ABSTRACT

KAYS, LAUREL ELAINE Forest-Based Sector Potential for Regional Economic Development in Western North Carolina (Under the direction of Dr. Robert Bardon and Dr. Dennis Hazel).

The economic impacts of export-oriented wood pellet markets in the Southeast coastal plain have led many to question whether such enterprises could provide economic growth in other rural, resource-rich regions such as Western North Carolina. While Western North Carolina is poorly poised to serve export-oriented wood pellet markets, the potential of other forms of wood pellet markets remains worth investigating. However, before the impacts of such an industry can be investigated, an overall analysis of forest-based sectors broadly is important to establish whether those sectors are capable of generating regional economic development.

In order to investigate the potential of forest-based sectors for economic development, two measures of sector strength were calculated using data from a customized IMPLAN input-output model for the 32 western most counties of North Carolina. The first identified key forest-based sectors based on from the backward and forward linkages contained within the matrix of regional economic multipliers. Sector level transactions data was downloaded to Excel, where the total requirements matrix of economic multipliers was determined. Both the backward linkages, the column sums, and the forward linkages, the row sums, were indexed to their regional averages. A backward linkage index greater than 1.0 indicated a unit change in final demand in forest sector \( j \) would create an above average increase in regional economic activity. Forward linkage indexes greater than 1.0 suggested a unit change in all sectors’ final demand would create an above average increase in forest sector \( i \). A key sector was one with both indices greater than 1.0. Out of 28 forest-based sectors 23 sectors had
above average backward linkages; only four had above average forward linkages. Two industries—Sawmills and Paperboard Container Manufacturing—had both indices greater than 1.0 and were therefore identified as key to the region.

Net linkages were then calculated using the same total requirements matrix as well as matrices representing value-added and employment coefficients and final demand for each forest-based sector. Sectors with net linkages for value-added and employment greater than 1.0 are those with a strong ability to generate exogenous economic growth, while those with value-added and employment net linkages less than 1.0 are those which contribute to the regional economy through import substitution. Six forest-based sectors had both value-added and employment net linkages less than 1.0, while 21 had both value-added and employment net linkages greater than 1.0. This indicates that forest-based sectors are likely poorly forward linked because they contribute to the regional economy by bringing new money to the region through exports. Additionally, the presence of forest-based sectors with net linkages greater and less than 1.0 indicates a health forest economy in which new money is brought to the region through exports and cycled back to resource-based sectors which provide locally sourced timber.

Within the IMPLAN model, the construction and annual operation of a pellet mill with a yearly output capacity of 10,500 tons was also modelled. Three different scenarios were constructed, with each successive scenario having stricter constraints upon indirect impacts to help overcome some of the input-output model’s well known limitations. While the mill would have a modest impact on the regional economy in terms of dollar value and jobs. However, the operation would compare very favorably with other forest-based sectors in
metrics such as value added to output ratio, indicating that while it would be a small-scale venture, it would be one with a strong ability to pay its employees and make a profit.

A western North Carolina pellet mill would likely serve bulk heating markets for facilities like poultry houses. NC State University is investigating what one such facility would mean for the regional economy. Using IMPLAN, we constructed a regional input-output model for a 32 county study area. Within this model, the construction and annual operation of a pellet mill with a yearly output capacity of 10,500 tons was modelled. Three different scenarios were constructed, with each successive scenario having stricter constraints upon indirect impacts to help overcome some of the input-output model’s well known limitations.

Preliminary results indicate the mill would have a modest impact on the regional economy in terms of dollar value and jobs. However, the operation would compare very favorably with other forest-based sectors in metrics such as value added to output ratio, indicating that while it would be a small-scale venture, it would be one with a strong ability to pay its employees and make a profit.
Forest-Based Sector Potential for Regional Economic Development in Western North Carolina

by
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A thesis submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the degree of
Master of Science

Forestry and Environmental Resources

Raleigh, North Carolina

2017

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DEDICATION

To Mom, Dad, Holly, and Ginger. Thanks for all the forced hikes, tree teaching, and support.
BIOGRAPHY

Laurel Kays has a B.A. in government and politics and American cultural studies from the University of Maryland, College Park. She has worked in an outreach oriented capacity in a wide range of positions including as a technology and digital policy associate and a National Park Service ranger.
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The forestland base of the United States, faces a number of sustainability-oriented challenges as the 21st century progresses. Water quality and availability, soil degradation, and climate change are only a handful of the issues that must be addressed in order to ensure our collective future (Synthesis GEO-3, 2002). Many social, environmental, cultural, and political factors underlie each of these issues. However, despite those problems, economic growth continues to be encouraged and even expected in the United States. In dealing with these dual realities—that we face environmental challenges while expecting and encouraging economic growth, it is only logical that meaningful solutions are likely to lie in finding means of economic development that are also environmentally sustainable.

Forest-based industries in the US South are uniquely well positioned for this cause. The forests that form the basis of those industries are a renewable resource, especially in the US South where many factors have contributed to it becoming the “wood basket” of the country. (U.S. forest resource facts, 2014) While sustainable forest management and use are imperfect outcomes, (National report on sustainable forests, 2011) both can be optimized in the face of limiting factors. Resources and research by which to do so are ongoing in countless universities, corporations, and organizations. This combined with the strong markets that exist especially in the South mean that when considering how to promote sustainable economic development, forest-based industries in the South must be examined.

Western North Carolina is a particular market region where forest-resource based economic development appears to have great potential. The 32 western-most counties of North Carolina contain significant forest resources, with approximately 66% of the land area covered by timberland (Jeuck, Bardon, Hazel, & Sugerik, 2012). In the mountain region of...
the state, 76% of the land is forested (Bardon, Megalos, New, & Brogan, 2010). Upland hardwoods dominate, with oak, hickory, and poplar accounting for much of the forested land (Bardon et al., 2010). This area also contains much of the state’s reserved timberland in Great Smoky Mountains National Park and the Pisgah and Nantahala National Forests (Bardon et al., 2010). Moving eastward into the Western Piedmont, hardwood stands begin to include sweetgum as well as the oaks, hickories, and poplars of the mountains, and mixed stands of hardwoods and loblolly pine become more abundant (Bardon et al., 2010). These considerable forest resources also contribute substantially to the regional economy, producing $7 billion in output and supporting over 30,000 jobs.

Not only is Western North Carolina a region with significant forests and forest-based industries which could contribute to economic growth, it is a region critically in need of that growth. By many economic indicators, Western North Carolina lags behind the state as a whole. Poverty levels, median household income, and per capita income are all below the North Carolina and national average and rank very low compared with other regions of the state (Table 1). Median household income for example, is the lowest across all regions of the state at just 82.5% of the state average (Brennan, Cooper, & Ha, 2014).

This examination of Western North Carolina’s forest resources and economic need suggests that those resources, and the industries based in them, could be used for economic development in that region. However, it is crucial to more closely examine forest-based sectors of the regional economy to evaluate those that are truly best poised to spur economic growth. This paper accomplishes that goal through two mechanisms. First, all forest-based industries are examined using two different linkage metrics to identify those whose inter-
industry relationships best position them to contribute to economic growth. Second, a case study in economic development—a small-scale pellet mill serving bulk heating markets, is modelled to examine the economic impact such a facility could have on the Western North Carolina economy.

**Literature Review**

The idea that understanding linkages within a regional economy is crucial to appreciating how to grow that economy is a now widely accepted idea (Sonis, Guilhoto, Hewings, & Martins, 1995). However, the means by which it is best to analyze those linkages is still a matter of debate. In order to understand the methods used in this analysis, it is important to understand the theoretical history of linkage analysis. To that end, this section examines the development and eventual intertwining of export base theory and input-output analysis and the ongoing conversations regarding the best means by which to identify sectors best able to stimulate regional economic growth.

Export base theory was developed roughly simultaneously by various economists in the 1950s. These included Douglass North in his Location Theory and Regional Economic Growth (1955), which contested the then accepted theory of regional economic development that posited regions gradually grow from subsistence economies to specialized tertiary industries largely as a result of improved transportation networks and subsequent industrialization. North instead proposed that the growth of a regional economy is tied to the success or failure of its export base. Around the same time period Andrews (1953, 1954) and Tiebout (1956) published their respective works on similar topics. All of the writings of North, Andrews, and Tiebout were based upon the even earlier work of Homer Hoyt, who
first developed an export-base model for application to the physical growth of urban areas
(Weimer & Hoyt, 1939). In replacing the variables of Hoyt’s model with variables such as
income, North, Andrews, and Tiebout developed the foundations of macroeconomic export
base theory.

A central pillar of export-base theory is distinguishing between the base and service sectors
of an economy, or respectively those sectors that contribute to exports and those that mostly
serve the local area (Capello, 2016). The location quotient (Hildebrand & Mace, 1950) and
minimum requirements approach (Ullman & Dacey, 1960) are two of the major means by
which to estimate a region’s base and service sectors. Results from each are then used to
calculate an income or employment multiplier (Lewis, 1976). Other methods by which to
estimate regional export-base multipliers were also developed, notably by Archibald (1967)

The export-base theory, while widely used, has also been widely criticized. Lewis (1976)
noted that different methods of multiplier estimation often yield very different results.
Meanwhile Krikelas (1992), posited that the practical usefulness of economic base models
had been widely overstated. Lewis also noted that using other types of models would resolve
some issues in multiplier estimation, notably pointing to the input-output framework. The
concept of input-output models and analyzing interindustry relationships within an economy
dates back to Wassily Leontief’s Nobel-winning work (1941). Since Leontief’s development
of the analytical framework of input-output, significant work has been done to refine and
apply it to many types of economic analysis, in fact Leontief himself in the publication
discussed input-output’s application to analyzing the role of exports. (pgs. 169-172) Since
then, numerous papers have in fact shown that under certain circumstances, economic base and input-output multipliers can be approximately equal (Garnick, 1970; Billings, 1969; Isard & Czamanski, 1965).

Using Leontief’s total requirements matrix, Rasmussen (1956) and Hirschman (1958) established the idea of calculating forward and backward linkages to identify key regional sectors. Forward linkages measure the sensitivity of dispersion (e.g., how a regional change affects a particular sector), while backward linkages measure the power of dispersion (e.g., how a change in a particular sector affects the region). Using key sector identification for a regional economy does come with certain issues as is well summarized by Hewings (1982). These include the fact that indices developed by Rasmussen and Hirschman do not account for unequal variation within sectors or the sectoral contribution to final demand. The indices of Rasmussen and Hirschman have also been the topics of significant further discussion, notably by Sonis, and Hewings, and their collaborators (Sonis & Hewings, 1989, 1999; Sonis, Guilhoto, Hewings, & Martins, 1995; Sonis, Hewings, Okuyama, & Guo, 1996; Sonis, Hewings, & Guo, 2000). The overarching conclusions of these works has been that, while alternative perspectives of evaluating intersectoral linkages exist, they should be looked on as complementary to, rather than superior to the measures of Rasmussen and Hirschman.

Input-output analysis has become a more widely available analysis tool in recent times as technology has greatly decreased the amount of time required to perform the many computations required. Leontief noted in his 1986 text on input-output economics, for example, that the use of such models would be limited for those without the resources of an industry analyst, due to the great number of equations that such models require to be solved.
Specifically, within the forestry field, most research using input-output models has focused on analyzing contributions or impacts of forestry sectors and enterprises (Cox & Munn 2001; Tilley & Munn 2007; Bailey, Dyer, & Teeter, 2011). Flick and Teeter (1988) conducted a multiplier analysis of forest industries in the US South to analyze both the then-current economic position of forestry and to understand its future potential. Within the broader natural resources field, the key sector methodology of Rasmussen and Hirschman has been used to analyze environmentally important sectors in the Australian economy (Lenzen, 2003). There remain, however, no studies that have employed the key sector indices of Rasmussen and Hirschman to forest-based sectors of a regional economy, not to mention the Western North Carolina regional economy.

While the key sector indices of Rasmussen and Hirschman are still used in studies decades after their development, work continues on developing alternative indices that address some deficiencies of traditional key sector analysis. Oosterhaven and Stelder (2002) are more recent contributors to this effort of developing alternative indices with their concept of the “net multiplier.” Oosterhaven and Stelder’s original work (2002) identified the concept of the “net multiplier.” Subsequently significant critique focused on whether the calculation should be interpreted as a true multiplier or an index of strength (De Mesnard, 2002, 2007; Dietzenbacher, 2005; Oosterhaven, 2007). Ultimately, Oosterhaven’s 2007 publication concluded that the so called net multiplier is not in fact “a multiplier in the narrow modeler’s interpretation of that term… after this discussion, it must have been clear that the net multiplier is a new key sector indicator, no more, no less” (pg. 9). Therefore the calculation’s
more correct interpretation as an index of a given sector’s ability to generate exogenous economic growth rather than a true multiplier.

Given the relative youth of Oosterhaven and Stelder’s net linkage and the debate over its interpretation, the application has been limited, especially within the natural resource field. Dyck and Sumaila (2010) used the technique in evaluating the economic impact of ocean fish populations. However, as with Rasmussen and Hirschman’s key sector indices, no studies have yet applied either method to forest-based sectors in the US South or specifically Western North Carolina.

Understanding different types of economic linkages is an excellent means by which to determine sectors likely to be the most capable of growing the regional economy. Evaluating the potential impact of specific projects, however, requires a different set of methods. Input-output models, input-output models with econometrics, and computable general equilibrium models are the three methods most commonly used for economic impact analysis. Multiple authors have addressed the ways in which these tools differ (West, 1995; Rose, 1995; Partridge and Rickman, 2007). West (1995) noted that the three tools can produce vastly different results even when using the same database and impact scenario, but that for small regions input-output models are often the only available option. Meanwhile Rose (1995), in examining the ways input-output is evolving as a tool of analysis stated that it has much in common with computable general equilibrium models in terms of the required data, range of use, and future need for refinement. Partidge and Rickman’s review of the use of CGE models (2007) notes that input-output, not CGE models are the dominant approach for regional economic analysis especially for small regions due to CGE deficiencies including
the need for structures informed by regional, rather than national or international models. In 
the same review, Partridge and Rickman referenced Batey and Rose’s 1990 Extended Input-
Output Models: Progress and Potential in noting that Social Accounting Matrices possess 
especially the same limitations and benefits of traditional input-output models as they are 
extended forms of those models.

When using a ready-made input-output models for regional economic analysis, three major 
forms of models are commonly used. They are 1.) IMPLAN, originally developed by the US 
Forest Service, 2.) RIMS II, produced by the US Department of Commerce Bureau of 
Economic Analysis, and 3.) REMI, run by Regional Economic Models, Inc. It is important to 
note that REMI does contain an input-output component, but its inclusion of price 
responsiveness and factor supplies and demands means it also has much in common with 
CGE models (Treyz, Rickman, & Shao, 1991). Richman and Schwer’s 1995 comparison of 
multipliers for the three models found that, for Clark County, NV the default version of 
multipliers varied greatly, but did not differ significantly in the benchmarked versions. A 
previous analysis by Richman and Schwer (1993) of REMI and IMPLAN, also concerning 
southern Nevada, found that between the two differences in regional purchase coefficients 
tended to make IMPLAN’s multipliers greater, and that the two programs disagreed on which 
industries had large or small multipliers. Analysis by Lynch (2000) examined the practical 
aspects of using each model, and noted that of the three IMPLAN boasts the most user 
friendly software that easily enables the modification of variables.
As the dominant method of regional economic impact analysis, input-output models have been widely applied to analyzing the impacts of renewable energy projects. Those that specifically use models constructed in IMPLAN are particularly widespread (Aksoy, Cullinan, Webster, Gue, Sukumaran, Eden, & Sammons, 2011; Brandeis & Guo, 2016; Hall, Hodges, & Haydu, 2006; Kebede, Ojumu, & Adozssi, 2013; Lazarus, Tiffany, Zalesny, & Reimenschneider, 2011; Little, Lester, Slesinger, & Jolley, 2013; Perez-Verdin, Grebner, Munn, Sun, & Grado, 2008;). This common use of IMPLAN for input-output based economic impact analysis has unfortunately also led to its common misapplication. Swenson (2006) and Swenson and Eathington (2006) cover some of these deficiencies in methodology in relation to the overstatement of impacts of biofuels projects, specifically ethanol. However, many of those criticisms are entirely relevant to broader impact analysis using input-output models, such as the assumption of fixed prices and the overstatement of impacts on industries such as electricity whose production is unlikely to marginally increase substantially. (Swenson, 2006)

Methods

Key Sector Analysis

An input-output model was constructed for a 32 county region of Western North Carolina (Figure 1) using data and software from IMPLAN for the year 2014. (IMPLAN professional, 2004). The region of interest extends from the Tennessee border east to approximately Interstate 77. This area extends well beyond what many entities, including the North Carolina Department of Commerce, identify as the western region of the state. (NC department of commerce, 2016) This expansive definition was used to ensure inclusion of
important regional economic linkages, such as those related to the furniture industry. As of 2009, the North Carolina wood furniture industry alone produced an output of $5.5 billion, representing over 20% of total sector output for the US South (Dahal, Henderson, & Munn, 2015). Furniture manufacturing of all varieties in North Carolina is concentrated in the north-central Piedmont region of the state. This includes counties such as Catawba and Caldwell that are included in the region of interest. Therefore, an inclusive definition of Western North Carolina is more likely to give a full picture of regional economic linkages as it will include important linkage such as those connected to the furniture industry.

The 32 county study region contained a total of 464 active sectors out of a possible 536 identified by version three of IMPLAN. In IMPLAN, sectors are classifications of industries based on North American Industry Classification Systems (NAICS) codes (IMPLAN Sectoring and NAICS Correspondences, 2015). Industries nested within the same NAICS code (generally to four or five digits for manufacturing sectors and three or four for services or agriculture) have a similar spending pattern. That spending pattern, derived from Bureau of Economic Analysis (BEA) data, means that sectors represent industries whose expenditures connect to other sectors in similar patterns (IMPLAN Sectoring and NAICS Correspondences, 2015).

The study region also contained 28 of the 29 sectors considered forest-based. These sectors fall within 4 categories (Table 2): resource and logging, wood products manufacturing, paper manufacturing, and wood furniture manufacturing (McConnell, Jeuck, & Hazel, 2016). The identified study region does not contain pulp mills, the only forest-based sector not present in the regional economy.
Given that IMPLAN’s data sources are generally federal level agencies and organizations, where specific regional data is available for sectors, it is preferable to use that data. Accordingly, the input-output model was customized using county level timber income data (Jeuck & Bardon, 2014) and the model was reconstructed.

The Z matrix of inter industry flows was downloaded to Microsoft Excel. Next, the A matrix of direct industry requirements was calculated by dividing the cells of each column by their column total. The Leontief inverse matrix of total requirements, \( A^* = (I - A)^{-1} \), was then determined, with \( I \) being the identity matrix of initial requirements.

Backward linkages for each forest sector, or the column sum for that sector, \( A^*_j \), is equivalent to the forest sector \( j \) Type I output multiplier. The backward linkages describe the total change in the regional economy resulting from a one-unit change in final demand for each forest sector \( j \). Forward linkages are the row sums, \( A^*_i \). Each forward linkage describes the total change in forest sector \( i \) resulting from a one-unit change in final demand across all sectors in the region.

In order to be able to better compare sector linkages, indices developed by Rasmussen (1956) were calculated to assess which of the forest-based sectors to be considered key. Equation 1 describes the power of dispersion for the backward linkages \( (BL_j) \), while equation 2 describes the sensitivity of dispersion for the forward linkages \( (FL_i) \). In both instances, \( V \) represents the global intensity of the total requirements matrix \( (V = 589.054) \) and \( n \) represents the number of sectors \( (n = 464) \).
\[ BL_j = \frac{A_j^*}{\frac{1}{n}V} \quad [1] \]

\[ FL_i = \frac{A_i^*}{\frac{1}{n}V} \quad [2] \]

Each index describes sectoral linkages relative to the regional average as a benchmark.

Above average changes occur in the regional economy of Western North Carolina per unit change of final demand in forest sectors \( j \) with \( BL_j > 1.000 \). Likewise, a unit change of final demand across the region will generate greater than average changes in forest sectors \( i \) whose \( FL_i > 1.000 \) (Sonis et al., 1996). Key forest sectors are those with both \( BL_j > 1.000 \) and \( FL_i > 1.000 \).

**Net Linkage Analysis**

Net linkages for value added and employment were calculated for each forest-based sector. Using data from the 32 county IMPLAN model previously constructed, a diagonal matrix of coefficients (value added and employment respectively) was created. The value added coefficients were in terms dollars of value added per dollar of output, while employment coefficients were in terms of jobs per dollar of output. The previously calculated Leontief total requirements matrix was also used. Finally, again using data from the IMPLAN model, a diagonal matrix of sectoral final demand was created. These matrices were multiplied according to the following:

Equation 3 represent the calculation of the net linkage matrix for value added. Equation 4 represents the calculation of the net linkage matrix for employment. For each final matrix,
row and column sums were calculated for each forest based sector. The column sums represent export base contributions while the row columns represent gross activities. The export refers to the direct and indirect economic activities required to produce a sector’s goods and services for export. Gross activities, meanwhile, represent how local activities are meeting regional needs. Finally, the column sums were divided by the row sums to calculate net linkages for each forest based sector (Equation 5; Equation 6).

\[ V_{Net} = \langle v_c \rangle (I - A)^{-1} \langle f \rangle \]  

\[ E_{Net} = \langle e_c \rangle (I - A)^{-1} \langle f \rangle \]  

\[ V_{net} = \frac{V_{j Base}}{V_{i Gross}} \]  

\[ E_{net} = \frac{E_{j Base}}{E_{i Gross}} \]

These net linkages, or more properly net backward linkages, demonstrate how dependent the regional economy is on sector x. When \( V_{net} > 1 \) and \( E_{net} > 1 \), for sector x, that sector has an above average capability to spur exogenous economic impacts, as both values being greater than one indicate that value added and employment for the regional economy are more dependent on them than they are on it (Temurshoev & Oosterhaven, 2014).
Pellet Mill Model Analysis

The Hunsberger and Mosey (2014) requirements for operation, maintenance, and employment for a 10,450 ton per year capacity pellet production facility producing 9,800 tons per year were used as a starting point for the model. That list of inputs was then customized to better reflect the intended markets and specifics of the study region (Table 3). The modelled facility was assumed to produce the same amount of output as the Hunsberger and Mosey mill, however with the intention of serving bulk heating markets while being situated within the study region, with no specific location intended.

Required labor positions were determined according to Hunsberger and Mosey (2014). Employee compensation for those positions was determined according to wage estimates from the Bureau of Labor Statistics (BLS) for the mountain North Carolina nonmetropolitan area. The BLS salary information was then adjusted upward by 30% of the given salary to account for other fringe benefits of employee compensation such as health insurance. That 30% figure reflects national averages for fringe benefits (Bureau of Labor Statistics, 2016).

To determine the cost of wood purchased by the mill, a moisture content of 45% (green basis) was assumed, meaning 19,000 green tons of wood would be required to produce the 9,800 dry tons per year output. The US Forest Service Forest Inventory and Analysis Timber Product Output Database for North Carolina (2014) was used to approximate the appropriate regional mix of hardwood and softwood raw materials. Prices for North American pellet grade wood for the South Atlantic region were weighted according to the calculated hardwood to softwood ratio to achieve a final price per ton in US dollars for the facility’s raw materials. (North American woodfiber & biomass markets, 2015) The market price that
manufactured pellets were assumed to sell for was approximated according to the best knowledge of the regional markets.

The facility considered by Hunsberger and Mosey was intended to serve markets for bagged pellets for domestic heating. Accordingly, expenses such as bags, plastic wrap, and pallets were eliminated as the mill modelled in this study was intended to serve bulk heating markets such as schools or poultry facilities. Other expenses associated with machinery and operational costs were included as in Hunsberger and Mosey.

Costs for land rent were calculated from the 2015 Use-Value Manual for Agricultural, Horticultural, and Forest Land (2014). Costs for agricultural and horticultural land rents were weighted by the percentage of counties in the 32 county study region that fall within either the Piedmont or Mountain region as defined by the Forest Inventory Analysis. Taxes for land costs were then determined by capitalizing land costs by 6.5% and applying the average tax rate for the 32 county region. (County property tax rates and revaluation schedules) Bank costs for loan payments were determined as straight line mortgage payments at a 4% interest rate.

Once the enterprise budget (Table 3) for the mill was adapted to reflect the target markets and study region, Willis and Holland’s method (1997) of converting enterprise budgets to input-output accounts was used to create an account compatible with analysis using IMPLAN. Expenses within the enterprise budget were assigned to their corresponding IMPLAN sector. Appropriate expenses such as parts, maintenance, and fuel were margined to convert those costs to the producer prices that IMPLAN uses. Those expenses that required margining were divided so that appropriate amounts were allocated to the original
industry, such as Other Parts and Maintenance, and industries that IMPLAN identified such as Wholesale Trade and transportation sectors. The operational budget item and corresponding IMPLAN sector representing 95% of the total yearly enterprise cost was calculated.

This final enterprise budget with all expenses allocated to corresponding IMPLAN sectors was then translated into a production function compatible with IMPLAN’s software. Since the wood pellet industry does not have an existing production function or sector in IMPLAN’s accounting system, a production function was created based on the production function for Other Wood Products Manufacturing. The percent of 95% of the total enterprise yearly cost was assigned to the IMPLAN sectors identified with costs in the enterprise budget. The remaining 5% share was allocated to the remaining sectors in the Other Wood Products Manufacturing production function according to their original share of that function. The final production function’s values sum to 1, with each sector within the function’s value representing that sector’s share of one dollar of the pellet mill’s yearly output.

The resulting production function was input to IMPLAN and analyzed at the total yearly enterprise output of $1,764,000 level. This multiplies the share of each sector in the production function by the event value. Costs for employees were input separately, with the owner/operator’s salary coded as proprietor income and other employees’ coded as labor income.

Together the operational costs totaling 1,764,000, proprietor income, and labor income were all analyzed under three different scenarios. While the model constraints were varied for each
of the three scenarios, for all three the operational costs, properties income, and labor income values analyzed were the same.

In the first scenario, the model was run with the direct, indirect, and induced effects all included without constraints; this represented a base case of the gross economic impacts. In the second scenario, two sectors, Electricity-sector 49, and Sawmills-sector 134, were constrained so as to produce no indirect effects. This scenario assumes that those two sectors will not increase their production in response to the mill, but that all other effects will take place as in the first scenario. In the final scenario, no indirect effects were included, with only direct and induced effects accounted for. This scenario assumes that no industries will increase their output in response to the pellet mill, and only accounts for the direct impacts of the mill and increased local spending due to labor income.

Construction impacts were also analyzed using the adjusted IMPLAN model. Costs for construction were taken from Hunsberger and Mosey. (2014) Those costs totaled $815,856.30, and each cost was assigned to an appropriate IMPLAN sector. In order to account for the fact that purchases related to construction events (such as machinery and employee purchases, or induced impacts) are often made outside the region, the local purchase percentage for all sectors in the construction event was changed from the default of 100 to the social accounting matrix (SAM) value within IMPLAN, a number which varies for each sector. This ensured that the construction impacts would not be overly inflated by purchases unlikely to occur within the region. Following this adjustment, impacts of the pellet mill’s construction were analyzed.
Results and Discussion

Region Overview

The 32 county study region of Western North Carolina generated $146 billion in output in 2014, which includes $66 billion in value added. Slightly more than 1 million jobs were supported by the regional economy. Out of a possible 526 sectors 464 were present. The largest sector, after Owner-Occupied Dwellings (a BEA sector developed to account for the expense of owning a home in a similar way to how rental payments are captured) \((IMPLAN\ professional, 2004)\) was Wholesale Trade, which supported just over 29,000 jobs and had a 2014 output just under $6 billion. Average output across the 464 sectors present was $314 million, with an average employment of 2,150 jobs.

The 28 forest-based sectors produced $7 billion in output, of which $1.8 billion was value added. A substantial portion of that $1.8 billion in value added-$1.3 billion, was made up of employee compensation or proprietor income. Forest-based sectors in Western North Carolina also supported 30,309 jobs.

Key Sector Analysis

Results. “Raw” unindexed backward linkages (BL) for forest-based sectors ranged from 1.113 for Support Services for Forestry to 1.556 for the Sawmills sector. Three sectors in Wood Furniture Manufacturing had the lowest forward linkage (FL) of 1.001, while the Sawmills sector had the highest value of 2.253.

Once indexed to the regional average (1.270), backward linkages for forest-based sectors ranged from .877 for Support Activities for Agriculture and Forestry to 1.226 for Sawmills (Table 4). Twenty-three sectors had \(BL_j > 1.000\). Of the five industries with \(BL_j < 1.000\), four
were $BL_j > 0.950$. Only one, Support Services for Agriculture and Forestry, displayed what could be considered a weaker backward linkage.

The region’s forest sectors did not appear to be strongly forward linked, $FL_i > 1.000$ (Figure 2). Only four, Commercial Logging (1.151), Paperboard Container Manufacturing (1.590), Support Services for Agriculture and Forestry (1.694), and Sawmills (1.775), displayed above average effects were the region to experience an economy wide change.

Two industries were found to be key regional forest-based sectors, Sawmills and Paperboard Container Manufacturing. Sawmills clearly possessed above average tendencies in both backward and forward linkages ($BL_j = 1.226$ and $FL_i = 1.775$), but slightly less so in Paperboard Container Manufacturing ($BL_j = 1.005$ and $FL_i = 1.590$). Both sectors require significant inputs of raw materials, thus growth in each sector will result in growth in the sectors that supply those inputs-leading to a high backward linkage. Paperboard Container Manufacturing was more sensitive to economy wide changes ($FL_i = 1.590$) but, it was not an overly strong source of generating economy-wide impacts ($BL_j = 1.005$). These finding are consistent with practical knowledge regarding the operation of both industries in the region.

The output of both Sawmills and Paperboard Container Manufacturing often serve as inputs for other industries, such as furniture makers in the case of sawmills and packaging used by many other industries in distribution of their goods in the case of Paperboard Container Manufacturing. Thus a growth in the overall economy will result in growth of those sectors as they work to meet the additional demand of the sectors they supply inputs for resulting in a high forward linkage.
Other sectors that were found to have an above average linkage in one direction but could not be considered key in the strictest interpretation were Veneer and Plywood Manufacturing ($BL_j = 1.155$ and $FL_i = 0.973$), Paper Mills ($BL_j = 1.057$ and $FL_i = 0.984$), and Commercial Logging ($BL_j = 0.968$ and $FL_i = 1.151$).

These results suggest forest industries in the region are strongly connected to their upstream suppliers. But because the forest industries produce specific goods required by a select few number of sectors, a high proportion of output is exported from the region. This potentially makes the Western North Carolina forest sector a significant contributor to the region’s export base. In fact, only five industries export less than 50% of their output. This reasoning also makes it logical to find the forest-based forward linkages were much weaker relative to the regional average.

The ability to multiply effects across the economy may not mean a great deal if the sector itself is a small contributor in the regional economy. One way to address this is by referencing the absolute size of each industry. When only sectors whose output is above the average for the region ($315$ million) were examined, 118 sectors in total remained with 6 of those being forest-based (Figure 3). Both key sectors- Sawmills ($338$ million) and Paperboard Container Manufacturing ($966$ million), were found to have a 2014 output above the regional average. Three sectors with $BL_j > 1.000$ and $FL_i < 1.000$ qualify for consideration when sectors are filtered by average output- Paper Mills ($854$ million), Nonupholstered Wood Household Furniture Manufacturing ($321$ million), and Upholstered Household Furniture Manufacturing ($2.3$ billion). Only 1 remaining sector- Paper Bag and
Coated and Treated Paper Manufacturing ($496 million), had both $BL_j < 1.000$ and $FL_i < 1.000$.

The fact that both key sectors-Sawmills and Paperboard Container Manufacturing, have outputs greater than the regional average is highly significant. This indicates that not only do both have an above average ability to generate both backward and forward impacts, but that both are large enough within the regional economy that it is likely such impacts would be substantive.

Using average output as a filter for sector size is a relatively harsh approach that eliminated nearly 75% of all sectors in the regional economy, with forest sectors being impacted slightly more severely. A less intensive approach is to use median output ($101 million) as a filter, eliminating the ability of very large sectors to greatly influence which sectors are included. Using this method, 232 sectors remained, with 13 being forest-based.

After filtering by median output, both key sectors, Sawmills and Paperboard Container Manufacturing were included (Figure 4). Also remaining after this filtering were eight sectors with $BL_j > 1.000$ and $FL_i < 1.000$-Upholstered Household Furniture Manufacturing ($2.3 billion), Paper Mills ($854 million), Nonupholstered Wood Household Furniture Manufacturing ($321 million), Reconstituted Wood Product Manufacturing ($273 million), Paperboard Mills ($199 million), Wood Kitchen Cabinet and Countertop Manufacturing ($172 million), Veneer and Plywood Manufacturing ($150 million), and All Other Miscellaneous Wood Product Manufacturing ($142 million). Two sectors remained with $BL_j < 1.000$ and $FL_i < 1.000$-Paper Bag and Coated and Treated Paper Manufacturing ($496 million) and Sanitary Paper Product Manufacturing ($171 million), while one sector- Support
Activities for Agriculture and Forestry ($101 million), remained with $BL_j < 1.000$ and $FL_i > 1.000$.

**Discussion.** Sawmills and Paperboard Container Manufacturing were the two sectors best poised to both spur region-wide economic impacts and respond favorably to region-wide economic growth. Not only did both have $BL_j > 1.000$ and $FL_i > 1.000$, but both had output values above both the mean and median values for the region.

Veneer and Plywood Manufacturing, with $BL_j = 1.155$ and $FL_i = .973$ and an output of $149$ million was both very close to being a key sector and had an output above the regional average. Thus while it was not nearly as strong a candidate to spur growth as Sawmills or Paperboard Container Manufacturing, it is certainly worth notice. Further study of this industry’s value chain could be beneficial for interested parties in the region.

Paper Mills, with $BL_j = 1.057$ and $FL_i = .984$ and an output above the regional average, may seem to be another sector with high potential to grow the Western North Carolina economy. The paper mill industry is generally understood to be declining overall nationally (*Paper mills: Industry outlook, 2016*). However, this sector is still a significant player in regional economies in which it operates. Should those factors contributing to paper mill decline at the national level, such as decreasing per capita consumption of paper, change course, this could have a significant impact at the regional level for some forest economies. Such a scenario, however, seems highly unlikely, at least in the near term (*Paper mills: Industry outlook, 2016*).

Finally, Commercial Logging, with $BL_j = 0.968$ and $FL_i = 1.151$, was also quite close to qualifying as a key sector. It’s output, however, is relatively small at only $84$ million,
significantly less than even the median output of $101 million. This does not, of course,
mean that it is an insignificant or unimportant sector, merely that it does not possess a
significant ability to spur economic growth in other sectors or respond in an above average
manner to region-wide economic growth. Its strength, however, is in its ability to sustain
regional economic activities through a steady supply of wood to the key manufacturing
sectors, as seen by its above average FL (Figure 2).

It is a crucial point that BLj < 1.000, FLi < 1.000 or both does not mean a sector is
unimportant. The practice of forestry and forest management planning itself, for example,
falls under the Support Activities for Agriculture and Forestry. That sector has an output of
just barely over the regional median ($101 million), well below the regional average ($314
million), a below average BLj = 0.877, and a strong FLi = 1.694. While not considered key,
other forest-based industries require forestry and forest management planning to function.

Key sector analysis’s strength is its ability to measure the degree to which a sector’s
multiplier effects are driven by its interactions with the rest of the world. Illustrated here was
the existence of a vibrant forest-based marketing chain in western North Carolina. Two forest
products manufacturing sectors were found to have competitive advantages through regional
interactions. The economic effects were found not to end there; local forest-based marketing
chains allowed money to recirculate back to the timber production sectors (Commercial
Logging and Support Activities for Agriculture and Forestry) when forest products
manufacturers purchased locally harvested timber. Timber production sectors, in turn,
provided support for the regional demand of wood.
Net Linkage Analysis

Results. One of the important limitations of key sector analysis is that the values of the indexed forward and backward linkages contain only information contained within the total requirements matrix. While that information is incredibly useful in the ways discussed in the previous section, the additional data considered within so called “net linkages” can provide a more complete picture of those sectors best able to provide exogenous economic growth.

Using those net linkages, the 28 regionally present forest sectors’ abilities to either actively or passively transmit ripple effects throughout the region were again evaluated versus a benchmarked value of 1.000. However, while backward and forward linkages were derived from output, net linkages were evaluated for employment ($E_{net}$) and value added ($V_{net}$). These are perhaps the most important of economic indicators, as they represent jobs and income returned to a region. Those sectors best able to generate exogenous change, are those for whom $V_{net} > 1.000$ and $E_{net} > 1.000$.

Employment net linkages ranged from .189 for Wood Windows and Door Manufacturing to Paperboard Mills, with an employment net linkage of 2.958. (Figure 5) Value added net linkages ranged from .193, once again for Wood Windows and Door Manufacturing, to 2.291 for Paperboard Mills. 21 of the 28 forest-based sectors had both $E_{net} > 1.000$ and $V_{net} > 1.000$ (Table 5). Six forest-based sectors had $E_{net} < 1.000$ and $V_{net} < 1.000$, while only 1 sector—Other Millwork, Including Flooring, had $E_{net} > 1.000$ and $V_{net} < 1.000$. 
Net linkage analysis addresses many of the issues that arise in traditional key sector analysis concerned with forward and backward linkages, specifically in highlighting a sector’s ability to generate exogenous economic growth by taking into account information outside the total requirements matrix. Like key sector analysis however, net linkages do not contain any accounting for sector size. The same filtering techniques used in key sector analysis can be applied to net linkage analysis. Given that net linkage analysis concerns employment and value added figures, it must be noted that filtering by output is still appropriate since all components used to calculate net linkages come from IMPLAN, whose models are ultimately based on an interindustry transactions table which describes the relationships between industries based on output (Miller & Blair, 2009).

When those forest based sectors with an output below the regional average are excluded, once again only 6 remained: Upholstered Household Furniture Manufacturing ($2.3 billion), Paperboard Container Manufacturing ($966 million), Paper Mills ($854 million), Paper Bag and Coated and Treated Paper Manufacturing ($496 million), Sawmills ($338 million), and Nonupholstered Wood Household Furniture Manufacturing ($321 million) (Figure 6). The remaining six sectors were all sectors with $E_{net} > 1.000$ and $V_{net} > 1.000$. Values ranged from Sawmills with $E_{net} = 1.027$ and $V_{net} = 1.174$ to Paper Mills with $E_{net} = 2.326$ and $V_{net} = 1.675$. (Figure 6)

Accounting for sector size by average regional output can be influenced by both the largest and smallest industries in a region. Doing so left only 25% of the region’s sectors when applied to all. Therefore, an alternative is to filter by median sector output ($101 million), leaving 13 forest-based sectors remaining. Of those 13, 12 were sectors with $E_{net} > 1.000$ and
These 12 sectors were, in order of output: Upholstered Household Furniture Manufacturing, Paperboard Container Manufacturing, Paper Mills, Paper Bag and Coated and Treated Paper Manufacturing, Sawmills, Nonupholstered Wood Household Furniture Manufacturing, Reconstituted Wood Product Manufacturing, Paperboard Mills, Wood Kitchen Cabinet and Countertop Manufacturing, Sanitary Paper Product Manufacturing, Commercial Logging, Veneer and Plywood Manufacturing, and All Other Miscellaneous Wood Product Manufacturing. The final above median output sector was Support Activities for Agriculture and Forestry, with $E_{net} = .481$ and $V_{net} = .498$. (Figure 7)

**Discussion.** Overall, forest-based sectors in Western North Carolina are well positioned to generate exogenous economic growth. Of the 28 present sectors, 21 were found to have both an employment and value added net linkage above 1.000. This indicates that the vast majority (75%) of forest-based sectors in Western North Carolina have an above average ability to generate economic impacts that do not require other industries to spur them. These industries inject new money into the region via rest-of-world interactions to the benefit of the economy as a whole.

Paperboard Mills has by far the highest net linkage for both employment and value added with $E_{net} = 2.958$ and $V_{net} = 2.291$. This indicates that the Paperboard Mill sector has the greatest ability to generate exogenous value added and jobs in Western North Carolina of all forest-based sectors. It is important, however, to reiterate that net linkages are merely indexed values that demonstrate relative ability to generate impacts, in this case employment and value added. Paperboard Mills’ $E_{net} = 2.958$, for example, *does not* mean that for every 1-unit growth in employment, Paperboard Mills will generate 1.958 additional jobs. That
figure does mean that Paperboard Mills are, relative to other forest-based industries, strongly positioned to grow employment and value added in the region.

Unlike Paper Mills, which is an industry generally understood to be in decline (Paper Mills: Industry Outlook), Paperboard Mills is a mature industry projected to grow in the next five years relative to the previous period of the same length. (Paperboard mills: Industry outlook, 2016) Therefore not only does it possess a highly significant ability to generate jobs and value added in Western North Carolina, but it is an industry that can reasonably be expected to grow given the best available information.

Paper Mills had the second highest net linkage for both employment and value added with $E_{net} = 2.326$ and $V_{net} = 1.675$. While this indicates that the Paper Mills sector has a significant ability to generate exogenous jobs and value added, the same caveats must be noted as were discussed in the key sector analysis relative to this sector. Paper Mills is a sector in decline according to the best available information on industry trends. (Paper mills: Industry outlook, 2016) Thus while it does have high net linkages, it would perhaps be unwise to significantly depend on it for regional economic growth over the long term.

As in key sector analysis, it is crucial to note that low net linkages only indicate a below average ability to generate exogenous value added and employment in the study region. They do not mean a sector is entirely unimportant within the regional economy. In fact, Support Activities for Agriculture and Forestry had $E_{net} = .481$ and $V_{net} = .498$, the second lowest of all forest-based sectors by both metrics. It would be tempting to label this sector as a minor player in the region; tempting but inadequate.
One particular advantage of the net linkage value is its ability to provide a dual interpretation. Sectors with $E_{net} < 1.00$ and $V_{net} < 1.000$ are not merely “minor contributors;” they are, in fact, considered above average providers of local goods and services. By providing said goods and services, these sectors preserve both jobs and income in the region through import substitution. In the case of Support Activities for Agriculture and Forestry, for example, that sector contains forest managers themselves as well as other professionals needed to properly manage forests such as fire management professionals. Their work ensures the regional wood supply is able to meet the needs of the forest products manufacturing sectors mentioned previously.

**Pellet Mill Model Analysis**

In the most optimistic scenario, or gross case, in which direct, indirect, and induced effects were analyzed without constraints, the mill would support 20.7 jobs producing $822,428 in labor income, $1,238,435.88 in total value added, and $3,053,276 in output. Under the scenario in which the Electricity (sector 49) and Sawmills (sector 134) were constrained so as not to increase their production in response to the mill, or the constrained case, the project would support 17.6 jobs while producing $687,642 in labor income, $948,718 in total value added, and $2,365,556 in output. Under the final scenario, in which no sectors increased production in response to the mill and only direct and induced impacts were considered, or the direct + induced only scenario, the mill would support 15.9 jobs, $600,996 in labor income, $773,191 in total value added, and $2,080,559 in output. (Figure 8, Figure 9)
Western North Carolina’s regional economy generated $146 billion in output in 2014, therefore it is no surprise that the impact of the modelled mill is unlikely to greatly influence the economy at the regional level. However, were the pellet industry in the region to expand beyond a single mill, measurements such as value added to output indicate that such an industry could have a substantial and beneficial impact on the regional level. In fact, when compared with other forest-based sectors, of which there are 28 present in the region (McConnell et al. 2016), the pellet mill ranked fourth in value added to output ratio (Figure 10). This indicates that should a pellet industry emerge, that industry could be more capable than many other industries of injecting money into the region through spending, such as labor income and profit generation.

The construction of the mill would support a total of 5.9 jobs and produce a total of $519,271 in labor income, $628,966 in total value added, and $997,800 in output. (Table 6)

Construction impacts must be interpreted very conservatively due to the unique nature of construction. While figures generated by impact analysis are yearly figures, construction impacts have a limited time frame, in this case 1 year, after which such impacts will no longer continue. Additionally, in this case, the size of the construction impacts relative to the regional economy as a whole combined with their temporary nature mean that, through the lens of regional economic development, they were relatively minor.

Overall, impacts from a single mill of the modelled size would be modest when compared to the entire Western North Carolina regional economy. However, indicators such as value added to output ratios indicate that an industry made up of multiple mills with spending
patterns similar to that of the modelled facility could substantially contribute to the regional economy, especially when compared with other forest-based sectors.

**Conclusion**

Forest-based sectors have a significant ability to contribute to regional economic growth in Western North Carolina by the metrics examined. Key sector analysis demonstrated that most forest-based sectors have above average backward linkages, indicating an above average ability to grow the overall economy given sectoral growth. By that same metric two industries (Paperboard Container Manufacturing and Sawmills) were also shown to be key sectors as they also showed above average forward linkages, indicating a simultaneous ability to respond in an above average way to overall regional economic growth. Net linkage analysis showed that forest-based sectors in general have an above average ability to generate exogenous regional economic growth in terms of both employment and value added. While neither key sector analysis nor net linkage analysis contain an accounting for sectoral size, these patterns remained when sectors were filtered by median and mean sector size.

While linkage analysis is important in understanding forest-based sectors’ ability to contribute to regional economic growth, so is the analysis of specific projects. The pellet mill modelled in this analysis, given its small size, would have a very modest impact on the Western North Carolina regional economy. However, metrics such as value added: output ratios show that a wood pellet manufacturing industry, if made up of mills with a similar spending pattern to the one modelled, could have potential to significantly contribute to the regional economy.
Overall, it is clear that forest-based sectors have great potential to contribute to regional economic growth. These findings, coupled with the clear need to achieve economic growth that is truly sustainable mean that forest-based sectors, specifically those in Western North Carolina, should certainly be considered in future evaluations of how to grow that area’s regional economy.
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Table 1. Economic Indicators of Western North Carolina Compared to State Averages and Regional Rankings

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<tr>
<th></th>
<th>State Average</th>
<th>Western NC</th>
<th>Regional Rank (1-7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median Age</td>
<td>37</td>
<td>44</td>
<td>7</td>
</tr>
<tr>
<td>Median Household Income</td>
<td>$46,000</td>
<td>$38,000</td>
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<tr>
<td>Percent Below Poverty Line</td>
<td>16%</td>
<td>17%</td>
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<tr>
<td>Category</td>
<td>Forest-Based Sector</td>
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<td>---------------------------------------</td>
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<tr>
<td>Resource (Forestry and Logging)</td>
<td>Forestry, Forest Products, and Timber Tract Production</td>
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<td></td>
<td>Commercial Logging</td>
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<td>Support Activities for Agriculture and Forestry</td>
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<tr>
<td></td>
<td>Sawmills</td>
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<td></td>
<td>Wood Preservation</td>
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<td>Veneer and Plywood Manufacturing</td>
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<td>Engineered Wood Member and Truss Manufacturing</td>
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<td>Reconstituted Wood Products Manufacturing</td>
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<td></td>
<td>Wood Windows and Door Manufacturing</td>
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<td></td>
<td>Cut Stock, Resawing Lumber, And Planing</td>
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<td>Other Millwork, Including Flooring</td>
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<td></td>
<td>Wood Container and Pallet Manufacturing</td>
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<td></td>
<td>Manufactured Home (Mobile Home) Manufacturing</td>
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<td>Prefabricated Wood Building Manufacturing</td>
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<td>All Other Miscellaneous Wood Product Manufacturing</td>
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<tr>
<td>Wood Products Manufacturing</td>
<td>Pulp Mills (Not Present in Study Region)</td>
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<td>Paper Mills</td>
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<td>Paperboard Mills</td>
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<td>Paperboard Container Manufacturing</td>
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<td></td>
<td>Paper Bag and Coated and Treated Paper Manufacturing</td>
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<td></td>
<td>Stationery Product Manufacturing</td>
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<td>Sanitary Paper Product Manufacturing</td>
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<td>All Other Converted Paper Product Manufacturing</td>
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<tr>
<td>Paper Manufacturing</td>
<td>Wood Kitchen Cabinet and Countertop Manufacturing</td>
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<td>Upholstered Household Furniture Manufacturing</td>
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<td>Nonupholstered Wood Household Furniture Manufacturing</td>
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<tr>
<td></td>
<td>Institutional Furniture Manufacturing</td>
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<td></td>
<td>Wood Office Furniture Manufacturing</td>
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<tr>
<td></td>
<td>Custom Architectural Woodwork and Millwork</td>
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### Table 3. Wood Pellet Mill Enterprise Budget

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost (Per Year)</th>
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<td>Employees</td>
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<tr>
<td>Proprietor</td>
<td>$65,468.00</td>
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<td>Land Rent</td>
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<td>Depreciation of Equipment</td>
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<tr>
<td>Raw Material (Assumes 50/50% Mix Delivered Chip to Sawmill Chip Ratio)</td>
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<tr>
<td>Die Costs</td>
<td>$20,000.00</td>
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<td>Roller Shell Costs</td>
<td>$4,800.00</td>
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<td>Roller Bearing Costs</td>
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<tr>
<td>Other Parts and Maintenance Costs</td>
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<tr>
<td>Fuel Cost</td>
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<tr>
<td>Truck Transport</td>
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<tr>
<td>Wholesale Trade</td>
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<td>Electricity Cost</td>
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<td>Working Capital (3% Of Annual Revenue)</td>
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<td>Pay to Bank</td>
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<td>Land Rent</td>
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<td>All Others Sectors</td>
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<tr>
<td><strong>Western NC Wood Pellet Interindustry Spending Pattern</strong></td>
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<tr>
<td>Taxes</td>
<td>$134.40</td>
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<tr>
<td><strong>Western NC Wood Pellet Total Costs</strong></td>
<td>$1,683,371.37</td>
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<td>Revenue - Costs</td>
<td>$80,628.63</td>
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<td><strong>Western NC Wood Pellet Production Function Value</strong></td>
<td>$1,764,000.00</td>
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Table 4. Forest-Based Sector Backward and Forward Linkages

<table>
<thead>
<tr>
<th>Sector Name</th>
<th>IMPLAN Sector Number</th>
<th>Indexed Backward Linkage</th>
<th>Indexed Forward Linkage</th>
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<tbody>
<tr>
<td>Forestry, Forest Products, And Timber Tract Production</td>
<td>15</td>
<td>1.222</td>
<td>0.812</td>
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<tr>
<td>Commercial Logging</td>
<td>16</td>
<td>0.968</td>
<td>1.151</td>
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Table 5. Forest-Based Sector Net Linkage

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Table 5 Continued

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Table 6. Pellet Mill Impact Analysis Results by Scenario

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<td></td>
<td>Induced Impact</td>
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<td>Total Impact</td>
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<tr>
<td>Constrained Case (No Indirect Impacts from Sawmills or Electricity)</td>
<td>Direct Impact</td>
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<tr>
<td></td>
<td>Indirect Impact</td>
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<tr>
<td></td>
<td>Induced Impact</td>
</tr>
<tr>
<td></td>
<td>Total Impact</td>
</tr>
<tr>
<td>Direct + Induced Only (No Indirect Impacts)</td>
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<td></td>
<td>Indirect Impact</td>
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<td>Induced Impact</td>
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<td>Total Impact</td>
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Table 6 Continued

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<td>$628,966</td>
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FIGURES

Figure 1: Study region counties shown in red with major North Carolina cities labelled
Figure 2. Plot of all forest-based sectors backward vs. forward linkages
Figure 3. Plot of forest sectors with above average regional output backward vs. forward linkages.
Figure 4. Plot of all forest sectors with above median regional output backward vs. forward linkages
Figure 5. Plot of all forest sectors employment vs. value added net linkages
Figure 6. Plot of all forest sectors above average output employment vs. value added net linkages
Figure 7. Plot of all forest sectors above median output employment vs. value added net linkages
Figure 8. Plot of total pellet mill impacts for labor income, value added, and output under three model scenarios
Figure 9. Plot of total pellet mill impacts for employment under three model scenarios
Figure 10. Plot of top five forest-based sectors’ value added to output ratios