industrial manufacturing processes. Therefore, supplying woody residues as a feedstock for, or integrating with, a wood-based bioenergy facility may be important for increasing competitiveness of traditional U.S. forest product industries (Heiningen 2006).

In all cases, a sustainable feedstock supply is an important prerequisite for establishing a wood-based bioenergy industry. In other words, entrepreneurs would likely want to ensure a sustainable feedstock supply before considering an investment in the wood-based bioenergy industry. Therefore, similarly to what was pointed out by Joshi and Mehmood (2011), attributes affecting woody biomass availability are likely to have an important role in an entrepreneur's decision to establish a bioenergy industry. It is important to note that issues pertaining to a sustainable woody biomass supply from privately owned forest land, which are likely be in the form of logging or thinning residues, have been analyzed in recent years (Gruchy et al. 2012, Susaeta et al. 2012, Joshi and Mehmood 2011). More importantly, these studies have suggested some communication and awareness related to the needs of nonindustrial private forest (NIPF) landowners regarding emerging markets for wood-based bioenergy (Gruchy et al. 2012, Joshi and Mehmood 2011).

It is imperative to note that persons involved in wood processing activities, unlike many NIPF landowners, would seek monetary benefits in their business. Their benefit maximizing behavior was reflected in a study conducted by Aguilar (2009), in which the author reported that stumpage prices, better road networks, availability of raw materials, energy costs, and land values were significant determinants of an entrepreneur's decision to select a county for establishing a sawmill in the southern United States. In short, given the corporate nature of the forest product industry, factors affecting a mill decision to supply woody biomass will likely be different than those of NIPF landowners. Therefore, literature pertaining to NIPF landowner timber or woody biomass harvesting (Gruchy et al. 2012, Susaeta et al. 2012, Joshi and Mehmood 2011, Joshi and Arano 2009, Amacher et al. 2003, Conway et al. 2003, Kuuluvainen 1996, Dennis 1989) is less relevant when accounting for the availability of mill residues for wood-processing facilities.

As previously indicated, although mill residues are considered to be a high quality feedstock for wood-based bioenergy, only a few studies (GC and Potter-Witter 2011, Carter 2010) have analyzed issues related to their availability for use in wood-based bioenergy industry. A review of the literature indicated that an econometric analysis on availability of mill residues for bioenergy use has yet to be undertaken. One possible reason could be attributed to the small unutilized portion of wood residues in the forest industry. The bioenergy industry, however, can obtain feedstocks from those mills which, despite their current involvement in woody residue sales, are seeking better ways to utilize woody residues generated in their facilities. Mills are likely to receive a higher premium if a considerable volume of woody residues, currently used in livestock feeding, mulching, or some other domestic needs, could be better utilized as feedstocks in wood-based bioenergy industry. Walsh (2008) supported the above argument at the time of his study and reported that 22.80 million dry tons (dt) of mill residues would be potentially available for bioenergy uses in the United States at $40/dt in the year 2010. Given that wood residues from the forest product industry can play an important role in creating sustainable bioenergy production in the United States, it was apparent that an econometric study was necessary to explore issues that could help explain the factors affecting availability of woody residue in mills.

3.3 Survey Method

3.3.1 Survey Design

Information pertaining to available woody residues from forest product industries in Mississippi was obtained by administering a mail survey questionnaire. The Mississippi Development Authority's online searchable Standard Industrial Classification (SIC) codes 24/25 and 26/27 were used to identify mailing addresses of individuals owning primary and secondary wood processing industries in Mississippi. While SIC codes 24/25 were used to obtain information on all other firms, SIC 26/27, in particular, provided information on the pulp and paper industries in Mississippi. Total population for this census survey, including the list of owners from SIC codes 24/25 and 26/27, was 582 mills. To minimize mistakes or confusion amongst respondents when completing a questionnare, the survey instrument was pilot tested in July 2011 amongst a randomly selected group of mills from the total population and their suggestions were incorporated accordingly into the instrument. After completing the pilot survey, a census survey was mailed to the 582 individuals involved in the wood processing businesses which included millowners, managers, and/or their representatives during the first week of August 2011. The survey was administered following the recommendations given by Dillman (2000), which also called for a reminder postcard and two mailings. As the total number of returned responses was not adequate to conduct an econometric study, telephone interviews of randomly selected non-respondent mills was conducted, using the identical mail survey, after the first two mailings.

The survey instrument consisted of three sections. The first contained queries on the type of forest product firm, amount of woody residue generated in the respondent's plant(s) on an annual basis, and methods of woody residue utilization. The second primarily included questions about woody residue disposal methods, mill interest in collaborating with others to determine better ways to utilize residues, existing markets, average hauling distances from the forest, and technical and operational capabilities of the forest product firm. The final section covered the facility location, employment size, years in operation, and annual sales.

Given the low response rate from the survey, the issue of non-response bias was carefully examined. To determine if the information provided by respondents were representative of wood processing facilities in Mississippi, socio-demographic variables such as total number of employees, total annual sales, and ownership duration from first and second mailings were statistically compared. Another approach to check for non-response bias was to compare survey results with the similar attributes from the entire population or existing literature. Therefore, numbers of employees for the respondents were compared with all firms in the database with similar SIC codes using a student t-test.

3.3.2 Empirical Econometric Model

Arguably, availability of unused woody residues in wood processing facilities depends upon millowner or decision maker's preference to reuse, sell, or give away produced woody residues. Following the insights on rationale decision making (Nicholson 1995), such decisions are guided by a millowner or decision maker's comparative analysis of net profits in each activity. However, there is wide variability in the way mills perceive benefits from woody residue utilization. For example, while some mills receive direct monetary benefits from wood residue sales, there are no financial gains other than cost savings in electricity bills for those who use them internally. Similarly, disposing mill residues would be a monetary burden for some mills. A regression equation was posited to analyze this issue empirically. Since volume of available mill residues was a continuous dependent variable, a multiple linear regression equation would be an appropriate choice to analyze the functional relationship between response and explanatory variables (Greene 2008). The structural form of regression equation was expressed as:

$$Y_i = \beta_i x_i + \varepsilon_i \qquad (3.1)$$

In equation 3.1, Y_i is a regressand, β_i represents the vector of parameter coefficients, x_i are the covariates, and ε_i is the random component. Since the availability of mill residues is likely to be affected by the variety of factors including the mill characteristics, market opportunities, and respondent socio-economic attributes, the empirical model regarding availability of unused woody residues can be written as:

$$\begin{aligned} \text{WOODRESIDUE} = {} & \beta_0 + \beta_1\text{PRI} + \beta_2\text{BETTER} + \beta_3\text{EMPLOYEE} + \beta_4\text{YEAR} \\ & + \beta_5\text{SEASON} + \beta_6\text{ORG} + \beta_7\text{MARKET} + \beta_8\text{WORK} \\ & + \beta_9\text{EDUCATION} + \varepsilon_i \end{aligned} \qquad (3.2)$$

The dependent variable WOODRESIDUE was obtained by summing up wood residue quantities sold, given away, or disposed of by the respondent firm. Since the econometric model proposed here is based on a linear regression framework, it must follow key assumptions pertaining to the linearity of a regression model. The important assumptions of an ordinary least square (OLS) based regression model are linearity, full rank, zero conditional mean of disturbance, independence of mean and variance, homoscedasticity, no autocorrelation, and normality (Greene 2008).

It is worth noting that there is some variation in the way the actual available volumes of mill residues are accounted for in equation 3.2. For instance, irrespective of the total volumes of generated mill residues, actual volume of unused wood residue would be zero if all mill residues were internally reused. While the actual number of mills reporting a zero volume was small, potential censoring in the available volumes of unused mill residues, particularly for those firms which entirely utilize it for energy generation, warrants a careful application of OLS model (Greene 2008, Long 1997). This situation requires checking the consistency of these results with a censored Tobit model. The above structural equation was rewritten as:

$$y_i^* = \beta_i x_i + \varepsilon_i \tag{3.3}$$

Where, $\varepsilon_i \sim n(0, \sigma^2)$, x's are observed for all cases and y^* is the latent variable observed for values $>\tau$ and censored for other values $\leq \tau$ (Long 1997).

$$y = y_i^* \text{ if } y_i^* > \tau_y \tag{3.4}$$

$$y = y_i \text{ if } y_i^* > \tau_y \tag{3.5}$$

Consequently,

$$P_r(\text{censored}) = P_r(y_i^* \leq \tau) = \Phi(\tau - \mu)|\sigma) \tag{3.6}$$

and ,

$$P_r(\text{uncensored}) = 1\text{-}\Phi(\tau - \mu|\sigma) = \Phi(\mu - \tau)|\sigma) \tag{3.7}$$

Finally, the expected value of censored variable equals (Long 1997):

$$E(y) = \{\Phi(\tau - \mu)|\sigma)[\mu + \sigma\lambda\,(\mu - \tau)|\sigma)]\} + \Phi(\tau - \mu)|\sigma)\tau_y \tag{3.8}$$

where,

μ= mean of latent dependent variable

σ= standard deviation of the latent variable

Φ= function of $(\mu - \tau)|\sigma)$, and

λ = the inverse mill ratio, obtained as the ratio of the identities in normal distribution function

As described previously, since some mills had no available woody residues, censored Tobit could be an appropriate econometric model (Greene 2008) to analyze this dataset. While this model is fundamentally sound, it is based on maximum likelihood estimates (Greene 2008) and population and sample size become a critical issue. As maximum likelihood estimates follow the asymptotic or large sample properties, estimates might be biased when sample size is small (Long 1997) and observations are obtained from a finite population (Greene 2008) such as in this study. On the other hand, OLS models avoid this pitfall as they are grounded upon finite sample properties (Greene 2008). Therefore, the dataset was analyzed with both regression models. This helped verify the consistency of the censored Tobit model with a finite sample model such as OLS.

All variables used in the econometric analysis with relevant descriptive statistics were reported in Table 3.1. In the absence of previous studies, the contribution of independent variables to the overall model fit, as well as economic rationale reasoning behind its explanatory power, were considered as the criteria when selecting independent variables. The variable ORG, explaining the organizational structure of a company, was initially considered in the empirical model. Since it did not contribute to the overall fit, following the above criteria, it was dropped from the final model. Therefore, independent variables measuring mill characteristics in the final model were PRI, BETTER, EMPLOYEE, YEAR, and SEASON. PRI was a descriptive measure of the respondent's wood processing facility. It was assigned as '1' for respondent having a primary wood processing facility, which included the forest products such as hardwood lumber, softwood lumber, hardwood dimensional parts, softwood dimensional parts, hardwood plywood, softwood plywood, hardwood logs, particleboard, medium density fiberboard, hardboard, OSB, and wood veener and 0 otherwise. As the name implies, since these facilities use the primary forest product directly obtained from forest as a raw material, it is likely that the amount of wood residue generated in such facilities will be higher than other secondary wood processing facilities. Therefore, the sign of PRI was expected to be positive.

Mississippi mills were asked to rate their wood processing facilities in terms of technological capabilities when compared to other nearby primary and/or secondary wood processing facilities. A respondent rating of a facility (BETTER) was assigned as '1' if the facility, in the respondent's opinion, was better than other similar nearby facilities and '0' otherwise. Since wood processing facilities using better technology would likely generate less waste, it was expected that this variable would be negatively related with the dependent variable. Another attribute of concern was firm size and its relationship with available volumes of woody residues in mills. Admittedly, since larger firms produce more output, actual forest product volumes would the best measure of size for a wood processing facility. However, many respondents did not report forest product volumes, perhaps due to propriety nature of this information. Therefore, following the approach used by Garrard and Leightley (2005) in their study, number of employees

(EMPLOYEE) was used as a proxy to account for firm size. Since larger firms have more employees, they process more volumes of woody materials than smaller firms in a specified timeframe and, are likely to generate more residues. Therefore, this variable was expected to have a positive association with wood residue availability.

The attribute accounting for the number of years a firm was in business (YEAR) was also measured in a quantitative scale. As mills were likely to find a better way to utilize their woody residues over time, it was expected that this variable would be negatively associated with the dependent variable. Finally, the attribute measuring a season in which the forest product firm was fully operational and using an 8-hour shift (SEASON) was qualitative in nature. It was assigned as '1' for the firms which were fully operated in all seasons and '0' otherwise. Since all-season operated firms process more volumes of wood in a year, there can be more unused residues available in such firms in comparison to facilities which only operate in a particular season. Therefore, this variable was expected to have a positive sign.

Another category of variables considered in the econometric model were those characterizing woody residue market opportunities. To account for the effect of a nearby market on the wood residue utilization behavior of a survey respondent, MARKET was assigned as '1' for facilities with a potential market for wood residues near their facility and '0' for others. Since a nearby market would provide the option to sell woody residues as well, the likelihood of selling woody residues for such firms will be higher in comparison to others who do not have a nearby market. Therefore, this variable was also expected to have a positive sign. Similarly, another explanatory variable considered was mill interest in working with other manufacturers to determine better ways to utilize wood residues for value-added products (WORK). This variable was assigned as '1' for respondents interested in collaborating and '0' for others who were not. Since availability of unused residues might have motivated mills to look for a better way to utilize by-products, this variable was also expected to have a positive sign.

As a third category, the socio-demographic variable used in the econometric model was the respondent's highest level of education. This variable was categorized into three groups signifying educational achievement: post graduate, undergraduate, and high school or less. Using all three dummy variables in a single regression model would create a specification error called a dummy variable trap (Greene 2008). Therefore, two dummy variables representing post graduate and undergraduate degrees were only used while analyzing data. The respondent group having a high school education or less (EDU1) served as the base category in the econometric model. The educational category (EDU2) was assigned as '1' for respondent who received an undergraduate degree and '0' otherwise. Similarly, EDU3 was assigned as '1' for respondent who received a post graduate degree and '0' otherwise. Despite the fact that education generally helps to enhance managerial skills, it was not certain as to whether there was a positive or negative association of this attribute on the dependent variable. Therefore, the sign of this variable could not be predicted.

3.4 Results

The questionnaire was mailed to all wood product manufacturers listed in the Mississippi Development Authority's online searchable database with SIC Codes 24/25 and 26/27. There were 99 returns from 458 delivered mailings leading to an adjusted response rate of 21.6%. While the adjusted response rate seemed low, it was comparable with other millowner surveys recently conducted in the United States (GC and Potter-Witter 2011, Carter 2010, Aguilar 2009, Hansen et al. 2006). Differences between early and late respondents were statistically insignificant. Similarly, there were no statistical differences between this study's respondents with available information on employees of Mississippi's forest product industry. The non-significant differences at the 5% level of significance indicated that respondents were representative of forest product industries in Mississippi and alleviated the issue of non-response bias in this survey. More importantly, since non-respondents were reluctant to answer the survey instrument in spite of multiple requests, consistent with the logic presented by Curtin et al. (2000), their absence in the survey would likely to have a minimal impact on the study implications. As a note, Curtin et al. (2000) found that the overall effects of non-respondent opinion on study implications, in particular of those who prefer not to answer after multiple attempts, are minimal.

The majority of respondents (54%) had a primary wood processing facility. In terms of volume, 92% of woody residues generated by respondents were attributed to primary wood processing facilities in Mississippi. Study results indicated that approximately 2.5 million dry tons of mill residues were generated by all respondent facilities in Mississippi, of which 30% were sold. About 40 % of survey respondents were looking for better ways to utilize mill residues in the states. This study's results revealed that approximately 208,492.8 dry tons of mill residues per month were obtained from 99 responding firms in Mississippi. Similarly, since nearly 99% percent of total wood residue from responding mills was either reused in the same facility or sold, only the remaining 1% percent, which equaled to 2,140.9 dry tons per month, was available for supplement or additional use. Likewise, total logging residue volumes sold by respondent firms equaled to 53,427.5 dry tons per month. Therefore, the total internally, unused volumes of mill residues, derived by summing up volumes sold, given away, or disposed of, equaled to 55,568.4 dry tons per month or 1,852.3 dry tons per day. Since the extrapolation multiplier of this survey was (i.e. 458/99) 4.6, total internally unused volumes of mill residues from all operating mills in Mississippi approximately equal to 8572 dry tons per day.

While autocorrelation and multicollinearity were not an issue, diagnostic tests revealed that the data was not normally distributed nor were the error terms homoscedastic. However, these conditions were met after a logarithmic transformation of the dependent variable, as suggested by Zar (2010). Therefore, a generalized least square regression resulted in an appropriate model. Results based on the generalized least square regression model using White's heteroscedasticity consistent standard errors were reported in Table 3.2. Similarly, results based on the censored Tobit model were reported in Table 3.3. All coefficients obtained from the generalized least square model and the censored Tobit model had the same signs, which was an indication of robustness of the econometric analysis. Since only few mills reported zero available volumes of unused mill residues, unlike suspected earlier, OLS regression did not suffer from potential censoring bias. Therefore, to avoid the pitfall of a low sample size issue and study implications, results based on a generalized least square (Table 3.2) regression framework were utilized for the remainder of the analysis.

The global F-test was significant at 5% indicating that the model was overall a good fit. Among the nine variables included in the final model, six variables were significant at the 10% level. More explicitly, three variables characterizing mill characteristics: PRI, EMPLOYEE, and SEASON were positive and significant at the 10% level. As a note, since the generalized least square model is set up in the form of a semi-logarithmic regression, dummy variables need to be interpreted following the procedure suggested by Halvorsen and Palmquist (1980)[3]. For instance, available median volumes of mill residues in primary wood processing facility will be 191% more than other mills. However, coefficient of EMPLOYEE, which was converted into a logarithmic scale, provides the direct measurement of elasticity (Greene 2008). This result indicated that 1% increase in employee number in a facility would increase the availability of mill residue by 0.79%. Among the variables characterizing woody residue market opportunities, MARKET was positive and significant at the 10% level and WORK was positive and significant at the 5% level. Finally, the variable accounting for survey respondent's highest level of education as postgraduate degree (EDU3) was negative and significant at the 10% level.

3.5 Discussion and Conclusion

Consistent with expectations and existing findings (Aldermann 1998), volumes of potentially available mill residues were greater in primary wood processing facilities than other secondary wood processing firms. Aldermann (1998) reported that 80% of total wood residues in the commonwealth of Virginia were produced in primary wood processing facilities. Walsh (2008) also noted higher availablity of unused mill residues in primary wood processing firms than others. Similarly, employee number in a firm was

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[3]Halvorsen and Palmquist (1980) suggested that an antilog of an estimated dummy coefficient should be multiplied by 100 after subtracting 1.

also a positive and a significant determinant of unused woody residues in a forest product firm. Employee numbers have been used as a proxy for size of forest product plants in the United States (GC and Potter-Witter 2011, Garrard and Leightley 2005). As larger mills, all else equal, would like to generate more primary wood products, perhaps this could be the rationale behind higher availability of unused woody residues in a firm having more employees.

Another significant determinant of available woody residues was year round versus seasonal operation of a wood processing facility. Study results resonate with the logic that regardless of the reason for a seasonal operation, total volumes of wood residues generated in such firms, would be less than a forest product firm that operated year round. However, implications of this result are not trivial as mill-residue based bioenergy industry is likely to suffer from the inherent seasonality in the forest product industry. As evident from the Georgia Timber Report (2005) report, supplies of forest products are significantly influenced by the weather conditions. Vila et al. (2005) further noted that strategies such as modification in production technology or the temporary shutdown of production, to account for the impact of potential market fluctuations in the supply chain network, are not uncommon in the forest products industry.

As noted earlier, it is logical to assume that mills having a woody residue market near their facilities are likely to have more options for utilizing it in their best interests. An economically rational decision dictates that mills having a nearby market for woody residues will not use them internally for energy generation unless the marginal benefits of doing so outweigh the forgone opportunities (Nicholson 1995). However, mills not having a nearby woody residue market would not have such flexibility. In other words, these entrepreneurs have limited options for reusing by-products in their own facilities or giving them away. Therefore, there was higher availability of unused woody residue in the mills having nearby markets, in comparison to those not having nearby markets. There was a direct and statistically significant relationship between the likelihood of mill interest to work with other forest product industries for better utilization of woody residues and amounts of wood residues potentially available for other uses. Perhaps these mills are looking for new economic opportunities to utilize by-products generated in their facility. The availability of unused woody residues might have prompted mills to explore these opportunities.

Finally, study results indicated that respondents having a post-graduate education were efficient in terms of utilizing mill residues obtained from their facilities. On the other hand, respondents having an undergraduate degree did not have a significantly different likelihood of having unused woody residues than those having a high school degree or less. One possible explanation is that managerial skills obtained through a post-graduate education might have helped such respondents to efficiently utilize woody residues obtained from their facility. It is worth noting that person having the best information on mill residues, product market, and with a vision for future collaboration plan of mill was requested to fill out the survey. While unlikely, it is possible that the survey respondent might not be a sole decision maker for the mill. Therefore, influence of education attribute on availability of mill residue needs to be interpreted accordingly.

Study results generally indicate that clean biomass obtained during wood processing can be utilized to develop wood-based bioenergy in the United States. As primary wood processing facilities and availability of unused woody residues were positively related, it can be argued that wood-based bioenergy can be generated at a cheaper price if the bioenergy producing facility can be located near a primary forest product mill. Given that most wood-residues generated in Mississippi (92%) were obtained from primary forest product manufacturing facilities, these results are promising for entrepreneurs who intend to establish a wood-based bioenergy industry in the state. Of note, Angular (2009) reported that primary wood processing facilities such as sawmills prefer to be located near raw materials rather than final markets. Hagadone and Grala (2012) also noted similar findings in Mississippi. Logging and thinning residues obtained during timber harvesting can also be used as feedstocks for a wood-based bioenergy industry. Thus, wood-based bioenergy facilities, if located nearby primary forest product plants such as sawmills, can obtain both mill and logging residues at a relatively lower price. Similarly, the likelihood of obtaining bioenergy feedstocks is greater if wood-based bioenergy could be located near a larger, year round operational forest product firm. While the available amount of woody residues is greater in mills located nearby a market, there might be competition among buyers to purchase woody residues from such facilities. Similarly, seasonal variations in the production activity in the forest product industry are not uncommon and the bioenergy industry might suffer from it. Therefore, an appropriate location of a wood-based bioenergy industry should be an important consideration to ensure low cost and sustainable wood-based bioenergy production. Given that most woody residues currently available are sold to existing markets, entrepreneurs should realize that they might need to pay a competitive feedstock price to ensure its supply to their wood-based bioenergy facilities. Since some amount of woody residue is not utilized in mills, the introduction of wood-based bioenergy might be good for some, if not all, mills in the state. Moreover, given the existing competition in forest product markets in the U.S., integrating existing facilities with wood-based bioenergy operations might be a better option than starting a stand-alone bioenergy facility.

This study did not account for the effect of price on availability of mill residues for utilization as a bioenergy feedstock. The reasoning was that many landowners did not reveal information pertaining to the revenue they generated by selling mill residues in Mississippi. Since most unused mill residues in Mississippi are currently sold, such information would help in developing mill residue supply projections for bioenergy feedstock use in the state. Therefore, future research pertaining to mill residue supply projection is suggested. While this study was conducted in Mississippi, given similarities in forest type, timber product needs, and forest product industry markets, study results are applicable to other southeastern states as well. Nonetheless, study results indicate that forest product industries can become important contributors for supplying wood-based bioenergy feedstock, if competitive feedstock prices could be offered to them.

Table 3.1 Variable descriptions used to determine availability of unused mill residues in Mississippi in 2011 based on a mail survey of wood processing facilities.

Variables	**Description**	**Mean**	**SD***
WOOD RESIDUE	Amount of wood residue, measured in tons, that was sold, given away or disposed by respondent mill in logarithmic scale	4.56	2.60
PRI	Type of respondent mill, 1 if primary, 0 otherwise	0.54	
BETTER	Technical capability of mill, 1 if better than nearby mills, 0 otherwise	0.37	
EMPLOYEE	Number of employees in a mill, measured in a logarithmic scale	1.52	0.63
YEAR	Mill years in business	32.07	20.60
SEASON	Season in which forest product industry was fully operational for 8 hour shift, 1 if all seasons, 0 otherwise	0.94	
MARKET	Potential market for wood residue near the facility, 1 if available, 0 otherwise	0.59	
WORK	Respondent interest in working with others to determine better ways to utilize wood residues, 1 if interested, 0 otherwise	0.81	
EDU1	Highest level of respondent education, 1 if high school degree, zero otherwise	0.28	
EDU2	Highest level of respondent education, 1 if Bachelor degree, zero otherwise	0.21	
EDU3	Highest level of respondent education, 1 if post graduate degree, zero otherwise	0.51	

*Standard deviation is only reported for quantitative variables

Table 3.2 Generalized least square regression model results to determine the availability of the unused mill residues in Mississippi in 2011 based on a mail survey of wood processing facilities.

Variables	Coefficient (Std. error)	T-value
PRI	1.06* (0.56)	1.93
BETTER	0.50 (0.54)	0.93
EMPLOYEE	0.80* (0.43)	1.87
YEAR	-0.01 (0.02)	-0.86
SEASON	2.50* (1.46)	1.72
MARKET	1.16* (0.61)	1.91
WORK	1.44 ** (0.68)	2.12
EDU2	-0.47 (0.70)	-0.68
EDU3	-1.61* (0.81)	-1.99
Intercept	-0.65 (1.68)	
Global F-test		2.54 (0.01)
N		61

**Significant at 5% level,*Significant at 10% level

Table 3.3 Results based on a censored Tobit regression model to determine availability of unused mill residues in Mississippi in 2011 based on a mail survey of wood processing facilities.

Variable	Coefficient (Std. Error)	Coefficient/Std. Error
PRI	0.999 (0.646)	1.546
BETTER	0.522 (0.665)	0.785
EMPLOYEE	0.764 (0.516)	1.479
YEAR	-0.012 (0.017)	-0.746
SEASON	2.466* (1.434)	1.719
MARKET	1.169* (0.629)	1.859
WORK	1.490* (0.805)	1.850
EDU2	-0.524 (0.814)	-0.644
EDU3	-1.680* (0.934)	-1.798
INTERCEPT	-0.585 (1.867)	
Log-likelihood	-133.771	
N	61	

*Significant at 10% level

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CHAPTER IV

INPUT-OUTPUT MODELLING OF WOOD-BASED BIOENERGY INDUSTRIES IN MISSISSIPPI

4.1 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 short period of time. Results showed that the operation of a wood-pellet facility would contribute 83 full- and part-time jobs and $12 million worth of economic output to the state economy annually. Likewise, operation of a bio-oil facility would provide 165 new full- and part-time jobs and an economic output of $17 million. Similarly, $96 million of economic output 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 substantial and likely to draw the attention of policy makers and investors towards developing wood-based bioenergy opportunities in Mississippi.

4.2 Introduction

The southern United States has abundant forest resources, covering approximately 29% 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., Henderson et al. 2008, Munn and Henderson 2003, Cox and Munn 2001). In particular, forest resources provide an important economic base in Mississippi as their annual contribution in terms of economic output is over a $17.4 billion (Henderson et al. 2011). The authors noted that forest product industry contributes to the 10.5% of the total economic output and 8.5% of all jobs in Mississippi.

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 provides an opportunity to establish wood-based bioenergy as a new market for forest resources in the southern United States (Perez-Verdin et al. 2008, Henderson 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 (Henderson et al. 2008, Guo et al. 2007).

Since existing energy production in Mississippi is far less than consumption (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 economy. Establishment of a wood-based bioenergy industry, apart from meeting the state energy requirements, would certainly generate employment opportunities (Perez-Verdin et al. 2008).

Research concerning economic impacts associated with wood-based bioenergy is limited because it is a relatively new opportunity. Gan and Smith (2007) evaluated the possibility of generating electricity by using of logging residues in East Texas along with the coinciding socio-economic and environmental benefits. Their study used input-output models to understand the total economic impacts of logging residue utilization on socio-economic indicators. The authors estimated 2.4 million tons of CO_2 displacement by replacing coal with logging residues in power generation. Other reported socio-economic benefits included the reduction of $7.3 to 9.1 million in forestry 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, Perez-Verdin et al. (2008) determined that logging and thinning residue recovery would generate 585 full- and part-time direct jobs, contributing $152 million of gross domestic output in Mississippi. 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 $64.5 million annually to the state economy. Moreover, results indicated that some 1,756 direct employment opportunities with a total gross output of $242.7 million per year would be created through the establishment of bio-fuel facilities in Mississippi. Other studies (Hodges et al. 2010, Timmons et al. 2007, Faaji et al. 1998) 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 bio-ethanol production have been analyzed to account for the economic impacts of woody biomass utilization for bioenergy (Perez-Verdin et al. 2008, Gan and Smith 2007).

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 (Spelter and Daniel 2009, Demirbas 2008, Badger and Fransham 2006). Accurate estimates of economic impacts will acknowledge the contribution of new bioenergy industries through employment opportunities, economic outputs, and taxes collected by 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.

Since the region contains a large amount of unused woody biomass, there is increasing interest among North American entrepreneurs for wood-pellets (Spelter and

Daniel 2009), a compact wood fuel currently popular in Europe. Production and marketing of wood-pellets has continuously increased since 2002, and North American production was expected to reach 6.2 million tonnes in 2009 (Spelter and Daniel 2009). Not surprisingly, wood-pellet processing facilities have already started production in Mississippi (Indeck 2009). Similarly, given its excessive handing 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, which 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 (Guo et al. 2007, Badger and Fransham 2006). Likewise, in recent years converting woody biomass into bio-methanol has emerged as a new opportunity (Demirbas 2008). Given that ligno-cellulosic bio-methanol 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 which have started receiving added attention from entrepreneurs and policy makers lately. Possibly because of this, none of the earlier research related to economic impact analysis of woody biomass utilization, to the best of my knowledge, has included wood-pellets, bio-oil, and methanol-based gasoline production. Economic impact analysis of these facilities would benefit policy making process and those investors who intend to establish such facilities in the state. Therefore, realizing this research gap, an economic impact analysis of construction and operation of methanol to gasoline (MTG) technology, of a bio-oil facility, and of a wood-pellet facility was conducted.

4.3 Input-output Modeling

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

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

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 (MIG, Inc. 2000). The IMPLAN database, which currently includes 440 sectors, is developed annually using data from the U.S. Census Bureau (MIG, Inc. 2000). IMPLAN separates out total impacts into direct, indirect, and induced impacts (MIG, Inc. 2000). Similarly, easiness in deflating or inflating model results and data customization capabilities are some of the other benefits of using IMPLAN (MIG, Inc. 2000).

4.4 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 (Perez-Verdin et al. 2008, Gan and Smith 2007). Requisite cost information pertaining to wood- pellets, bio-oil, and the methanol-based gasoline industry were obtained from secondary sources. The input-output model of the Mississippi economy was developed using the IMPLAN 2010 dataset.

The North American wood-pellet industry generally relies on primary wood processing facilities for biomass feedstocks and annual plant capacity of the firms varies from 30,000 to 100,000 tonnes (Pirranglia et al. 2010, Spleter and Toth 2009). Therefore, to account for a realistic industry scenario in United States, a wood-pellet firm having 75,000 tonne[4] per year processing plant was considered for analysis. Pirranglia et al. (2010) also noted that wood-pellets require 6 to 8% of moisture to meet the product standard. 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 (Pirranglia et al. 2010). Pirranglia et al. (2010) reported that the total construction and installation cost of a 75,000 tonne per year plant was approximately \$12.25 million with an additional \$ 13.85 million annual

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[4] Information available in US ton are converted into tonne (SI Unit) by a conversion factor of 1 tonne=1.102311 ton.

operating costs. Detailed information on construction and operational costs of a wood-pellet industrial plant is reported in Table 4.1.

Despite its U.S. commercial production, market and technologies available for bio-oil production are currently in their 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 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 tonne of biomass per day was about $58 million. Ringer et al. (2006), however, estimated total capital costs of $48.29 million for the establishment of a 550 dry tonnes per day bio-oil facility for year 2003. Similar variations were reported in mid-size bio-oil facilities. Badger et al. (2011) reported a total investment need of $6.03 million for establishment of 90.71 dry tonne per day facility. In contrast, a report submitted by Short Elliott Hendrickson (2009) to the Bios Forte Band of Chippewa provided a business plan with detailed construction and operating costs needed for establishment of small- to mid-size bio-oil facilities. Total investment needed for establishment of a 90.71 dry tonne per day facility was estimated at about $19 million. The report revealed that a bio-oil facility having a plant capacity of 181.44 dry tonne per day 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 $29.22 million. Likewise, total operating costs of bio-oil facilities, assuming delivered feedstock costs at $33.06 per green tonne, was $10.46 million. Short Elliott Hendrickson (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 tonne per day.

Therefore, this data was utilized to develop the IMPLAN model used in the current analysis. A detailed breakdown of construction and operational costs of a 181.44 dry tonne per day bio-oil facility is reported in Table 4.2.

The third category considered for economic impact analysis was a methanol-based gasoline facility. The National Renewable Energy Laboratory (NREL) has conducted an assessment of producing gasoline from methanol by way of a thermo-chemical process (Philips et al. 2011). This facility requires 2000.34 dry tonnes of biomass per day, which by the process of gasification, is converted into methanol via a syngas route. Finally, gasoline is produced from methanol through the "methanol-to-gasoline" (MTG) process. Total estimated construction and annual operating costs of this facility were $199 million and $84 million, respectively (Table 4.3).

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 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. Bailey et al. (2011), however, 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 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, being a “snapshot model” of an economy; IMPLAN cannot estimate economic impacts over a long time-span (Day 2012). In this study, while wood-pellet and bio-oil facilities were expected to be constructed within a year, secondary literature revealed that 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 assumptions of the IMPLAN model, 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 (Day 2012, Grover 2009, Perez-Verdin et al. 2008), it would be interesting to examine 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 break down, were also estimated in the IMPLAN model. Such a comparison, however, was possible only for the methanol-based gasoline facility, as 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. Since wood-pellet facility primarily relies on mill residues (Spleter and Toth 2009), total available volumes of mill residues, reported in chapter III of this dissertation, 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% of the available woody biomass was contributed by mill residues, 97% 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), other than mill residues, were used for estimating overall economic impacts associated with bio-oil and methanol facilities in Mississippi. Information available in IMPLAN 2010 database was used for these estimates.

4.5 Results

IMPLAN results related to economic impacts of bioenergy industries in Mississippi are reported in Tables 4.4, 4.5, and 4.6. As suggested in the literature (Day 2012, Grover 2009), construction and operation related activities are separately simulated for economic impact analysis. Construction related activities in the wood-pellet facility would create 15 jobs and generate $2.34 million of gross output directly. These construction activities would create an additional 32 full- and part-time jobs due to indirect and induced impacts. The industries benefiting the most from construction activities included: construction of other new nonresidential structures, and food services and wholesale trade businesses among others. Total value added, obtained as a sum of employee compensation, proprietor income, and taxes was $2.93 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 $2.09 of value-added economic return, after taking state leakages into account. Of note, construction related economic impacts are short-term and do not persist after the completion of a construction period. Similarly, annual operation and management related activities in the wood-pellet facility are expected to contribute $12.37 million in economic output in Mississippi, including $3.74 million in wages and 83 full- and part-time jobs. Of total output, the value added component had $8.45 million or 68% share. Based on output, industries that benefited the most from the operation of a wood-pellet plant were support activities for forestry or timber production, electric power generation, food services and drinking places; forestry, forest product and timber production. Table 4.4 shows the economic impacts of construction and operation of a wood-pellet facility in Mississippi. As a note, direct and total economic impacts take the out of state leakage into account.

The economic impacts of constructing a bio-oil facility are greater than a wood-pellet facility (Table 4.5). Construction related activity was estimated to create 122 new full- and part-time jobs and $15.50 million of economic output. Of these, 67 new full- and part-time jobs and $9.71 million of economic output came from direct economic impacts in Mississippi. The SAM multiplier of 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 $0.60 after taking state leakages into account. Total estimated value-added economic impacts were $7.38 million, of which $4.09 million was direct impacts. Based on output, the most positively affected sectors by the construction of a bio-oil facility were architectural, engineering, and related activities; construction of new nonresidential structures; and metal tank manufacturing. Similarly, operation-related expenses in the bio-oil facility, which were separately simulated for impact analysis, were estimated to create a total of 165 new full- and part-time employment opportunities and $17.20 million of economic output in Mississippi. The SAM output multiplier for a bio-oil facility operation was 1.65 and its total value-added contribution was $11.58 million. As a note, all direct and total economic impacts of this facility take the out of state leakage into account. Sectors most affected by the operation of a bio-oil facility were support activities for forestry and related activities; employment and payroll; and commercial machinery repair, and maintenance.

Economic impacts associated with the construction and operations of methanol-based gasoline facility are reported in Table 4.6. 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 is estimated to create 107 full- and part-time jobs and $12.04 million of economic output in the first year. There would be 763 new full- and part-time jobs and $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 $47.48 million of economic contributions in Mississippi. In total, the operation would contribute economic value of $96 million and 795 full- and part-time jobs, annually. The SAM employment multiplier for methanol-based gasoline operations, after taking state leakages into account, was 3.27, indicating a strong ripple effect for this facility. As a note, all direct and total economic impacts of this facility take the out of state leakage into account. The largest sector impacted was forestry support activities, with the next two largest sectors being forestry/forest products, and building and dwelling services.

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 (Table 4.6 and 4.7). Similarly, state economic impacts of hypothetical wood-pellet, bio-oil and methanol facility based on per unit tonne of biomass use are reported in Table 4.8.

Available mill residues would be sufficient for establishing 37 hypothesized wood-pellet facilities, should the entire potentially available mill residues could be used for generating wood-pellet within state. Wood-pellet industry, in such case, would generate 3119 full and part-time jobs with $468 million of economic output in Mississippi. Likewise, 60% use of the potentially available mill residues in wood-pellet facilities would generate 1877 full and part-time jobs with 280 million of economic output in Mississippi (Table 4.9).

Utilizing all potentially available woody biomass reported by Grebner et al. (2009), except mill residues, would be sufficient to establish 53 bio-oil facilities or four methanol facilities. Given that both facility types are likely to compete for same source of biomass feedstock (Philips et al. 2011, Short Elliott Hendrickson 2009), total economic impacts in Mississippi economy, similar to what argued by Perez-Verdin et al. (2008), would depend upon the proportion of available woody biomass for an individual facility type. For example, 100% distribution of available woody biomass for bio-oil facilities would generate 8676 full and part-time jobs with $882 million of economic output. Likewise, 40% distribution of available biomass in bio-oil facilities and remaining 60% use in methanol facilities would generate 5752 full and part time jobs with 629 million of economic output (Table 4.10). Results indicated that three facility types would roughly contribute 1.47% of the Mississippi GRP, should all the potentially available biomass could be used for generating bioenergy (Table 4.9 and 4.10). Of note, even with a 60% use of potentially available biomass, combined economic impacts of three facility types, in terms of total economic output, would be slightly higher than 1% of the Mississippi GRP.

4.6 Discussion

These results provided an estimate of the economic impacts of some selected wood-based bioenergy facilities in Mississippi. Henderson et al. (2011) reported that forest products industry contributes 10.5% of the total economic output in the state of Mississippi. As a part of forest product industry, overall economic impacts associated with selected facilities are not trivial and depict the prospect of wood-based bioenergy industries in Mississippi. IMPLAN results from this study are comparable to other employment-related information available in the region and the U.S. for the same industry. For instance, Pirranglia et al. (2010) revealed that operation of a typical wood-pellet facility would create 30 new jobs in the United States. Similarly, Indeck (2009) reported that a typical wood-pellet plant would likely provide 10-15 full time permanent jobs in Mississippi. Direct and total employment impacts based on the IMPLAN model were comparable to these estimates (Pirranglia et al. 2010, Indeck 2009) and make intuitive sense.

Smaller economic impacts derived from wood-pellet and bio-oil industries are attributed to the small size of their production facilities. Generally, since comparatively small construction and operation costs are needed for establishing such facilities, relatively small economic impacts are generated compared to an investment-intensive methanol-based gasoline facility. Consistent with projections, these facilities would be created in greater numbers and 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 established in Wiggins and Amory in Mississippi (Coblentz 2010), is likely to have substantial impacts on the economy of Mississippi. Indeck (2009) indicated that establishing one pellet mill with a production capacity of 63503 dry tonnes per year could replace 5% of annual fuel requirements in a 250 MW electricity generating plant. Following the logic forwarded by Grado et al. in their waterfowl hunting study (2011), perhaps localized production/ utilization and an established market within Mississippi might have been the reasons behind a higher multiplier effect and fewer dollar leakages in the case of a wood-pellet facility.

Apart from biomass availability, economic viability could be another major concern for the sustainable production of bioenergy in Mississippi. Pirraglia et al. (2010) revealed that a wood-pellet facility in 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 $221 per dry tonne. Based on the average estimates of prices for wood-pellets in United States, it can be a profitable business (Bourque 2012). Most importantly, similar to what characterized in Indeck (2009), established production technology, relatively small transportation costs, and small biomass feedstock requirements are likely to make this industry an attractive investment venture among small or medium investors in the long-run. Similar to the wood-pellet facility, a medium sized bio-oil facility would not require large amounts of biomass feedstock. Since a wood-pellet facility mostly relies on feedstocks from primary wood processing facilities (Spleter and Toth 2009), competition for biomass feedstock between the wood-pellet industry and bio-oil industry will likely be minimal in the short-run. The bio-oil industry is still improving in terms of its technical efficiency; and it should become a more resource efficient industry in the future. Bio-oil is an important chemical product that has multiple uses (Bagder et al. 2011). Bio-oil and char are important ingredients in producing industrial natural gas, propane, and other fuel oils (Bagder et al. 2011). Therefore, establishing this industry would also contribute to other industries in the state and region as well.

Amongst all industry types, the methanol-based gasoline plant, which on a daily basis requires 2,000 dry tonnes of biomass to operate, had the highest impact on the economy of Mississippi. Given that investment required building a methanol-based gasoline facility was the greatest of the three types of facilities considered, having markedly higher impacts makes intuitive sense. Based on the Grebner et al. (2009) estimates, available biomass feedstocks are sufficient to establish four methanol-based gasoline plants in Mississippi. In addition, the unit cost incurred for gasoline and liquefied petroleum gas (LPG), produced from 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 4.8). In other words, a methanol-based gasoline facility, all else being equal, would use the greatest volumes of woody biomass for same amount of economic output in the state economy.

Of note, since 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 over-simplified assumptions, if any, related to construction impacts of an industry should be avoided (Day 2012). Over-simplified assumptions, as seen in Table 4.6 and 4.7, might inflate or at least provide unrealistic information related to the economic impacts of an industry.

4.7 Conclusion

Given Mississippi's large forest resource base, it has an enormous 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 generating jobs and economic outputs in the state. While construction related jobs are temporary and short-term, operations of 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. This study's results revealed that the establishment of a bio-oil industry would contribute to the state economy by providing markets for logging residues and 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 amongst all three bioenergy industries considered in this economic analysis. However, as 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 negative impacts on wildlife and the environment. Therefore, financial burdens in minimizing negative environmental consequences, given excessive uses of woody biomass in these industries also need to be examined. Nevertheless, the establishment of all three industries would not only create jobs and other economic opportunities, but the state would surely contribute to the goal of making the United States an energy independent nation.

Table 4.1 Estimated operation and capital cost (2007 US$) for a hypothetical wood-pellet manufacturing facility in the United States based on techno-economic analysis study by Pirranglia et al. (2010).

IMPLAN Sector	Cost category/industry	Million $/year
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 costs	2.70
Employee compensation	Labor	3.76
Tax	Tax	0.52
Total Operating costs		13.85

Table 4.2 Estimated operation and capital costs (2008 US$) for a hypothetical bio-oil manufacturing facility in Mississippi as reported by Short Elliott Hendrickson (SEH) (2009).

IMPLAN sector	Cost category/industry	Million $/year
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
Tax	Licensing fee	3.52
Total capital cost		29.29
Operation costs		
15	Biomass cost	3.942
19	Biomass grinding cost	0.66
31	Electricity cost	0.99
121	Nitrogen and chemical	0.80
260	Propane	0.05
380	Misc. supplies and service	0.24
417	Equipment maintenance	2.00
384	Administration.	0.50
Employee compensation	Labor	1.30
Total operation costs		10.46

Table 4.3 Estimated operation and capital cost (2007US$) for a hypothetical methanol-based gasoline manufacturing facility in the United States based on techno-economic analysis study by Philips et al. (2011).

IMPLAN sector	Cost category/ industry	Million $/year
Capital cost		
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	MTG 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 and others	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 operating costs		84.06

Table 4.4 State economic impacts of a hypothetical wood-pellet facility in Mississippi based on the Impact Analysis for Planning (IMPLAN) 2010 database.

	Economic impacts				
Activities	Direct	Indirect	Induced	Total	Type SAM
Construction					
Employment	15.3	5.4	26.8	47.04	3.09
Labor income (M$)	0.70	0.23	0.89	1.83	2.61
Total value added (M$)	0.95	0.34	1.65	2.93	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

Table 4.5 State economic impacts of a hypothetical bio-oil facility in Mississippi based on Impact Analysis for Planning (IMPLAN) 2010 database.

	Economic impacts				
Activities	Direct	Indirect	Induced	Total	Type SAM
Construction					
Employment	67.04	25.52	29.78	122.34	1.82
Labor income (M$)	3.39	0.97	0.99	5.35	1.58
Total value added(M$)	4.09	1.46	1.83	7.38	1.81
Output(M$)	9.71	2.73	3.06	15.50	1.60
Operation					
Employment	91.53	25.95	47.06	164.54	1.80
Labor income (M$)	4.72	0.88	1.57	7.17	1.52
Total value added(M$)	7.54	1.15	2.89	11.58	1.54
Output(M$)	10.40	1.96	4.84	17.20	1.65

Table 4.6 State economic impacts of a hypothetical methanol-based gasoline facility in Mississippi based on Impact Analysis for Planning (IMPLAN) 2010 database.

	Economic impacts				
Activities	Direct	Indirect	Induced	Total	Type SAM
1st Year Construction					
Employment	67	9	32	107	1.60
Labor income (M$)	4.33	0.26	1.05	5.64	1.30
Total value added(M$)	6.58	0.48	1.94	9.00	1.37
Output(M$)	8.36	0.80	3.24	12.40	1.48
2ndyr Construction					
Employment	448.50	126.45	188.57	763.52	1.70
Labor income (M$)	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
3rdyr 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

Table 4.7 Variations in state economic impacts of a hypothetical methanol-based gasoline facility in Mississippi based on the assumption of one year construction impact based on Impact Analysis for Planning (IMPLAN) 2010 database.

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

Table 4.8 State economic impacts of hypothetical wood-pellet, bio-oil and methanol industries on Mississippi economy based on per unit tonne of biomass use by using IMPLAN 2010 database.

Industry	Total ($M)	Per unit ($)
Wood-Pellet	12.37	164.93
Bio-oil	17.2	259.72
Methanol	96.4	132.03

Table 4.9 Economic impacts of wood-pellet facilities on overall Mississippi economy based on contributions to growth regional product (GRP) by using IMPLAN 2010 database.

Biomass Use (%)	No of facility	Employment	Output	Contribution to GRP (%)
100%	37.83	3129	456.99	0.50
80%	30.27	2503	365.60	0.40
60%	22.70	1877	274.20	0.30
40%	15.13	1251	182.80	0.20
20%	7.57	626	91.40	0.10
0%	0.00	0.00	0.00	0.00

Table 4.10 Economic impacts of bio-oil and methanol on overall Mississippi economy based on contributions to growth regional product (GRP) by using IMPLAN 2010 database.

Biomass use distribution		Number of potential facilities		Total Employment		Total Output		Combined contribution to GRP (%)	
Bio-oil	Methanol	Bio-oil	Methanol	Bio-oil	Methanol	Bio-oil	Methanol	Employment	Output
100%	0%	52.73	0.00	8676	0.00	882.47	0.00	0.58	0.97
80%	20%	42.18	0.96	6941	760	705.98	92.21	0.52	0.88
60%	40%	31.64	1.91	5206	1521	529.48	184.43	0.45	0.78
40%	60%	21.09	2.87	3471	2281	352.99	276.64	0.39	0.69
20%	80%	10.55	3.83	1735	3042	176.49	368.86	0.32	0.60
0%	100%	0.00	4.78	0.00	3802	0.00	461.07	0.25	0.51

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CHAPTER V

CONCLUDING REMARKS

The overall goal of this study was to understand the socio-economic opportunities and concerns associated with wood-based bioenergy. Sustainability of bioenergy is likely to be affected by factors such as feedstock availability, motivations of those who own woody biomass, socio-economic impacts, and acceptance of bioenergy among others. Feedstock availability is an important prerequisite for sustainable production of bioenergy. As mentioned in the previous chapters, private forest lands and the forest product industries are two primary sources of woody biomass in the state of Mississippi. Therefore, from a strategic planning standpoint, issues and aspirations of these feedstock suppliers become critical to ensure long-run biomass supply in Mississippi. To this end, Chapter II covered choice experiment research and provided important insights into the harvesting behavior of NIPF landowners, in light of attributes such as logging residue utilization, site preparation requirement, and potential environmental concerns. Results revealed that while NIPF landowners preferred to sell most of their available logging residues, they were also concerned about the potential negative impacts of timber harvesting on the environment. While large percentage of landowners were in favor of some form of biomass harvesting in the state of Mississippi, elderly landowners and those in lower income categories were relatively less receptive to biomass harvesting. These results were consistent with recent studies conducted in the southern United States and indicate the need of bioenergy related awareness amongst elderly landowners and those in low income groups.

Similarly, estimates based on a mill survey provided base-line information pertaining to the wood-based bioenergy production potential in Mississippi. Study results generally indicated that mill residues generated during wood processing activities can be utilized to develop some wood-based bioenergy industries in the state. Study results also indicated that likelihood of obtaining bioenergy feedstocks will be higher, if the facility locates nearby a primary forest product mill. Findings of this study indicated that some information related to wood-based bioenergy and other mill residue markets might help less formally educated millowners to efficiently utilize mill residues. Nonetheless, study results indicated that forest product industries can become important contributors in supplying wood-based bioenergy feedstocks in the state.

Owing to continuous research and development (R&D) activities, new technologies have been developed to ensure low-cost and sustainable bioenergy in the United States. While such technologies have received significant attention in the nation, their cost-effectiveness and economic impacts on local and/or regional level are yet to be known for sure. Therefore, it was imperative to understand the economic impacts of some potential bioenergy industries in Mississippi. To this end, Chapter IV of this dissertation was focused on analyzing economic impacts of wood-pellet, bio-oil and methanol facilities in Mississippi. As expected, results from an input-output model indicated that the total economic impacts to the state from new forms of bioenergy industry are substantial. Study results revealed that the wood-pellet industry, which is already in operation in Mississippi, has contributed to the economy by creating a substantial number of jobs in the state. Study results also indicated that bio-oil and methanol facilities, which are yet to be established in Mississippi, will also contribute to the state economy by providing avenues for new logging residue markets and job creation.

These study results generally indicated a promising future of bioenergy in Mississippi. Despite having some degree of skepticism amongst elderly respondents, landowners, as a group, were in favor of supplying logging and thinning residues for bioenergy. Likewise, majority of mills were also in favor of finding a better way to utilize available mill residues in Mississippi. Given that both these groups have positive opinions and motivations, actual available volumes of woody biomass would be even more than 3.6 million dry tonnes for bioenergy use. Therefore, bioenergy industry would likely to suffer little, if any, from the issue of feedstock shortage in Mississippi. With an ample feedstock supply, wood-pellet, bio-oil and methanol facilities would substantially contribute to the state economy by creating large number of jobs and economic outputs in Mississippi.

Of note, this study was not without its limitations. For instance, since wood-based bioenergy is a relatively new opportunity, not many studies in the past have analyzed this issue econometrically. While both econometric studies certainly contribute to the existing body of knowledge, the selected independent variables in absence of well-documented literature are likely to suffer from selectivity bias. Another concern worth noting is the potential effect of non-response bias in the both survey based studies. Despite the lack of evidence concerning non-response bias, its impact in case of a lower response rate cannot be ruled out completely. Similarly, the choice experiment survey did not explicitly take into account the opinion of smaller landowners having landholding sizes less than 100 acres. While these landowners are less likely to contribute to the biomass feedstock supply, admittedly, this study does not cover motivations of such landowners in Mississippi.

Likewise, despite the best efforts, information on operation and construction related costs could not be obtained from firms located within Mississippi or neighboring states. Therefore, this economic impact analysis study relied on secondary data. Actual costs in establishing these facilities in Mississippi can be somewhat different than those used for the economic impact analysis. Given the policy implications of these impacts, an empirical verification of economic impacts, by using the data from industries located within or nearby Mississippi, is recommended. Likewise, this study did not take into account opportunities and concerns associated with urban wood waste availability, bioenergy potentials of bottomland hardwoods, and landowner motivations for planting short-rotation woody crops. Therefore, continued, future research in these topics is recommended.

Nonetheless, this study has substantially contributed to the existing body of knowledge pertaining to the issue of sustainable feedstock supplies and economic impacts of wood-based bioenergy in Mississippi. Given the similarity in geography and the socio-economic demographics, findings of this study are also applicable in other states, in particular, within the southern United States.

APPENDIX A

SURVEY INSTRUMENT

Mill Owner Survey on Wood Residues in Primary and Secondary Forest Products Industries in Mississippi

Section A: We would like to obtain information about primary and secondary forest products you produce. Please have the most appropriate person complete the survey.

A1. To segregate the information on wood residues from primary and secondary sources, we have divided applicable wood products into the following categories. Please indicate the forest products used or produced in your facility. (Mark circle)

Group A			**Group B**
o	Hardwood Lumber	Hardwood Logs	Furniture
o	Softwood Lumber	Softwood Logs	Flooring
o	Hardwood Dimension Parts	Particleboard	Cabinet/Millw
o	Hardwood Dimension Parts	Medium Density Fibreboard(MDF)	Pellets
o	Hardwood Plywood	OSB, Hardboard, Wood Veneer	Other wood products
o	Softwood Plywood		

A2. Indicate below the type of business activities you engage in, based on the two groups listed above. (Check (√) one)

□ Group A □ Group B □ Both

A3. Provide us the following information about forest products produced that you checked earlier.

	Product	Average products produced/used per month*	Unit s	Percent wood residue/waste generated
Grou p A	Hardwood Lumber			
	Softwood Lumber			
	Hardwood Dimension Parts			
	Hardwood Dimension Parts			
	Hardwood Plywood			
	Softwood Plywood			
	Hardwood Logs			
	Softwood Logs			
	Particleboard			
	MDF			
	Hardboard			
	OSB			
	Wood Veneer			
Grou p B	Furniture			
	Flooring			
	Millwork (Cabinet, molding, door etc)			
	Pellets			
	Other products (specify _____________)			

Questions A4 and A5 are related to groups A and B. If wood residues are not generated from any of the categories in **Group A**, skip to Question **A5**.

A4. On average, how much of the following type of woody residues are generated in your facility on a monthly basis from **Group A?**

Types of Wood Residue	Dry Tons/Month	Green Ton/Month
Bark		
Chips		
Sawdust		
Scrap Lumber		
Shavings		
Wood Flour		
Other		

A5. On average, how much of the following type of woody residues are generated in your facility on a monthly basis from **Group B?**

Types of Wood Residue	Dry Tons/Month	Green Ton/Month
Bark		
Chips		
Sawdust		
Scrap Lumber		
Shavings		
Wood Flour		
Other		

A6. How do you utilize the wood residues generated in your facility?

Wood Residue Utilization	Tons/Month
Energy Generation	
Sold	
Other	

Section B: We would like information on how you dispose of wood residue at your facility.

B1. Mark the method by which you dispose of excess wood residues produced in your facility (CHECK (√) ALL THAT APPLY)

□ Re-use on site □ Sell

□ Disposed at own cost □ Given away

B2. Provide the **average monthly volume (in tons)** disposed of by each method. (Ignore the options that you did not check in Question B1)

Re-use ____________ Tons/Month

Sell ____________ Tons/Month

Disposed at Own Cost ____________ Tons/Month

Given Away: ____________ Tons/Month

If you have checked multiple options in Question **B1**, then continue to answer the next question. Instead, if you checked only **Sell**, then skip to Question **B5**. If you checked only **Dispose at Own Cost**, then skip to Question **B8**. If you checked only **Given Away**, then skip to Question **B10**.

B3. If you recycle wood residues, then how are they recycled at your facility?

□ Manufacture another product □ Burned for generating energy

□ Finger jointing/lamination □ Other, specify ________________

B4. Given the volume information you provided above, provide the nearest dollar estimates to the (in US dollars) recovered per month from re-use. $__________________

B5. If you sold the wood residues, provide the average amount earned per month from selling them (in US dollars)? $___________________

B6. If you sell wood residues, then do you know the purchasers intended to use for the wood-residue purchased?

□ Manufacture another product □ Burnt to generate energy

□ Finger jointing/lamination □ Other, specify ____________

B7. If you sell wood residues, then provide information on its removal from your facility. Fill in all appropriate spaces.

Mode of transportation	Average miles transported to destination (miles)	Average estimated cost per ton to transport wood-residue ($/ton)
Use own company trucks		
Hire outside trucking company		
Transported at buyer's expense		

B8. If you paid to dispose the wood residues, then provide the average amount paid per month for disposal (in US dollars)? $_____________

B9. If you paid to dispose of wood-residues, then provide information on its removal from your facility. Fill in all appropriate spaces.

Mode of transportation	Miles transported to destination miles	Average estimated cost per ton to transport wood residues $/ton
Our own company trucks		
Outside trucking company		
Other, specify		

B10. If wood residues were given away at your facility, then do you know for what they were used?

□ Manufacture another product □ Burn to generate energy

□ Finger jointing/ lamination □ Other (specify) _____________

B11. Have you discussed collaborating with other nearby manufacturing plants to dispose of wood residues?

□ Yes □ No (Skip to Question B13)

B12. Provide the type of manufacturing plant you discussed collaborating with?

□ Engineered Wood □ Furniture □ Other, specify _____________

B13. Would you be interested in working with other manufacturers to determine better ways to utilize wood residues for value-added products?

□ Yes □ No

B14. Is there a potential market for wood residues near your facility?

□ Yes □ No

If yes, then how far away is it?

□ Within 0-30 miles □ Between 31-60 miles

□ Between 61-90 □ More than 90 miles

B15. What is the average hauling distance of woody raw materials from the forest to your facility?

□ Within 0-30 miles □ Between 31-60 miles

□ Between 61-90 miles □ More than 90 miles

B16. Characterize the organizational structure of your company.

□ Sole Ownership □ Partnership □ Corporation

□ Limited Liability Company (LLC) □ Other, specify__________

B17. In what season of the year is your facility fully operational for 8 hour shift? (Check all that apply)

□ Summer □ Spring □ Winter □ Fall

□ All season

B18. How do you rate your company in terms of technological capabilities, with other similar primary and/or secondary wood processing industries near you within Mississippi?

□ Same as others □ Better than others □ Not as good as others

Section C: **You are almost done!** We would like to ask you about yourself to help us provide a summary of results for all mill-owners.

C1. Where is your facility located?

County: ________________ City:__________________

C2. How long your firm has been in this business?

Years: ______________

C3. How many employees work in your facility?

Number: ____________

C4. What are your annual sales (to the nearest US dollars)?
$_____________

C5. What is the highest level of education you have completed? (CHECK **ONE**)

□ Did not complete high school □ High school or Equivalent

□ Bachelors degree or equivalent □ Postgraduate degree (for example, M.S., M.D., Ph.D.)

Thank you for participating in this study. Individual responses will be kept confidential.