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economics

Employment and Wage Impacts of Timber Harvesting and Processing in the United States

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Each unit of timber has some number of jobs and income associated with it. We developed regional estimates of employment per million cubic feet of timber harvested, referred to as employment direct response coefficients (DRCs), and wages per worker in 16 sectors of the US primary forest products industry. Estimates are based on timber product output and federal employment data. These estimates offer comparisons of direct timber processing employment associated with various sectors and geographic regions. They also provide potentially more accurate direct impacts that can be used in conjunction with input-output analysis to estimate indirect and induced impacts. Results show substantial differences among regions and industry sectors. The lowest employment DRCs among timber processing sectors are in the biomass energy and oriented-strandboard sectors. The hardwood plywood/veneer, log home, and log furniture sectors have the highest employment ratios. Workers in the pulp and paper sector are among the highest paid in the forest products industry. The capital intensity of the facilities, the variety of products produced, and the degree of manufacturing contribute to ratio differences among sectors and regions.

Keywords: direct response coefficients, employment ratios, forest economics, forest industry, timber product output

The forest products industry was severely affected by the Great Recession and related housing collapse. Timber harvest and use declined dramatically, forest product output levels hit lows not seen in decades, and accompanying job losses were substantial (Woodall et al. 2012). This article gives insight on the employment and wage impacts that states or regions reliant on harvesting and processing timber may expect as the economy and forest products markets recover.

In an effort to better quantify the economic impacts of timber harvesting and forest product manufacturing throughout the United States, we used information from previous studies and public databases to estimate recent *direct* employment and wage impacts created for a given volume of timber harvested. The wage and employment impacts per unit of timber harvested are referred to as direct response coefficients (DRCs).

Federal land managers have developed and continue to use input-output (I-O) models with periodically updated DRCs to improve estimates of economic effects (e.g., employment, income, and taxes) of proposed forest management activities such as those associated with the Collaborative Forest Landscape Restoration Program (USDA Forest Service 2014a), National Forest Assessments (USDA Forest Service 2014b, 2014c), and National Economic Contribution Report (USDA Forest Service 2013a). These DRCs are useful at the project planning, forest planning, and national strategic planning levels (USDA Forest Service 2013b). However, the major impetus for DRC development is compliance with policy mandates. Internal agency policies (e.g., the Forest Service Handbook and Forest Service Manual) call for these analyses, and practical concerns dictate an understanding of project costs and benefits relative to program budgets (USDA Forest Service n.d.).

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Periodically updated DRCs can be used to supplement *direct* employment and income response coefficients generated from a nonsurvey type I-O model such as IMPLAN. The data sources discussed and the resulting DRCs improve estimates of direct employment and wage effects. These estimates have been used by I-O practitioners to improve the estimated direct effects of forest management and timber processing (USDA Forest Service 2013a). Furthermore, local collaborative groups appreciate the fact that local information is used in the economic modeling process to produce the results tailored to a specific region.

In this article, state or regional estimates of annual direct private sector employment and wages associated with harvesting and processing timber throughout the United States, referred to as the primary forest products industry, are provided. The primary forest products industry, as discussed here, includes logging, processing logs into lumber and other wood products, and processing wood residues from timber processing plants into outputs such as paper, particleboard, fiberboard, or electricity. The secondary industry includes the further processing of the outputs from the primary manufacturers, regardless of the location of the primary manufacturers.

Employment is expressed as number of workers per unit volume of timber harvested and processed on an annual basis, and timber volume is expressed in million cubic feet (MMCF) of logs inside bark. Wages are expressed in thousands of dollars annually per job. The following 16 forest products industry sectors are examined:

- Forestry and logging
- Softwood sawmills
- Hardwood sawmills
- Facilities using residue from sawmills
- Softwood plywood/veneer plants
- Hardwood plywood/veneer plants
- Facilities using residue from plywood/veneer plants
- Oriented-strandboard (OSB) and other structural composite panel manufacturers using roundwood
- Pulp and paper mills processing roundwood pulpwood
- Small (<5 MMCF annual input) biomass energy plants
- Large (>5 MMCF annual input) biomass energy plants
- Post and pole manufacturers
- Utility pole manufacturers
- House log and log home manufacturers
- Log furniture manufacturers
- Facilities processing wood fiber (mill) residue from mills other than sawmills and plywood/veneer plants

These sectors account for >99% of the timber volume harvested for industrial products in the United States (Smith et al. 2009). Residential fuelwood (firewood) is not included in this analysis.

Methods and Data Sources

The calculation of DRCs requires data on the volume of timber harvested and processed by various sectors of the forest products industry, the use of mill residue generated in processing timber, and the employment and wages associated with each of these activities. Publicly available national employment and timber product output databases, recent and ongoing mill censuses, and other sources were used to calculate DRCs for various geographic regions. Employment DRCs were estimated for individual states where possible and then combined into geographic regions with similar industry structures (Figure 1). When multistate regions were used, states were grouped, and the DRCs were volume-weighted by each state's proportion of harvest volume by timber product to allow release of sector level information. Four states (i.e., Hawaii, Kansas, North Dakota, and Nebraska) are not included in the analysis because of small numbers of facilities and limited data availability.

The most comprehensive and nationally consistent source of information on timber harvest and use by the forest products industry is the Forest Inventory and Analysis (FIA) Resources Planning Act (RPA)/Timber Product Output (TPO) publication (Smith et al. 2009) and TPO database (USDA 2012). The TPO database contains timber harvest volumes by species, ownership, and timber product type, as well as mill residue type, volume, and use. TPO data used in this article are for the "2012 RPA year," which were developed from state-level mill censuses from 2005 through 2011 (e.g., Johnson et al. 2011, Gale et al. 2012, Piva and Josten 2013). The censuses contain facility-level information on timber and mill residue characteristics, use, and employment.

The North American Industry Classification System (NAICS) provides the framework for grouping establishments into industries based on the activities in which they are engaged (US Department of Labor, Bureau of Labor Statistics 2014). Under the NAICS system, annual employment and wages are reported at various levels of specificity. The system is hierarchical, using two- to six-digit industry codes to classify and report economic activity. Various federal and state data sets report employment and other economic variables at the state and county levels using the NAICS categories. Employment data corresponding to the individual states' TPO data years were used for the employment DRCs, and 2011 wage data were used for the wage DRCs. Three federal databases used in this analysis offer annual employment by industry sector with varying levels of detail: US Department of Commerce, Bureau of Economic Analysis, Regional Economic Information System (REIS) (2014a), US Department of Commerce, Census Bureau, County Business Patterns (CBP) (2014b), and the US Department of Labor, Bureau of Labor Statistics (2013), Quarterly Census of Employment and Wages.

When adequate sector-level specificity

Management and Policy Implications

Harvesting and processing timber are important sources of jobs and wages, especially in rural communities throughout much of the United States. The employment and wage direct response coefficients (DRCs) provided in this article will be useful for assessing the direct economic impacts of dynamic harvest levels, changes in the mix of timber products offered from management activities, and changes in industry structure. This information will allow forest managers to identify which timber products from their lands produce higher versus lower levels of employment and wages in the area. The DRCs may also be useful for economic analysis of policy formulations that significantly increase or decrease harvest levels in a region or policies that favor one industry sector over another, for example, the use of wood fiber for biomass energy versus manufacturing pulp and paper. These DRCs can be used in conjunction with other research such as input-output modeling, which can be used to calculate broader economic impacts such as indirect and induced employment.

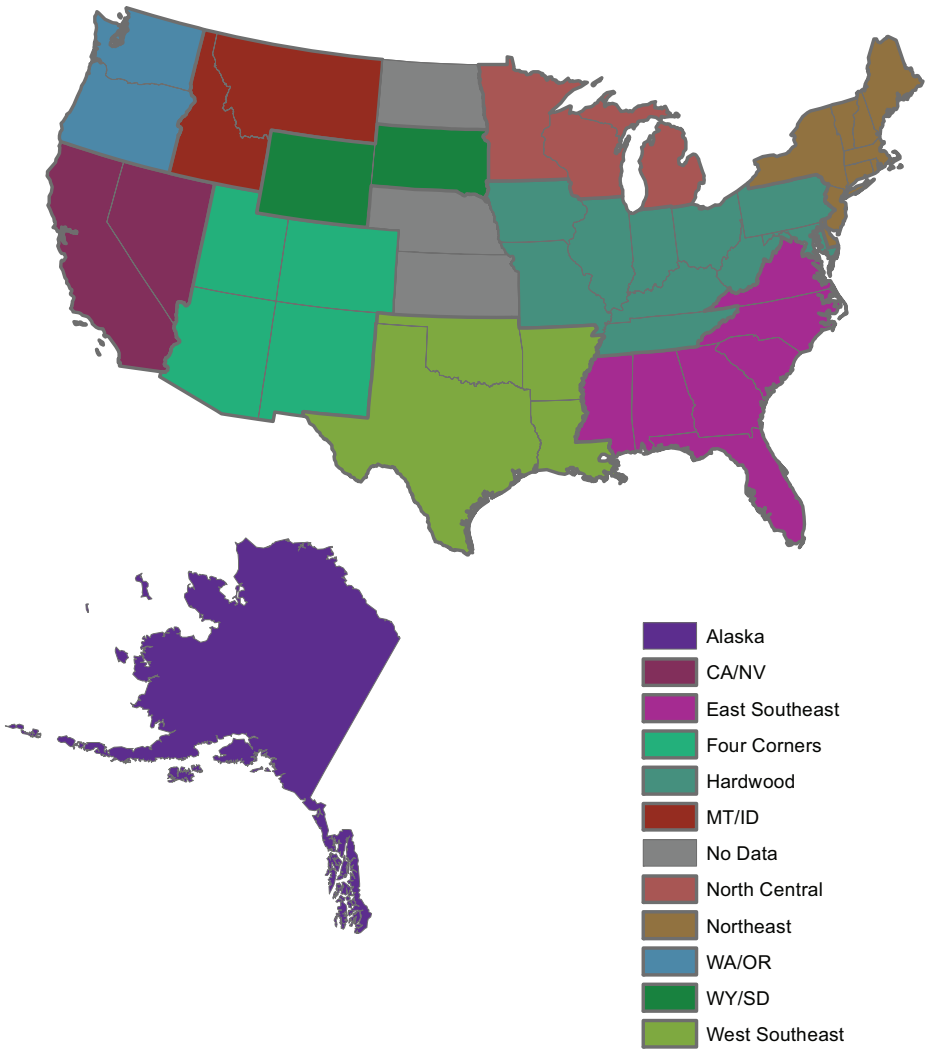

Figure 1. Direct response coefficient regions.

was available, employment DRCs were constructed at the state level by using total employment by sector from the federal employment databases and the volume of timber from the TPO database. Mill censuses, coordinated by the various FIA units, provide data on timber or mill residue processed and employment for individual facilities in numerous states throughout the country. These were used to corroborate employment DRCs estimated from CBP data. Mill censuses and other sources (e.g., Spelter et al. 2006, Western Wood Products Association [WWPA] 2006–2012) were used to develop employment DRCs for sectors for which CBP employment data were not available. The FIA-coordinated mill censuses and other sources also provide information on structural and operational characteristics such as milling equipment, capacity and operating levels, and the range of products produced.

In states with both softwood and hardwood sawmills, a DRC for all sawmills was calculated for each state. The TPO data were then used to identify the percentage of softwood versus hardwood sawlog volume for each state, and DRCs for all-softwood and all-hardwood sawmills in the region were used to apportion the sawmill DRCs to softwood versus hardwood components. The regional DRCs for hardwood and softwood sawmills were then calculated as the volume-weighted average of hardwood and softwood sawmill DRCs for each state.

The initial DRC estimates for states were made by dividing state-level hardwood and/or softwood veneer/plywood sector (NAICS 321211 and 321212) employment as reported in CBP by the hardwood or softwood veneer log volumes in the TPO database. These initial estimates were verified using mill censuses. However, because of the broad range of facilities and the fact that hardwood veneer logs are often shipped long distances (Widmann et al. 1998), only a nationwide employment DRC is presented for hardwood veneer and plywood.

Employment in the pulp and paper, OSB, mill residue, energy, and five other timber processing sectors is based on mill census data and other sources. The use of mill-level data allowed us to precisely identify all of the sources of fiber processed. This was especially important in dealing with facilities such as pulp and paper mills and power plants that use mixes of mill residue, timber in round form, and other sources of fiber such as recycled paper or urban wood waste. The total volume of fiber was used to estimate fiber use at the plant in units equivalent to wood fiber in cubic feet of wood, solid wood equivalent (SWE). This cubic feet SWE was divided into the employment reported at the mill to yield a DRC for that facility.

National or multiregion averages are presented when the number of facilities was too small for state-level reporting. Employment in many of the smaller sectors such as post, pole, and log home producers is reported in categories (e.g., NAICS 32199 or 321999) that include a variety of facility types. In these cases, summary data from the mill censuses were used to develop DRCs.

The employment DRCs for mill residue from sawmills and plywood plants and for the other sectors represent the employment generated when a given volume of a timber is processed at a facility and the resulting mill residue is used as raw material or fuel at another facility. The proportionate uses of mill residue and employment per unit volume of wood fiber processed by the various sectors were utilized to calculate a volume-weighted mill residue DRC for sawmills, plywood/veneer plants, and other timber processors.

Calculation of Wage DRCs

TPO mill censuses do not report payroll, wages, or earnings per worker. Therefore, annual wages per employee by the timber processing sector were derived from the CBP data and the REIS wage and salary employment data. Wage DRCs are rounded to the nearest $5,000 and represent annual wages per worker using employment and wage data from calendar year 2011, the most recent available data at the time of this analysis.

Wages and salaries for *forestry and logging* (NAICS 113) were estimated using Ta-

Table 1. Employment DRCs by industry sector and region (number of jobs per MMCF of timber harvested, excluding fuelwood).

Industry sector	Alaska	CA/NV	WA/OR	MT/ID	Four Corners	WY/SD	North Central	West Southeast	East Southeast	Hardwood	Northeast
Forestry and logging	14	18	11	12	32	14	15	9	8	18	22
Softwood sawmills	20	15	12	14	17	12	14	9	11	15	12
Hardwood sawmills	—[a]	—[a]	—[a]	—[a]	—[a]	—[a]	28	30	28	26	25
Residue (sawmills)	2	3	5	5	6	4	4	4	4	4	4
Softwood plywood/veneer	—[a]	—[a]	31	32	—[a]	—[a]	—[a]	17	22	—[a]	—[a]
Hardwood plywood/veneer	—[a]	—[a]	—[a]	—[a]	—[a]	—[a]	80	80	80	80	80
Residue (plywood/veneer)	—[a]	—[a]	4	4	—[a]	—[a]	4	4	4	4	4
OSB and other structural composite panels	—[a]	—[a]	—[a]	—[a]	—[a]	—[a]	8	8	8	8	8
Roundwood for pulp and paper	—[a]	9	9	9	9	—[a]	9	9	9	9	9
Energy—large	—[a]	2	2	2	2	—[a]	2	2	2	2	2
Energy—small	10	10	10	10	10	10	10	10	10	10	10
Other mills											
Post and pole	—[a]	15	15	14	15	15	—[a]	30	30	—[a]	—[a]
Utility pole	—[a]	14	14	14	14	14	—[a]	11	11	—[a]	—[a]
House log/log home	100	100	100	100	100	100	75	75	75	75	75
Log furniture	125	125	125	125	125	125	125	125	125	125	125
Residue (other mills)	2	2	2	2	2	2	2	2	2	2	2
States in each region	Alaska	California Nevada	Oregon Washington	Idaho Montana	Arizona Colorado New Mexico Utah	Wyoming South Dakota	Michigan Minnesota Wisconsin	Arkansas Louisiana Oklahoma Texas	Alabama Florida Georgia Mississippi North Carolina South Carolina Virginia	Illinois Indiana Iowa Kentucky Maryland Missouri Ohio Pennsylvania Tennessee West Virginia	Connecticut Delaware Maine Massachusetts New Hampshire New Jersey New York Rhode Island Vermont

[a] Value not reported either due to lack of industry in the region, or to maintain confidentiality of existing operations.

ble SA07N (Wages and Salaries by NAICS Industry) from REIS. The REIS data were deemed superior to CBP for this sector because CBP is based on a given date and is more affected by the seasonal nature of the logging industry. For the timber processing sectors, it was not possible to develop earnings DRCs in each sector and state using CBP and QCEW. For the larger sectors (softwood and hardwood veneer and plywood, OSB, and pulp and paper), CBP provided sufficient detail on employment and total wages to estimate wages per worker directly. For hardwood and softwood sawmills and residue from sawmills and plywood/veneer plants, estimation of wages required using wages from multiple sectors, weighted by the volume of wood fiber used by each sector. For example, the major users of sawmill residue in many states were pulp and paper mills, reconstituted board plants, and the energy sector, with small volumes going to other uses. The wages estimated for workers processing residue were based on the wages of workers in these sectors and the proportion of mill residue used by each sector.

Wages per worker for the larger energy plants were based on CBP nationwide averages for *sawmills* (NAICS 321113) and *other electric power generating plants* (NAICS 221119). These two categories were used because the large energy facilities category includes facilities that are colocated and jointly operated with large sawmill operations, as well as stand-alone facilities that generate energy. Wages for small energy producers and "other mills" were estimated based on the broader NAICS categories with which they are associated.

Results and Discussion

Employment DRCs by Sector

Employment DRCs, expressed as workers per MMCF of timber, are presented in Table 1. Substantial differences exist among regions and industry sectors. These differences are discussed below. The timber use by mill type information is based on censuses rather than on a sample of wood product manufacturers. Federal employment data bases are likewise populated primarily with industry censuses. Because the data are based on censuses, they are not the results of stochastic analysis and therefore have no sampling error (US Department of Commerce, Census Bureau, County Business Patterns 2015).

Forestry and Logging. The lowest employment DRCs in the *forestry and logging* sector are found in the Southeast regions at eight to nine workers per MMCF. Contributing to relatively low DRCs in these regions are long operating seasons, high volumes of relatively homogeneous timber, and the prevalence of plantations, all of which facilitate mechanized harvesting. The Northwest states (i.e., Oregon, Washington, Idaho, and Montana) have somewhat higher employment DRCs because of more cable yarding, and hand felling of larger timber is more common.

California and Nevada and the Hardwood states have *forestry and logging* sector employment DRCs of 18, approximately twice that of the Southeast regions. A higher percentage of timber in California is hand felled and merchandized before skidding; this is also the case with hardwood sawtimber. Harvested trees in California are the largest in the western continental United States and probably in the nation (Keegan et al. 2010). These larger trees have relatively high value and require more merchandising, and the merchandising is more often done by hand where the tree is felled. The hardwood sawlogs and veneer logs harvested in the Hardwood states are a high-value, nonhomogeneous resource that requires considerable merchandising. Quality hardwood logs tend to be found in relatively low volumes per acre and often on steeper terrain,

making mechanized harvest systems uneconomical. The hand felling and log-length skidding that are common in California and the Hardwood states are more labor intensive than mechanical harvesting and tree-length skidding, which are much more prevalent in the Northwest and Southeast.

The highest employment DRCs for *forestry and logging* are in the Four Corners states. These higher DRCs are thought to primarily be a function of relatively low timber harvest volumes and the Forest Service's significant use of stewardship end-result contracts in the region, which include multiple objectives and activities in addition to logging (Moseley and Davis 2010). The logging workforce in the Four Corners states historically has comprised more part-time operations than those in regions with higher timber production. To put harvest levels in perspective, the total harvest in the Four Corners states was 46 MMCF, for an average of <12 MMCF per state, compared to a harvest of 4,567 MMCF in the eastern Southeast states, an average of 652 MMCF per state (USDA 2012).

Softwood Sawmills. The lowest employment DRCs for the *softwood sawmills* sector are in the major US lumber-producing regions. The lowest DRC was nine workers per MMCF in the western Southeast states, followed by 11 in the eastern Southeast states. Oregon and Washington and Idaho and Montana had 12 and 14 workers per MMCF, respectively. These regions are dominated by large, highly automated sawmills, many of which have the capability to process smaller logs at high speed. The somewhat higher employment DRC in California, which is typically the third- or fourth-largest lumber-producing state behind Oregon, Washington, and occasionally Georgia (WWPA 2006–2012), stems from the fact that sawmills in California process relatively large timber (Morgan and Spoelma 2008, Keegan et al. 2010), more of which is sawn for grade rather than maximum volume recovery (Keegan et al. 2010). Regions with low levels of timber harvest, such as the Four Corners states and Alaska, have more multiproduct sawmills that produce an array of specialty products such as house logs in addition to softwood lumber (Halbrook et al. 2009, Hayes et al. 2012).

Hardwood Sawmills. Regional DRCs in the *hardwood sawmills* sector ranged from 25 to 30 workers per MMCF of timber processed. Hardwood sawmills generally produce higher value products than softwood sawmills and have production processes that focus more on value than on volume. Hardwood mills tend to be smaller, are somewhat less mechanized, and often produce a wider array of lumber products. They also are more likely to have a remanufacturing component directly associated with the lumber production, further contributing to the higher DRCs than those of softwood sawmills in most regions.

Plywood/Veneer. More workers per MMCF of timber processed are employed to manufacture softwood plywood and veneer in the western regions versus the southeastern regions. This is probably because of a strong emphasis among western firms on specialty plywood products such as marine grade plywood, specialty siding, and underlayment (Spelter et al. 2006).

Employment DRCs for the *hardwood plywood/veneer* sector were difficult to estimate for a number of reasons. First, the industry sector contains a broad mix of types and sizes of facilities. Included are facilities that produce only veneer from logs and veneer and plywood from logs, as well as facilities that produce plywood from purchased veneer. Hardwood plywood also often has one or more layers of softwood veneer in the core, confounding a simple calculation using only hardwood veneer log volume as the denominator. Further, there is considerable log flow and purchase of veneer across state lines (Perry et al. 2010). Hardwood veneer logs have historically moved substantial distances, including overseas, making harvest and point of processing difficult to identify, thus causing difficulty in matching harvest and use (Widmann et al. 1998).

State-level employment DRCs for *hardwood plywood/veneer* ranged from 25 to >1,500 workers per MMCF in individual states. However, states at the high end of the range represent a very small portion of the regional total and do not have a significant impact on regional averages. This phenomenon is evident in states that process logs or veneer from other states. The 80 workers per MMCF average presented in Table 1 for *hardwood plywood/veneer* appears to be a reasonable estimate based on the employment DRCs calculated for the major states harvesting hardwood veneer logs. When DRCs are used for hardwood veneer logs in particular, it is important to know the local and regional industry structure and consider where the timber is expected to be processed.

House Log/Log Home and Log Furniture. The DRCs for house log manufacturers are 100 jobs per MMCF in the western regions and 75 in other regions of the country. Log furniture manufacturing was found to have an average of 125 jobs per MMCF throughout the country (Table 1). Both of these sectors have wide ranges of employees per MMCF at individual facilities and high average DRCs because they often do considerably more processing of logs and more hand-crafting than other sectors of the forest products industry. Softwood sawmills are generally highly automated and process logs into finished lumber, which is then sold for use in construction or remanufacturing at secondary facilities. A few log home plants may produce only house logs, but many log home plants produce custom-designed shells or full homes, as well as log accents or other hand-crafted features. Based on the mill surveys and census done in support of the RPA/TPO process, log furniture plants likewise make a wide range of products, and the initial processing of the logs is often a very small portion of the labor required to complete the finished furniture products (McIver et al. 2013).

OSB, Pulp, and Paper. Table 1 reports employment DRCs for the *OSB and other structural composite panels* sector (eight employees per MMCF) and the *roundwood for pulp and paper* sector (nine employees per MMCF) as national averages. Limited information is available for most states because of the limited number of facilities in each state. The number of workers per MMCF appears similar among states with data, and the data do not provide sufficient detail to refine estimates by region. These sectors are dominated by large, highly capital-intensive facilities which tend to employ few workers per unit of input. As discussed in the Wages per Worker section below, workers in these sectors are among the highest paid in the forest products industry.

Roundwood to Energy Facilities. Numerous facilities throughout the country use timber in round form to produce energy in the form of process heat and steam, electricity, and fuel pellets. The use of wood by these energy facilities results in relatively low employment per volume of wood fiber because most simply combust the wood rather than manufacture it into value-added products. Even in the case of pellet mills, operations involve a relatively simple manufactur-

Table 2. Wage DRCs by industry sector and region (annual wages in thousands of 2011 dollars per worker).

Industry sector	Alaska	CA/NV	WA/OR	MT/ID	Four Corners	WY/SD	North Central	West Southeast	East Southeast	Hardwood	Northeast
Forestry and logging	50	40	50	40	40	35	35	40	35	25	40
Softwood sawmills	35	45	45	40	25	35	35	40	40	30	40
Hardwood sawmills	—[a]	—[a]	—[a]	—[a]	—[a]	—[a]	35	30	30	30	30
Residue (sawmills)	30	55	55	55	35	35	50	50	50	45	45
Softwood plywood/veneer	—[a]	—[a]	45	45	—[a]	—[a]	—[a]	40	40	40	—[a]
Hardwood plywood/veneer	—[a]	—[a]	—[a]	—[a]	—[a]	—[a]	40	40	35	40	35
Residue (plywood/veneer)	—[a]	—[a]	55	55	—[a]	—[a]	50	50	50	45	40
OSB and other structural composite panels	—[a]	—[a]	—[a]	—[a]	—[a]	—[a]	50	50	45	45	45
Roundwood for pulp and paper	—[a]	—[a]	75	75	—[a]	—[a]	65	75	75	65	65
Energy—large	—[a]	60	60	60	60	60	60	60	60	60	60
Energy—small	30	30	30	30	30	30	30	30	30	30	30
Other mills[b]	30	30	30	30	30	30	30	30	30	30	30
States in each region	Alaska	California Nevada	Oregon Washington	Idaho Montana	Arizona Colorado New Mexico Utah	Wyoming South Dakota	Michigan Minnesota Wisconsin	Arkansas Louisiana Oklahoma Texas	Alabama Florida Georgia Mississippi North Carolina South Carolina Virginia	Illinois Indiana Iowa Kentucky Maryland Missouri Ohio Pennsylvania Tennessee West Virginia	Connecticut Delaware Maine Massachusetts New Hampshire New Jersey New York Rhode Island Vermont

[a] Value not reported either due to lack of industry in the region or to maintain confidentiality of existing operations.
[b] Other Mills includes post and poles, utility poles, house log/log homes, log furniture, and mills that process residues from these plants.

ing process compared to those of other wood fiber users. There are substantial economies of scale among energy facilities (including pellet manufacturers), and separate employment DRCs were calculated for large energy facilities (two employees per MMCF), defined as processing >5 MMCF of wood fiber annually, versus small facilities (10 employees per MMCF) that process <5 MMCF annually.

Post and Pole and Utility Pole. Employment DRCs for the *post and pole* sector and *utility pole* sector were calculated for those states and regions with sufficient data. A post and pole DRC of 14–15 workers per MMCF is consistent throughout the western regions, whereas the western utility pole sector has a DRC of 14 jobs per MMCF of timber. However, the DRCs in the southeast regions are divergent, with 30 workers per MMCF in the *post and pole* sector and just 11 jobs per MMCF in *utility poles*. It is believed there is higher employment associated with post and pole plants in the Southeast regions because many of these facilities have treating plants that chemically treat posts and poles and other forest products (e.g., lumber).

Residue (Sawmills and Plywood/Veneer). The use of the mill residue from 1 MMCF of logs processed at sawmills typically generates three to five additional jobs (Table 1). Alaska has the lowest DRC (i.e., two employees per MMCF) for sawmill residue, because a relatively high proportion of Alaska mill residue goes unused (Halbrook et al. 2009, USDA Forest Service 2012). Somewhat higher employment DRCs for mill residue in Idaho and Montana and Oregon and Washington are due to a higher percentage of residue being used by the pulp and paper and reconstituted board sectors in these states versus more mill residue being used for energy in the eastern regions and California (Johnson et al. 2011, USDA Forest Service 2012, Morgan et al. 2012). The Four Corners states have the highest employment DRC (i.e., six workers per MMCF) for sawmill residue. Residue use in this region is dominated by facilities producing animal bedding, decorative bark, and landscape material, which are usually smaller and more labor intensive (Hayes et al. 2012) than biomass energy, pulp mills, and particleboard plants (Gale et al. 2012, Morgan et al. 2012). The national average DRC for plywood/veneer plant mill residue is four employees per MMCF of timber processed.

Residue (Other Mills). Mill residue from other timber-processing facilities has an employment DRC of two workers per MMCF of timber processed. The DRC is relatively low because less of the residue from these other mill types is used to manufacture products and more is unused, given away, or used as industrial fuelwood or residential firewood.

Wages per Worker

Workers at mills, especially the categories dominated by large facilities, generally earn more than workers in the woods (Table 2). Based on state-level employment and wage and salary data for *forestry and logging* (NAICS 113) in REIS, the regional average wages and salaries per employee vary from $25,000 in the Hardwood states to $50,000 in Alaska and $50,000 in Oregon and Washington.

The wages per worker in the remainder of the sectors were derived from CBP data due to the greater sector-level detail down to 6-digit NAICS codes. The highest annual wages per worker are typically found in sectors dominated by large, highly capital-intensive plants such as pulp and paper mills, OSB plants, and large sawmills and plywood plants. The pulp and paper sector is the major user of mill residue throughout most of the country, which contributes to high wages in the residue sectors. The sawmill and plywood/veneer residue sectors also have relatively high wages because in most regions of the country the residue from these sectors goes to the pulp and paper industry as well as medium-density fiberboard (MDF) and particleboard producers, which also pay relatively high wages.

The *softwood sawmill* sector wages vary from $25,000 per worker in the Four Corners states to $45,000 per worker in Oregon and Washington and California.

The low wages for lumber production in the Four Corners states stem from the fact that many of the operations in the region operate on a part-time basis (Hayes et al. 2012). This is in contrast to most other regions, which are characterized by large sawmill industries with high-volume mills employing full-time workers throughout the year.

There is less variation in wages per worker among regions in the *softwood plywood/veneer* sector, which has annual wages per worker of $40,000 in the Hardwood states and the Southeast states and $45,000 in the two regions of the northwestern United States (Oregon and Washington and Idaho and Montana) that have softwood plywood manufacturing sectors. A *hardwood plywood/veneer* sector exists in the North Central states, the Hardwood states, the Northeast states, and the two southeastern regions. Whereas the hardwood veneer log harvest is only 11% of the total veneer log harvest in the 2012 RPA/TPO data set (USDA Forest Service 2012), >45% of the jobs, 40% of the wages, and 70% of the establishments in the plywood sector are in the hardwood plywood sector. This is consistent with the much higher employment DRCs per unit of timber harvested and smaller average size of each hardwood plywood plant, compared with those of softwood plywood plants.

The *other mills* sector in Table 2 includes posts and poles, utility poles, house log/log homes, log furniture, and mills that process residue from these facilities. Because of the lack of wage data for these individual sectors by state, a national average annual wage for these mills was calculated, which came to $30,000 per job. It should be noted that this aggregated sector has a wide range of wages per job, depending largely on the degree of processing of the products and the proportion of jobs that are full-time as opposed to part-time.

Illustrating the Use of Direct Response Coefficients

To illustrate the use of the DRCs reported in this paper, the following example is provided. A timber sale program of 10 MMCF annually is offered by a landowner with property in Oregon and Washington with the expectation that 75% of the timber will go to sawmills, 20% will be processed by the pulp and paper industry, and 5% will be processed by utility pole plants. The expected annual employment and wages from the harvesting and processing of those logs are as follows:

- Harvesting the 10 MMCF of timber would employ 110 workers, each earning $50,000 per year, for $5.5 million in total annual wages.
- The processing of 7.5 MMCF of logs into lumber at Oregon and Washington sawmills would employ 90 more workers, each earning $45,000 per year, for $4.05 million in total annual wages.
- The use of the sawmill residue at other facilities would employ an additional 37.5 workers, each earning $55,000 per year, for $2,062,500 in total annual wages.
- The processing of 2 MMCF of logs at Oregon and Washington pulp and paper mills would employ 18 more workers, each earning $75,000 per year, for $1.35 million in total annual wages.
- The processing of 0.5 MMCF of logs at Oregon and Washington utility pole plants would employ seven and a half more workers, each earning $30,000 per year, for $225,000 in total annual wages.
- The use of the utility pole residue at other facilities would employ one additional worker, earning $30,000 per year.

Thus, the total *direct* private sector employment from harvesting and processing 10 MMCF of logs in Oregon and Washington based on the assumed product use would be 264 workers for a year, with total annual wages of $13,217,500 in 2011 dollars. As indicated in the introduction, these DRCs represent the direct employment related to harvesting and primary processing of timber. The operations of the industry and related expenditures, as well as the spending of the workers directly employed, generate additional (i.e., indirect and induced) employment in other sectors of the economy, as does the further processing of the outputs by the secondary industry. If the data user's goal is to fully account for the *total* employment associated with forest management in a region, these DRCs should be used in conjunction with other research such as input-output modeling (e.g., IMPLAN), which can be used to calculate broader economic impacts, including indirect and induced employment.

Conclusions

In examining the DRCs for the primary forest products industry, this article illustrates that there is considerable variability by industry sector and region. For example, employment in logging is influenced by terrain, timber size and quality, and the volume of timber harvested in a given area. Other major factors influencing DRCs are the length of operating seasons, which vary depending on the weather patterns and climate from one region to another. Lower DRCs tend to correlate with industry sectors that are more capital intensive and specialize in higher volumes of similar products. The southeastern United States, with a large industry, long operating season, relatively gentle terrain, and relatively homogeneous resource of young-growth (pine) plantation timber makes considerable use of mechanized harvesting and has the lowest employment DRCs in *forestry and logging* (eight to nine workers per MMCF).

The lowest employment DRCs in the primary wood product manufacturing sectors are found at highly capital-intensive facilities such as pulp and paper mills, OSB plants, and large wood energy facilities. These facilities also have the highest wages per worker and low variability in DRCs among regions. Large softwood sawmills are the major industry component in much of the West and the South. These mills are also comparatively capital intensive and make relatively homogeneous products compared with those of hardwood sawmills and have lower DRCs and higher average wages.

The hardwood sawmill and plywood industry, the log home industry, and the log furniture industry have high employment DRCs because they use relatively low capital-intensive facilities to produce high-value products and add considerable value through remanufacturing. To illustrate, softwood sawmills generally process logs into well-defined grades of finished lumber, which is then sold for use in construction or remanufacturing. Hardwood sawmills and plywood/veneer plants often produce a range of high-value products that do not lend themselves to high-volume processing. In addition, these hardwood mills often have manufacturing processes in addition to production of the primary product—lumber or plywood/veneer. Log home plants often produce custom-designed shells or full homes, and log furniture plants not only peel logs but manufacture them into custom-built pieces of furniture.

The degree of processing also affects employment at large wood energy producers versus large facilities such as pulp and paper mills or OSB plants, which can use similar inputs. The large wood energy fa-

cilities (e.g., pellet plants and biomass electricity facilities) have fewer employees per unit volume of wood fiber compared to OSB plants or pulp mills because energy operations typically have a less complex manufacturing process than pulp mills or OSB plants.

Using mill residue from the primary processing of logs is also important to consider when employment impacts from timber processing are estimated. For example, the use of the mill residue from 1 MMCF of logs processed at sawmills typically generates three to six additional workers. The softwood lumber industry, which produces the largest volumes of mill residue in most states, supports approximately one worker processing residue for every three workers employed at softwood sawmills.

The DRCs presented in this analysis reflect the relationship between direct employment (and wages) and timber harvested in different regions of the country. They can be readily used to portray how much employment and wages are directly associated with a volume of timber harvested and processed by geographic region and industry sector. These DRCs are useful to estimate near-term changes in employment and wages that would occur with different levels of timber harvest volume and/or different mixes of timber products being offered. Relatively small (<1 MMCF) shifts in harvest volume can cause impacts different from those that the DRCs suggest, particularly in very small geographic areas or where substitute volumes are readily available. The DRCs yield the most accurate results if they are used to estimate impacts of relatively large (>1 MMCF), near-term changes in total harvest volume in a given area. The DRCs may not accurately reflect changes due to an individual timber sale. Rather, they offer an average associated with timber harvested and processed in a region and provide reasonable near-term estimates of the direct employment and wage impacts of an agency's or company's timber program in a multicounty area, state, or multistate region.

The DRCs presented are conservative estimates in that they deal only with the direct employment in the primary forest products industry and do not include the secondary industry, forestry support service, or log hauling/trucking. Data for the log hauling/trucking sector are reported in industry categories (e.g., NAICS 484 or 484220) that include other types of trucking, making it difficult to identify the components directly associated with timber harvesting and primary wood/paper product manufacturing. Likewise, forestry support services (NAICS 1153) includes some employment that may be associated with timber harvesting but also includes firefighting and pest control.

The secondary industry includes the further processing of the outputs (e.g., lumber, plywood) from primary manufacturers, regardless of the location of the primary manufacturers. The distinction between primary and secondary is not always clear. Portions of the secondary industry in some regions are directly linked and highly integrated with the primary industry. Examples include hardwood furniture manufacturers in states with large hardwood sawmill and veneer industries and cut-stock manufacturers in some western and southern states. Other portions of the secondary industry may have limited links to and dependence on the local timber resource and primary industry and may respond differently or not at all to changes in forest management. Awareness of the region's timber supply, primary and secondary industry structure, and timber flow is important for appropriately using the DRCs and understanding the predicted employment and wage impacts.

Changes in technology, market conditions, and the relative shares of labor and capital inputs to forest sector production processes would have an effect on the actual employment per unit volume of timber over time. Therefore, we suggest that these DRCs be interpreted as "baseline" direct effects. The DRCs are best suited for relatively near-term analyses for which the impacts of technology, new product development, and long-term market trends are limited. Plans call for these DRCs to be updated every 4–6 years, providing new estimates and developing a time series to assess changes and trends in employment and wages per unit of timber harvested. Sensitivity analyses could be applied to the DRCs to investigate different scenarios and the range of impacts that are expected under changing conditions in the forest sector of a given region.

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