EMPIRICAL INDICATORS OF THE LOGGING INDUSTRY IN THE US SOUTH

by

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(Under the Direction of W. Dale Greene)

ABSTRACT

Timber harvesting is a critical component of the US forest products supply chain. Despite the importance of the logging industry, relatively little reliable data are available on the composition and performance of logging contractors either within a given geographic region or nationally. We develop methods for estimating logging capacity across a ten state region in the US South and provide a quarterly index which describes changes in logging costs for the southern timber harvesting industry.

Logging capacity was found to have declined between 12% and 14% across the US South from 2006 to 2012 with some variation between multi-state sub-regions within the South. The excess or surge logging capacity within these regions measures the amount of logging capacity in excess of the actual demand for harvested products. The variation in this excess capacity was found to vary much more significantly across the South.

The UGA Logging Cost Index was developed using data gathered in face-to-face interviews with logging contractors. Based on the percentage breakdown of annual logging costs from these contractors in 2011, we created a logging cost index using publicly available data on costs of diesel, equipment, maintenance, labor, interest, and other factors. Labor (32.8%), fuel (22.8%), and depreciation (19.3%) represented the greatest proportion of costs amongst respondents. The calculated cost index was found to match historical trends in logging costs. In addition, cost data gathered from contractors in 2012 and 2013 aligned well with the cost trends represented by the UGA Logging Cost Index. After correcting for inter-year production variation, the deviation of predicted costs (as represented by the UGA Logging Cost Index) and actual costs was 0.1%.

The gap between prices paid for logging services (logging rates) and logging costs shrank between 2006 and 2013, indicating a reduction in the potential profit in the logging industry. Over this timeframe, logging capacity shrank considerably. Initial data from 2014 indicate that logging rates have increased relative to logging costs. While data are not yet available to indicate the impacts on capacity, the measures described here allow us to determine the effect of market forces on the logging industry.

INDEX WORDS: Timber Harvesting, Industry Capacity, Index Numbers, Cost Analysis

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I arrived at the University of Georgia years ago seeking to exploit my fascination with the logging industry through a forestry research job. I owe a debt of extreme gratitude to Bob Shaffer of Virginia Tech for engendering that fascination in me through a tapestry of tales that brought to life the challenges, rewards, and absurdity of the forest industry. Bob's uncanny skill in telling a story (always free from exaggeration) never rubbed off on me, but he first let me peak behind the curtain of academia to see how we can contribute to the benefit of the forestry business.

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CHAPTER 1

INTRODUCTION AND LITERATURE CITED

The logging industry is a vital component of the US forest products supply chain. The Bureau of Labor Statistics listed over 8,000 logging businesses employing 50,000 people across the United States in 2013 (Bureau of Labor Statistics 2013d). In employee wages alone, the logging industry generates $2 billion annually. Despite the importance of the industry, detailed information about the logging industry in the US has been difficult to find, particularly since it was reclassified from manufacturing to agriculture in the late 1990's and removed from the Economic Census (Xu et al. 2014). Because the business is dominated by small independent contractors, substantial effort is required to gather sufficient information to make generalizations about the industry as a whole.

Purchasing companies (sawtimber and pulp and paper industries) continue to distance themselves from in-woods operations, having divested of landholdings and procuring large percentages of raw material through corporate landowner purchase agreements, wood dealer networks and gatewood purchases. These changes decrease the amount of knowledge regarding the logging business that flows into the forest industry. In addition, the proliferation of Timberland Investment Management Organizations and Real Estate Investment Trusts investing in timberland has created a large class of landowners seeking strong returns on their investments. This necessitates a healthy logging infrastructure to harvest and deliver timber. These organizations want some level of knowledge about the logging industry, particularly when they sell timber on the open market. Many of these forest industry trends highlight the need for improved information on logging.

Historical data on the growth in the industry as it transitioned increasingly into mechanization were provided by periodic surveys spearheaded by trade associations, predominantly the American Pulpwood Association (since renamed the Forest Resources Association). These surveys provided data on the logging industry across the south (focusing on loggers producing pulpwood), but as the forest industry structure changed, these surveys were found less representative and ultimately discontinued (Greene et al. 1988). The final southwide surveys were performed shortly before the designation of logging in national statistics shifted from manufacturing to agriculture, effectively ending two of the largest sources of data on the logging industry (Munn et al. 1998). While national statistics are still reported on some aspects of the logging industry (primarily related to labor), the only consistent information covering the logging industry as a whole come from reader surveys of trade magazines (Knight 2006, Knight 2011). Reliable indicators of trends in the logging industry are needed to increase the visibility of this vital link in the wood supply chain.

The remainder of this dissertation is comprised of a joint review of the literature relevant to the following three chapters, each of which is structured as a separate manuscript. These three chapters include (1) description of a measure which estimates the production capacity of the logging industry in the US South, (2) the development of a quarterly index of logging costs for the US South, and (3) verification of the trends in logging costs represented by the logging cost index. A final chapter is provided to summarize the findings of these three manuscripts and discuss their contributions.

ESTIMATION OF LOGGING COSTS

Harvesting cost estimates are generated as a component of many harvest system analyses. Cost estimates are typically a combination of a detailed costing of the machinery and personnel involved in the harvesting system (typically based on either machine rate or cash flow calculations) in addition to productivity calculations collected during a time and motion study or estimated using computer simulations (Wackerman 1966, Miyata and Steinhilb 1981). Estimates of this form are useful for assessing likely costs on a given harvest site or comparing candidate harvesting systems, but are of little value in generalizing cost trends for the logging industry as the system productivity will be site specific.

Operating costs for logging machinery were reported frequently through the late 1980's (Plummer 1982, Werblow and Cubbage 1986, Cubbage et al. 1988, Brinker et al. 1989) and have been updated less frequently since (Brinker et al. 2002). These were typically based on machine rate calculations for the common machines operating in the industry. While useful for tracking trends in the owning and operating costs associated with machinery, machine rate estimates are often based on little empirical evidence beyond updated purchase prices for machinery and fuel. Instead, standard assumptions are used regarding many of the costs. For example, the updated machine rates published in 2002 still reference maintenance and repair costs of harvesting machinery calculated in 1981 (Brinker et al. 2002). Some researchers have questioned the accuracy of these rules of thumb (Loving 1991). Additional shortcomings of the machine rate method have been discussed in detail, though it remains as a common costing methodology (Miyata 1980, Burgess and Cubbage 1989, Stuart 2003, Bilek 2009). Calculating average costs to harvest timber which include all cost sources, not just machinery owning and operating costs, requires greater data collection efforts.

Surveys of harvesting contractors provide another method of generating cost data for a large swath of the industry, and when repeated periodically, offer the potential to compare cost trends over time (Cubbage and Carter 1994, Baker and Greene 2008). However, unless the surveys are specifically designed to capture financial information, the trends are usually indicative only of changes in the number, types, and ages of machinery as well as general information about the business (number and type of employees, physical space, etc.). Surveys or interviews of contractors specifically requesting detailed cost information are uncommon and often involve a greater time investment to provide the data (Stuart and Grace 1999, Leon and Benjamin 2013).

COST INDICES

The calculation of index numbers to provide an estimate of the change in value of goods or services goes back to the 18th century, and hundreds of possible index formulations have been proposed (Balk 2008). The debate over the “best” formulation continues in economic theory with new equations still being proposed (Afriat 2014). Some of the earliest formulations benefit from their ease of calculation and comprehension. Despite falling short in the most rigorous axiomatic tests, the two most commonly applied methods, Paasche and Laspeyres, are the only formulations which meet the most vital requirements of an index for an aggregation of other indexed values (Balk 2008). Indeed the Laspeyres index, formulated in 1871, remains a standard formulation for many national calculations of consumer inflation, potentially because it has the desirable property of examining the change in price for a basket of goods wherein the quantity of each good remains constant at the level of the base period (Laspeyres 1871). Thus, the inflation can be estimated knowing only the prices of goods in the new time period, updated data on quantities are not necessary. The common concern with a Laspeyres *price* index is that it serves as an upper bound on the value change between two periods (i.e., it has an inflationary bias as a price index). Fisher and Shell (1972) suggest that a Laspeyres *quantity* index would be an excellent formulation for an industry or nation's productivity index as it would serve as a lower bound, while noting that they are rarely used in this fashion.

Cost indexes provide a means for comparing the changes in cost for something (or often a group of things) over time and use an initial base year as the starting point for this comparison (Koop 2005). The Consumer Price Index (CPI) reported by the Bureau of Labor Statistics (BLS) is a Laspeyres index that estimates inflation using a representative basket of goods and services. Producer Price Indices (PPI), also reported by the BLS, provide an indication in the changes in price for output of producers in over 500 industries. Both PPI and CPI deal with the changes in prices paid for either consumer goods or the goods and services provided by certain types of producers. While informative for consumers of either type of goods or services, they do not directly relate to the *cost* of manufacturing the goods or services, only the price charged.

Cost indices deal specifically with the costs of generating some output. The Construction Cost Index reported by the Engineering News Record since 1921 is a measure of this form specific to the building construction industry, which focuses on the aggregate costs of lumber, steel, cement, and labor in proportions consistent with the cost of constructing a building (Grogan 1992). The *Chemical Engineering* Plant Cost Index (CEPCI) is a composite cost index reported since 1963 that uses PPIs for 66 components weighted into eleven sub-indices that, when combined, provide an indication of the change in cost for construction of a chemical plant (Vatavuk 2002). An interesting feature of the CEPCI is that it also incorporates a labor productivity factor which is "a technological productivity factor predicated on advances in working tools and techniques" (Matley 1982). This acknowledges the fact that labor productivity generally increases over time and will reduce the magnitude of changes in the cost of labor (Arnold and Chilton 1963).

The Construction Cost Index provides an interesting example of the utility of a composite index for tracking and analyzing an industry. The CPI and US GDP were found to have strong correlation (> 0.99) with the Construction Cost Index (Ashuri et al. 2012). The price of oil and interest rate on prime loans have similarly been found to correlate well with the CEPCI (Mignard 2014). The presence of strong correlations with economic factors has led researchers to attempt to forecast both of these indices in a variety of functional forms (Earl 1977, Wang and Mel 1998, Shahandashti and Ashuri 2013). While an indicator of the cost changes in an industry is useful, providing some means of forecasting future changes in cost is a valuable contribution.

Previous efforts have generated cost indices for components of the forest industry. *Forest Landowner* (formerly *Forest Farmer*) reports cost indices of common forest management practices biennially, based on surveys of private firms, public agencies and individuals across the South (Barlow and Dubois 2011). Dubois et al. (1991) described an aggregate index of the management practices reported by *Forest Landowner* to show the trend in forest management costs generally. Neither of the indices includes timber harvesting cost, although pre-commercial thinning is included as a management practice. Tufts et al. (1981) detailed an aggregate index of forestry equipment costs based on annual purchase prices for a collection of logging and forest management machinery. However, they found that the harvesting equipment index was not statistically different from the Producer Price Index (PPI) for Machinery and Equipment. To date, the logging industry has not had an aggregate cost index that tracks the cost of a collection of key inputs over time.

Annual collection of detailed logging cost data from a group of contractors allows for an empirically-based cost trend over time (Stuart and Grace 1999, Swedish Forest Agency 2012). While the quality provided by this data is high, the cost and time involved in collecting and analyzing them introduces a time lag which limits the utility of the data for operational purposes. Detailed cost information on southern logging operations first reported by Loving (1991) provided a comprehensive analysis of the costs incurred in the logging industry. This methodology was subsequently employed by Lebel (1993), Shannon (1998), Walter (1998), and Jackson (2003) to provide a time series of annual costs in a series of projects maintained first by the Virginia Tech Industrial Forestry Operations Research Co-op and later supported by the Forestry and Wildlife Research Center at Mississippi State University, the American Pulpwood Association and the Wood Supply Research Institute.

These studies became the foundation for an annual logging cost index, reported through the Wood Supply Research Institute (Stuart et al. 2003a). The cost index developed by Stuart has been one of the most widely available indicators of US logging cost changes over the past 20 years. Stuart's reports had a 1-2 year delay between the recording of the cost information by a contractor and the availability of reports to potential users, which was a limitation to their use. They relied on detailed accounting information from a group of contractors (typically 30-40), which was a time-consuming approach that yielded explanatory detail on causes for many of the changes in costs over time. Stuart et al. (2003b) also demonstrated that due to the relatively small pool of data providers and the large amount of variability in the logging industry, expanding the sample size contributing to the index can shift the index value and in some cases drastically changes the magnitude and direction of changes between periods.

One additional weakness of the Stuart approach is that the index was structured as a unit value, wherein both the cost and the volume produced in the base year and the comparison year are needed to calculate the index value, a situation known as the index number problem (Balk 2008, Afriat 2014). A unit value index makes it impossible to discern the changes in value due to actual cost changes and those due to production changes of the sample population. This formulation can indicate a change in costs between two periods even if all input costs stay the same, simply because the production levels of the population have changed (Balk 2008). The unit value formulation is extremely effective at indicating the actual change in the unit cost over time, but does not identify true cost inflation. If a representative sample of the population could be gathered to assure that production changes were representative of the entire population, the unit value formulation would be a valuable measure of simultaneous productivity and cost changes. Stuart et al. (2003b) clearly stated that their sample cannot be shown to be representative of the larger logging company population, and therefore generalization of the index trends to the entire industry cannot be assured. A production index published alongside the logging cost index greatly aids in understanding the underlying causes of cost changes, however, this is only rarely available (e.g. Stuart et al. 2003a). The early efforts by Lebel and Stuart (1998) and Shannon (1998) explicitly evaluated the change in technical efficiency for contractors in these data, highlighting the separate effects of cost and productivity changes.

INDUSTRY CAPACITY

The US recession of 2008 and 2009 caused tremendous reductions in forest products production. Southern pine sawtimber production dropped 60% from the peak in 2005 to 2009 (Harris et al. 2010). Nationally, unemployment levels hit 10%, and employment losses from the forest industry exceeded 30% (Woodall et al. 2011, Bureau of Labor Statistics 2013d). While estimates of employment impacts provide an indication of the effects of the recession, they fail to encompass the aggregate impact to the entire industry. Assessing the production capacity, the aggregate potential production volume of firms in the industry, is more informative.

Tracking production capacity for either the pulp or solid wood products industries is relatively straightforward, and a number of government and industry trade reports provide these estimates on an ongoing basis (e.g., Spelter et al. 2011, Bentley and Steppleton 2013). The traditional forest industries are dominated by large businesses which are comparatively easy to track over time. The logging industry, however, is composed of small, privately-owned, independent contractors which have neither need nor expectation to provide information on their business production capacity, making industry capacity estimation challenging.

Some attention has been given to the concept of capacity in the southern logging industry. Past efforts to understand production capacity have focused primarily on analyzing small groups of individual businesses to make inferences about the industry. In the late 1980's, a group of 24 logging contractors distributed from Maryland to Alabama was found to be utilizing only 51% of their maximum sustainable capacity (Loving 1991). Laestadius (1990) contrasted the southern US wood supply system with that of Sweden and highlighted the strategic underutilization of logging capacity by the US forest industry. LeBel (1998) noted the negative impact of low capacity utilization on the ability of contractors to operate efficiently. A study in the early 2000's found a group of contractors across the South and Maine were operating at roughly 65% of their capacity (Greene et al. 2004). The methodology employed for both of these studies involved comparing the maximum weekly or monthly production (total tons harvested) over a period of time to the average production each contractor achieved. Participants must provide detailed monthly or weekly production data over an extended period of time to enable these calculations. While this approach is data-driven and extremely informative, the quality of data needed and length of participation can bias the sample towards larger, more efficient contractors who are able and willing to collect, process, and share the data, making inference regarding the entire industry challenging.

Examinations of the logging industry on the regional or national level using a broader cross-section of businesses have primarily focused on characterizing the industry, though some studies have estimated productivity changes by examining the industry over multiple periods. Using a national survey of pulpwood producers, Cubbage and Carter (1994) estimated that annual productivity gains for southern longwood harvesting crews were roughly 2.2% between 1979 and 1987. Labor productivity for loggers in Georgia increased slightly less than 2% per year between 1987 and 2007, with the greatest gains occurring from 1987 to 1992 (Baker and Greene 2008). A survey of Alabama logging firms in 2000 estimated that average weekly production was unchanged from 1995 through 2000, with an average weekly production lower than reported in Georgia in 1997 (Duc et al. 2009). The labor productivity reported for Alabama contractors in 2000 was slightly lower than similar measures reported in 1997 for Georgia contractors, while the capital productivity was slightly higher (Greene et al. 2001).

Total Factor Productivity (TFP), also termed multi-factor productivity, is a measure representing total output per unit of input used to compare productivity across firms. In cases involving multiple inputs (such as both labor and capital), aggregate output and input indices need to be developed. Often the development of an aggregate productivity measure is not possible due to the lack of data. When TFP cannot be calculated, partial productivity measures such as labor productivity may offer a viable alternative.

While useful, these partial productivity measures do come with some limitations (Windle and Dresner 1992). Labor productivity does not account for all possible tradeoffs with other production inputs. Further, all categories of labor (e.g., manager, secretary, equipment operator, or truck driver) are treated in the same way. Lastly, this measure may combine different outputs of labor (e.g., pulpwood vs. sawtimber) and different dimensions of labor (e.g., thinning vs. final harvest operations). Nevertheless, this is a legitimate approach for assessing differences in labor productivity across firms. For example, Windle and Dresner (1992) found in the air transport industry, labor productivity was strongly correlated with TFP when outputs and inputs were expressed in physical units rather than monetary values subject to inflation. However, Parry (1999) found that TFP for the logging industry declined from 1970-1992 while partial productivity of labor increased. As Parry comments "labor productivity growth overstates multi-factor productivity growth when the quantity of capital and intermediate inputs are increasing relative to labor input over time." Between 1970 and 1992, the transition to primarily mechanized operations would have created precisely this scenario.

SUMMARY

This joint literature review provides a discussion of the setting in which the research of Chapters 2-4 occurs. While the logging industry plays a crucial role in the wood supply chain, the quality of information available regarding the current status of the industry is poor. Many of the currently available methods for gaining insight into the industry are limited by the time and expense involved in gathering reliable data from individual businesses. The logging industry needs current, low-cost indicators of changes to better understand and respond to shifts in the operating environment. In the following chapters, we develop empirically-based measures of logging cost and logging capacity which are a starting point to address this need.

LITERATURE CITED

Afriat, S. N. 2014. *The index number problem : construction theorems*. Oxford,UK Oxford University Press.

Arnold, T. H. & C. H. Chilton. 1963. New Index Shows Plant Cost Trends. *Chemical Engineering,* 70(2)**:**143-148.

Ashuri, B., S. M. Shahandashti & J. Lu. 2012. Empirical tests for identifying leading indicators of ENR Construction Cost Index. *Construction Management & Economics,* 30(11)**:**917-927.

Baker, S. A. & W. D. Greene. 2008. Changes in Georgia's logging workforce, 1987-2007. *Southern Journal of Applied Forestry,* 32(2)**:**60-68.

Balk, B. M. 2008. *Price and quantity index numbers : models for measuring aggregate change and difference*. Cambridge, UK Cambridge University Press.

Barlow, R., J. & M. R. Dubois. 2011. Cost and cost trends for forestry practices in the South. *Forest Landowner,* 70(6)**:**14-24.

Bentley, J. W. & C. D. Steppleton. 2013. *Southern pulpwood production, 2011*. Asheville, NC : United States. Dept. of Agriculture, Forest Service, Southern Research Station, [2013]. pp. 38.

Bilek, E. M. 2009. *ChargeOut! Discounted cash flow compared with traditional machine-rate analysis*. FPL-GTR-178, Madison; USA: USDA Forest Service, Forest Products Laboratory. pp. 15.

Brinker, R. W., J. Kinard, B. Rummer & B. L. Lanford. 2002. Machine rates for selected forest harvesting machines. *Circular - Alabama Agricultural Experiment Station,* 296 (revised))**:**32.

Brinker, R. W., B. L. Lanford, B. J. Stokes & D. Miller. 1989. Machine rates for selected forest harvesting machines. *Circular - Alabama Agricultural Experiment Station,* 296).

Bureau of Labor Statistics. 2013d. Quarterly Census of Employment and Wages. Accessed at. http://www.bls.gov/cew/home.htm: U.S. Department of Labor. Last accessed on: June 27, 2013.

Burgess, J. A. & F. W. Cubbage. 1989. Comparison of machine rate and cash flow approaches for estimating forest harvesting equipment costs. *American Society of Agricultural Engineers - Paper No. 89-7548***:**24.

Cubbage, F. & D. Carter. 1994. Productivity and cost changes in southern pulpwood harvesting, 1979 to 1987. *Southern journal of applied forestry,* 18(2)**:**83-90.

Cubbage, F. W., J. E. Granskog & B. J. Stokes. 1988. Trends in southern forest harvesting equipment and logging costs. *Forest Products Journal,* 38(2)**:**6-10.

Dubois, M. R., W. F. Watson & T. J. Straka. 1991. A cost index for Southern forest practices. *Southern Journal of Applied Forestry,* 15(3)**:**128-133.

Duc, N. M., Y. Shen, Y. Zhang & M. Smidt. 2009. Logging productivity and production function in Alabama, 1995 to 2000. *Forest Products Journal,* 59(7/8)**:**22-26.

Earl, P. H. 1977. Specifying escalation indexes to aid in process plant cost forecasting. *Engineering and Process Economics,* 2(4)**:**281-294.

Greene, W. D., F. W. Cubbage & J. F. McNeel. 1988. Characteristics of Independent Loggers in Georgia. *Forest Products Journal,* 38(7-8)**:**51-56.

Greene, W. D., B. D. Jackson & J. D. Culpepper. 2001. Georgia's logging businesses, 1987 to 1997. *Forest Products Journal,* 51(1)**:**25-28.

Greene, W. D., J. H. Mayo, C. F. deHoop & A. F. Egan. 2004. Causes and costs of unused logging production capacity in the southern United States and Maine. *Forest Products Journal,* 54(5)**:**29-37.

Grogan, T. 1992. First quarterly cost report: Cost history keeping track of a moving target. *Engineering News-Record*, 228(13)**:**2.

Harris, T. G., J. Smith, R. Simmons & S. Baldwin. 2010. Timber Mart-South Market News Quarterly. Athens, GA: Timber Mart-South. 14(4): 43.

Jackson, B. D. 2003. *Examining the performance of independent harvesting firms in the eastern United States*. M.S. Thesis. Mississippi State University. Starkville, MS

Knight, D. 2006. Deeper Hole? *Timber Harvesting,* Montgomery, AL: Hatton Brown. 54(3)**:**10-14, 40.

---. 2011. Nowhere to turn. *Timber Harvesting and Wood Fiber Operations,* Montgomery, AL: Hatton Brown. 59(3)**:**10-19.

Koop, G. 2005. *Analysis of economic data*. John Wiley & Sons: Chichester, England.

Laestadius, L. 1990. *A Comparative Analysis of Wood-Supply Systems from a Cross-Cultural Perspective*. PhD Dissertation. Virginia Tech. Blacksburg, VA: 149.

LeBel, L. 1993. *Production capacity utilization in the southern logging industry*. M.S. Thesis. Virginia Polytechnic Institute and State University. Blacksburg, VA

LeBel, L. G. & W. B. Stuart. 1998. Technical efficiency evaluation of logging contractors using a nonparametric model. *Journal of Forest Engineering*, 9(2)**:**15-24.

Leon, B. H. & J. G. Benjamin. 2013. A survey of business attributes, harvest capacity and equipment infrastructure of logging businesses in the Northern forest. Orono, ME: University of Maine. pp. 29.

Loving, R. E. 1991. *Components of Logging Costs*. M.S. Thesis. Virginia Tech. Blacksburg, VA: 205.

Matley, J. 1982. Chemical Engineering Plant Cost Index - Revised. *Chemical Engineering,* 89(1)**:**153-156.

Mignard, D. 2014. Correlating the chemical engineering plant cost index with macro-economic indicators. *Chemical Engineering Research & Design: Transactions of the Institution of Chemical Engineers Part A,* 92(2)**:**285-294.

Miyata, E. S. 1980. *Determining fixed and operating costs of logging equipment*. GTR-NC-55, Saint Paul, MN: North Central Forest Experiment Station, Forest Service, U.S. Dept. of Agriculture. pp.

Miyata, E. S. & H. M. Steinhilb. 1981. *Logging system cost analysis : comparison of methods used*. Research paper NC-208, St. Paul, Minn.: U.S. Dept. of Agriculture Forest Service North Central Forest Experiment Station. pp. 15.

Munn, I. A., J. B. Cutshall & D. G. Hodges. 1998. 1993 pulpwood logging contractor survey. *Forest Products Journal,* 48(7)**:**47-53.

Parry, I. W. H. 1999. Productivity Trends in the Natural Resource Industries: A Cross-Cutting Analysis. In *Productivity in natural resource industries: Improvement through innovation,* ed. R. D. Simpson, 175-204. Washington, D.C.: Resources for the Future.

Plummer, G. 1982. Harvesting developments: Machine costs and rates. ed. W. D. Georgia Kraft Company. Georgia Kraft Company, Woodlands Division.

Shahandashti, S. M. & B. Ashuri. 2013. Forecasting Engineering News-Record Construction Cost Index Using Multivariate Time Series Models. *Journal of Construction Engineering & Management,* 139(9)**:**1237-1243.

Shannon, J. T. 1998. *Productivity, cost, and technical efficiency evaluation of southeastern U.S. logging contractors*. M.S. Thesis. Virginia Polytechnic Institute and State University. Blacksburg, Va.

Spelter, H., R. Goodnow, J. Sweitzer & A. Schmon. 2011. Profile 2011: Softwood sawmills in the United States and Canada. Westford, MA: Forest Economic Advisors, LLC. pp. 55.

Stuart, W. B. 2003. Checking our foundations: Matthews' least cost models revisited. *Southern Journal of Applied Forestry*, 27(1)**:**30-35.

Stuart, W. B. & L. A. Grace. 1999. Wood supplier productivity and cost survey. In *Technical Paper 99-A-7*, Rockville, MD: American Pulpwood Association. pp. 46.

Stuart, W. B., L. A. Grace, B. D. Jackson & R. Stutzman. 2003a. Logging Cost Indices. Starkville, MS: Wood Supply Research Institute. pp. 21.

---. 2003b. Logging cost indices: The effect of increasing the sample size. Starkville, MS: Wood Supply Research Institute. pp. 17.

Swedish Forest Agency. 2012. *Swedish Statistical Yearbook of Forestry 2012*. Jonkoping, Sweden. pp. 380.

Tufts, R. A., J. Thurber, D. Simmons & B. Izlar. 1981. Forestry equipment cost index: 1968-1978. *Southern Journal of Applied Forestry,* 5(4)**:**201-204.

Vatavuk, W. M. 2002. Updating the CE Plant Cost Index. *Chemical Engineering,* 109(1)**:**62-70.

Wackerman, A. E. 1966. *Harvesting timber crops*. McGraw-Hill: New York.

Walter, M. J. 1998. *Documentation of productivity and efficiency relationships for a group of southern logging contractors*. M.S. Thesis. Virginia Polytechnic Institute and State University. Blacksburg, Va.

Wang, C.-h. & Y.-h. Mel. 1998. Model for forecasting construction cost indices in Taiwan. *Construction Management & Economics,* 16(2)**:**147-157.

Werblow, D. A. & F. W. Cubbage. 1986. Forest harvesting equipment ownership and operating costs in 1984. *Southern Journal of Applied Forestry,* 10(1)**:**10-15.

Windle, R. J. & M. E. Dresner. 1992. Partial productivity measures and total factor productivity in the air transport industry: limitations and uses. *Transportation Research Part A: Policy & Practice,* 26A(6)**:**435-445.

Woodall, C. W., P. J. Ince, K. E. Skog, F. X. Aguilar, C. E. Keegan, C. B. Sorenson, D. G. Hodges & W. B. Smith. 2011. An overview of the forest products sector downturn in the United States. *Forest Products Journal,* 61(8)**:**595-603.

Xu, Y., M. Smidt & Y. Zhang. 2014. Logging Worker Wage, Performance and Experience. *Forest Products Journal,* 64(5/6)**:**210-216.

CHAPTER 2

CAPACITY CHANGES IN THE SOUTHERN LOGGING INDUSTRY[1]

[1] Baker, S.A., W.D. Greene, and J.P. Siry. Capacity changes in the southern logging industry. Article is currently in review with the Forest Products Journal.

ABSTRACT

The logging industry in the US South suffered job losses during the recent recession and the subsequent slow recovery in housing markets; however, no effort has previously been made to estimate the corresponding impact to the logging capacity. We gathered data on the ten states comprising the US South and calculated estimates of logging capacity between 2006 and 2012 in four multi-state regions of the South. Total harvest levels largely reached their nadir in 2009, but by 2012 were still 6-23% lower than 2006 levels. Increasing labor productivity has mitigated some of the impact of employment losses on the total logging capacity. While logging employment levels in each region declined by 14-22%, logging capacity declined 8-17%. The excess logging capacity (the difference between logging capacity and total production) has declined in only one of the four regions (Georgia-Florida-South Carolina). Regions in which sawtimber represented greater than 50% of the pre-recession total harvest suffered larger losses in logging capacity.

INTRODUCTION

The US recession of 2008 and 2009 caused tremendous reductions in production of forest products. Southern pine sawtimber production dropped 60% from the peak in 2005 to 2009 (Harris et al. 2010). Nationally, unemployment levels hit 10%, and employment losses from the forest industry exceeded 30% (Woodall et al. 2011, Bureau of Labor Statistics 2013d). While estimates of unemployment levels are informative, they fail to encompass the aggregate impact to the entire industry. Assessing the production capacity, the aggregate potential production volume of firms in the industry, is more informative.

Tracking production capacity for either the pulp or solid wood products industries is relatively straightforward, and a number of government and industry trade reports provide these estimates on an ongoing basis (e.g., Spelter et al. 2011, Bentley and Steppleton 2013). The traditional forest industries are dominated by large businesses which are comparatively easy to track over time. The logging industry, however, is composed of small, privately-owned, independent contractors which have neither need nor expectation to provide information on their business production capacity, making industry capacity estimation challenging.

Some attention has been given to the concept of capacity in the southern logging industry. Laestadius (1990) contrasted the southern US wood supply system with that of Sweden and highlighted the strategic underutilization of logging capacity by the US forest industry. LeBel (1998) noted the negative impact of low capacity utilization on the ability of contractors to operate efficiently. Past efforts to understand production capacity have focused primarily on analyzing small groups of individual businesses to make inferences about the industry. In the late 1980’s, a group of 24 logging contractors distributed from Maryland to Alabama was found to be utilizing only 51% of their maximum sustainable capacity (Loving 1991). A study in the early 2000’s found a group of contractors across the South and Maine were operating at roughly 65% of their capacity (Greene et al. 2004). The methodology employed for both of these studies involved comparing the maximum weekly or monthly production (total tons harvested) over a period of time to the average production each contractor achieved. Participants must provide detailed monthly or weekly production data over an extended period of time to enable these calculations. While this approach is data-driven and extremely informative, the quality of data needed and length of participation can bias the sample towards larger, more efficient contractors who are able and willing to collect, process, and share the data, making inference regarding the entire industry challenging.

Examinations of the logging industry on the regional or national level using a broader cross-section of businesses have primarily focused on characterizing the industry, though some studies have estimated productivity changes by examining the industry over multiple periods. Using a national survey of pulpwood producers, Cubbage and Carter (1994) estimated that annual productivity gains for southern longwood harvesting crews were roughly 2.2% between 1979 and 1987. Labor productivity for loggers in Georgia increased slightly less than 2% per year between 1987 and 2007, with the greatest gains occurring from 1987 to 1992 (Baker and Greene 2008). A survey of Alabama logging firms in 2000 estimated that average weekly production was unchanged from 1995 through 2000, with an average weekly production lower than reported in Georgia in 1997 (Duc et al. 2009). The labor productivity reported for Alabama contractors in 2000 was slightly lower than similar measures reported in 1997 for Georgia contractors, while the capital productivity was slightly higher (Greene et al. 2001).

Total Factor Productivity (TFP), also termed multi-factor productivity, is a measure representing total output per unit of input used to compare productivity across firms. In cases involving multiple inputs (such as both labor and capital), aggregate output and input indices need to be developed. Often the development of an aggregate productivity measure is not possible due to the lack of data. When TFP cannot be calculated, partial productivity measures such as labor productivity may offer a viable alternative. While useful, these partial productivity measures do come with some limitations (Windle and Dresner 1992). Labor productivity does not account for all possible tradeoffs with other production inputs. Further, all categories of labor (e.g., manager, secretary, equipment operator, or truck driver) are treated in the same way. Lastly, this measure may combine different outputs of labor (e.g., pulpwood vs. sawtimber) and different dimensions of labor (e.g., thinning vs. final harvest operations). Nevertheless, this is a legitimate approach for assessing differences in labor productivity across firms. For example, Windle and Dresner (1992) found in the air transport industry, labor productivity was strongly correlated with TFP when outputs and inputs were expressed in physical units rather than monetary values subject to inflation.

In this study, we propose a methodology for estimating logging capacity for the southern logging industry by combining data on employment levels, industry production, and measures of labor productivity. We develop capacity estimates and compare them to actual production levels. The difference between our estimated capacity and actual production is an estimate of the surge or excess logging capacity. Our analysis covers 2006 through 2012, providing insight into the impact of the recession on the southern logging industry.

DATA

Estimates of total employment in the logging industry (denoted by the North American Industry Classification System [NAICS] code number 113310) were gathered from the Quarterly Census of Employment and Wages (QCEW) (Bureau of Labor

Statistics 2013d). QCEW data are derived from the quarterly unemployment insurance filings of businesses, and represent an employment level in the state on the twelfth day of each month (Bureau of Labor Statistics 2011). While concerns have been raised regarding the accuracy of BLS employment figures for logging employees (e.g. Hodges et al. 2011), we assume any inaccuracies will be consistent across the seven year timeframe of our analysis.

Annual timber harvest levels by state were collected from the Wood Demand Report (Sydor 2012) by summing the pine chip-n-saw, hardwood palletwood, and pine and hardwood sawtimber and pulpwood purchases quarterly within each state of the US South. In this analysis we considered the states of Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Texas and Virginia. Data on wood consumption from the Wood Demand Report are gathered directly from consuming mills each quarter, with 2006 as the initial year of reporting. The annual values in each state were compared against US Forest Service Timber Product Output (TPO) data, available in odd years only, to ensure consistency of the data (Johnson et al. 2011). Annual harvest levels from TPO were calculated as the sum of volumes retained and exported from a given state in a given year. TPO data were converted from cubic foot volumes into tons based on conversion ratios of ft^3 per cord suggested for each state by the US Forest Service (Johnson et al. 2011) and a fixed weight conversion of 5,350 lbs/cord for pulpwood and 5,800 lbs/cord for hardwood (Harris et al. 2013). These conversions varied slightly by state, but averaged roughly 74 lbs/ft^3 for softwood and 77 lbs/ft^3 for hardwood.

We divided the ten states of the US South into four multi-state regions (Figure 2.1): Alabama and Mississippi (AL-MS); Arkansas, Louisiana and Texas (AR-LA-TX); Florida, Georgia, and South Carolina (FL-GA-SC); North Carolina and Virginia (NC-VA). Substantial interstate movement of wood amongst many of the states prompted this decision (Johnson et al. 2011). States were grouped into regions in such a fashion to ensure that over 90% of the wood consumed in each region is harvested within the region. Many logging contractors will still work across multiple regions; however, this approach minimizes the effect of interstate movement of harvested wood while still allowing for comparisons across the southern region. After combining the harvested weights within a region, production levels for the Wood Demand Report did not always align well with TPO data (Table 2.1). The differences appeared to be consistent in a given region over time. Altering cubic foot-to-ton conversion ratios for different product classes could improve the accuracy of the production estimates; however, the precision of the two data sources appears uniform.

Figure 2.1: Four sub-regions of the US South.

Table 2.1: Estimates of total harvest levels from each state of the US South as estimated by the US Forest Service Timber Product Output and the Wood Demand Report.

	AL-MS		AR-LA-TX[3]		FL-GA-SC		NC-VA	
	USFS TPO[1]	WDR[2]	USFS TPO	WDR	USFS TPO	WDR	USFS TPO	WDR
2005	81,412		59,668		83,256		47,772	
2006		74,847		52,632		80,664		44,073
2007	74,768	73,752	54,833	51,154	85,371	79,749	44,266	43,254
2008		68,336		46,716		76,057		40,586
2009	55,721	57,433	40,239	39,948	76,986	70,584	36,607	36,550
2010		61,008		40,985		74,806		35,383
2011	63,056	62,900	44,443	40,954	81,786	75,341	39,447	35,438
2012		65,028		39,989		75,972		33,956

[1] Aggregate harvest amount in thousand tons from US Forest Service Timber Product Output and Use biennial reports (Johnson et al. 2011).

[2] Aggregate harvest amount in thousand tons from the Wood Demand Report (Sydor 2012).

[3] USFS TPO reports from Texas were unavailable so volumes in the table exclude the Texas production reported by the Wood Demand Report as well.

Data on logging employee productivity in Southern states are not widely available. Periodic surveys of the logging industry in some states provide a reference point for comparison. The logging industry in Georgia has been surveyed every five years since 1987 (Baker and Greene 2008), South Carolina's industry was surveyed in 2008 (Moldenhauer and Bolding 2009) and again in 2012 (Marchman et al. 2013), and Virginia's logging industry was surveyed in 2009 (Bolding et al. 2010). From these surveys, we were able to ascertain the average production per man-hour of logging employees in certain states. Many of the surveys also contained data on capital productivity; however, data on capital investments in logging businesses is not readily available to allow for a comparison of changes over time.

METHODS

Using the data described above we sought to estimate the total logging capacity in each state, as well as the "excess" logging capacity, the capacity exceeding the total harvest level in each state for a given year. The composition of the logging industry varies by state, making accurate estimation of logging production levels challenging. For example, in 2007, a survey of the Georgia logging industry found that 85% of logging firms used fully-mechanized feller-buncher/grapple skidder harvesting systems (Baker and Greene 2008). A similar survey in 2009 of Virginia logging firms found that only 50% of firms used feller-bunchers in their harvesting systems (Bolding et al. 2010). In order to estimate the potential harvest levels of the logging industry in each state, an estimate of the production potential of employees in each state was needed.

We divided the actual harvest levels from both the TPO data and the Wood Demand Report by the total logging employment to determine the amount of wood harvested per logging employee. This annual value was divided by 2000 annual hours worked for logging employees, to generate a production per man-hour for each region.

While we use the annual production levels reported by the Wood Demand Report for increased resolution in our logging capacity calculations, they are limited to 2006-2012. The USFS TPO data are only reported every two to three years with a two-year lag, but are available to compare the trends in worker productivity over a longer time period. Mailed surveys of the logging industry in Georgia were administered in early 2007 and mid-2012 (Baker and Greene 2008, Marchman et al. 2013). The average production per man-hour of employees reported in these surveys provides a consistent point of comparison regarding the change in productivity of labor in the industry. As comparable data were not available in any other Southern state, we used this value as a starting point for a capacity computation. By comparing actual production per man-hour (tons harvested based on TPO data divided by QCEW employment numbers) in Georgia to production per man-hour values reported in the survey over time it is possible to see how the two diverged for a number of years and recently converged (Figure 2.2). Productivity reported by contractors was greater than actual productivity between 1997 and 2009; however, the most recent data (available in 2011) reveals the actual productivity matching well with productivity reported by contractors. While there are a number of possible explanations for the divergence in values, including decreased utilization of potential labor productivity due to market forces, it appears that data from the Georgia Logging Survey provide a reasonable estimate of growth in labor productivity. The change in worker productivity based on the Georgia Logging Survey shows a nearly linear growth rate over the ten years from 2002 to 2012. A linear interpolation was therefore used to estimate the annual productivity of logging workers in Georgia between 2006 and 2012.

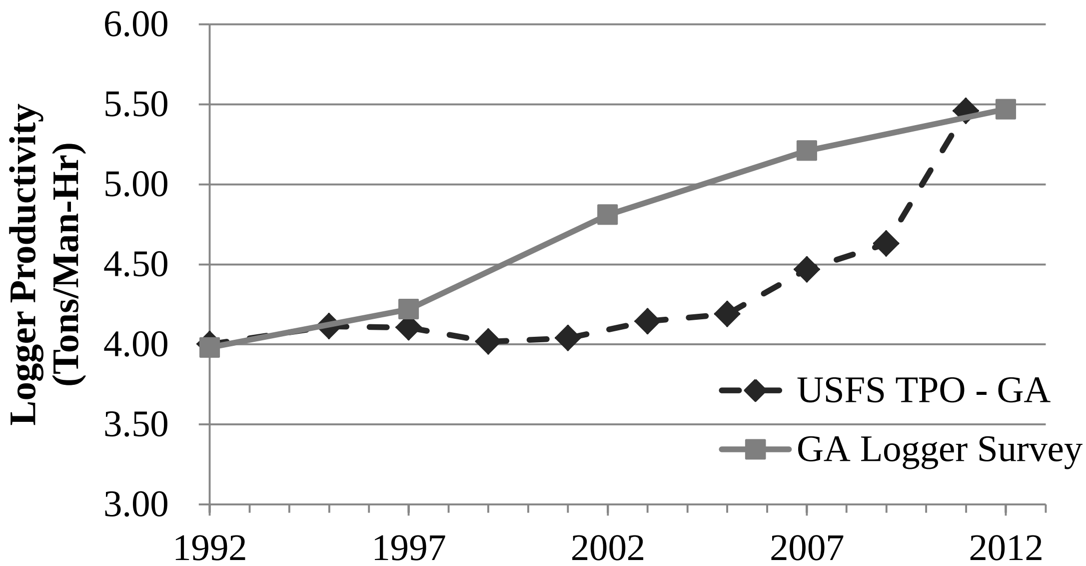

Figure 2.2: Logging employee productivity in Georgia as estimated by the Georgia Logger Survey and the US Forest Service timber harvest levels combined with logging employment estimates from the Bureau of Labor Statistics.

The actual production per employee in each state was compared to the actual production per employee in Georgia via a ratio:

Production per man-hour in state *x*, year *y* / Production per man-hour in Georgia, year *y*

This ratio was calculated for 2006 and 2007, the last two years of production preceding the US recession. The ratio calculated in 2006 and 2007 was averaged to provide a measure of the production level of logging employees in each state relative to the production level of Georgia logging employees prior to the recession (the peak production period for our analysis). This ratio was used to convert the potential production per man-hour derived for Georgia from the Georgia Logging Survey into a potential production for logging employees in each of the southern states.

The logging capacity in each state was calculated by multiplying the logging employment with the potential logging production per man-hour described above, and finally multiplying by 2000 hours to generate an annual capacity figure. Subtracting the actual harvest level from the calculated logging capacity yields a measure of the excess logging capacity in a given state. The excess logging capacity represents the amount of wood, in addition to the actual production, which could theoretically be harvested given the current employment level of the logging industry.

RESULTS

Each of the four regions had reductions in logging employment between 2006 and 2012 (Figure 2.3). The decline was greatest in the AR-LA-TX region, where total logging employment declined 22%, while the NC-VA region experienced the least decline (14%). The pace of logging job losses was greatest from 2007-2009. In each region, employment levels in 2012 are at best equivalent to the 2009 level, and in both GA-FL-SC and AR-LA-TX, logging employment has continued to decline. Harvest levels follow a similar pattern to the employment data, with steep declines through 2009, the heart of the recession (Table 2.1). Since 2009, only VA-NC has shown continued reductions in total harvest levels. All regions were still harvesting less in 2012 than they harvested in 2006, with the total decline over that time period ranging from 6 – 23%.

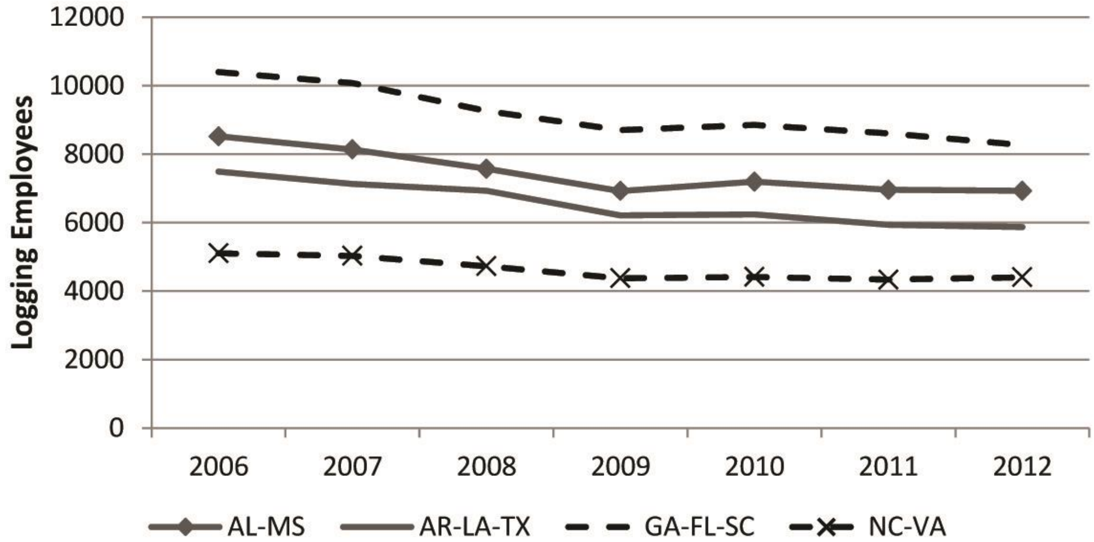

Figure 2.3: Logging employment in four sub-regions of the US South, 2006-2012. Source: Bureau of Labor Statistics, 2013.

When combined with the employment numbers, worker productivity is the basis for the calculation of total logging capacity in each region of the South (Figure 2.4). Worker productivity (tons/man-hour) increased 6.7% between 2006 and 2012. This increase in part offsets the employment reductions in the logging industry. While employment reduction varied from 14% to 22% across the four regions, total logging capacity only declined between 8% and 17%.

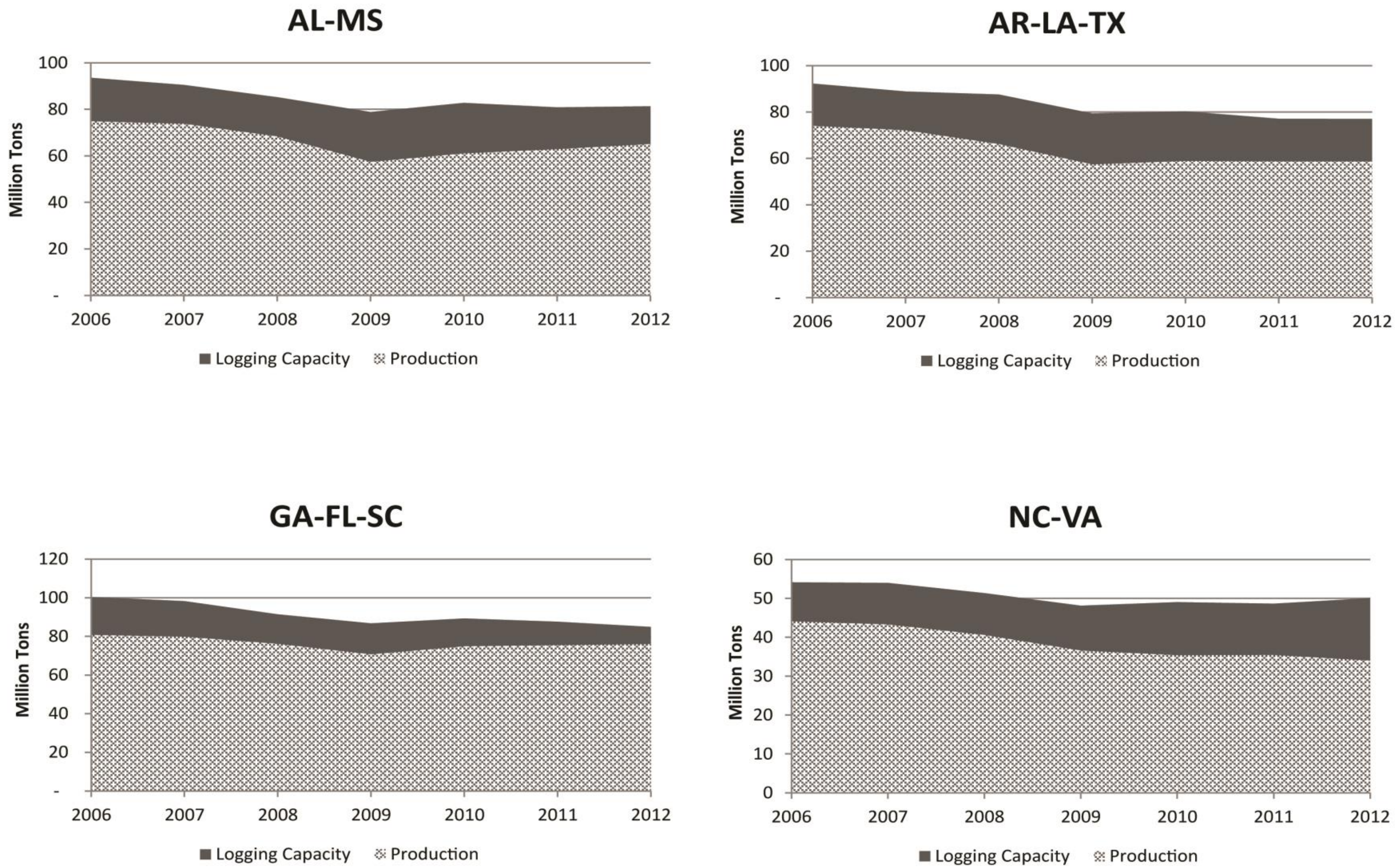

Figure 2.4: Total logging production and logging capacity in four sub-regions of the US South, 2006-2012.

The excess logging capacity, the additional production which could be generated in excess of the actual production, fluctuated over the period of study (Figure 2.4). Prior to the recession, excess capacity was roughly 20-25%, a level widely viewed as efficient for the logging industry (Greene et al. 2004). Starting in 2008, however, excess capacity levels began fluctuating, coinciding with the start of the recession. Both western regions (AR-LA-TX and AL-MS) experienced excess logging capacity increases through 2009 and have had decreasing excess capacity through 2012. Excess capacity in FL-GA-SC has decreased in all years except 2009, with excess capacity in 2012 near 10% of the total production. In NC-VA, excess capacity has increased in all years except 2011, with the excess capacity in 2012 at roughly 40% of the total production.

Solid and engineered wood product markets were impacted more by the recession than pulp and paper markets (Woodall et al. 2011). While paper production nationally fell by 20% between 2006 and 2012, wood products production fell by 38%. In the South, the difference was even more pronounced, as 2008, 2010, and 2011 represented the three largest years for pulpwood production since the start of the millennium (Johnson and Steppleton 2013). Demand for roundwood pulpwood increased to compensate for a decline in sawmill residuals typically produced by the solid wood products mills. Thus, demand for pulpwood logging was not greatly impacted during the recession, while sawtimber demand declined substantially. Of the four regions, solid and engineered wood products markets represented the smallest percentage of the total harvest volume in the FL-GA-SC region, which was the only region with a net decrease in excess logging capacity (Figure 2.5). The NC-VA region was most reliant on sawtimber and had the greatest increase in excess capacity. In addition to the numerous sawmill closings across the US South during the recession AR-LA-TX and NC-VA suffered pulp capacity losses of 10% and 22% respectively (Figure 2.6). The resulting reduction in pulpwood demand in these two regions further impacted the balance between logging and production capacity.

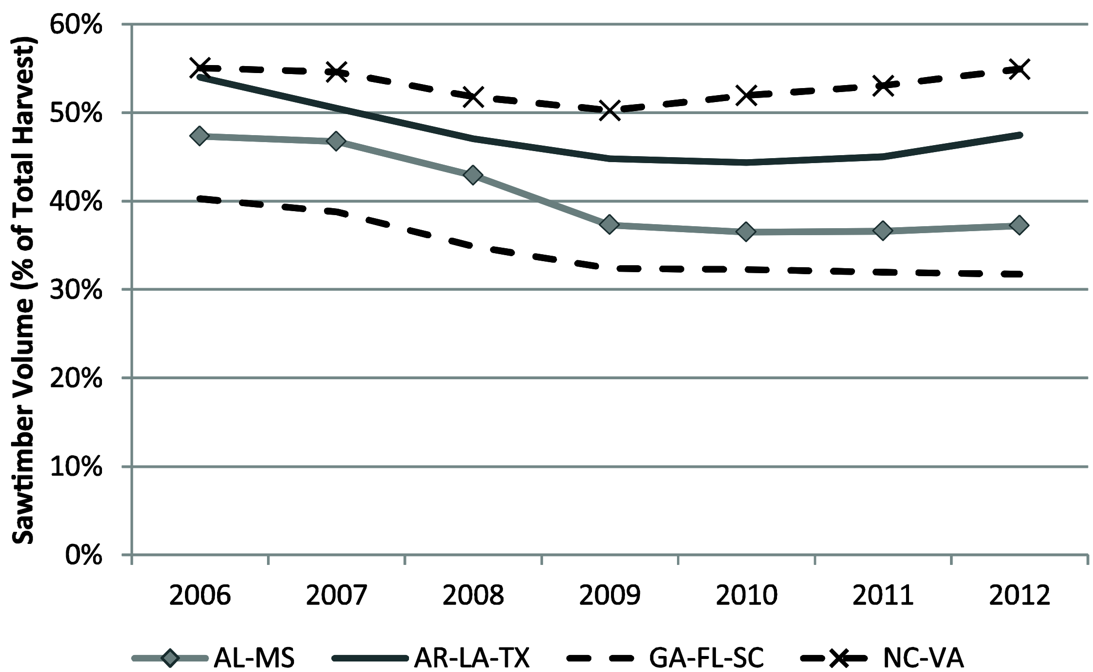

Figure 2.5: The percentage of sawtimber in the total harvest volume for four sub-regions of the US South from 2006-2012.

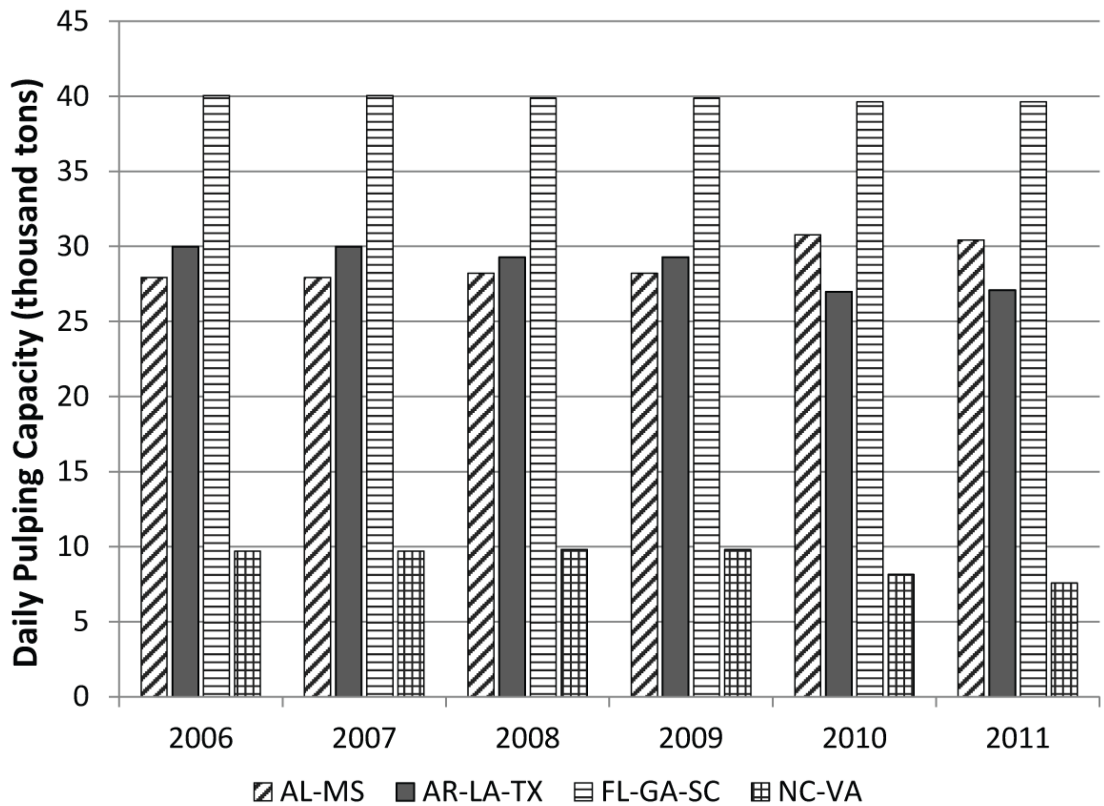

Figure 2.6: Southern wood pulping capacity in four sub-regions of the US South, 2006-2011. Source: US Forest Service Southern Pulpwood Production, 2006-2011.

DISCUSSION

The curtailment and closing of many solid wood product mills across the South limited markets for a large proportion of harvested wood. While landowners increasingly shifted their harvests to partial cuts and thinning to take advantage of healthier pulp and paper demand, total demand for logging services still declined during the recession (Baker et al. 2012). The logging industry shrank by roughly 20% across the South. Per ton logging costs peaked during the recession due to higher diesel costs and lower production volumes (Baker et al. 2013). Data on logging rates paid across the South indicate, however, that most rates increased during the heart of the recession helping offset cost pressures (Harris 2013). The historic reductions in sawtimber demand and the resulting reduction in demand for logging services caused the rapid reduction in logging capacity. The slow recovery of solid-wood products demand through 2012 further hindered a recovery in the logging sector. In 2010 and 2011, diesel costs once again returned to near record highs; however, logging rates have not increased a commensurate amount over this timeframe. While the employment levels in the logging industry have essentially equilibrated, cost pressures may now be a greater challenge for logging contractors than limited demand. An increase in logging rates commensurate with the increase in logging costs will indicate pressure on forest products industries to increase logging capacity.

Through 2012, the losses in total production have outpaced the overall decrease in logging capacity in the NC-VA region. The region seems best prepared to respond to increased demand in the short term; however, without an increase in logging demand, additional capacity losses could be expected.

Unknown are factors related to capital expenditures and the impact to productivity of delayed investment. Harvesting equipment has aged during the recession and investment has not kept pace with historic levels. Similar behavior was seen during the logging capacity contraction of the early 2000's as well (Forest Resources Association 2001). While productivity per unit of labor has been increasing, the net effect may not have been an increase in total productivity if older machinery has yielded lower production levels due to reduced mechanical availability.

LITERATURE CITED

Baker, S. A., D. Greene, T. G. Harris & B. Mei. 2013. Regional cost analysis and indices for conventional timber harvesting operations. Athens, GA: Wood Supply Research Institute. pp. 39.

Baker, S. A. & W. D. Greene. 2008. Changes in Georgia's logging workforce, 1987-2007. *Southern Journal of Applied Forestry*, 32(2)**:**60-68.

Baker, S. A., W. D. Greene & T. G. Harris. 2012. Impact of timber sale characteristics on harvesting costs. In *Applied Forest Economics at Work. Proceedings of the Southern Forest Economics Workers Annual Meeting*, ed. M. E. Aronow, Charlotte, NC: Hancock Timber Resource Group. 94-105.

Bentley, J. W. & C. D. Steppleton. 2013. *Southern pulpwood production, 2011*. Asheville, NC : United States. Dept. of Agriculture, Forest Service, Southern Research Station, [2013]. pp. 38.

Bolding, M. C., S. M. Barrett, J. F. Munsell & M. C. Groover. 2010. Characteristics of Virginia's logging businesses in a changing timber market. *Forest Products Journal*, 60(1)**:**86-93.

Bureau of Labor Statistics. 2011. Employment and Wages Online Annual Averages. Accessed at. http://www.bls.gov/cew/cewbultn10.htm: Quarterly Census of Employment and Wages. Last accessed on: September 19, 2013.

---. 2013d. Quarterly Census of Employment and Wages. Accessed at. http://www.bls.gov/cew/home.htm: U.S. Department of Labor. Last accessed on: June 27, 2013.

Cubbage, F. & D. Carter. 1994. Productivity and cost changes in southern pulpwood harvesting, 1979 to 1987. *Southern journal of applied forestry,* 18(2)**:**83-90.

Duc, N. M., Y. Shen, Y. Zhang & M. Smidt. 2009. Logging productivity and production function in Alabama, 1995 to 2000. *Forest Products Journal*, 59(7/8)**:**22-26.

Forest Resources Association. 2001. Summary Report: Financial health of the logging industry survey. Rockville, MD. pp. 36.

Greene, W. D., B. D. Jackson & J. D. Culpepper. 2001. Georgia's logging businesses, 1987 to 1997. *Forest Products Journal,* 51(1)**:**25-28.

Greene, W. D., J. H. Mayo, C. F. deHoop & A. F. Egan. 2004. Causes and costs of unused logging production capacity in the southern United States and Maine. *Forest Products Journal,* 54(5)**:**29-37.

Harris, T. G., J. Smith & S. Baldwin. 2013. Timber Mart-South: First Quarter 2013. Athens, GA: Timber Mart-South. 38(1).

Harris, T. G., J. Smith, R. Simmons & S. Baldwin. 2010. Timber Mart-South Market News Quarterly. Athens, GA: Timber Mart-South. 14(4): 43.

Hodges, D. G., A. J. Hartsell, C. Brandeis, T. J. Brandeis & J. W. Bentley. 2011. Recession Effects on the Forests and Forest Products Industries of the South. *Forest Products Journal,* 61(8)**:**614-624.

Johnson, T. G., J. W. Bentley & M. Howell. 2011. *The South's timber industry - an assessment of timber prodct output and use, 2009*. Resource Bulletin SRS-182, Asheville, NC. pp. 44.

Johnson, T. G. & C. D. Steppleton. 2013. Southern pulpwood production, 2011. In *Resource bulletin SRS-194*, 38. Asheville, NC : United States. Dept. of Agriculture, Forest Service, Southern Research Station, [2013].

Laestadius, L. 1990. *A Comparative Analysis of Wood-Supply Systems from a Cross-Cultural Perspective*. PhD Dissertation. Virginia Tech. Blacksburg, VA: 149.

LeBel, L. G. & W. B. Stuart. 1998. Technical efficiency evaluation of logging contractors using a nonparametric model. *Journal of Forest Engineering*, 9(2)**:**15-24.

Loving, R. E. 1991. *Components of Logging Costs*. M.S. Thesis. Virginia Tech. Blacksburg, VA: 205.

Marchman, S. C., S. A. Baker & W. D. Greene. 2013. Southeastern logging contractor survey results over 25 years. Rockville, MD: Forest Resources Association. Tech. Release 13-R-10: 2.

Moldenhauer, M. C. & M. C. Bolding. 2009. Parcelization of South Carolina's private forestland: loggers' reactions to a growing threat. *Forest Products Journal*, 59(6)**:**37-43.

Spelter, H., R. Goodnow, J. Sweitzer & A. Schmon. 2011. Profile 2011: Softwood sawmills in the United States and Canada. Westford, MA: Forest Economic Advisors, LLC. pp. 55.

Sydor, T. 2012. Wood Demand Report. Athens, GA: Center for Forest Business. 5(4): 8.

Windle, R. J. & M. E. Dresner. 1992. Partial productivity measures and total factor productivity in the air transport industry: limitations and uses. *Transportation Research Part A: Policy & Practice*, 26A(6)**:**435-445.

Woodall, C. W., P. J. Ince, K. E. Skog, F. X. Aguilar, C. E. Keegan, C. B. Sorenson, D. G. Hodges & W. B. Smith. 2011. An overview of the forest products sector downturn in the United States. *Forest Products Journal,* 61(8)**:**595-603.

CHAPTER 3

AN INDEX FOR LOGGING COST CHANGES ACROSS THE US SOUTH[1]

[1] Baker, S.A., B. Mei, T.G. Harris, and W.D. Greene. 2014. An index for logging cost changes across the US South. Journal of Forestry. 112(3): 296-301. Reprinted here with permission from the Society of American Foresters, 5400 Grosvenor Lane, Bethesda, MD 20814-2198. Not for further reproduction.

ABSTRACT

A timely, accurate indicator of changes in logging costs would establish a baseline against which logging contractors could compare their own costs and would offer buyers and sellers of timber a reference for shifts in cut and haul rates. Using data from face-to-face interviews, we developed percentage breakdowns of the key factors driving logging costs and proposed a logging cost index for the US South. Publicly available data on costs of diesel, equipment, maintenance, labor, interest, and other factors were used to drive the changes in the cost index over time. Labor (32.8%), fuel (22.8%), and depreciation (19.3%) represented the greatest proportion of costs amongst respondents. The calculated cost index was found to match historical trends in logging costs. The gap between prices paid for logging services (logging rates) and logging costs shrank between 2006 and 2013, indicating a reduction in the potential profit in the logging industry.

Keywords: cost indexing, forest operations, timber harvesting,

INTRODUCTION

The Bureau of Labor Statistics listed 8,300 logging businesses employing 46,300 people across the United States as of the 2nd quarter of 2012 (Bureau of Labor Statistics 2013d). In employee wages alone, the logging industry generates $1.9 billion. It is also a vital component of the US forest products supply chain. Despite the importance of the logging industry, information on the condition of the logging workforce has historically been limited. The business is dominated by small independent contractors, and substantial effort is required to gather sufficient information to make generalizations about the industry as a whole.

Costs of operating machinery were reported frequently through the late 1980's (Plummer 1982, Werblow and Cubbage 1986, Cubbage et al. 1988, Brinker et al. 1989) and have been updated less frequently since (Brinker et al. 2002). These were typically based on machine rate calculations for the common machines operating in the industry. While useful for tracking trends in the owning and operating costs associated with machinery, machine rate estimates are often based on little empirical evidence beyond updated purchase prices for machinery and fuel. Instead, standard assumptions are used regarding many of the costs. For example, the updated machine rates published in 2002 still reference maintenance and repair costs of harvesting machinery calculated in 1981 (Brinker et al. 2002). Calculating average costs to harvest timber which include all cost sources, not just machinery owning and operating costs, requires greater data collection efforts.

Harvesting costs are generated as a component of many harvest system analyses. Cost estimates are typically a combination of a detailed costing of the machinery and personnel involved in the harvesting system (many times based on machine rate calculations) in addition to productivity calculations collected during a time and motion study or estimated using computer simulations. Estimates of this form are useful for assessing likely costs on a given harvest site or comparing candidate harvesting systems, but are of little value in generalizing cost trends for the logging industry as the system productivity will be site specific.

Surveys of harvesting contractors provide another method of generating cost data for a large swath of the industry, and when repeated periodically, offer the potential to compare cost trends over time (Cubbage and Carter 1994, Baker and Greene 2008). However, unless the surveys are specifically designed to capture financial information, the trends are usually indicative only of changes in the number, types, and ages of machinery as well as general information about the business (number and type of employees, physical space, etc.). Surveys or interviews of contractors specifically requesting detailed cost information are uncommon and often involve a greater time investment to provide the data (Stuart and Grace 1999, Leon and Benjamin 2013).

Annual collection of detailed logging cost data from a group of contractors allows for an empirically-based cost trend over time (Stuart and Grace 1999, Swedish Forest Agency 2012). While the quality provided by this data is high, the cost and time involved in collecting and analyzing them introduces a time lag which limits the utility of the data for operational purposes. The information in reports generated by Stuart *et al.* (2008) has been one of the most widely available indicators of US logging cost changes over the past 20 years. Stuart's reports had a 1-2 year delay between the recording of the cost information by a contractor and the availability of reports to potential users.

Previous efforts have generated cost indices for components of the forest industry. *Forest Landowner* (formerly *Forest Farmer*) reports cost indices of common forest management practices biennially, based on surveys of private firms, public agencies and individuals across the South (Barlow and Dubois 2011). Dubois *et al.* (1991) described an aggregate index of the management practices reported by *Forest Landowner* to show the trend in forest management costs generally. Neither of the indices includes timber harvesting cost, although pre-commercial thinning is included as a management practice. Tufts *et al.* (Tufts et al. 1981) detail an aggregate index of forestry equipment costs based on annual purchase prices for a collection of logging and forest management machinery. However, they found that the harvesting equipment index was not statistically different from the Producer Price Index (PPI) for Machinery and Equipment. To date, the logging industry has not had an aggregate cost index that tracks the cost of a collection of key inputs over time. The Consumer Price Index (CPI) reported by the Bureau of Labor Statistics uses this approach for a representative basket of goods and services. The Construction Cost Index reported by the Engineering News Record since 1921 is another measure of this form specific to the building construction industry (Grogan 1992).

Our objective was to generate a timely, accurate indicator of changes in logging costs that is initially based on the cost records of a group of logging contractors and subsequently updated using publicly available data on the key cost centers. It would establish a baseline against which logging contractors could compare their own costs and would offer buyers and sellers of timber a reference for shifts in cut and haul rates.

DATA AND METHODS

We contacted 95 logging contractors around the country to gauge their interest in participating in the study. Regional differences in harvesting systems made it necessary to divide the participants into four distinct groups: South, West, Lake States, and Northeast. Names of potential participants were gathered from industry contacts and logging associations based on their reputations as reliable record-keepers and above average performers. The goal of the study was not to estimate an average cost for the industry, but to collect accurate cost data from a collection of contractors to determine the percentage contribution of major cost categories to efficient operations. Contractors who agreed to participate were visited for a face-to-face interview during the summer and fall of 2012, during which data on the structure of their business were collected. Detailed breakdowns on the distribution of costs incurred in 2011as well as their total production (tons) were requested. Follow-up phone calls were made in an attempt to collect data not shared during the interviews.

We used the accounting records of participants as the starting point to calculate a logging cost index by separating the costs into major cost categories: labor, depreciation, interest, repair & maintenance, petroleum-based consumables, insurance, and administrative expenses (Table 3.1). Data on production was limited to total tons harvested, with no detail provided on products or species harvested during the year. Hauling costs were not included in the index due to the separate and unique distribution of costs associated with operating heavy trucks. Many of the participants in the study did not maintain separate cost records for hauling, making calculation of a detailed cost breakdown problematic. Thus, the index covers only the cut and load portion of logging costs.

Table 3.1: Aggregation of common logging costs into major cost categories.

Labor	**Repair and Maintenance**
Salaries and Wages	Repairs
Payroll Taxes	Spare Parts
Pension/Retirement Contribution	Shop Supplies
Non-Trucking Contract Labor	Tires and Tire Repair
Equipment	**Interest Expense**
Depreciation	Loan Interest
	Bank Charges
Fuel	
Off-Road Diesel	**Administrative**
Oil and Lubricants	Telephones
Gasoline	Utilities
Hydraulic Fluid	Advertising
	Employee Training
Insurance	Taxes and Licenses
Equipment Insurance	Office Supplies
Workman's Compensation	Legal and Accounting
Health Insurance	Leases
General Liability	

We found publicly available cost data tied to most of the major logging cost components. Weekly wage data are reported quarterly by the Bureau of Labor Statistics for many industries as a component of the Quarterly Census of Employment and Wages (Bureau of Labor Statistics 2013d). Logging (NAICS 113310) wage is reported by county in all states. We weighted the average weekly wage reported in each of the states by the total number of logging employees in the state. This weighted average wage was then used to modify the labor portion of the cut and load rate. Costs for construction machinery manufacturing (NAICS 333120), which includes logging equipment, and heavy equipment parts (WPU 112J0202) are both reported monthly as PPIs by the Bureau of Labor Statistics. These measures were used to update the depreciation and repair portions of the index, respectively. Retail diesel prices are reported weekly by the Energy Information Administration (2013). The Federal Reserve reports a number of key interest rates, which can be an indicator of interest expenses (Federal Reserve Board 2013). The Federal Funds Rate was found to track closely with historic loan rates on farm machinery reported by the US Farm Credit Administration, though the nominal interest rates on machinery were typically four to five percentage points higher due to the greater risk associated with machinery loans (Federal Reserve Bank of Kansas City 2013). Interest expense was updated using the Federal Funds Rate plus 4.5%. Combined, these data represented over 90% of the cut and load cost of participating logging operations. Indicators in changes of administrative and insurance costs were not readily apparent. As a result, the CPI minus food and fuel (CUSR0000SA0L1E) was used to modify these portions of the cut and load cost (Bureau of Labor Statistics 2013a).

The UGA Logging Cost Index (LCI) is structured as a weighted average of each of the indicators, with the weights set by the percentage of the cost represented in the 2011 records of our survey respondents. Formally,

$$LCI_N = \sum_{i=1}^{7} \frac{X_{iB} * Y_{iN}}{Y_{iB}}$$

where:

LCI_N = The Logging Cost Index value in period N.

X_{iB} = Per ton value of the cost component X_i in the 4th quarter of 2011

Y_{iN} = Value of the cost change indicator of component X_i in period N

Y_{iB} = Value of the cost change indicator of component X_i in the 4th quarter of 2011

To aid interpretation by end users, the index value was set to a dollar figure commensurate with the approximate cut and load cost of our interview respondents rather than scaling to 100 in the base period. The UGA LCI was compared against the logging cost index reported by Stuart and Grace (Stuart et al. 2008) by compiling values of the cost change indicators backwards in time through 1995. A major difference between the UGA LCI and the previous logging cost index reported by Stuart and Grace is the exclusion of hauling costs in the UGA LCI methodology. The UGA LCI is also structured as a quarterly index compared to the annual index generated by Stuart and Grace, so comparisons between the two are made using both the annual average and year-end values of the UGA LCI. Kendall's τ is used to compare the correlation of the two measures (Hollander and Wolfe 1999).

RESULTS

Of the 95 contractors contacted, 47 agreed to interviews, and 28 ultimately shared cost data (Table 3.2). Nineteen of the 28 contractors who shared cost data were located in the southern US (AL, AR, FL, GA, LA, NC, SC, VA). As a result, our sample size of contributors was only large enough to allow for development of a cost index for the South. Respondents in the South worked predominantly as tree-length, pine plantation harvesting contractors; however, detailed data on the species and products harvested was not collected at either the crew or company level. All respondents operated wheeled feller-bunchers, skidders and knuckleboom loader. Four contractors also operated tracked feller-bunchers on at least one crew and five contractors operated cut-to-length processors as well.

Table 3.2: Breakdown of participating contractors by region of the country, including those who provided cost data.

	South	West	Lake States	Northeast
Contractors contacted	40	19	20	16
Participants	23	8	9	7
No. providing cost data	19	5	2	2
Total participating logging crews	63	34	35	22
Avg. contractor weekly production (tons)	4200	4050	1800	3650

The production-weighted mean cut and haul cost for southern respondents was $17.01 per ton. Excluding haul costs ($4.67 per ton), labor was the largest cost component, followed by fuel, depreciation and repair and maintenance (Table 3.3). Most of the cost percentages varied within a narrow inter-quartile range for the participating contractors, however, both labor and depreciation varied in a range of roughly ±13%. The variance in labor and capital costs between logging firms may be a result of an increased reliance on older machines with low levels of depreciation amongst some contractors. Firms relying on purchases of new equipment reported 24% (±4%) labor costs and 17% (±4%) depreciation while firms considering used equipment purchases reported 27% (±4%) labor cost and 9% (±5%) depreciation. In addition, Internal Revenue Service bonus depreciation regulations in place in 2011 allowed for vastly accelerated depreciation of assets, which could be a source of some variability as well (Hadrich et al. 2013).

The distribution of cut and haul costs from southern logging contractors was similar to previously reported cost distributions (Figure 3.1). This percent breakdown of costs has changed over time as prices for inputs have shifted. In 1994, labor represented 35% of logging costs, equipment 19%, fuel and repairs 21%, and hauling 19% (Stuart and Grace 1999). Improved labor productivity (Baker and Greene 2008) and increased costs for fuel are probably the primary drivers changing this distribution. The average cut and haul cost in 1994 was roughly $12.00 per ton (Altizer et al. 2004). Adjusting for inflation, this corresponds to $18.20 per ton in 2011.

Table 3.3: Descriptive statistics of cut and load cost components for a group of Southern logging contractors, 2011.

	Minimum	Median	Max	IQR
Labor	24.3%	32.8%	44.6%	12.9%
Depreciation	5.1%	19.3%	39.8%	13.5%
Interest expense	0.0%	1.4%	7.4%	1.6%
Repair & maintenance	2.9%	11.2%	25.4%	5.1%
Fuel & oil	13.3%	22.8%	35.2%	5.8%
Administrative	0.2%	4.2%	10.6%	3.5%
Insurance	3.1%	5.3%	8.3%	1.9%

IQR: inter-quartile range.

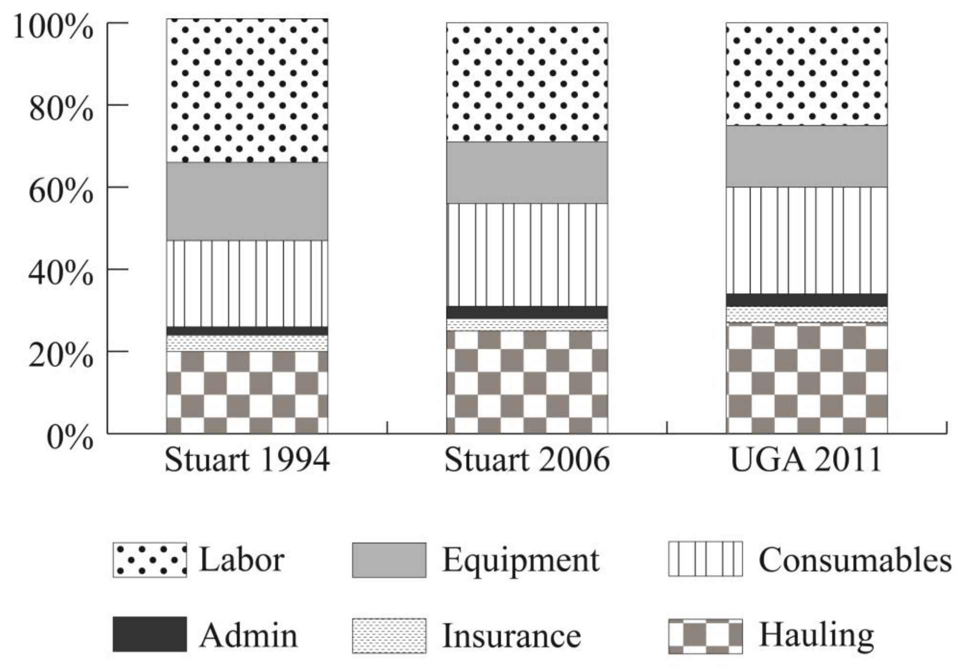

Figure 3.1: Percent breakdown of major cut and haul cost categories reported by Stuart and Grace (1999) for 1994, Stuart et al. (2008) for 2006 and for Southern contractors from this study.

As noted above, UGA LCI excludes haul costs (largely represented as “Contract Services” by Stuart *et al.* (2008)). While contractor records usually included detailed information on the cost associated with contract hauling, contract hauling comprised roughly 45% of the total loads delivered for participating contractors. Detailed breakdowns of the cost to operate their own heavy trucks were not available from the majority of respondents, hindering our ability to accurately link the major cost components to cost indicators. Our index therefore only reports cut and load costs.

Data from the Quarterly Census of Employment and Wages (2013d) displayed a clear pattern of seasonality in wage rates for logging employees (Figure 3.2). Our interviews with contractors did not suggest any seasonality of labor costs, yet over the past 30 quarters of data from the Bureau of Labor Statistics, 1^{st} quarter wages were always exceeded by 2^{nd} quarter wages and always lagged the preceding 4^{th} quarter wages. In no year did wages decrease from quarter to quarter, except for a sizeable drop between the 4^{th} quarter and 1^{st} quarter of the following year. Because we could not verify this seasonality in logging cost records, we used a four-quarter moving average of Average Weekly Wage as an indicator of changes in labor costs.

The initial index value for the UGA LCI was set to \$12.50 per ton, which was the average cut and load cost for participating contractors in 2011, rounded to the nearest \$0.50. The proportion of the cost in each of the major cost categories was linked to the fourth quarter 2011 value of the public data source selected as an indicator for that category. For example, depreciation represented 19% of the cut and load cost (\$2.34 per ton). The value of the PPI for construction machinery manufacturing (NAICS 333120) over the last three months of 2011 averaged 231.6. The contribution of equipment depreciation to the index in any quarter is the initial depreciation cost ($2.34) multiplied by the PPI for heavy equipment in that quarter divided by the initial PPI for heavy equipment (231.6). Each of the components is calculated in this manner for the fourth quarter of 2012 in Table 3.4. Continuing with the calculation of depreciation described above, in the fourth quarter of 2012, depreciation is $2.34 * 237.1 / 231.6 = $2.40. The sum of the individual components provides the updated value for the UGA LCI.

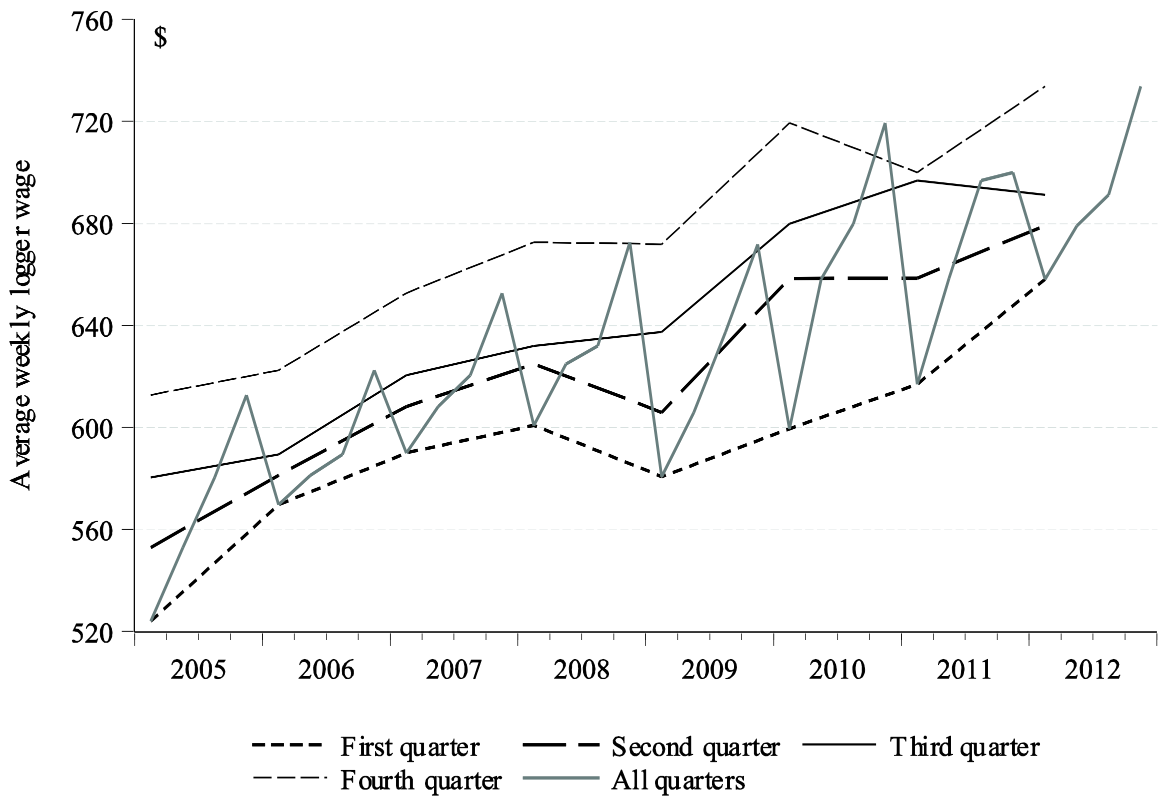

Figure 3.2: Average weekly wage paid to logging employees in the US South shown by quarter and combined for all quarters, 2005-2012.

Table 3.4: Sample calculation of the UGA Logging Cost Index for the base period (4th quarter 2011) and for the 4th quarter of 2012. The calculated component cost in the updated period is the product of the component cost in the base period and the indicator value in the updated period, divided by the indicator value in the base period.

	Base Period - 4Q 2011		Updated Period - 4Q 2012	
	Indicator Base Value	Component Base Cost	Indicator Current Value	Calculated Component Cost
Labor	699.90[a]	$4.31	682.83	$4.20
Equipment	231.60[b]	$2.34	237.10	$2.40
Interest	4.57[c]	$0.18	4.66	$0.18
Repairs	134.77[d]	$1.73	137.13	$1.76
Fuel	3.87[e]	$2.68	4.02	$2.78
Insurance and Admin	226.84[f]	$1.26	231.26	$1.28
Sum of UGA LCI component costs		**$12.50**		**$12.61**

[a] The average weekly wage reported by the Quarterly Census of Employment and Wages for logging employees, weighted by the total logging employment in each state.

[b] The Producer Price Index for Construction Machinery Manufacturing (NAICS 333120).

[c] The Federal Funds Rate reported by the US Federal Reserve Board.

[d] The Producer Price Index for Heavy Equipment Parts (WPU 112J0202)

[e] Average diesel retail price reported by the Energy Information Administration.

[f] The Consumer Price Index less fuel and food (CUSR0000SA0L1E)

Using this methodology, we were able to track the logging cost index moving forward past 2011 as well as compare the index value backward to the values reported by Stuart *et al.* (Stuart et al. 2008). To compare index values back to 1995, we had to replace the PPI for heavy machinery parts (NAICS 33312093), which was created in 1999, with the PPI for Industrial Commodities less fuels, as no comparable data were available. The trend of the quarterly index we generated compared favorably with the annual trend of Stuart *et al*. (Figure 3.3). Comparing either year-end ($\tau = 0.785$, $p < 0.001$) or annual average values ($\tau = 0.785$, $p < 0.001$) of the UGA LCI to the annual values of the Stuart and Grace index showed strong positive correlations.

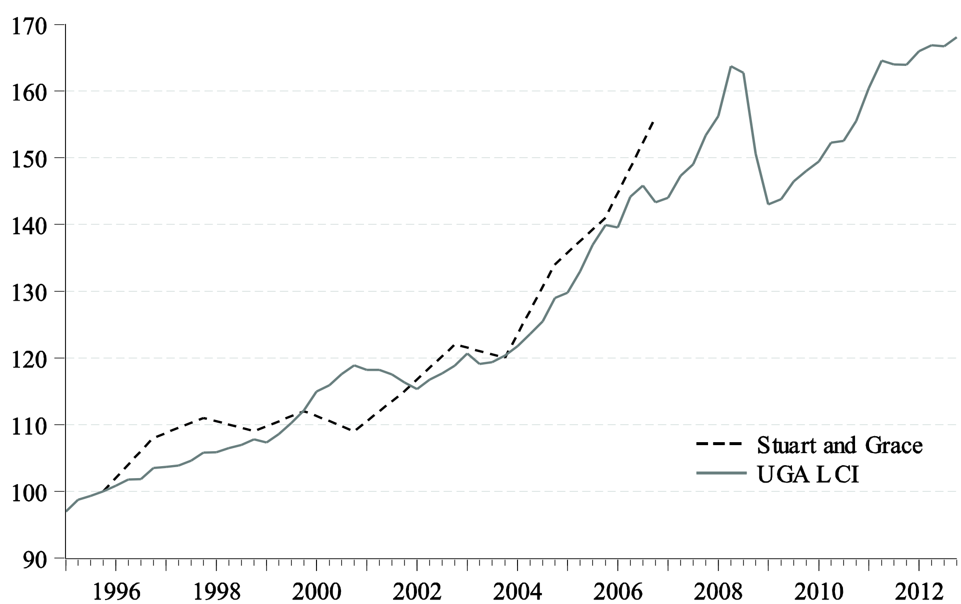

Figure 3.3: The quarterly UGA Logging Cost Index rescaled to a value of 100 in 1995 for comparison against Stuart and Grace's annual Logging Cost Index.

DISCUSSION

The UGA LCI tracks *logging costs* as incurred by logging businesses. It is important to note that the value of the cost index is set near the average cost reported by our respondents, while the actual average logging cost of all contractors in the South will vary widely. The trends over time are the important component and provide insight into changes in harvesting cost relative to changes in price paid for logging services.

It is also possible to monitor the prices paid for logging services – or *logging rates*. Two sources of information about trends in logging rates are Timber Mart-South (a quarterly price-reporting service covering the US South) and the Bureau of Labor Statistics Producer Price Index. It is reasonable to expect logging rates paid to loggers and logging costs borne by them to track closely over time and for logging rates to generally exceed logging costs. Logging rates as reported by Timber Mart-South (2013) have been as volatile as the costs (Figure 3.4). Rates increased rapidly in response to the first major diesel price increase in 2008 which occurred before the economic recession. The more gradual but equally large increase in cost between 2009 and 2011 was not accompanied by a similar increase in rates perhaps due to pervasive soft demand and reduced profitability across the industry. Logging rates structured with a supplemental payment for diesel price increases may not be adequately represented in the Timber Mart-South values, which could also be one cause for this gap.

On the national level, the PPI also reports prices paid for logging services (Bureau of Labor Statistics 2013b). Setting the initial value to $12.00 per ton in the first quarter of 2006, it can be seen that the PPI for logging services does not respond to the large diesel price increase in 2008, but does decline following the diesel price reduction. The rate of increase in both the PPI for logging services and the UGA LCI has been similar since the start of 2011. Compared to either measure of logging rates, the margin between logging costs and logging rates appears to have declined since 2006.

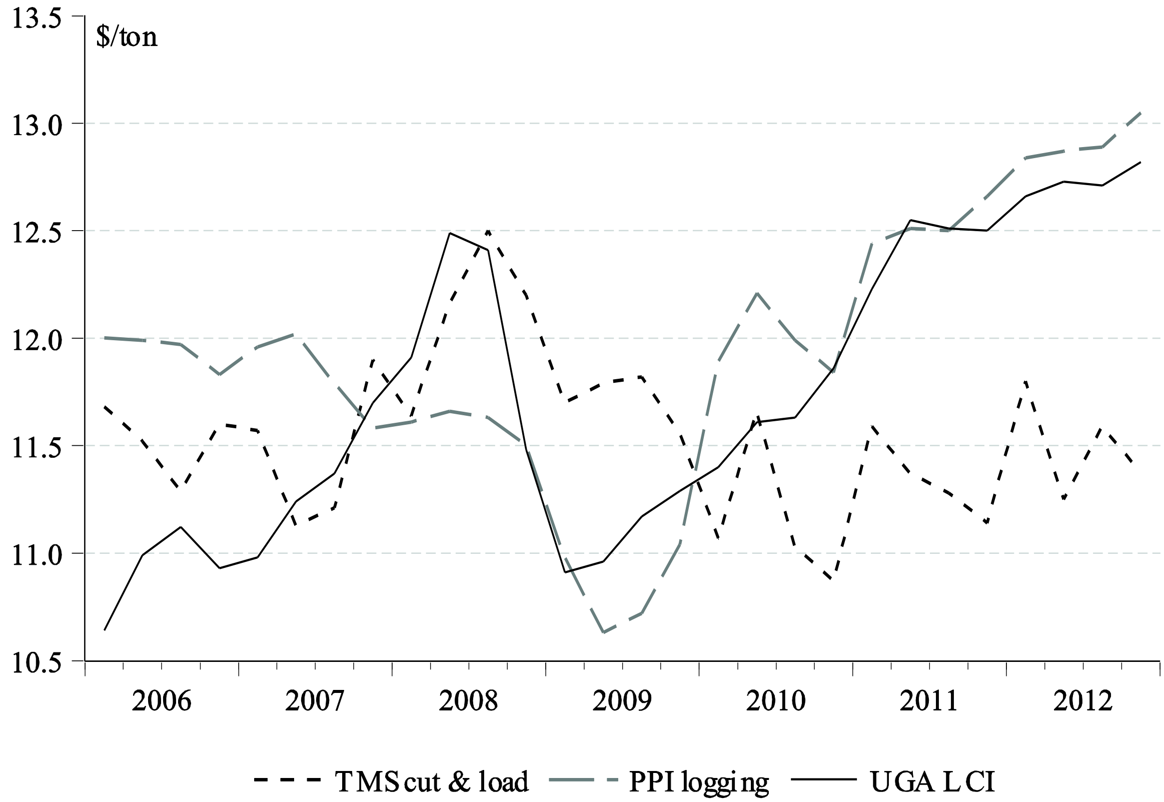

Figure 3.4: Logging costs measured by the UGA Logging Cost Index (LCI) and two measures of rates paid for logging services, a south-wide average of four cut and load rates reported quarterly by Timber-Mart South (the mean final harvest and plantation thin rates in the Piedmont and Coastal Plain) and the Producer Price Index (PPI) for logging services (NAICS 113310) converted to a quarterly value and used to inflate an initial cost of $12.00 in the 1st quarter of 2006.

Changes in annual or weekly production or the productivity of labor and capital are not currently incorporated in the UGA LCI. While significant shifts in either of these measures could impact per ton logging costs, periodic validation of the cost trends against actual contractor data will ensure that any major changes in either productivity or production levels are incorporated into the UGA LCI calculation. Annual production (tons per year) is assumed constant over the duration of the index. Baker and Greene (2008) showed that annual production has increased for Georgia logging contractors, but there has not been a consistent trend over the past fifteen years. Productivity changes (tons harvested per unit of input) are also not directly incorporated into the UGA LCI calculation. Production per man-hour has consistently increased while production per $1000 of invested capital has had little net change over that past fifteen years (Marchman et al. 2013). Improving productivity would mitigate increases in the cost of inputs while decreasing productivity would exacerbate cost increases. Production per man-hour of logging contractors in Georgia has increased at roughly 1.7% per year over the past fifteen years (Marchman et al. 2013). If this trend were valid for the entire southern region, increases in labor costs would be reduced to 98.3% of their annual magnitude. Incorporating a labor productivity adjustment into the index since the end of 2011 based on the long-term trend data from Georgia would have negated half of the increase in labor costs through the 1st quarter of 2013.

Data on productivity improvements in the logging industry are not available for most of the southern region, which precludes incorporating a quarterly productivity adjustment. Fuel consumption per ton, for example, is largely unknown for the industry, and trends over time are not available. While reliable productivity indicators would allow for further refinements of the UGA LCI, until these data are developed periodic re-surveys of contractor cost records will be necessary to ensure that estimates of the cost distributions remain valid.

The UGA LCI has been added to quarterly Timber Mart-South publications, and they will continue publish the UGA LCI on an ongoing basis. Any modifications required to adjust for productivity or technology changes will be incorporated into the index and reported in the Timber Mart-South newsletter.

CONCLUSION

Trends in the UGA LCI compare favorably with other cost and price time series tied to the logging industry. Of course, historic performance of an index methodology is not a guarantee of future accuracy. The approach provides a simple, rapid measure of changes in logging costs which can aid the industry in identifying large shifts in logging cost. The structure of the index should also indicate the scale of changes in volatile cost components, such as diesel fuel. We intend to evaluate the trends in logging cost reported by the index in the future using data provided by logging contractors.

LITERATURE CITED

Altizer, C. B., L. A. Grace & W. B. Stuart. 2004. Trends in workers' compensation insurance costs in the logging industry. In *Competitiveness of southern forest products markets in a global economy: trends and predictions. Proceedings of the*

Southern Forest Economics Workers Annual Meeting, eds. J. R. R. Alavalapati & D. R. Carter, St. Augustine, FL: University of Florida. 145-155.

Baker, S. A. & W. D. Greene. 2008. Changes in Georgia's logging workforce, 1987-2007. *Southern Journal of Applied Forestry,* 32(2)**:**60-68.

Barlow, R., J. & M. R. Dubois. 2011. Cost and cost trends for forestry practices in the South. *Forest Landowner,* 70(6)**:**14-24.

Brinker, R. W., J. Kinard, B. Rummer & B. L. Lanford. 2002. Machine rates for selected forest harvesting machines. *Circular - Alabama Agricultural Experiment Station,* 296 (revised))**:**32.

Brinker, R. W., B. L. Lanford, B. J. Stokes & D. Miller. 1989. Machine rates for selected forest harvesting machines. *Circular - Alabama Agricultural Experiment Station,* 296).

Bureau of Labor Statistics. 2013a. Consumer Price Index. In *All Urban Consumers, All items less food and energy,* Accessed at. http://data.bls.gov/timeseries/CUUR0000SA0L1E: U.S. Department of Labor. Last accessed on: June 27, 2013.

---. 2013b. Producer Price Index. In *Logging,* Accessed at. http://data.bls.gov/timeseries/PCU113310113310: U.S. Department of Labor. Last accessed on: March 10, 2013.

---. 2013d. Quarterly Census of Employment and Wages. Accessed at. http://www.bls.gov/cew/home.htm: U.S. Department of Labor. Last accessed on: June 27, 2013.

Cubbage, F. & D. Carter. 1994. Productivity and cost changes in southern pulpwood harvesting, 1979 to 1987. *Southern journal of applied forestry*, 18(2)**:**83-90.

Cubbage, F. W., J. E. Granskog & B. J. Stokes. 1988. Trends in southern forest harvesting equipment and logging costs. *Forest Products Journal*, 38(2)**:**6-10.

Dubois, M. R., W. F. Watson & T. J. Straka. 1991. A cost index for Southern forest practices. *Southern Journal of Applied Forestry*, 15(3)**:**128-133.

Energy Information Administration. 2013. Retail on-highway diesel price. Accessed at. http://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_nus_w.htm Last accessed on: March 28, 2013.

Federal Reserve Bank of Kansas City. 2013. Table A.5. In *Agricultrual Finance Databook*. http://www.kansascityfed.org/research/indicatorsdata/agfinance/index.cfm.

Federal Reserve Board. 2013. H.15 Release - Selected Interest Rates. Accessed at. http://www.federalreserve.gov/releases/h15/current/default.htm. Last accessed on: June 28, 2013.

Grogan, T. 1992. First quarterly cost report: Cost history keeping track of a moving target. *Engineering News-Record*, 228(13)**:**2.

Hadrich, J. C., R. Larsen & F. E. Olson. 2013. Impact of the Section 179 tax deduction on machinery investment. *Agricultural Finance Review*, 73(3)**:**458-468.

Harris, T. G., J. Smith & S. Baldwin. 2013. Timber Mart-South: First Quarter 2013. Athens, GA: Timber Mart-South. 38(1).

Hollander, M. & D. A. Wolfe. 1999. *Nonparametric Statistical Methods*. J. Wiley: New York.

Leon, B. H. & J. G. Benjamin. 2013. A survey of business attributes, harvest capacity and equipment infrastructure of logging businesses in the Northern forest. Orono, ME: University of Maine. pp. 29.

Marchman, S. C., S. A. Baker & W. D. Greene. 2013. Southeastern logging contractor survey results over 25 years. Rockville, MD: Forest Resources Association. Tech. Release 13-R-10: 2.

Plummer, G. 1982. Harvesting developments: Machine costs and rates. ed. W. D. Georgia Kraft Company. Georgia Kraft Company, Woodlands Division.

Stuart, W. B. & L. A. Grace. 1999. Wood supplier productivity and cost survey. In *Technical Paper 99-A-7*, Rockville, MD: American Pulpwood Association. pp. 46.

Stuart, W. B., L. A. Grace, C. B. Altizer & J. J. Smith. 2008. 2006 Preliminary Logging Cost Indices. Starkville, MS: Wood Supply Research Institute. pp. 14.

Swedish Forest Agency. 2012. *Swedish Statistical Yearbook of Forestry 2012*. Jonkoping, Sweden. pp. 380.

Tufts, R. A., J. Thurber, D. Simmons & B. Izlar. 1981. Forestry equipment cost index: 1968-1978. *Southern Journal of Applied Forestry,* 5(4)**:**201-204.

Werblow, D. A. & F. W. Cubbage. 1986. Forest harvesting equipment ownership and operating costs in 1984. *Southern Journal of Applied Forestry,* 10(1)**:**10-15.

CHAPTER 4

VERIFICATION OF THE UGA LOGGING COST INDEX[1]

[1] Baker, S.A., B. Mei, and W.D. Greene. Verification of the UGA Logging Cost Index. To be submitted to the Journal of Forestry.

ABSTRACT

Logging cost estimation can be a challenging aspect of the modern forest industry, despite the fact that timber harvesting is a large component of the raw material cost of any wood-consuming production facility. In 2012, the UGA Logging Cost Index (LCI) was first published as a quarterly measure to track changes in logging cost over time. The initial construction of the UGA LCI was based on actual cost records of logging companies from 2011. The reported quarterly changes in the UGA LCI since 2011 were calculated using publicly available price indices related to the major logging cost components. We compared actual cost records of logging contractors from 2011, 2012, and 2013 against the reported changes in logging costs based on the UGA LCI. Production increases among the sample population drove their average cost per ton lower, while the UGA LCI increased each year. After correcting for production variation between the years and excluding one outlier, the average deviation between the UGA LCI values and the actual costs differed by 0.1% ($P > 0.97$). The UGA LCI appears to be a reasonable representation of changes in the input costs required to harvest timber for contractors in the southern US in the recent past. Care must be taken when comparing cost index trends to the actual costs of logging companies, however, because the production variation can be a greater source of cost variation than input costs alone.

INTRODUCTION

Timber harvesting is a crucial component of the wood supply system. The cost of harvesting and delivering wood can represent 60% or more of the delivered value of forest products (Harris et al. 2015b). For decades, the forest industry has worked to increase efficiency and productivity in logging in an attempt to reduce costs. The focus on cost minimization has often been in lieu of a focus on logging contractor profit maximization due to the structure of the forest industry (Stuart 2003). Lower logging costs should logically increase stumpage prices and/or decrease raw material costs for consuming mills. This attention has led to an array of methods and tools for estimating logging costs in order to determine reasonable logging rates (Miyata and Steinhilb 1981, Tufts et al. 1985, Bilek 2007, Smidt et al. 2009, Bick 2010). For any cost estimation method, however, the input costs are a vital component to ensuring the accuracy of the final estimate. An index tracking changes in these costs over time provides a means to quickly understand how input price changes are impacting the timber harvesting costs of contractors.

Cost indices for components of the logging industry have existed for some time, either in the form of Producer Price Indexes (PPI) published by the Bureau of Labor Statistics (BLS) or proposed machinery cost index formulations (Tufts et al. 1981). These fail to include all of the costs associated with logging, however, focusing specifically on individual cost centers. The PPI for logging tracks changes in prices or rates for logging services, and therefore includes more than just the costs associated with logging. In 2003, Stuart et al. published the first logging cost index, based on data gathered since 1995 from logging contractors throughout the eastern United States (heavily focused in the southeastern US). This index was published through 2008 (relating cost information through 2006) as an annual index, representing the change in per ton costs of a shifting group of logging contractors (Stuart et al. 2008). The Stuart index was the first effort to show how all costs for the logging industry were changing over time. As an index, it was structured in a way that both production and cost changes between periods were incorporated into the index value. As a result, it was not possible to identify how much of the change in the index value was due to cost increases in individual components, and how much was due to production changes for a given period. Stuart et al. (2010) argued that none of the component costs in logging were fixed over time periods of one year or more, implying that any change in the component cost from period to period would be entirely due to inflation, as the production change would not affect the variable costs on a per unit basis.

The UGA Logging Cost Index (LCI) was developed in 2012 as a quarterly indicator of cost changes in the logging industry. The UGA LCI represents actual fixed and operating costs for a logging business, not the payment for logging services. This distinction is important because from the perspective of a landowner or wood-buying company, the logging rate can be seen as a cost to perform logging. The logging rate will include profit for the business owner and will fluctuate with changes in the demand and supply of logging contractors in a given region. For the purpose of this study, logging costs are reported from the standpoint of logging contractors. The market prices paid for logging services will be referred to as logging rates. The initial index calculation used values from the fourth quarter of 2011 based on the annual cost data collected from a group of logging contractors in 2012 (Baker et al. 2013). It has been reported in the Quarterly Market News of Timber-Mart South since the fourth quarter of 2012. Quarterly values of the UGA LCI have been calculated for three years (fourth quarter of 2011 through fourth quarter 2014) providing an indication of the extent of changes in logging costs over that period (Figure 4.1).

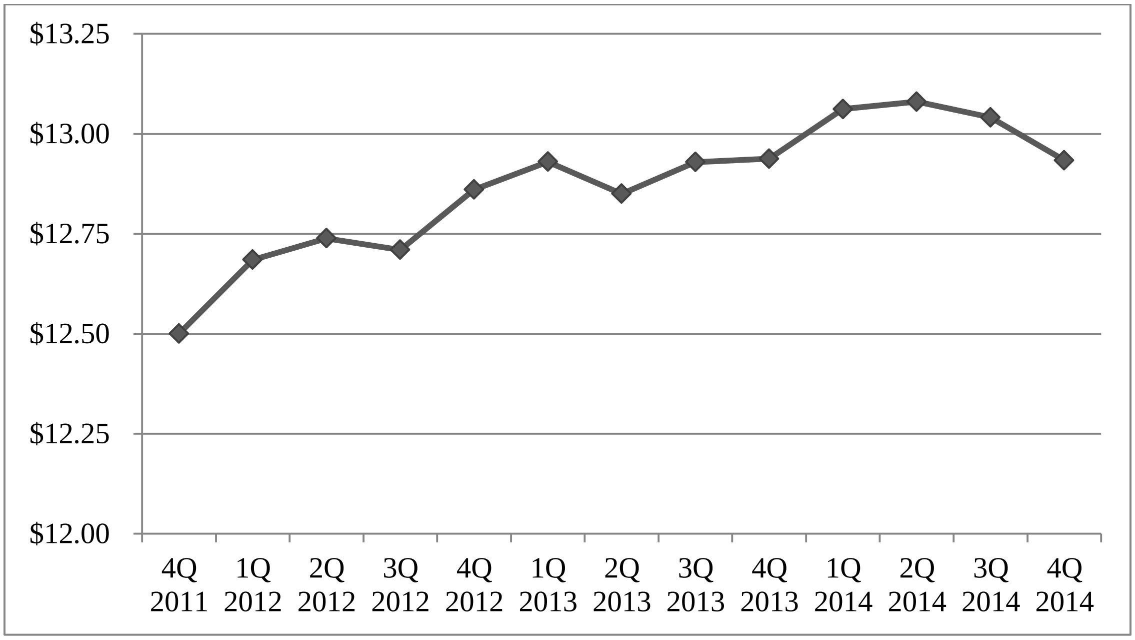

Figure 4.1: The UGA Logging Cost Index, 4th Quarter 2011 through 4th Quarter 2014.

The UGA LCI value is calculated based on publicly available data on the main cost components of logging, not on summarized quarterly cost data of logging contractors. It is therefore informative to compare the actual cost data of contractors with the trends represented by the UGA LCI to ensure that it is an accurate representation of the true costs incurred by the industry. This study sought to gather a set of detailed logging cost records covering 2011, 2012, and 2013 to determine if the trends represented in the UGA LCI since its initial publication are an accurate representation of cost changes experienced by logging contractors over the same time period.

METHODS

We compiled a list of possible participants by requesting names and contact information of logging companies from member companies of the Wood Supply Research Institute and industry contacts across the South. We began with the 23 companies which participated in the previous study (Baker et al. 2014). Five of these were excluded from this study based on their stated unwillingness to share cost data during the previous study. Eight additional companies indicated a willingness to participate in the project after responding to a notice in the trade magazine *Timber Harvesting and Wood Fiber Operations*. We supplemented this group with an additional 21 names from our industry contacts. This gave us a list of 47 potential participants.

There are no detailed data on the composition of the southern logging industry, though individual state-level surveys indicate reasonable diversity in the size of firms in the industry (Baker and Greene 2008, Moldenhauer and Bolding 2009, Bolding et al. 2010). Rather than relying on a purely random sample, we focused on a directed, purposive sample, attempting to gather data from contractors described by industry contacts as efficient operators to develop a realistic distribution of costs into a group of broad categories identical to Baker et al. (2014). While a purely random sample helps ensure representativeness and allows generalization about the population as a whole, purposive sampling in the construction of indexes has been shown to perform as well or better in minimizing variability and accurately representing cost trends (Dorfman et al. 2006).

Each prospective participant was sent a letter describing the project and seeking their participation. A brief description of the UGA LCI was included in the contact letter in an attempt to gain some legitimacy with contractors unfamiliar with our research. We called each contractor to request their participation and attempted to arrange a visit to perform a face-to-face interview. We described the types of data sought and informed them that the interview might last 2-3 hours.

During interviews, participants were asked to provide a detailed description of their business based on a structured interview questionnaire (Appendix A). Employment and production levels, types and ages of machinery and haul trucks, employee benefits, and fuel consumption information were all included. In addition, we requested a detailed breakdown of costs for their logging business in 2012 and 2013. We offered to work with whatever level of detail contractors had, whether from profit and loss statements, internal accounting systems, or tax forms. No data on revenue were recorded.

For each year in which cost data were shared, we also requested an exact production level in order to calculate the per unit cost of harvesting. While each company was required to maintain a minimum level of cost records for their tax purposes, a surprising number made little effort to record their production volumes. The accounting systems focused on the revenue produced, not the tons. Unless a separate record was maintained of weekly or monthly production volume, these data were often left in physical records, unable to be readily compiled (if they were kept at all). While compiling cost records from contractors required crossing a threshold level of trust, production records often presented a more daunting threshold of actual availability.

To ensure comparability with Baker et al. (2014), costs associated with hauling were excluded from the analysis. Where logging companies contracted a significant portion of hauling, these costs were easily identified. Most companies hauled some percentage of their wood with company-owned trucks. The costs of operating company-owned trucks (on-road diesel, truck driver salaries, etc.) were subtracted whenever possible from the costs to cut, skid, and load. No effort was made to remove haul costs unless they were explicitly identified as such in the company's accounting records. In many instances, depreciation and administrative costs of both logging and hauling were blended and indistinguishable inflating those costs in the final results. The cost breakdown presented here is our best effort to isolate the cut, skid and load costs; however, there is still some portion of haul cost in these distributions for those firms which blended the two operational costs. Excluding those businesses which combined their cut and haul costs would have drastically limited the sample size available for our analysis.

Annual production variations make direct comparison between per ton costs for a given firm and the change in input costs represented by a cost index problematic. Even if component costs did not change over a given timeframe, per ton costs would alter with production shifts. For this analysis, depreciation, interest, insurance, and administration costs were all considered fixed. Labor costs are some combination of fixed and variable. Most of the study participants paid their woods laborers on an hourly basis and trucking labor was most commonly paid per load. A portion of labor was salaried, and many contractors tried to ensure a minimum pay level for their hourly workers even when production levels were low. When large increases and decreases in production were characterized by changes in staffing levels through the addition or cessation of logging crews, labor costs were certainly a variable component. For purposes of our analysis, we treated labor as a fixed cost unless the business had changed the number of production crews working for them. In these cases, labor was viewed as a variable cost.

In order to verify the cost trends reported by the UGA LCI, we needed to account for the production changes incorporated in the individual logging company cost data. To do this, we compared year-over-year costs for each individual company to the costs the index would report if production had increased for the index by a comparable amount. The index is structured as a per ton cost for each of the seven main components (labor, fuel, equipment, interest expense, insurance, administrative, and repairs and maintenance) which is inflated or deflated based on cost data available for that particular component.

$$LCI_N = \sum_{i=1}^{7} \frac{X_{iB} * Y_{iN}}{Y_{iB}}$$

where:

LCI_N = The Logging Cost Index value in period N.

X_{iB} = Per ton value of the cost component X_i in the 4^{th} quarter of 2011

Y_{iN} = Value of the cost change indicator of component X_i in period N

Y_{iB} = Value of the cost change indicator of component X_i in the 4^{th} quarter of 2011

For purposes of our analysis, we further converted this original formulation into a unitless index by dividing by the sum of the base period component costs, $\sum_{i=1}^{7} X_{iB}$. This unitless index is how the UGA LCI has been reported since the 4^{th} quarter of 2014 (Harris et al. 2015a).

With a varying production level, the variable component costs would retain their cost per ton, having no net effect on the overall cost per ton. Fixed cost components, however, needed to be adjusted based on the new production level. Thus, each company's change in production year-over-year was used to recalculate the fixed cost components in the UGA LCI. The predicted cost without correcting for production is calculated as:

$$C_N = LCI_N * C_0$$

where:

C_N	= Predicted per ton cost in period N.
LCI_N	= Value of the UGA LCI in period N.
C_0	= Actual cost per ton in period 0.

Correcting for production requires decomposing C_0 into fixed and variable components, denoted as F_0 and Var_0. For the purpose of illustration, F_0 and Var_0 will denote total costs, not per ton costs, and a production level, P will convert them to a per ton basis, thus:

$$C_0 = \frac{F_0}{P} + \frac{Var_0}{P}$$

When a change in production, λ, occurs between period 0 and period N, the change affects P and Var_0, but not F_0. Therefore, the formula for production-corrected cost per ton is:

$$C_N = LCI_N * \left(\frac{F_0}{\lambda P} + \frac{\lambda Var_0}{\lambda P} \right) = LCI_N * \left(\frac{F_0}{\lambda P} + \frac{Var_0}{P} \right)$$

The production-corrected cost index values were calculated using the initial data for the UGA LCI and the actual production changes for each pair of data for which a year-over-year cost and production change was available. The production-corrected cost index values were subtracted from the actual change in cost to provide a measure of the prediction error. The data were tested with a paired *t*-test to determine if the prediction error was statistically different from zero. A Wilcoxon Signed Rank test was also used to account for the small sample size in the analyses (Hollander and Wolfe 1999).

RESULTS

In total, we contacted 47 contractors across the South. Ten of the participants were from the original 23 participants in the Baker et al. (2014) study. Of the 13 original participants not included in this study, eight declined requests for participation or could not be reached, and five were not contacted due to an unwillingness to provide cost data in the previous study. Two contractors agreed to participate, but simply could not make time to sit for the interview. Forms were left with them and follow-up calls were placed, but no information was provided. The lack of repeat participation was a significant, unexpected challenge given the design of our study. We collected 23 face-to-face interviews from the 47 contractors contacted. Participants were spread across six states in the South (Table 4.1). As with the previous study, not all of these participants shared detailed cost data. We collected cost data for 2013 from 17 contractors and 14 provided data from 2012.

Table 4.1: Participation in face-to-face interviews by state.

State	No. of Participants
AL	5
AR	3
GA	3
LA	5
MS	2
SC	5

The 23 firms who participated in the face-to-face interviews harvested over 92,000 tons per week. The 17 firms sharing detailed cost and production data for 2013 harvested 3,000,000 tons (around 60,000 tons per week). Thus, despite the small sample size, the participating companies represented roughly 1% of the total timber harvest in the US South in 2013 (Bentley et al. 2014). The responding companies operate 60 logging crews, with seven of the 23 respondents representing single crew companies. The average company had 18 employees, with 10 of those employees working in the woods. The average production of woods-workers was 7.7 tons per hour.

Companies contracted roughly one-third of their hauling, handling the remaining two-thirds with their own haul trucks. They reported an average fuel use of 5.1 miles per gallon on haul trucks and roughly 0.8 gallons of on-road diesel per ton. The reported average haul distance was 49 miles. Woods equipment averaged 0.5 gallons of off-road diesel per ton, which is consistent with other estimates of fuel usage for southern operations (Kenney et al. 2014).

Roughly 40% of the participating companies purchased all of the wood they harvested, 40% worked exclusively as a cut and haul contractor for a larger company, and the remaining 20% operated with a mix of the two strategies. Mean weekly production of participating companies was 4,200 tons, though the median was considerably lower at 3,600 tons per week. This median value is still more than double the reported average from a mailed survey of logging contractors in South Carolina and Georgia (Marchman et al. 2013). The average production per logging crew for our participants was 1,540 tons per week, very close to the 1,610 tons per week reported by the mailed survey of Georgia and South Carolina. Thus the companies providing data appear larger than typical companies operating in the US South (more logging crews), but the production of the crews within those companies are more representative of reported averages.

The equipment fleet of respondents had a large representation of older used machinery (5+ years), however substantial new investment was apparent in 2012, 2013 and 2014 model years (Figure 4.2). A similar pattern was also apparent among haul vehicles to a lesser extent (Figure 4.3). The introduction of untested emissions controls and a recession combined to create a noticeable gap in truck purchases from 2008-2010. Some recent investment has begun to build, but truck fleets are still older on average than woods equipment.

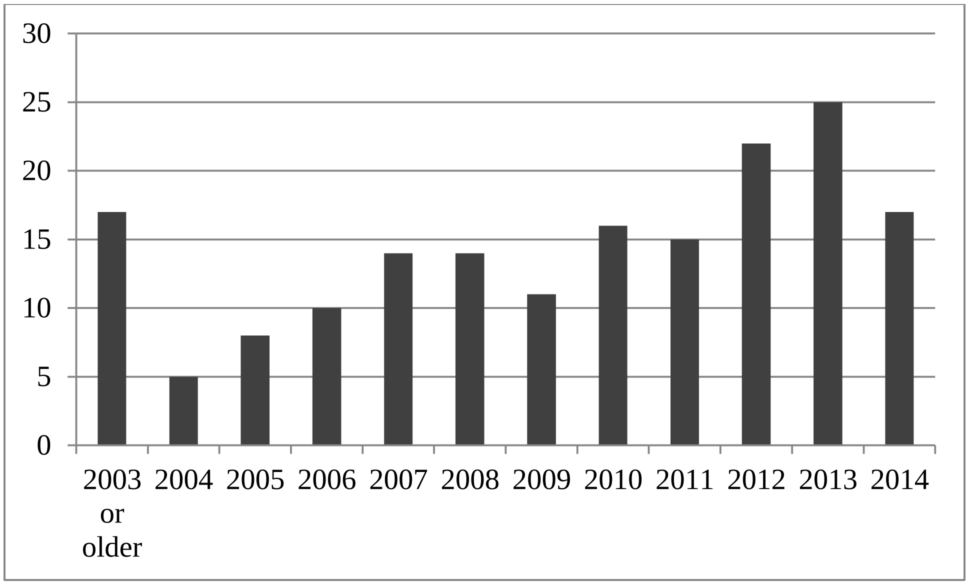

Figure 4.2: Model years of all logging equipment reported in the face-to-face interviews.

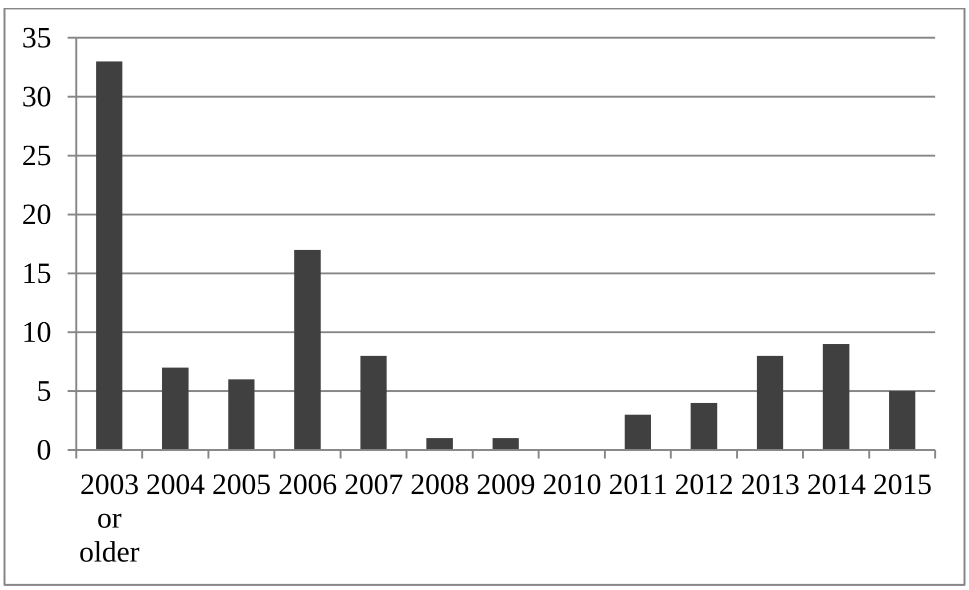

Figure 4.3: Model years of all haul trucks reported in the face-to-face interviews.

The composition of the study group differs considerably from 2011 to 2013. Only eight companies provided data in both 2011 and 2013. The exact breakdown of costs will differ from year to year as the sample changes (Figure 4.4). It is informative to note that the distribution of costs is largely similar between the three years, despite the sample changes. Labor and depreciation costs are a higher percentage of the total in 2011, with fuel a slightly lower percentage. This difference is important when comparing the percentages represented in the UGA LCI. The UGA LCI used the percentages derived from the 2011 data as the basis for future computations. Thus comparing the 2012 and 2013 actual cost distributions alongside the model distributions reveals a uniform overestimation of labor and depreciation and underestimation of fuel (Table 4.3). This is a function of the composition of the companies in the samples. Only two companies that provided data for 2013 did not do so for 2012 so the distributions of these two years on a percentage basis are very similar.

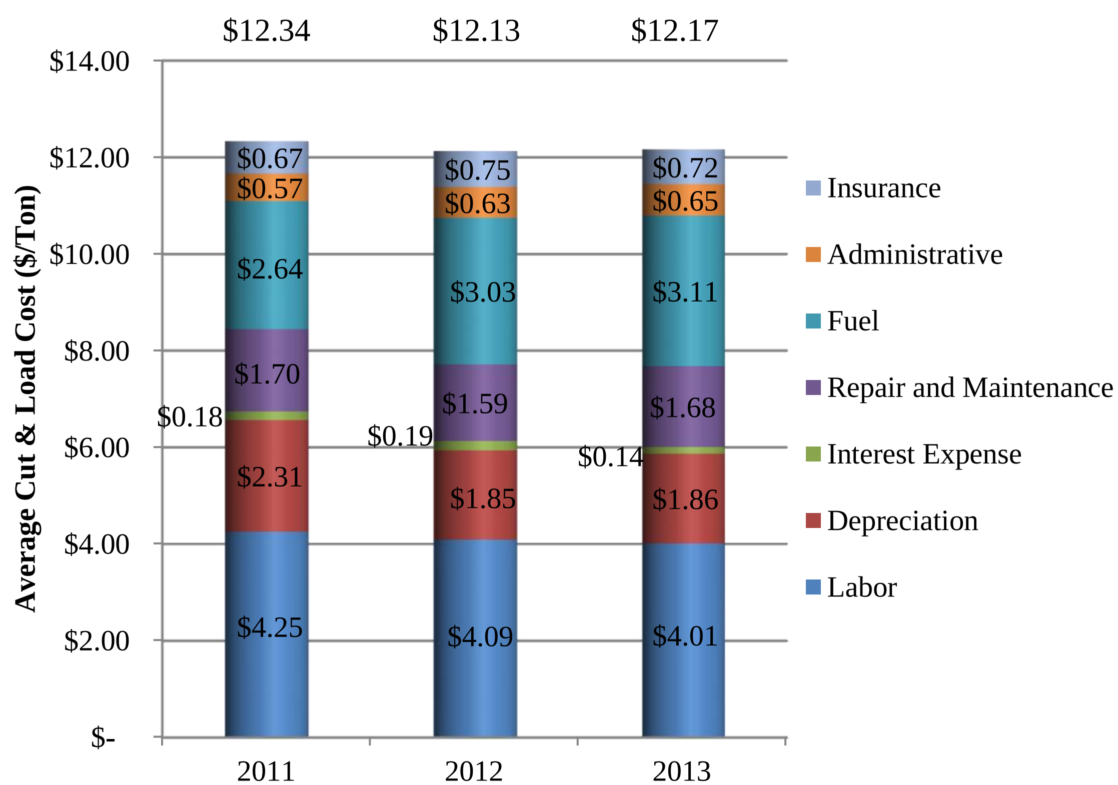

Figure 4.4: Breakdown of production-weighted average annual cut and load costs ($/ton) for a sample of logging contractors. Data from 2011 are reported from Baker et al. (2014).

Table 4.3: Logging cost component data (% of total cost) for study participants in 2012 and 2013 and projections for component cost data based on the UGA Logging Cost Index.

	Actual Data		UGA LCI Projection	
	2012	2013	2012	2013
Labor	33.6	32.9	34.7	35.5
Depreciation	14.9	15.3	18.6	18.8
Interest	1.6	1.1	1.4	1.4
Repairs & Maintenance	12.6	13.8	13.7	13.8
Fuel	25.3	25.6	21.7	20.9
Insurance and Administrative	12.0	11.3	10.0	10.2

The production-weighted average cost in 2013 was 0.6% lower than in 2012, and 1.4% lower than in 2011. The large shift in the sample composition from 2011 to 2012 could certainly affect these percentages, as would the changes in annual production for each company.

Correcting for the impact of contractor production is critical to accurately representing the changes to component costs for logging contractors. Plotting the average annual logging costs for all data shared in this project against the quarterly values of the UGA LCI shows wide divergence from year to year (Figure 4.5). This is due to the change in the companies providing cost data each year and the varied production levels for those companies. A core group of data providers are needed to ensure that the addition of new contractors does not cloud the actual cost changes occurring.

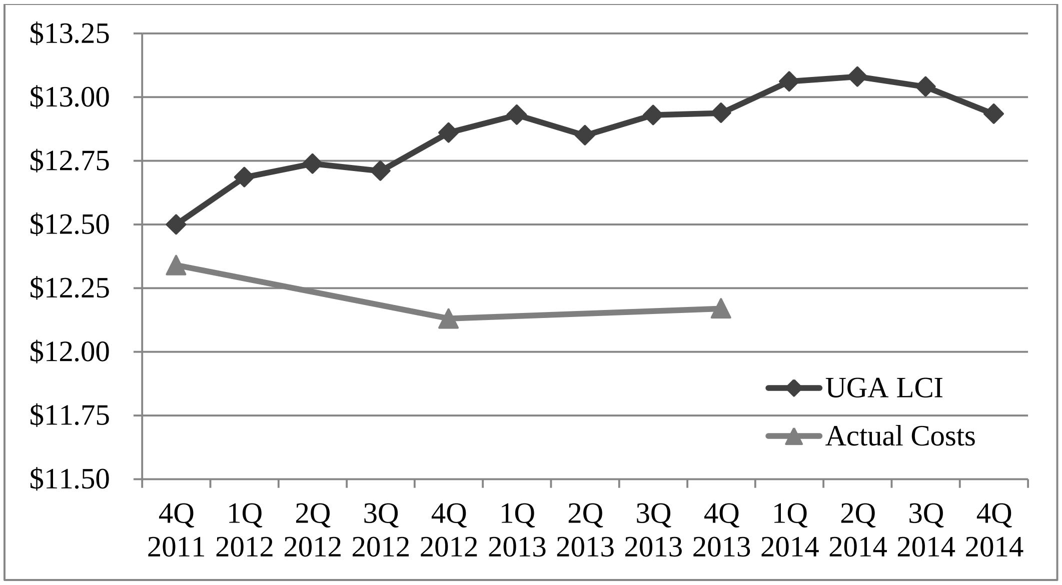

Figure 4.5: The UGA Logging Cost Index and the average annual cut and load cost of study participants, 4th Quarter 2011 through 4th Quarter 2014.

Six companies provided cost data for 2011, 2012, and 2013. The average production of these six companies increased 8% from 2011 to 2012 and remained essentially unchanged from 2012 to 2013. Plotting the average cost per ton of these six companies against the UGA LCI (correcting for the changes in production from year to year with labor treated as a fixed cost) shows close agreement in the amount of change in per ton costs (Figure 4.6). This suggests that the UGA LCI reasonably represents the changes in component costs for these contractors; however, it also highlights the limitation of using a cost index to determine real-world impacts without additional context. The production of contractors is the more variable component and is necessary to understand the impact that cost changes have on a given business. The UGA LCI focuses solely on the component cost changes for the industry as a whole.

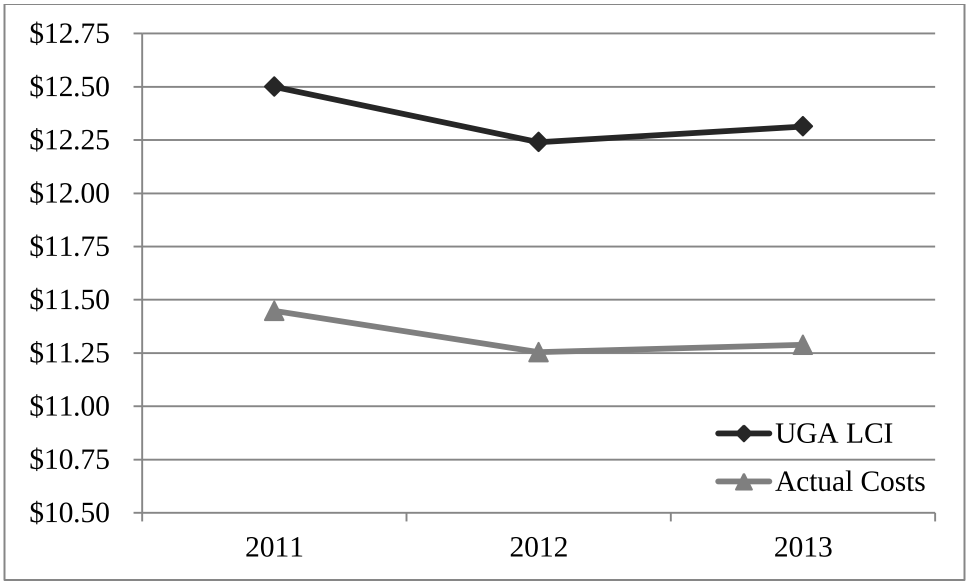

Figure 4.6: Annual values for the UGA Logging Cost Index adjusted for annual changes in production and average logging cost of six contractors in 2011, 2012, and 2013.

Using all cost data provided, we have 21 separate year-over-year cost measures. Thirteen collected for the 2012-2013 period, six for the 2011-2012 period, and two which cover 2011-2013. Using the methodology described above to correct the UGA LCI value for the observed change in each contractor's annual production, we tested the difference between the observed cost and the expected cost based on the UGA LCI. When labor costs for all companies were considered as fixed costs, paired *t*-tests on these data showed no statistical difference from zero ($P > 0.6$), but the average difference was 1.4%, suggesting there is still some deviation. A nonparametric Wilcoxon Signed Rank test (which is less affected by extreme outliers in a small sample) provided strong evidence as well that there was no difference between the observed cost and the UGA LCI cost ($P > 0.9$).

In our sample, three of the 21 year-over-year values corresponded to companies which had changed their composition, yielding drastic changes in production (over 25%) due in part to changes in the number of employees. When annual labor costs for these companies in these three years were treated as variable costs the average deviation of logging contractors true costs from those predicted by the index was 2.0% (p = 0.47). One company radically changed how they handled trucking during the study period, causing major changes in their cost structure for a one year period that was substantially different from the predicted change based on the UGA LCI (Figure 4.9). Excluding this outlier, the average deviation was 0.1% (p = 0.96).

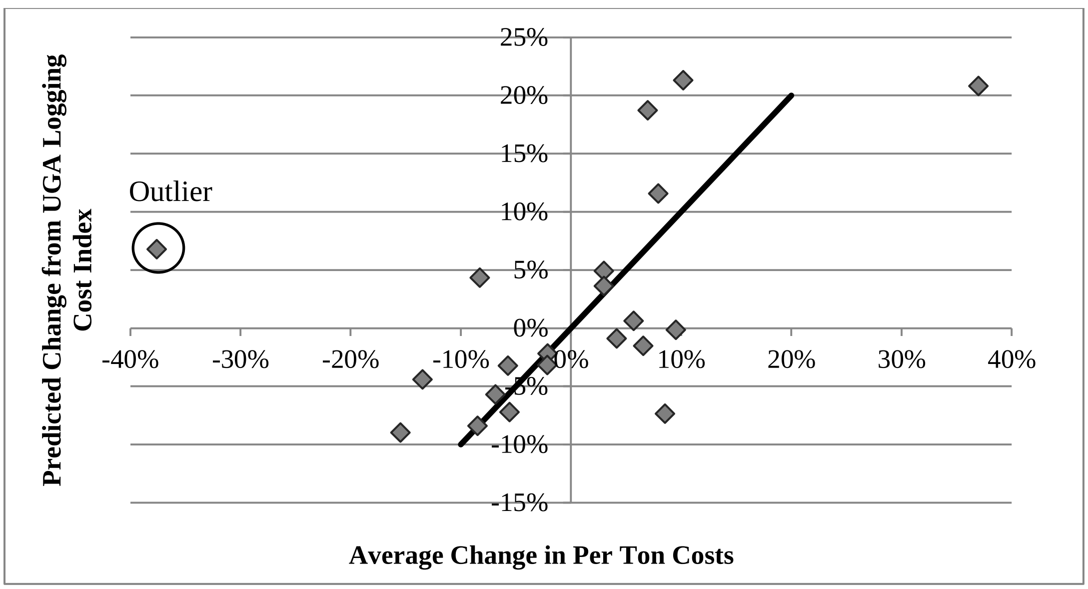

Figure 4.9: Actual percent change in per ton logging costs versus change suggested by the UGA Logging Cost index after correcting for individual contractors' annual production. Black line indicates perfect agreement between the two.

Labor, insurance, administrative, and repair and maintenance costs were all reasonably well represented by the cost change indicators comprising the UGA LCI (Figure 4.7). Wages for logging employees reported in the Quarterly Census of Employment and Wages increased between 5% and 6% from the 2011 to 2013 (Bureau of Labor Statistics 2013d). Companies reported a 3.5% increase in labor cost per ton over this period. The PPI for heavy machinery replacement parts increased 4% while reported repair and maintenance costs increased 2% (Bureau of Labor Statistics 2013c). Insurance and administrative costs were inflated using core CPI (CPI without food or energy). Core CPI increased 4% while insurance and administrative costs increased 6%. Including cost data shared by all contractors reduces the accuracy of the publicly available data as a measure of cost changes; however, the trends are similar for most of the cost components.

Fuel and petroleum-based consumable costs diverged substantially in 2013 from the trend in diesel prices. Both the core group of six contractors and the entire group of data providers saw significant increases in per ton diesel costs (13% and 18% respectively). Diesel prices ended 2011 at $3.87 and ended 2013 at $3.87 per gallon. While there was variability within that stretch, there is no indication that per ton cost should increase so substantially. Examining the responses to the face-to-face interviews, participants reported their average off-road diesel consumption per ton declined from 0.6 gallons in 2011 to 0.5 gallons in 2013. There is no indication what is driving the higher cost. A generation of new machinery requiring diesel exhaust fluid (DEF) to meet air quality regulations could be increasing the cost somewhat. DEF consumption is supposed to represent 6-10% of fuel consumption, and would rsuggest a new cost requirement. Diesel engines requiring DEF were intended to have greater efficiency to offset DEF costs with reduced fuel consumption (one possible explanation for the decline in off-road diesel consumption). It is possible the first generation of Tier IV engines did not meet this goal and the DEF costs increased the total per ton fuel and consumables cost.

Depreciation expenses are highly variable, in part due to tax regulations passed during the recession. Businesses are able to expense the entire purchase price of machinery costing less than $500,000 in the year of purchase. They can also choose to depreciate over 60% of the value of the machine in the first year (using bonus depreciation laws). Thus, for small companies purchasing new machinery infrequently, depreciation can vary widely depending on the choices made to offset taxes. A small number of contractors recorded the more realistic "book" depreciation on machinery, and were willing to share this, but the majority reported their tax basis depreciation. Large variation in depreciation expenses from year to year was common. Contractors fluctuated from no depreciation to $200,000 or more in consecutive years. As a result, the annual change in depreciation cost was very difficult to mirror with a national data index (Figure 4.7). Depreciation and the closely related interest expense were the only two component costs which were not at least somewhat represented by trends in the publicly available cost indicators comprising the UGA LCI. Both costs declined substantially each year at a time when new equipment prices have been increasing steadily. The ages of equipment operated by contractors suggest that they have been buying some newer equipment (Figure 4.2); however, the aggregate cost information indicates that many have been using up their depreciation and minimizing their debt burdens.

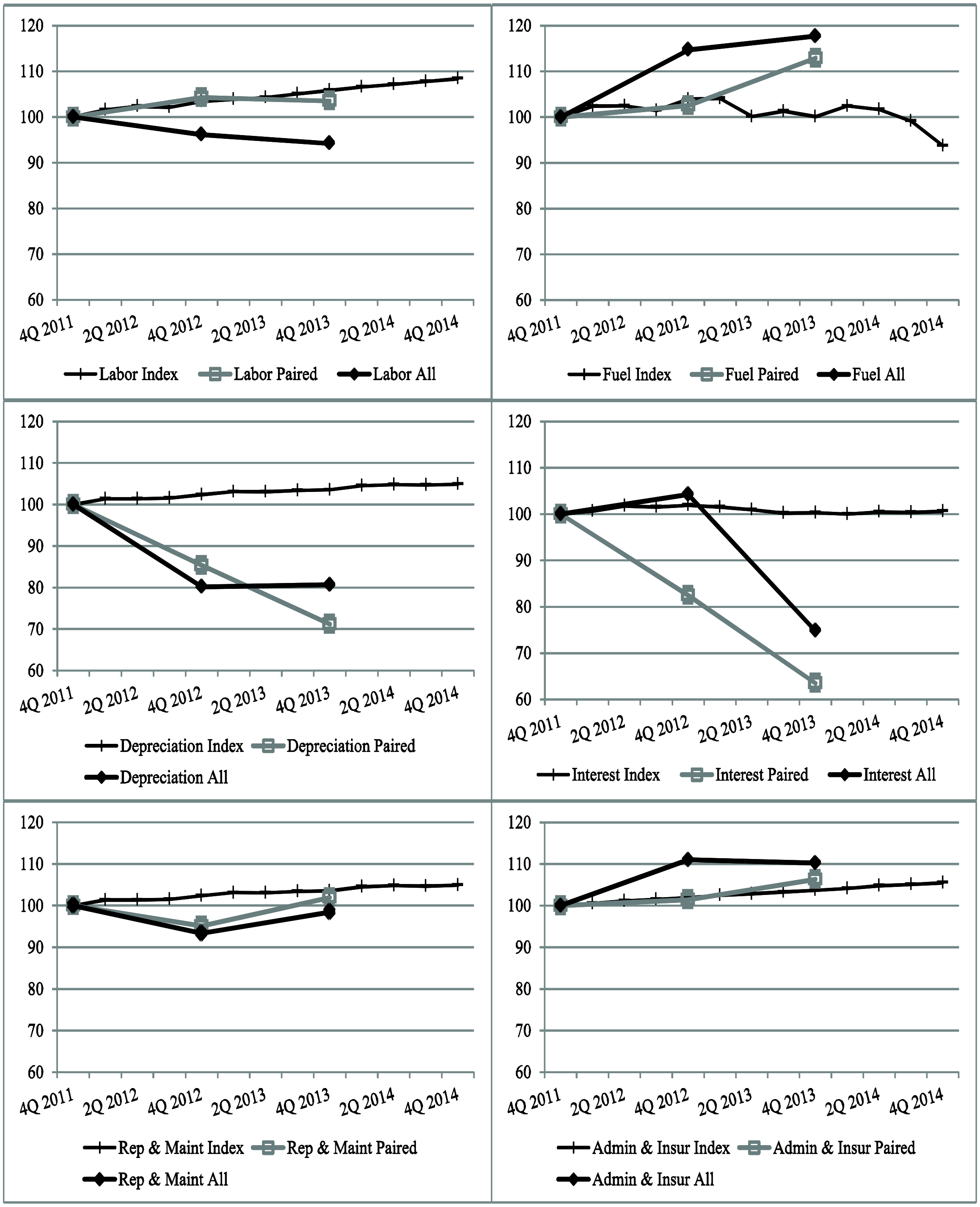

Figure 4.7: Each logging cost component is shown with the annual change for all available logging cost data, the annual change for the subset of loggers providing data for all three years (paired), and the quarterly cost component inflator used to calculate the UGA Logging Cost Index.

It is also noteworthy that the PPI for heavy machinery has been increasing slowly and steadily over the past three years. Reported purchase prices for skidders, shared by our study participants, show that the trends in price reported by the PPI were relatively consistent with average purchase prices until the Tier IV equipped machinery became available (Figure 4.8). Purchase prices for skidders in 2014 increased substantially, at a rate much faster than the PPI indicates. While this trend is not mirrored in the cost data gathered from participants, it is possible that depreciation expenses will rise in 2014 and 2015 as purchases of these newer machines continue. Tracking the PPI versus actual purchase prices will be imperative to ensuring that the cost increases are accurately represented.

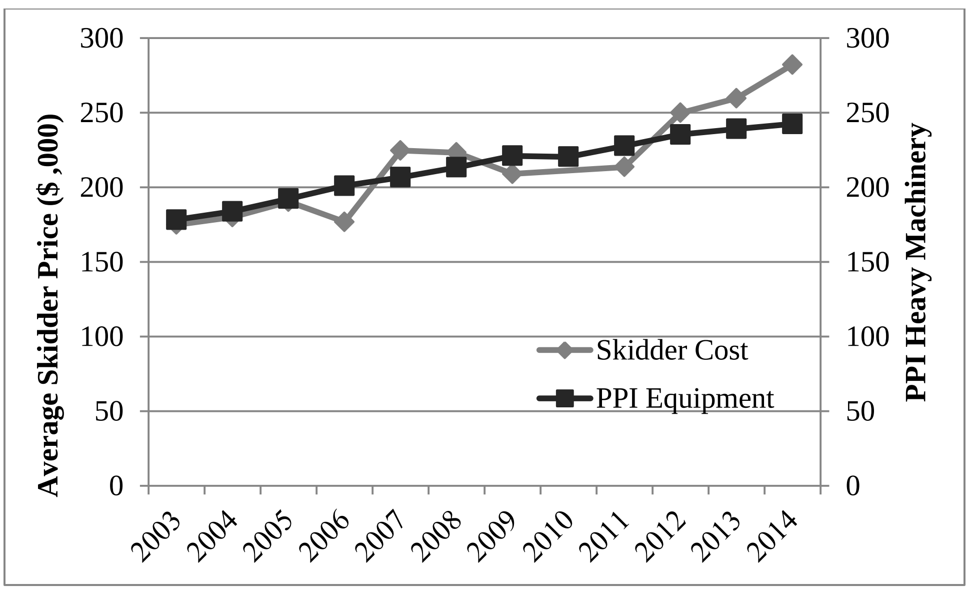

Figure 4.8: The Producer Price Index for Heavy Machinery (Series ID PCU33120) and average reported skidder prices 2003 – 2014.

DISCUSSION AND CONCLUSION

Changes in logging cost are not only impacted by component cost changes. Production is perhaps the greatest driver of logging costs because it is the source of most of the volatility in operations. Despite analyzing costs on a “per ton” basis to reduce the effect of production variation, total tons produced determines the magnitude of fixed costs per ton. As a logging contractor harvests more volume, their total cost per ton decreases. The UGA LCI currently assumes a fixed production level over time.

Without accounting for the production variation, the average cost of all respondents increased 0.3% from 2012-2013 and declined 1.6% from 2011-2012, with corresponding production increases of 1.5% and 8% over those same periods. Through increased production, companies were able to reduce costs on average. It should be noted, however, that these average values do not represent the extreme variability present amongst the study participants. Production changes from 2012 to 2013 varied from a 46% increase to a 14% decrease. The much smaller sample of companies providing data from 2011 through 2012 ranged from a 45% increase to a 22% decrease. Only one company experienced a production difference of less than 10% over this two year timeframe. Correspondingly, per ton costs for this group also swung wildly from a 37% increase to a 38% decline. The combination of volatile production and unexpected expenses results in substantial cost variability for an individual company.

Participating companies were larger, on average, than typical companies operating in the US South. This could provide skewed cost distributions, particularly regarding administrative costs if a fixed level of administrative expense could be distributed amongst multiple logging crews. In addition, volume discounts for bulk purchases of repair parts, fuel, lubricants, etc. could also reduce the per ton cost of these components relative to a smaller company. Given the limited sample size in this study, it is not feasible to further subdivide the data to determine the effect of company size on the cost distribution and the subsequent impact on cost changes over time. Stuart et al. (2003a) argued that company size did affect the pattern of cost changes over time. They reported their logging cost index in three company-size categories as a result. Further data would be needed to assess if this approach would yield different trends for the UGA LCI. The cost distributions reported by Stuart et al. (2003a) did not differ substantially between small and large firms suggesting the cost change patterns may not differ appreciably.

To provide further clarity on production variability, three contractors shared detailed weekly production data for 2012 and 2013. The coefficient of variation on weekly production averaged 29% for this group. This value is slightly lower than the variability reported by Shannon (1998) and significantly lower than reported by Greene et al. (2004). Increasing the time period to monthly production decreased the average CV to 18%, which is still a significant amount of variation in expected cash flow from month to month. The UGA LCI is currently reported as a quarterly value, and when production was viewed as a quarterly figure, the average CV of production dropped further to 9%. A ±9% change in production in the 4th quarter of 2013 would correspond to a range of [$12.24, $13.78] around the mean UGA LCI value of $12.94 for the quarter. Thus, while the UGA LCI appeared to track closely with the aggregate cost changes experienced by the sample group, the inherent volatility of the business should not be overlooked.

Our goal in this project was to determine if the approach taken to calculate the UGA Logging Cost Index was a valid method for estimating cost changes for the southern logging industry. Based on the data we gathered, it appears to perform reasonably well. The key variable of concern is production and productivity. As the logging industry increases its productivity, the cost per ton may decline for a firm with a fixed production level. Thus, new developments in equipment or operating procedures would require a recalculation of the index. Other cost indexes have incorporated a fixed labor productivity factor to account for the impact of increasing labor productivity (Vatavuk 2002). While there is evidence of increasing labor productivity in the logging industry, an arbitrary labor productivity factor has not been incorporated into the UGA LCI. Many of the national price indexes are recalibrated on a five year interval (Balk 2008). A similar strategy would likely prove useful for the UGA LCI.

Over the three-year period we analyzed, publicly available data appeared to track fairly closely with actual logging cost data. The major divergence was in equipment and interest costs. We believe the unusual financing environment resulting from the worldwide recession in 2008 and 2009 may have caused some of these unexpected results. The limitations of using depreciation rather than actual cash flows as a measure of equipment expense have been highlighted by past researchers (Loving 1991, Bilek 2009). Baker et al. (2014) chose to use depreciation in their initial calculation of the UGA LCI to provide a uniform measure across different businesses with different machine investment approaches (cash purchase, partial and full financing). A calculated depreciation cost, such as that described by Butler and Dykstra (1981), would be a better measure than the tax depreciation shared by most of the contractors in this study. The variability in the first-year taxable deductions allowed under current tax policy provides opportunities for variation in annual depreciation much greater than the actual annual decline in the value of a given machine. A re-inspection of capital costs in the future is warranted to determine if longer term cost trends align with changes in cost of machinery.

The approach used to generate the regional logging cost index for the US South should be applicable to other regions without significant reservation. Particularly in areas with industry uniformity (a large percentage of the industry operating similar harvesting systems), this approach of determining the breakdown of major cost components and inflating each with publicly available data should provide a useful, rapid indicator of shifts in logging costs.

Periodic validation of the index is recommended; however, failing significant shifts in the industry, we do not believe annual cost comparisons are necessary, particularly if multiple regional indices are developed. Maintaining a group of contractors interested and willing to share the necessary data for multiple years at a time will pose a greater challenge. Our analysis of the individual cost components shows that even when group of data providers changes over time, the trends in most of the cost components mirror the trends for a uniform group; however, similar work should be conducted over a longer timeframe to ensure this remains the case.

LITERATURE CITED

Baker, S. A., D. Greene, T. G. Harris & B. Mei. 2013. Regional cost analysis and indices for conventional timber harvesting operations. Athens, GA: Wood Supply Research Institute. pp. 39.

Baker, S. A. & W. D. Greene. 2008. Changes in Georgia's logging workforce, 1987-2007. *Southern Journal of Applied Forestry*, 32(2)**:**60-68.

Baker, S. A., B. Mei, T. G. Harris & W. D. Greene. 2014. An index for logging cost changes across the US South. *Journal of Forestry*, 112(3)**:**296-301.

Balk, B. M. 2008. *Price and quantity index numbers : models for measuring aggregate change and difference*. Cambridge, UK Cambridge University Press.

Bentley, J. W., J. A. Cooper & M. Howell. 2014. *The South's timber industry - an assessment of timber prodct output and use, 2011*. e-Science Update SRS-SU-090, Asheville, NC. pp. 4.

Bick, S. 2010. Planning and analysis in timber harvesting: A user manual. 39. Thendara, NY: Forest Enterprise Institute, Ltd.

Bilek, E. M. 2007. *ChargeOut! : determining machine and capital equipment charge-out rates using discounted cash-flow analysis*. Madison, WI : U.S. Dept. of Agriculture, Forest Service, Forest Products Laboratory, [2007]. pp. 33.

Bilek, E. M. 2009. *ChargeOut! Discounted cash flow compared with traditional machine-rate analysis*. FPL-GTR-178, Madison; USA: USDA Forest Service, Forest Products Laboratory. pp. 15.

Bolding, M. C., S. M. Barrett, J. F. Munsell & M. C. Groover. 2010. Characteristics of Virginia's logging businesses in a changing timber market. *Forest Products Journal*, 60(1)**:**86-93.

Bureau of Labor Statistics. 2013c. Producer Price Index. In *Commercial Machinery Repair and Maintenance*, Accessed at. http://data.bls.gov/timeseries/PCU811310811310 U.S. Department of Labor. Last accessed on: June 27, 2013.

---. 2013d. Quarterly Census of Employment and Wages. Accessed at. http://www.bls.gov/cew/home.htm: U.S. Department of Labor. Last accessed on: June 27, 2013.

Butler, D. A. & D. P. Dykstra. 1981. Logging Equipment Replacement: A Quantitative Approach. *Forest Science*, 27(1)**:**2-12.

Dorfman, A. H., J. Lent, S. G. Leaver & E. Wegman. 2006. On Sample Survey Designs for Consumer Price Indexes. *Survey Methodology*, 32(2)**:**197-216.

Greene, W. D., J. H. Mayo, C. F. deHoop & A. F. Egan. 2004. Causes and costs of unused logging production capacity in the southern United States and Maine. *Forest Products Journal*, 54(5)**:**29-37.

Harris, T. G., J. P. Siry, S. Baldwin & J. Smith. 2015a. Timber Mart-South Market News Quarterly. Athens, GA: Timber Mart-South. 19(4): 45.

Harris, T. G., J. Smith & S. Baldwin. 2015b. Timber Mart-South: Fourth Quarter 2014. Athens, GA: Timber Mart-South. 39(4).

Hollander, M. & D. A. Wolfe. 1999. *Nonparametric Statistical Methods*. J. Wiley: New York.

Kenney, J., T. Gallagher, M. Smidt, D. Mitchell & T. McDonald. 2014. Factors that affect fuel consumption in logging systems. In *37th Council on Forest Engineering Annual Meeting*, ed. C. Blinn, Moline, IL: University of Minnesota. 6.

Loving, R. E. 1991. *Components of Logging Costs*. M.S. Thesis. Virginia Tech. Blacksburg, VA: 205.

Marchman, S. C., S. A. Baker & W. D. Greene. 2013. Southeastern logging contractor survey results over 25 years. Rockville, MD: Forest Resources Association. Tech. Release 13-R-10: 2.

Miyata, E. S. & H. M. Steinhilb. 1981. *Logging system cost analysis : comparison of methods used*. Research paper NC-208, St. Paul, Minn.: U.S. Dept. of Agriculture Forest Service North Central Forest Experiment Station. pp. 15.

Moldenhauer, M. C. & M. C. Bolding. 2009. Parcelization of South Carolina's private forestland: loggers' reactions to a growing threat. *Forest Products Journal*, 59(6)**:**37-43.

Shannon, J. T. 1998. *Productivity, cost, and technical efficiency evaluation of southeastern U.S. logging contractors*. M.S. Thesis. Virginia Polytechnic Institute and State University. Blacksburg, Va.

Smidt, M. F., R. A. Tufts & T. V. Gallagher. 2009. Stump to Mill Cost Program (STOMP). In *2009 Council on Forest Engineering Annual Meeting: Environmentally Sound Forest Operations*, ed. B. R. Hartsough, 7. Lake Tahoe, NV.

Stuart, W. B. 2003. Checking our foundations: Matthews' least cost models revisited. *Southern Journal of Applied Forestry*, 27(1)**:**30-35.

Stuart, W. B., L. A. Grace, C. B. Altizer & J. J. Smith. 2008. 2006 Preliminary Logging Cost Indices. Starkville, MS: Wood Supply Research Institute. pp. 14.

Stuart, W. B., L. A. Grace & R. K. Grala. 2010. Returns to scale in the Eastern United States logging industry. *Forest Policy & Economics*, 12(6)**:**451-456.

Stuart, W. B., L. A. Grace, B. D. Jackson & R. Stutzman. 2003a. Logging Cost Indices. Starkville, MS: Wood Supply Research Institute. pp. 21.

Tufts, R. A., B. L. Lanford, W. D. Greene & J. O. Burrows. 1985. Auburn harvesting analyzer. *The COMPILER,* Florence, AL: Forest Resources Systems Institute. 3(2)**:**2.

Tufts, R. A., J. Thurber, D. Simmons & B. Izlar. 1981. Forestry equipment cost index: 1968-1978. *Southern Journal of Applied Forestry*, 5(4)**:**201-204.

Vatavuk, W. M. 2002. Updating the CE Plant Cost Index. *Chemical Engineering*, 109(1)**:**62-70.

CHAPTER 5

DISCUSSION AND CONCLUSION

The topics presented in the preceding chapters introduce methods to increase visibility in trends affecting the logging industry. We provided a means of estimating changes in the aggregate logging capacity in the US South. We also developed a logging cost index and tested its performance over a two-year period. Accurate measures of both logging cost and logging capacity will greatly expand our insight into an industry that has lacked widely-available, regular, and reliable information.

Logging capacity is a measure of the total production ability of the industry. Our methods of calculating capacity relied on the partial productivity of labor, which does not account for changes in capital. Parry (1999) stated that “labor productivity growth overstates multi-factor productivity growth when the quantity of capital and intermediate inputs are increasing relative to labor input over time.” Surveys of the Georgia logging workforce found that productivity of capital in logging enterprises had been mostly unchanged from the late 1990’s through the 2000’s (Marchman et al. 2013). This suggests that a capacity estimate based on the partial productivity of labor should not be positively biased.

Reduced aggregate logging capacity in the US South has significant implications to the forest industry as demand for forest products increases. Capacity must be increased to meet the level of demand either through growth in the size and/or number of businesses in the logging industry, increased utilization of existing logging businesses, or both. Past studies on individual logging businesses have found that capacity utilization is often under 70% (Loving 1991, Greene et al. 2004). If production variability can be minimized and utilization of existing businesses increased, the production capacity could be increased. Barynin et al. (2013) estimated that logging businesses delayed reinvestment during the recession and the industry would require an additional $1.4 billion in capital investments to match the expected demand increases through 2017. Thus, even a more thorough utilization of the industry will require additional investment, a finding which is supported by our sampling of equipment and truck ages (Figures 4.2 and 4.3). Evidence of increased investment in machinery was already apparent, but haul trucks were not being purchased as readily. In order to attract new businesses and increase investment in existing businesses, evidence of an operating environment conducive to positive financial returns is needed for logging contractors.

Figure 3.4 showed that logging costs had increased faster than logging rates during the recession. A shrinking of this gap would serve as an initial indicator of improving financial environment. The UGA Logging Cost Index (LCI) enables the evaluation of this relationship. The UGA LCI has remained relatively level in 2013 and 2014 (Figure 5.1). The value of the UG ALCI in the fourth quarter of 2014 was $12.93, exactly the same as in the first quarter of 2013. Over the same period, logging rates have increased, particularly toward the end of 2014. This may be an indication of the market responding to tightened logging capacity and an improvement in the financial environment.

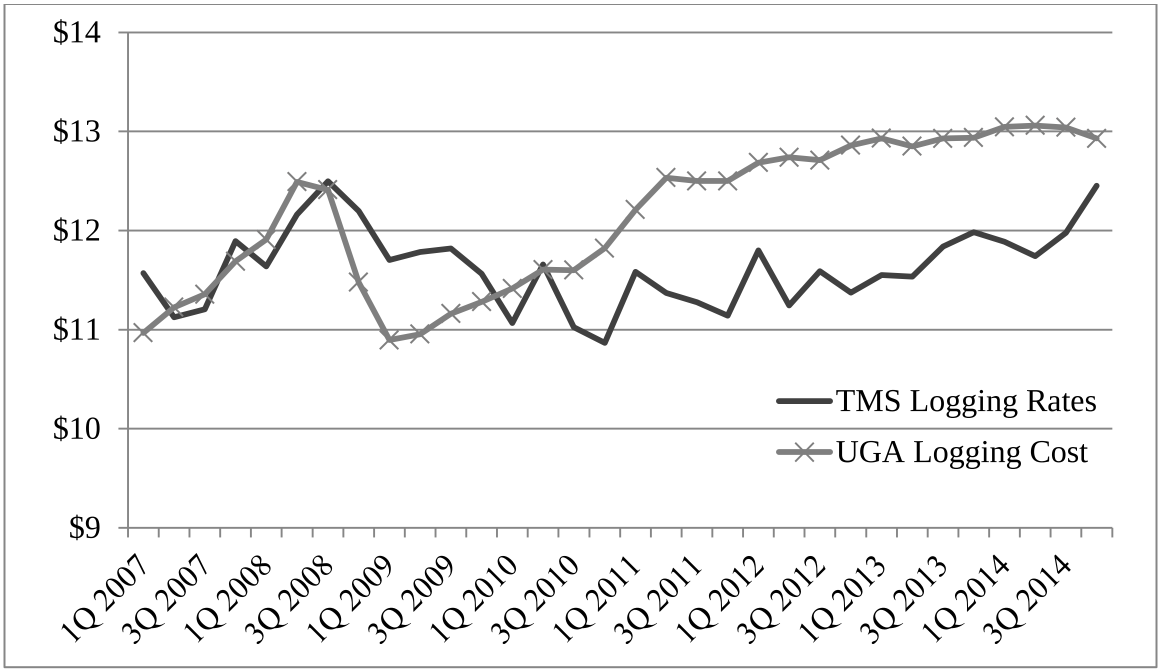

Figure 5.1: Logging costs measured by the UGA Logging Cost Index (LCI) and a south-wide average of four cut and load rates reported quarterly by Timber Mart-South (the mean final harvest and plantation thin rates in the Piedmont and Coastal Plain).

The UGA LCI can be used as a measure of cost inflation for logging contractors. It can therefore be used to deflate the actual logging rates reported in Timber Mart-South to give an indication of real changes in rates over time (Figure 5.2). Overlaying this information with the data available on changes in logging employment, we are able to identify the effect of declining real rates (i.e. corrected for inflation) on logging employment during the recession. At the time of this writing, employment numbers were not available for the last two quarters of 2014, which correspond with an increasing real logging rate. As discussed in Chapter 3, the additional impact of declining production (due to reduced demand for logging services during the recession) provided further negative pressure on the industry. The importance of production in reducing per ton costs was discussed extensively in Chapter 4, and the relatively higher rates shown in Figure 5.2 during late 2008 and 2009 were likely offset by the negative production impacts of the recession. The declines in employment over much of this period suggest that this was likely the case. We know of no credible data on per crew annual production to verify these trends in 2008 and 2009.

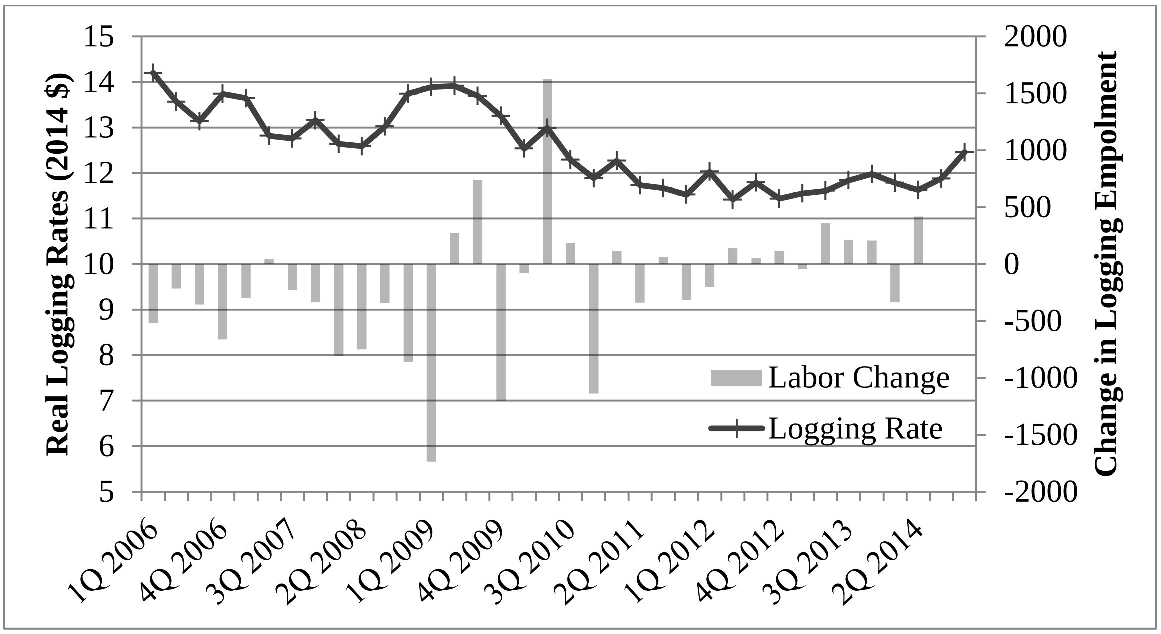

Figure 5.2: “Real” logging rates (adjusted for cost changes by the UGA Logging Cost Index) as reported by Timber Mart-South and quarterly change in logging employment in the US South.

As noted in Chapter 2, the recession had a significant negative effect on the logging industry, decreasing the total production capacity by 12-14% through 2012. In 2013 and 2014, demand for forest products began to rebound as housing markets strengthened slightly (Harris et al. 2015a). Given that the contraction in the logging industry followed the contraction in the forest industry, it is reasonable to question how quickly the market will drive expansion of the logging industry to match increased demand. Our measure of logging capacity provides a means to track changes in the aggregate capacity of the industry. It differs from previous measures of logging capacity which focused on the ability of individual businesses to increase their production relative to their current production levels (e.g., LeBel and Stuart 1998, Greene et al. 2004). We focus on the increase and/or decrease in labor productivity rather than a detailed comparison of maximum or potential production to actual production. This distinction is critical as it enables us to calculate a change in industry capacity more quickly and at lesser cost, but does not provide the same level of insight into individual business capacity utilization as previous researchers.

Calculation of logging capacity relied heavily on survey research focused on the logging industry in Georgia. As noted in Chapter 2, these data provide some of the only reliable indicators of labor productivity for the logging industry. Prior to 1998, logging was considered a manufacturing industry by the Bureau of the Labor Statistics, and labor productivity numbers were reported regularly as a component of the Annual Survey of Manufacturers (Xu et al. 2014). Parry (1999) notes that logging labor productivity increased at 1.4% per year from 1970-1992 (a period which included extensive adoption of mechanized felling). This is in contrast with the estimate of 1.0% increase in labor productivity per year suggested by Marchman et al. (2013) and used to generate our estimates of logging capacity. Over the past two decades, harvesting systems have not developed at the rate seen in the 1970’s and 1980’s. Particularly in the US South, the conversion of the majority of the industry to fully mechanized operations was completed by the late 1990's (Baker and Greene 2008). As such, the observed decline in the rate of labor productivity growth is expected.

SUGGESTIONS FOR FURTHER RESEARCH

There are a number of possible topics for future research suggested by these studies. As noted in the discussion of the logging cost index, treatment of depreciation expenses by logging contractors varied widely from the PPI for heavy machinery. Further work is needed to determine if longer term machine cost trends match depreciation cost trends for the industry.

With both a measure of logging capacity and a measure of logging cost, there exists an opportunity to forecast logging rates. A time series analysis could determine if the trends in either capacity or cost correlate with future changes in logging rates. From a purely economic perspective, extraneous costs and an indicator of demand/supply (if excess or surge logging capacity is used as such an indicator) offer the prospect of a reasonable model for future logging rates.

Both the calculation of logging capacity and the logging cost index rely heavily on measures of logging productivity. In the case of logging capacity, it was a critical component as we lacked any data on the amount of capital in the industry and were reliant on labor data. Increasing labor productivity, as noted in Chapter 4, will serve to minimize labor cost increases over time, and would be a useful addition to the cost index calculations. Failing either better insight into the causes of increased labor productivity or a regular means of measuring it, incorporating an accurate labor productivity adjustment into the UGA LCI will be problematic. Each study was challenged by a lack of basic productivity information. In the case of logging capacity, this challenge was handled by a time series on the logging industry limited to the state of Georgia, but the industry as a whole would benefit from a rigorous effort to capture regular, detailed data. The studies presented here are meant to provide some basic measures regarding the logging industry, but they would benefit from reliable data on the entire logging industry in the US.

Our research has been limited to the southern US states for reasons described in each of the manuscripts above. Typically, we were limited by the data available in other regions or we felt that our results best represented the relatively uniform industry in the US South (heavy reliance on wheeled feller-buncher and grapple skidder harvesting systems). Similar empirical measures would be useful for the industry in other regions of the country; however, as noted above, a measure of logging labor productivity would be needed to estimate logging capacity with our methodology.

A logging cost index could be developed in any region, if a suitable number of contractors were willing to share their cost data. Because of our reliance on a fixed distribution of costs as a starting point for an index calculation, we recommend targeting a base harvesting system to minimize variability in the component cost. For example, combining cable yarding and ground-based operations into a single logging cost index would likely provide some indication of the general trend in costs for both systems, but would likely not provide an accurate measure for either.

LITERATURE CITED

Baker, S. A. & W. D. Greene. 2008. Changes in Georgia's logging workforce, 1987-2007. *Southern Journal of Applied Forestry*, 32(2)**:**60-68.

Barynin, P., D. Taylor, W. Ghouri & C. Warth. 2013. Wood Supply Chain Analysis: Special Market Analysis Study. Boston, MA: RISI. pp. 27.

Greene, W. D., J. H. Mayo, C. F. deHoop & A. F. Egan. 2004. Causes and costs of unused logging production capacity in the southern United States and Maine. *Forest Products Journal*, 54(5)**:**29-37.

Harris, T. G., J. P. Siry, S. Baldwin & J. Smith. 2015a. Timber Mart-South Market News Quarterly. Athens, GA: Timber Mart-South. 19(4): 45.

LeBel, L. G. & W. B. Stuart. 1998. Technical efficiency evaluation of logging contractors using a nonparametric model. *Journal of Forest Engineering*, 9(2)**:**15-24.

Loving, R. E. 1991. *Components of Logging Costs*. M.S. Thesis. Virginia Tech. Blacksburg, VA: 205.

Marchman, S. C., S. A. Baker & W. D. Greene. 2013. Southeastern logging contractor survey results over 25 years. Rockville, MD: Forest Resources Association. Tech. Release 13-R-10: 2.

Parry, I. W. H. 1999. Productivity Trends in the Natural Resource Industries: A Cross-Cutting Analysis. In *Productivity in natural resource industries: Improvement through innovation,* ed. R. D. Simpson, 175-204. Washington, D.C.: Resources for the Future.

Xu, Y., M. Smidt & Y. Zhang. 2014. Logging Worker Wage, Performance and Experience. *Forest Products Journal*, 64(5/6)**:**210-216.

REFERENCES

Afriat, S. N. 2014. *The index number problem : construction theorems*. Oxford,UK Oxford University Press.

Altizer, C. B., L. A. Grace & W. B. Stuart. 2004. Trends in workers' compensation insurance costs in the logging industry. In *Competitiveness of southern forest products markets in a global economy: trends and predictions. Proceedings of the Southern Forest Economics Workers Annual Meeting*, eds. J. R. R. Alavalapati & D. R. Carter, St. Augustine, FL: University of Florida. 145-155.

Arnold, T. H. & C. H. Chilton. 1963. New Index Shows Plant Cost Trends. *Chemical Engineering*, 70(2)**:**143-148.

Ashuri, B., S. M. Shahandashti & J. Lu. 2012. Empirical tests for identifying leading indicators of ENR Construction Cost Index. *Construction Management & Economics*, 30(11)**:**917-927.

Baker, S. A., D. Greene, T. G. Harris & B. Mei. 2013. Regional cost analysis and indices for conventional timber harvesting operations. Athens, GA: Wood Supply Research Institute. pp. 39.

Baker, S. A. & W. D. Greene. 2008. Changes in Georgia's logging workforce, 1987-2007. *Southern Journal of Applied Forestry*, 32(2)**:**60-68.

Baker, S. A., W. D. Greene & T. G. Harris. 2012. Impact of timber sale characteristics on harvesting costs. In *Applied Forest Economics at Work. Proceedings of the*

Southern Forest Economics Workers Annual Meeting, ed. M. E. Aronow, Charlotte, NC: Hancock Timber Resource Group. 94-105.

Baker, S. A., B. Mei, T. G. Harris & W. D. Greene. 2014. An index for logging cost changes across the US South. *Journal of Forestry,* 112(3)**:**296-301.

Balk, B. M. 2008. *Price and quantity index numbers : models for measuring aggregate change and difference*. Cambridge, UK Cambridge University Press.

Barlow, R., J. & M. R. Dubois. 2011. Cost and cost trends for forestry practices in the South. *Forest Landowner,* 70(6)**:**14-24.

Barynin, P., D. Taylor, W. Ghouri & C. Warth. 2013. Wood Supply Chain Analysis: Special Market Analysis Study. Boston, MA: RISI. pp. 27.

Bentley, J. W., J. A. Cooper & M. Howell. 2014. *The South's timber industry - an assessment of timber prodct output and use, 2011*. e-Science Update SRS-SU-090, Asheville, NC. pp. 4.

Bentley, J. W. & C. D. Steppleton. 2013. *Southern pulpwood production, 2011*. Asheville, NC : United States. Dept. of Agriculture, Forest Service, Southern Research Station, [2013]. pp. 38.

Bick, S. 2010. Planning and analysis in timber harvesting: A user manual. 39. Thendara, NY: Forest Enterprise Institute, Ltd.

Bilek, E. M. 2007. *ChargeOut! : determining machine and capital equipment charge-out rates using discounted cash-flow analysis*. Madison, WI : U.S. Dept. of Agriculture, Forest Service, Forest Products Laboratory, [2007]. pp. 33.

Bilek, E. M. 2009. *ChargeOut! Discounted cash flow compared with traditional machine-rate analysis*. FPL-GTR-178, Madison; USA: USDA Forest Service, Forest Products Laboratory. pp. 15.

Bolding, M. C., S. M. Barrett, J. F. Munsell & M. C. Groover. 2010. Characteristics of Virginia's logging businesses in a changing timber market. *Forest Products Journal*, 60(1)**:**86-93.

Brinker, R. W., J. Kinard, B. Rummer & B. L. Lanford. 2002. Machine rates for selected forest harvesting machines. *Circular - Alabama Agricultural Experiment Station*, 296 (revised))**:**32.

Brinker, R. W., B. L. Lanford, B. J. Stokes & D. Miller. 1989. Machine rates for selected forest harvesting machines. *Circular - Alabama Agricultural Experiment Station*, 296).

Bureau of Labor Statistics. 2011. Employment and Wages Online Annual Averages. Accessed at. http://www.bls.gov/cew/cewbultn10.htm: Quarterly Census of Employment and Wages. Last accessed on: September 19, 2013.

---. 2013a. Consumer Price Index. In *All Urban Consumers, All items less food and energy*, Accessed at. http://data.bls.gov/timeseries/CUUR0000SA0L1E: U.S. Department of Labor. Last accessed on: June 27, 2013.

---. 2013b. Producer Price Index. In *Logging*, Accessed at. http://data.bls.gov/timeseries/PCU113310113310: U.S. Department of Labor. Last accessed on: March 10, 2013.

---. 2013c. Producer Price Index. In *Commercial Machinery Repair and Maintenance,* Accessed at. http://data.bls.gov/timeseries/PCU811310811310 U.S. Department of Labor. Last accessed on: June 27, 2013.

---. 2013d. Quarterly Census of Employment and Wages. Accessed at. http://www.bls.gov/cew/home.htm: U.S. Department of Labor. Last accessed on: June 27, 2013.

Burgess, J. A. & F. W. Cubbage. 1989. Comparison of machine rate and cash flow approaches for estimating forest harvesting equipment costs. *American Society of Agricultural Engineers - Paper No. 89-7548***:**24.

Butler, D. A. & D. P. Dykstra. 1981. Logging Equipment Replacement: A Quantitative Approach. *Forest Science*, 27(1)**:**2-12.

Cubbage, F. & D. Carter. 1994. Productivity and cost changes in southern pulpwood harvesting, 1979 to 1987. *Southern journal of applied forestry,* 18(2)**:**83-90.

Cubbage, F. W., J. E. Granskog & B. J. Stokes. 1988. Trends in southern forest harvesting equipment and logging costs. *Forest Products Journal,* 38(2)**:**6-10.

Dorfman, A. H., J. Lent, S. G. Leaver & E. Wegman. 2006. On Sample Survey Designs for Consumer Price Indexes. *Survey Methodology,* 32(2)**:**197-216.

Dubois, M. R., W. F. Watson & T. J. Straka. 1991. A cost index for Southern forest practices. *Southern Journal of Applied Forestry,* 15(3)**:**128-133.

Duc, N. M., Y. Shen, Y. Zhang & M. Smidt. 2009. Logging productivity and production function in Alabama, 1995 to 2000. *Forest Products Journal,* 59(7/8)**:**22-26.

Earl, P. H. 1977. Specifying escalation indexes to aid in process plant cost forecasting. *Engineering and Process Economics,* 2(4)**:**281-294.

Energy Information Administration. 2013. Retail on-highway diesel price. Accessed at. http://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_nus_w.htm Last accessed on: March 28, 2013.

Federal Reserve Bank of Kansas City. 2013. Table A.5. In *Agricultrual Finance Databook.* http://www.kansascityfed.org/research/indicatorsdata/agfinance/index.cfm.

Federal Reserve Board. 2013. H.15 Release - Selected Interest Rates. Accessed at. http://www.federalreserve.gov/releases/h15/current/default.htm. Last accessed on: June 28, 2013.

Forest Resources Association. 2001. Summary Report: Financial health of the logging industry survey. Rockville, MD. pp. 36.

Greene, W. D., F. W. Cubbage & J. F. McNeel. 1988. Characteristics of Independent Loggers in Georgia. *Forest Products Journal,* 38(7-8)**:**51-56.

Greene, W. D., B. D. Jackson & J. D. Culpepper. 2001. Georgia's logging businesses, 1987 to 1997. *Forest Products Journal,* 51(1)**:**25-28.

Greene, W. D., J. H. Mayo, C. F. deHoop & A. F. Egan. 2004. Causes and costs of unused logging production capacity in the southern United States and Maine. *Forest Products Journal,* 54(5)**:**29-37.

Grogan, T. 1992. First quarterly cost report: Cost history keeping track of a moving target. *Engineering News-Record*, 228(13)**:**2.

Hadrich, J. C., R. Larsen & F. E. Olson. 2013. Impact of the Section 179 tax deduction on machinery investment. *Agricultural Finance Review,* 73(3)**:**458-468.

Harris, T. G., J. P. Siry, S. Baldwin & J. Smith. 2015a. Timber Mart-South Market News Quarterly. Athens, GA: Timber Mart-South. 19(4): 45.

Harris, T. G., J. Smith & S. Baldwin. 2013. Timber Mart-South: First Quarter 2013. Athens, GA: Timber Mart-South. 38(1).

---. 2015b. Timber Mart-South: Fourth Quarter 2014. Athens, GA: Timber Mart-South. 39(4).

Harris, T. G., J. Smith, R. Simmons & S. Baldwin. 2010. Timber Mart-South Market News Quarterly. Athens, GA: Timber Mart-South. 14(4): 43.

Hodges, D. G., A. J. Hartsell, C. Brandeis, T. J. Brandeis & J. W. Bentley. 2011. Recession Effects on the Forests and Forest Products Industries of the South. *Forest Products Journal,* 61(8)**:**614-624.

Hollander, M. & D. A. Wolfe. 1999. *Nonparametric Statistical Methods*. J. Wiley: New York.

Jackson, B. D. 2003. *Examining the performance of independent harvesting firms in the eastern United States*. M.S. Thesis. Mississippi State University. Starkville, MS

Johnson, T. G., J. W. Bentley & M. Howell. 2011. *The South's timber industry - an assessment of timber prodct output and use, 2009*. Resource Bulletin SRS-182, Asheville, NC. pp. 44.

Johnson, T. G. & C. D. Steppleton. 2013. Southern pulpwood production, 2011. In *Resource bulletin SRS-194*, 38. Asheville, NC : United States. Dept. of Agriculture, Forest Service, Southern Research Station, [2013].

Kenney, J., T. Gallagher, M. Smidt, D. Mitchell & T. McDonald. 2014. Factors that affect fuel consumption in logging systems. In *37th Council on Forest*

Engineering Annual Meeting, ed. C. Blinn, Moline, IL: University of Minnesota. 6.

Knight, D. 2006. Deeper Hole? *Timber Harvesting*, Montgomery, AL: Hatton Brown. 54(3)**:**10-14, 40.

---. 2011. Nowhere to turn. *Timber Harvesting and Wood Fiber Operations*, Montgomery, AL: Hatton Brown. 59(3)**:**10-19.

Koop, G. 2005. *Analysis of economic data*. John Wiley & Sons: Chichester, England.

Laestadius, L. 1990. *A Comparative Analysis of Wood-Supply Systems from a Cross-Cultural Perspective*. PhD Dissertation. Virginia Tech. Blacksburg, VA: 149.

LeBel, L. 1993. *Production capacity utilization in the southern logging industry*. M.S. Thesis. Virginia Polytechnic Institute and State University. Blacksburg, VA

LeBel, L. G. & W. B. Stuart. 1998. Technical efficiency evaluation of logging contractors using a nonparametric model. *Journal of Forest Engineering*, 9(2)**:**15-24.

Leon, B. H. & J. G. Benjamin. 2013. A survey of business attributes, harvest capacity and equipment infrastructure of logging businesses in the Northern forest. Orono, ME: University of Maine. pp. 29.

Loving, R. E. 1991. *Components of Logging Costs*. M.S. Thesis. Virginia Tech. Blacksburg, VA: 205.

Marchman, S. C., S. A. Baker & W. D. Greene. 2013. Southeastern logging contractor survey results over 25 years. Rockville, MD: Forest Resources Association. Tech. Release 13-R-10: 2.

Matley, J. 1982. Chemical Engineering Plant Cost Index - Revised. *Chemical Engineering*, 89(1)**:**153-156.

Mignard, D. 2014. Correlating the chemical engineering plant cost index with macro-economic indicators. *Chemical Engineering Research & Design: Transactions of the Institution of Chemical Engineers Part A,* 92(2)**:**285-294.

Miyata, E. S. 1980. *Determining fixed and operating costs of logging equipment*. GTR-NC-55, Saint Paul, MN: North Central Forest Experiment Station, Forest Service, U.S. Dept. of Agriculture. pp.

Miyata, E. S. & H. M. Steinhilb. 1981. *Logging system cost analysis : comparison of methods used*. Research paper NC-208, St. Paul, Minn.: U.S. Dept. of Agriculture Forest Service North Central Forest Experiment Station. pp. 15.

Moldenhauer, M. C. & M. C. Bolding. 2009. Parcelization of South Carolina's private forestland: loggers' reactions to a growing threat. *Forest Products Journal,* 59(6)**:**37-43.

Munn, I. A., J. B. Cutshall & D. G. Hodges. 1998. 1993 pulpwood logging contractor survey. *Forest Products Journal,* 48(7)**:**47-53.

Parry, I. W. H. 1999. Productivity Trends in the Natural Resource Industries: A Cross-Cutting Analysis. In *Productivity in natural resource industries: Improvement through innovation,* ed. R. D. Simpson, 175-204. Washington, D.C.: Resources for the Future.

Plummer, G. 1982. Harvesting developments: Machine costs and rates. ed. W. D. Georgia Kraft Company. Georgia Kraft Company, Woodlands Division.

Shahandashti, S. M. & B. Ashuri. 2013. Forecasting Engineering News-Record Construction Cost Index Using Multivariate Time Series Models. *Journal of Construction Engineering & Management,* 139(9)**:**1237-1243.

Shannon, J. T. 1998. *Productivity, cost, and technical efficiency evaluation of southeastern U.S. logging contractors*. M.S. Thesis. Virginia Polytechnic Institute and State University. Blacksburg, Va.

Smidt, M. F., R. A. Tufts & T. V. Gallagher. 2009. Stump to Mill Cost Program (STOMP). In *2009 Council on Forest Engineering Annual Meeting: Environmentally Sound Forest Operations,* ed. B. R. Hartsough, 7. Lake Tahoe, NV.

Spelter, H., R. Goodnow, J. Sweitzer & A. Schmon. 2011. Profile 2011: Softwood sawmills in the United States and Canada. Westford, MA: Forest Economic Advisors, LLC. pp. 55.

Stuart, W. B. 2003. Checking our foundations: Matthews' least cost models revisited. *Southern Journal of Applied Forestry,* 27(1)**:**30-35.

Stuart, W. B. & L. A. Grace. 1999. Wood supplier productivity and cost survey. In *Technical Paper 99-A-7,* Rockville, MD: American Pulpwood Association. pp. 46.

Stuart, W. B., L. A. Grace, C. B. Altizer & J. J. Smith. 2008. 2006 Preliminary Logging Cost Indices. Starkville, MS: Wood Supply Research Institute. pp. 14.

Stuart, W. B., L. A. Grace & R. K. Grala. 2010. Returns to scale in the Eastern United States logging industry. *Forest Policy & Economics,* 12(6)**:**451-456.

Stuart, W. B., L. A. Grace, B. D. Jackson & R. Stutzman. 2003a. Logging Cost Indices. Starkville, MS: Wood Supply Research Institute. pp. 21.

---. 2003b. Logging cost indices: The effect of increasing the sample size. Starkville, MS: Wood Supply Research Institute. pp. 17.

Swedish Forest Agency. 2012. *Swedish Statistical Yearbook of Forestry 2012*. Jonkoping, Sweden. pp. 380.

Sydor, T. 2012. Wood Demand Report. Athens, GA: Center for Forest Business. 5(4): 8.

Tufts, R. A., B. L. Lanford, W. D. Greene & J. O. Burrows. 1985. Auburn harvesting analyzer. *The COMPILER,* Florence, AL: Forest Resources Systems Institute. 3(2)**:**2.

Tufts, R. A., J. Thurber, D. Simmons & B. Izlar. 1981. Forestry equipment cost index: 1968-1978. *Southern Journal of Applied Forestry,* 5(4)**:**201-204.

Vatavuk, W. M. 2002. Updating the CE Plant Cost Index. *Chemical Engineering,* 109(1)**:**62-70.

Wackerman, A. E. 1966. *Harvesting timber crops*. McGraw-Hill: New York.

Walter, M. J. 1998. *Documentation of productivity and efficiency relationships for a group of southern logging contractors*. M.S. Thesis. Virginia Polytechnic Institute and State University. Blacksburg, Va.

Wang, C.-h. & Y.-h. Mel. 1998. Model for forecasting construction cost indices in Taiwan. *Construction Management & Economics,* 16(2)**:**147-157.

Werblow, D. A. & F. W. Cubbage. 1986. Forest harvesting equipment ownership and operating costs in 1984. *Southern Journal of Applied Forestry,* 10(1)**:**10-15.

Windle, R. J. & M. E. Dresner. 1992. Partial productivity measures and total factor productivity in the air transport industry: limitations and uses. *Transportation Research Part A: Policy & Practice,* 26A(6)**:**435-445.

Woodall, C. W., P. J. Ince, K. E. Skog, F. X. Aguilar, C. E. Keegan, C. B. Sorenson, D. G. Hodges & W. B. Smith. 2011. An overview of the forest products sector downturn in the United States. *Forest Products Journal*, 61(8)**:**595-603.

Xu, Y., M. Smidt & Y. Zhang. 2014. Logging Worker Wage, Performance and Experience. *Forest Products Journal*, 64(5/6)**:**210-216.

APPENDIX A: LOGGER INTERVIEW FORM

Description of business

1) How many years have you been in the logging business?

2) What is your business structure?

Sole Proprietorship _____ LLC ____ Partnership _____

Corporation _____ Subchapter S_____

3) Is harvesting your company's only business? If no, what else?

4) What is your average weekly production?

5) What is your perceived breakeven weekly production?

6) What are your normal work hours (per week and per day)? How many days per week?

7) Do you run multiple logging crews?

8) How many employees per crew and total in your business?

9) How many total employees are working in the woods?

10) How many total markets do you deliver products to?

11) What is the average haul distance to each of these markets?

12) How many weeks per year do production quota negatively affect your production?

13) Describe the impacts of quotas on your production over the past year.

14) What is the source for the timber you harvest?

Company owned (contract harvest only) ______%

Purchased ______%

Dealer owned______%

Equipment Costs

15) What equipment do you currently operate in the woods, and what are the ages and original purchase price of each machine? (Use Attached Form)

16) Do you have any spare equipment not currently in use?

17) Do you typically purchase new or used equipment?

18) How do you determine when to purchase new equipment or replace existing equipment?

19) Do you finance equipment?

20) With whom do you pursue financing?

21) What level of financing do you try to maintain? Has this changed over time?

22) Do you lease any equipment?

23) What taxes or license fees are required on equipment?

24) Describe the insurance policies you maintain on equipment.

Operating Expenses

25) Do you keep track of off-road diesel consumption? If so, at what level of detail?

Daily by machine ____ Weekly by machine____ Daily per crew____

Weekly per crew_____ By fuel delivery_____ No record_____

26) What is your average fuel consumption?

_______ gallons per day ______gallons per ton _______ gallons per _______

27) Where do you purchase your off-road diesel?

Local retail station ____ Delivery to tank ____ Delivery to equipment ____

Other: ______________________________

28) If you utilize an off-road diesel tank, how many do you have? __________

What size(s) ______________ gallons

29) Do you maintain records of repair and maintenance costs by machine?

30) Who performs routine maintenance on your harvesting machines?

Owner ____ Full time mechanic ____ Part time mechanic____ Operator____

Equipment Dealer____ Subcontractor____

31) Who performs larger repair and maintenance tasks?

Owner ____ Full time mechanic ____ Part time mechanic____ Operator____

Equipment Dealer____ Subcontractor____

32) How many tires did you purchase for woods equipment in the past 12 months? At what cost?

33) What are your monthly costs in other machine consumables (e.g. hydraulic fluid, oil, grease…)?

34) Do you have other tools which are an annual expense for the company (e.g. chainsaws,)?

35) How much did you spend on road construction and BMP's in the past 12 months?

36) Do you employ a procurement forester?

Overhead Expenses

37) How many passenger trucks/vehicles does your company own? What is the annual business mileage driven on these vehicles?

38) How much are your rental or mortgage payments on any physical space for your business (e.g. shop, office, etc.)?

39) What services do you provide for in-house (e.g. accounting)?

40) Do you pay an administrative assistant or other office staff?

Labor Costs

44) How are your employees compensated?

All salary ____ All hourly wage ____ ___ No. salary ____ no. wage

By production _____ Per day ____

45) Do machine operators earn a different rate than each other and/or a foreman?

46) Are there any bonuses paid?

47) Do you pay yourself a salary?

48) What is your workers comp rate?

__________ per ton   __________ per month   ___________ per $100 payroll

49) What is your experience mod?

50) Do you offer any additional employee benefits?

____ Retirement   ____ Health Ins.   ____ Vacation   ____ Sick leave

____ Transportation   ____ Holiday Bonus   ____ Other __________________

51) What has been your employee turnover in the past 24 months?

52) Is there sufficient available labor to meet your company's needs?

53) Do you hire any contract labor?

Trucking

54) What percent of contract trucking do you perform?

55) What rates do you pay for contract trucking?

Base miles _____________ Per ton-mile ___________________

56) Do you insure contract truckers?

57) How many over-the-road trucks and trailers do you own?

58) What is the average fuel mileage for your tractor-trailers (mgp)?

69) How much fuel do your trucks consume in an average day/week?

60) Where do you purchase fuel for your on-road trucks?

Local retail station _____ Tank on property ______ Other __________________

61) If you own a tank for highway diesel, what size? ______________ gallons

62) Are contract trucks able to utilize your diesel tanks?

63) How much have you paid in overweight and safety inspection fines in the past 12 months?

$______ overweight $_______ safety inspection

64) Do you utilize on-board or in-woods scales?

65) How do you pay your drivers?

Per ton-mile ____ Hourly _____ Salary _____ Per ton or load ____

66) What are your costs for operating trucks?

Participant # ____________

Operating Equipment List

2014 Logging Cost Study

Felling

Model	Age	Original Price (if less than 5 yrs.)

Skidding

Model	Age	Original Price (if less than 5 yrs.)

Loading

Model	Age	Original Price (if less than 5 yrs.)

Other

Model	Age	Original Price (if less than 5 yrs.)

Summary of Cost Categories

Calendar Year 2012

	Logging	Hauling
Labor		
Depreciation		
Interest Expense		
Repair & Maintenance		
Tires		
Fuel		
Other Consumables		
Administrative		
Insurance		
Contract Hauling		
Total Cost		
Annual Production (Tons)		

Summary of Cost Categories

Calendar Year 2013

	Logging	Hauling
Labor		
Depreciation		
Interest Expense		
Repair & Maintenance		
Tires		
Fuel		
Other Consumables		
Administrative		
Insurance		
Contract Hauling		
Total Cost		
Annual Production (Tons)		