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Regional Analysis of U.S. Sawn Hardwood Product Prices from 2000 to 2020



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Abstract

An examination of hardwood lumber prices in the eastern United States adjusted for inflation and regional differences in forest composition found declines in aggregate (combined species) prices across all regions. Still, the movements of the three aggregate prices examined were highly correlated among regions. The greatest declines in lumber price occurred in the Northeast and Lake States regions, with smaller declines occurring in the Central, Southern, and Mid-Atlantic regions. With the exception of white oak and walnut, prices of high-value species declined more than prices of low-value species. For most of this century, the Northeast region has had the highest aggregate prices for lumber products. However, the Central region had the highest price for high-quality lumber since 2017. While lumber prices have declined, prices for industrial hardwood products have increased, and these increases were consistent among regions. In 2020, the price of pallet cants exceeded the price of lower quality hardwood lumber for most species, and crosstie prices exceeded that of aggregate mid-quality lumber. The declines in hardwood lumber prices were the result of reduced domestic demand and insufficient increases in exports to offset this decrease. While increased domestic and export demand will result in increased prices, the prolonged period of low lumber prices may reduce the expected returns to timber management.

Keywords: Hardwood lumber, lumber prices, pallet prices, crosstie prices, forest composition.

1 Introduction

Since the beginning of the 21st century, the hardwood lumber price reported by the U.S. Department of Labor, Bureau of Labor Statistics (BLS), has trended downward in real (inflation adjusted) terms (Figure 1). This trend contrasts with the upward trend in this series in the last 19 years of the 20th century. But what does the downward trend in hardwood lumber price since 2000 actually indicate? This question is especially relevant for long-term timber management and investment decisions

since hardwood lumber price influences the value of higher quality hardwood timber. A prolonged period of declining lumber price could reduce expected returns to timber management.

The term “hardwood lumber” embodies a large number of sawn products that can be separated by species, quality (grade), and end use (appearance, industrial, and other applications) (Luppold & Bumgardner 2016). Lumber prices for different species can vary considerably and do not follow similar paths over time (Luppold & Prestemon 2003, Luppold & Bumgardner 2007). Hardwood composition (mix of species) also differs among five discernable regions of the eastern United States as defined in Luppold and Bumgardner (2021) (Figure 2). Given these considerations, we ask the question: Is the overall decline in lumber prices similar among species and regions?

Hardwood lumber used in appearance applications is primarily graded and sold under National Hardwood

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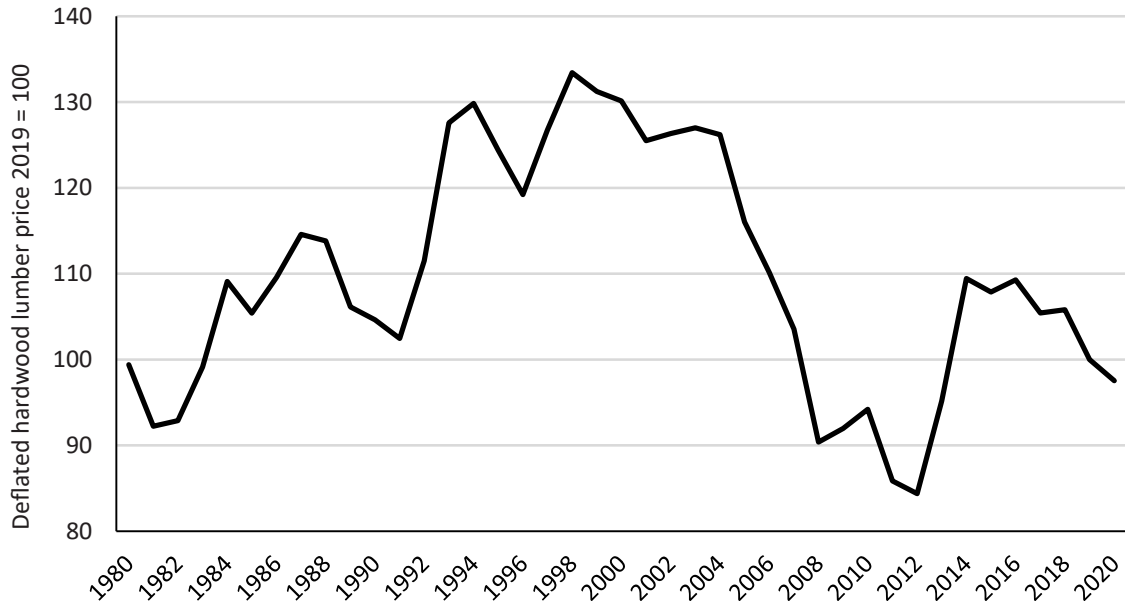


Figure 1. Deflated* hardwood lumber price index 1980 to 2020 (USD L BLS 2020).

* Hardwood lumber price index WPU0812 (1982 = 100) divided by wholesale price index WPU00000000 (1982 = 100) times 100 and then adjusted to represent 2019 dollars (2019 = 100).



Figure 2. States included in the Northeast, Lake States, Central, Mid-Atlantic, and Southern regions.

Lumber Association (NHLA 2019) rules. Lumber of differing grades can trade at considerably different price ranges (Luppold & Bumgardner 2007). Pallet cants and crosstie (industrial products) prices also have varied over time, but historically have traded well below the levels of most graded lumber products (HMR 2000–2020). This raises a second question: Have the prices of hardwood lumber and industrial products moved in a similar manner between 2000 and 2020?

To address the first question, regional aggregate (combined species) prices are developed for different grades of hardwood lumber based on regional differences in forest composition. We then analyze these price series to determine the influences of forest composition and species price on aggregate regional prices. To examine the second question, we compare changes in mid- and lower grades of aggregated hardwood lumber prices to changes in pallet cant and crosstie prices throughout the eastern United States (hereafter referred to as “eastwide”).

2 Methods and Study Data

2.1 Lumber, Pallet Cant, and Crosstie Prices

All lumber prices used in this study were obtained from the Hardwood Market Report (HMR). Luppold (1996) found that this publication emphasized the reporting of long-term contractual prices, which are appropriate prices to use for the problem being analyzed. The specific lumber products being examined are NHLA graded 4/4 (2.54 cm), random length and width, green (not air- or kiln-dried) lumber sold in truckload lots (HMR 2000–2020). The lumber grades examined are FAS (high-quality), 1C (mid-quality), and 2A (lower quality used in appearance applications). Pallet cants are mixed-species green-log centers normally sawn to 10.16 by 10.16 cm or 12.7 by 12.7 cm dimensions.

Lumber and pallet cant prices are reported by HMR in U.S. dollars per thousand board feet for three geographic areas of the eastern United States: Southern Hardwoods, Appalachian Hardwoods, and Northern Hardwoods. All prices were transformed to 2019 dollars using the wholesale price index for industrial commodities (USD BLS 2020). Prices per cubic meter (m^3) were developed by dividing thousand board foot price by 2.36 (Howard 2003). Any discussions of price in the remainder of this paper are in inflation adjusted or real (2019) terms per m^3 .

Green crosstie prices are the mid-points of the ranges reported for their respective areas. Crosstie prices are multiplied by 9.494 (assumed 0.1054 cubic meters per tie using a board foot estimate per tie developed by Johnson 2020) to convert to price per m^3 . Annual prices for lumber, pallet cants, and crossties were developed from the average prices reported in the first weekly issues for January, April, July, and October for the 2000 to 2020 period (HMR 2000–2020).

2.2 Regional and Eastwide Price Formulation

We used data on species composition of the timber resources in the five regions collected and compiled by the USDA Forest Service, Northern and Southern Forest Inventory Analysis (FIA) units, and accessed through the EVALIDator web application (USDA FS 2020a). We developed species “weighting” factors from data for inventory panels ending in 2010, which was the approximate midpoint of the study period. The variable from which weights were developed was net cubic-foot volume in the sawlog portion of sawtimber trees. The sawlog portion is the volume of sound wood in the central stem of a timber species tree of sawtimber size (27.9 cm d.b.h. minimum for hardwoods), from a 30.5 cm stump to a minimum top diameter, (20.9 cm for hardwoods) or to the point where the central stem breaks into limbs (USDA FS 2020b). While industrial sawn products can be manufactured from portions of trees above the sawlog top diameter, sawlog volume is the most appropriate weighting factor for NHLA-graded lumber products. The regional net sawlog volumes (cubic meters) of sawtimber trees and proportional regional volumes are presented in Table 1. Table 2 presents the proportional distribution of species or species groups that accounted for at least 2% of sawtimber volume for species for which HMR reported prices.

The prices used for species/groups from the Northeast and Lake States regions were reported prices for the Northern Hardwoods area with the exception of black cherry “cherry” (*Prunus serotina*) where Appalachian Hardwoods price was used. The prices used for the Central region were Appalachian Hardwoods; and the prices used for the Southern region were Southern Hardwoods. Most of the prices used for the Mid-Atlantic region were Appalachian Hardwoods, with the exception of sweetgum (*Liquidambar styraciflua*), where the Southern Hardwoods price was used.

Table 1. Volume and percent of net sawlog volume of sawtimber trees on timberland trees in the five eastern regions of the United States, 2010 (Source: USDA FS 2020a).

Region	Volume (million cubic meters)	Percent
Northeast	1,308	20.9
Lake States	592	9.5
Central	2,026	32.4
Mid-Atlantic	885	14.2
Southern	1,436	23.0

Table 2. Percent distribution of species, by region, used to develop regional weighted estimates for high quality (FAS), mid-quality (1C), and lower quality (2C) hardwood lumber prices based on net sawlog volume (measured in cubic feet) of sawtimber trees. No values listed for some species in some regions indicates insufficient (less than 2%) relative volume.

Species group	Northeast	Lake States	Central	Mid-Atlantic	Southern
	—Percent—				
White oak	8	8	26	23	19
Red oak	18	20	23	20	35
Hickory	2	—	10	5	7
Yellow birch	4	2	—	—	—
Hard maple	16	17	6	—	—
Soft maple	21	15	7	7	3
Beech	4	—	3	2	—
Sweet/black gum	—	—	—	12	24
Ash	7	8	5	3	3
Aspen/cottonwood	6	20	—	—	—
Basswood	2	8	2	—	—
Yellow-poplar	3	—	14	28	9
Walnut	—	—	2	—	—
Cherry	9	2	2	—	—

Regional resource weighted aggregate prices (aggregate price) of FAS, 1C, and 2A lumber for region (i) in year (j), were developed using the following formulae:

$$PFAS_{ij} = \sum(PFAS_{ijk}) * (W_{ik})$$

$$P1C_{ij} = \sum(P1C_{ijk}) * (W_{ik})$$

$$P2A_{ij} = \sum(P2A_{ijk}) * (W_{ik})$$

Where

$PFAS_{ij}$ = Aggregate resource volume-weighted FAS lumber price in region (i) year (j)

$PFAS_{ijk}$ = FAS lumber price in region (i) year (j) for species (k)

W_{ik} = Proportional weighting factor in region (i) for species (k), shown in Table 2

$P1C_{ij}$ = Aggregate resource volume-weighted 1C lumber price in region (i) year (j)

$P1C_{ijk}$ = 1C lumber price in region (i) year (j) for species (k)

$P2A_{ij}$ = Aggregate resource volume-weighted 2A lumber price in region (i) year (j)

$P2A_{ijk}$ = 2A lumber price in region (i) year (j) for species (k)

Any discussion of FAS, 1C, or 2A price in this paper refers to the resource volume-weighted aggregate real price, unless stated otherwise.

Pallet cant and crosstie prices are not reported by species; therefore, we examined prices for the Northern, Appalachian, and Southern geographic areas reported in

the HMR. Eastwide price series were developed for the three lumber grades, crossties, and pallet cants using regional price estimates weighted by relative regional net sawlog volume of sawtimber trees (percent column in Table 1). In this weighting structure, crosstie and pallet prices reported for Northern Hardwoods are used for FIA data reported for Northeast and Lake States regions, Appalachian Hardwoods are used for the Central and Mid-Atlantic regions, and Southern Hardwoods are used for the Southern region.

2.3 Development of Correlation Coefficients

Price movements between regions and products were analyzed using correlation coefficients (r) developed with SAS Enterprise Guide vers. 7.1. For lumber grades FAS, 1C, and 2A, the Central region's price vectors were used as the base to examine price movements between regions. The Central region has the largest volume of timber, as well as being centrally located. Correlation coefficients for pallet cant and crosstie prices are examined between HMR's designated Southern, Appalachian, and Northern Hardwood regions, with the centrally located Appalachian region being the base.

2.4 Species Examined

The species groups examined were based on FIA categories as follows: select white oak, primarily white oak *Quercus alba*, bur oak (*Q. macrocarpa*), and chinkapin oak (*Q. muehlenbergii*); select red oak, primarily northern red oak (*Q. rubra*) and cherrybark oak (*Q. falcata* var. *pagodifolia*.); other white oak, primarily chestnut oak (*Q. prinus*), post oak (*Q. stellate*), and overcup oak (*Q. lyrata*); other red oaks, primarily black oak (*Q. velutina*), water oak (*Q. nigra* L.), scarlet oak (*Q. coccinea*), southern red oak (*Q. falcata* Michx. var. *falcata*), laurel oak (*Q. laurifolia*), willow oak (*Q. phellos* L.), and pin oak (*Q. palustris*); yellow birch (*Betula alleghaniensis*); hard maple, primarily sugar maple (*Acer saccharum*); soft maple, primarily red maple (*A. rubrum*) and silver maple (*A. saccharinum*); ash, primarily white ash (*Fraxinus americana*), green ash (*F. pennsylvanica*), and black ash (*F. nigra*); tupelo blackgum; primarily swamp tupelo (*Nyssa sylvatica* var. *biflora*), blackgum (*N. sylvatica* Marsh. var. *sylvatica*), and water tupelo (*N. aquatica*); aspen/cottonwood, primarily quaking aspen (*Populus tremuloides*), bigtooth aspen (*P. grandidentata*), and eastern cottonwood (*P. deltoides*); hickory (*Carya spp.*), basswood (*Tilia americana*), beech (*Fagus grandifolia*),

sweetgum, yellow-poplar (*Liriodendron tulipifera*), black walnut "walnut" (*Juglans nigra*), and cherry.

Red oak prices were weighted by the combined volume of select red and other red oaks, and white oak prices were weighted by the combined totals of select white and other white oaks. Blackgum/tupelo is an important species group in the Mid-Atlantic and Southern regions for which no price was reported during the study period. In the absence of a reported price for this species group, the proportional volumes of blackgum/tupelo were combined with sweetgum to develop a weight for a grouping termed sweet/black gum.

3 Results

3.1 Changes in Aggregate FAS Prices

Regional aggregate FAS lumber prices from 2000 to 2020 are presented in Figure 3. While the levels of regional FAS aggregate prices differ, they are highly correlated. The correlations between the Central and the Mid-Atlantic and Southern regions were $r = 0.99$. The lowest coefficient value ($r = 0.94$) for FAS lumber was between the Central and Northeast regions.

In 2000, regional aggregate FAS price estimates ranged from \$515 per m³ in the Southern region to \$757 per m³ in the Northeast region (Figure 3). This 47% range in price is the result of differences in forest composition as represented in the weighting factors in Table 2 and corresponding FAS lumber prices (HMR 2000). Sixty-eight percent of the sawtimber in the Northeast region is composed of red oak, hard and soft maple, birch, and cherry. In 2000, the FAS prices for these species in the Northeast exceeded \$600 per m³ (Table 3). The Southern region contains higher proportional volumes of lower priced yellow-poplar and sweetgum, which reduced aggregate FAS price in that region. The high proportion of yellow-poplar in the Mid-Atlantic region also resulted in a relatively low aggregate FAS price.

The large proportion of higher priced maple species and red oak in the Lake States region was partially offset by high volumes of low-priced aspen (Tables 2 and 3), causing FAS price in this region to be lower than the Northeast (Figure 3). The Central region contains the greatest variety of species that meet the criteria to be included in the price estimate (Table 2). Just 40% of the species in the Central region exceeded \$600 per m³ in 2000 (HMR 2000), but relatively large volumes of species

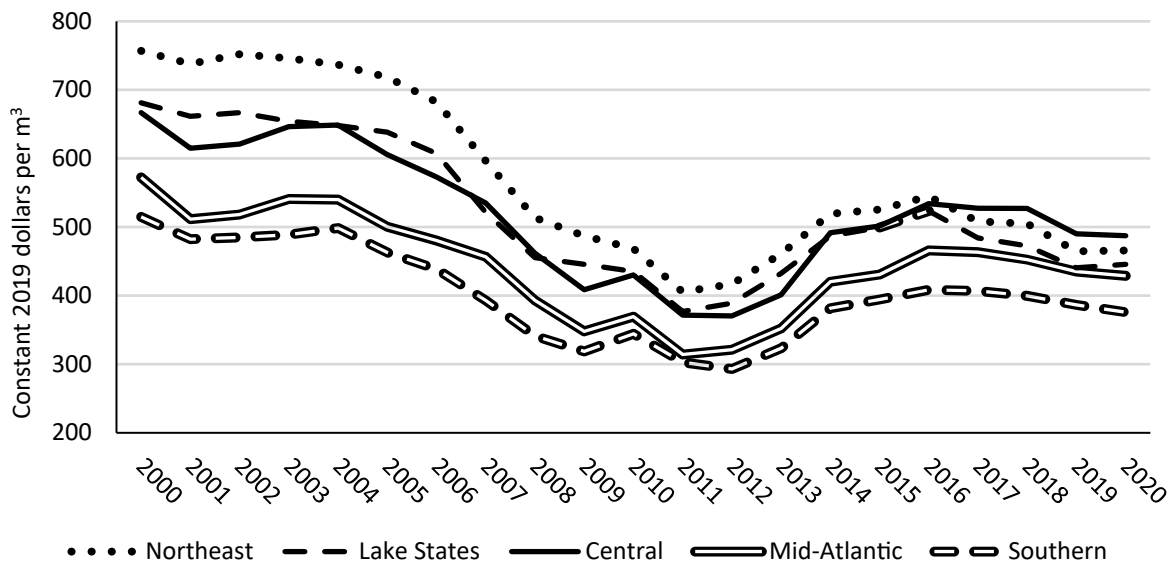


Figure 3. Resource volume-weighted aggregate regional price for high-quality (FAS) green hardwood lumber, 2000 to 2020. Correlation coefficients: Central and Northeast ($r = 0.94$); Central and Lake States ($r = 0.95$); Central and Mid-Atlantic ($r = 0.99$); Central and Southern ($r = 0.99$)

Table 3. Real (2019) prices of high-quality (FAS) green lumber for major hardwood species in selected years (Source: HMR 2000–2020).

	2000	2004	2009	2012	2014	2016	2020
	—2019 U.S. Dollars per cubic meter—						
FAS White oak ¹	598	657	449	423	564	705	760
FAS Red oak ²	860	809	412	357	582	514	371
FAS Hickory ¹	546	489	309	294	387	378	341
FAS Yellow birch ²	640	711	620	545	535	595	481
FAS Hard maple ²	1,032	902	608	514	655	664	546
FAS Soft maple ²	610	699	507	446	533	619	556
FAS Beech ²	449	406	347	293	288	318	293
FAS Sweetgum ^{3,4}	237	215	182	155	156	174	173
FAS Ash ²	514	396	318	355	404	469	349
FAS Basswood ²	559	460	337	299	358	399	336
FAS Aspen ²	374	366	335	288	271	366	326
FAS Yellow-poplar ¹	548	401	302	280	334	380	332
FAS Walnut ¹	909	1,109	918	813	1,095	1,140	988
FAS Cherry ¹	1,422	1,499	820	558	541	498	424

1 Appalachian Hardwoods reporting area.

2 Northern Hardwoods reporting area.

3 Southern Hardwoods reporting area.

4 Reported as sap gum in the Hardwood Market Report.

with prices that exceeded \$750 per m³ (cherry, walnut, hard maple, and red oak) resulted in the aggregate FAS price in this region to be similar to the Lake States price.

While differences in composition explain much of the regional differences in aggregate FAS price in 2000, there also are aesthetic and availability factors that influence price. Slower tree growth in the northern portion of the eastern U.S. results in lumber with higher per inch ring counts than in the southern portion. The northern trees also have lower average diameters (USDA FS 2020a). Smaller diameter trees result in fewer boards that meet the width requirement of FAS grade, but the associated higher ring count results in lumber with a finer texture. While not all users of FAS lumber are willing to pay for this aesthetic property provided by slower growth, the combined impact of ring count and lower availability due to diameter causes a regional gradient in FAS prices. An example is with red oak: in 2000, the reported HMR price of FAS red oak was \$860 m³ for northern hardwoods (used for the Northeast and Lake States regions), \$760 m³ for Appalachian hardwoods (used for the Central and Mid-Atlantic regions), and \$665 m³ for southern hardwoods (used for the Southern region).

Aggregate FAS lumber prices started to decline in all regions after 2004, and this trend continued through 2009. The small increase in Central, Mid-Atlantic, and Southern region FAS price in 2010 primarily was the result of increased red and white oak prices (HMR 2010). Prices of FAS lumber declined after 2010, with Northeast, Lake States, and Mid-Atlantic region prices hitting their study period low points in 2011 and the two remaining regions having their lowest prices in 2012. As prices declined, regional differences contracted to under \$110 m³ (34%) in 2011. This contraction occurred as the prices of most higher value species decreased at greater rates than lower valued species. Prices in all regions increased between 2012 and 2016, and this increase was accompanied by an increase in regional price divergence.

After 2016, aggregate FAS prices declined and regional price differences again contracted to 2011 levels in 2019 and 2020. The declines in the Central, Mid-Atlantic, and Southern regions were smaller than the declines in the Northeast and Lake States regions. These smaller declines in the Central, Mid-Atlantic, and Southern regions were primarily the result of the higher proportion of white oak (Table 2), the only major species group that had a higher FAS price in 2020 than in 2016 (Table 3). The

contraction between regional prices was influenced by smaller regional difference in FAS red oak prices, which in 2020 ranged from \$371 m³ for northern hardwoods to \$324 m³ for southern hardwoods (HMR 2020).

3.2 Changes in Aggregate 1C Prices

The movement of aggregate 1C prices in the five regions was similar to that of FAS, but the relative difference of these prices among regions in 2000 was smaller (Figure 4). In the early 2000s, aggregate 1C price in the Northeast region was 33% higher than in the Southern and Mid-Atlantic regions. Over 75% of the sawtimber in the Northeast region is red oak, hickory, birch, hard and soft maple, ash, and cherry. In 2000, the 1C prices for these species exceeded \$350 m³ (Table 4).

While Mid-Atlantic and Southern 1C red oak prices were slightly lower than in the Northeast region, higher proportional volumes of lower priced yellow-poplar and sweetgum were the primary reason for the lower 1C price in these regions. Lake State aggregate 1C price in 2000 was noticeably higher than that of the Central region. This is in contrast to aggregate FAS price which was similar in the Lake States and Central regions.

Regional 1C prices reached their highest levels in 2004, then declined in a similar manner as regional FAS prices. Aggregate 1C prices reached their lowest levels in the Northeast and Lake States regions in 2011; the low points for the Central, Mid-Atlantic, and Southern regions occurred in 2012. Similar to FAS prices, the decline in 1C prices was accompanied by regional price convergences. Prices in all regions increased between 2012 and 2014, as did the difference between Southern and Northeast region prices. This divergence was again the result of the prices of higher value species increasing more than the prices of lower value species.

Since 2014, aggregate 1C prices in all regions have trended downward, but prices in the Southern regions declined the least, while prices in the Central region declined the most. Prices in the Southern region had the smallest decline, as sweetgum price remained relatively constant. The combined declines in 1C red oak, yellow-poplar, and white oak prices were the primary reason for the 22% decline in the Central region.

3.3 Changes in Aggregate 2A Prices

Regional price movements of 2A lumber followed similar paths as grades FAS and 1C, but with some important differences (Figure 5). The range of the highest and

Table 4. Real (2019) prices of mid-quality (1C) green lumber for major hardwood species, crossties, and pallet cants in selected years
(Source: HMR 2000–2020).

	2000	2004	2009	2012	2014	2016	2020
	—2019 U.S. Dollars per cubic meter—						
1C White oak ¹	342	418	242	233	374	357	316
1C Red oak ²	582	575	261	245	396	309	241
1C Hickory ¹	386	360	244	244	325	246	223
1C Yellow birch ²	383	439	319	300	306	343	299
1C Hard maple ²	617	629	337	344	467	381	355
1C Soft maple ²	394	374	250	272	355	397	359
1C Beech ²	318	287	243	201	197	217	195
1C Sweetgum ^{3,4}	234	200	170	145	146	162	162
1C Ash ²	383	315	216	258	268	281	210
1C Basswood ²	278	251	169	165	225	246	181
1C Aspen ²	242	221	190	168	160	215	194
1C Yellow-poplar ¹	285	229	178	178	218	222	163
1C Walnut ¹	499	549	419	410	586	581	521
1C Cherry ¹	725	897	332	273	363	327	219
Crossties ¹	220	261	246	199	241	286	313
Pallet Cants ¹	163	183	154	143	172	170	174

1 Appalachian Hardwoods reporting area.

2 Northern Hardwoods reporting area.

3 Southern Hardwoods reporting area.

4 Reported as sap gum in the Hardwood Market Report.

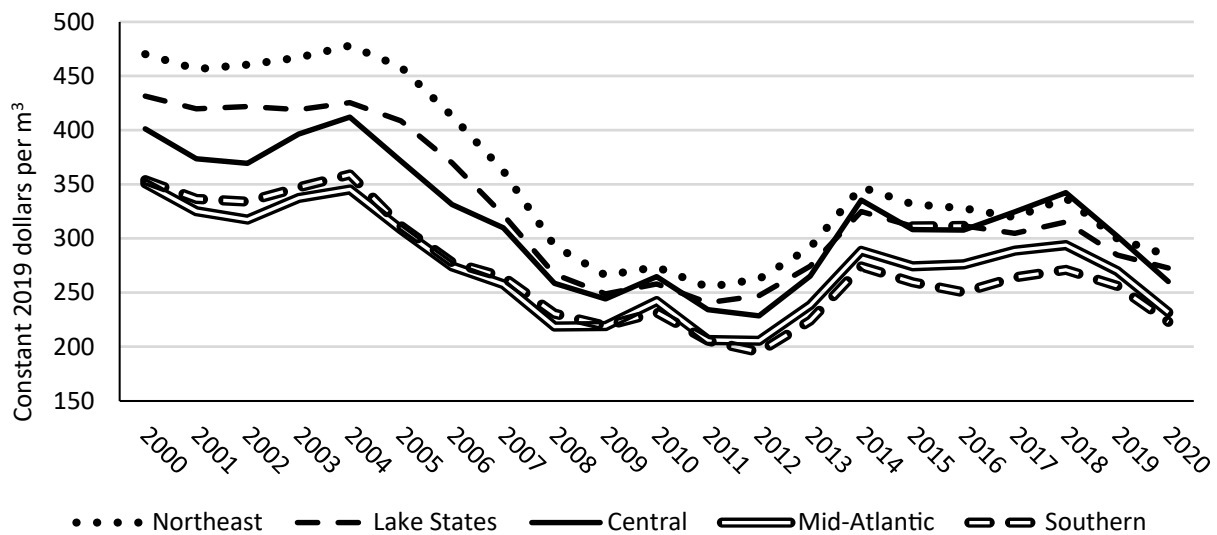


Figure 4. Resource volume-weighted aggregate regional price for mid-quality (1C) green hardwood lumber, 2000 to 2020. Correlation coefficients: Central and Northeast ($r = 0.95$); Central and Lake States ($r = 0.96$); Central and Mid-Atlantic ($r = 0.99$); Central and Southern ($r = 0.98$).

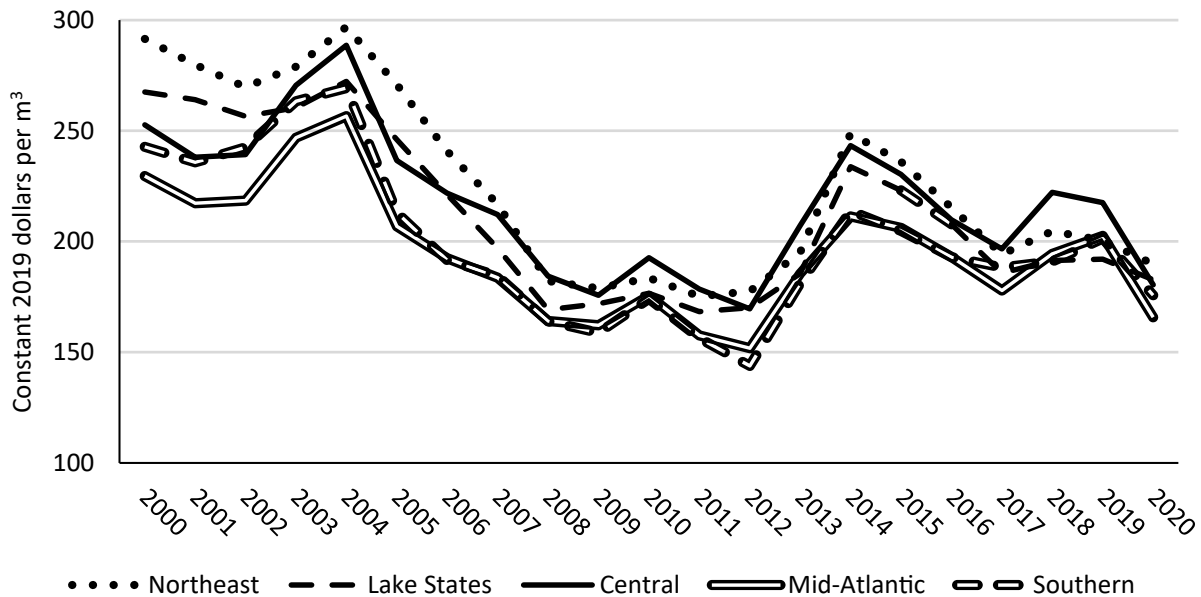


Figure 5. Resource volume-weighted aggregate regional price for lower quality (2A) green hardwood lumber, 2000 to 2020. Correlation coefficients: Central and Northeast ($r = 0.93$); Central and Lake States ($r = 0.92$); Central and Mid-Atlantic ($r = 0.99$); Central and Southern ($r = 0.96$).

lowest regional aggregate 2A prices was considerably smaller than ranges recorded for the higher lumber grades. These ranges declined from 27% (Northeast region versus Mid-Atlantic region) in 2000 to 14% in 2020. In general, interspecies price differences between 2A lumber are considerably smaller when compared to FAS and 1C lumber (HMR 2000 to 2020). Another major difference is the cause of the peaks in 2A price in 2004 and 2014, which are attributed to large increases in 2A red oak prices in those years.

3.4 Changes in Crosstie and Pallet Cant Prices

Crosstie prices for the three geographic areas reported in the HMR were highly correlated with one another, but Southern crosstie prices were normally higher than Appalachian and Northern prices (Figure 6). The largest variation in crosstie price was in 2019, with Southern prices 16% greater than Northern prices. Appalachian crosstie prices have been the most variable and were 6% less than Southern prices in 2020.

Pallet cant prices were highly correlated across the three areas, with no area having a continual “higher” price (Figure 6). In the years examined, the largest variation between regions for cant prices was 10% in 2000; in

most years, the difference was less than 5%. One reason for the lack of regional variation in pallet cant prices is that pallets can be produced using nearly any species.

3.5 Eastwide Aggregate Lumber, Crosstie, and Pallet Cant Prices

Eastwide price of crossties was 11% lower than the price of 2A lumber in 2000 (Figure 7). Accompanying correlation coefficients are presented in Table 5. While the ranges of eastwide aggregate FAS, 1C, and 2A differed, the three series were highly correlated. The strongest correlation was between FAS and 1C price ($r = 0.98$) but the $r = 0.91$ correlation between FAS and 2A price also was relatively high.

Crosstie prices trended with 2A prices between 2000 and 2004. As both price series started to decline after 2004, the reduction in crosstie price was considerably less than that of 2A price through 2008. While 2A price approached crosstie price in 2014, since that year, crosstie price has trended upward, while 2A price has trended downward. In 2020, the eastwide price of crossties was 73% higher than the price of 2A lumber. As a result, these two similarly priced products were highly uncorrelated ($r = 0.18$) during the study period.

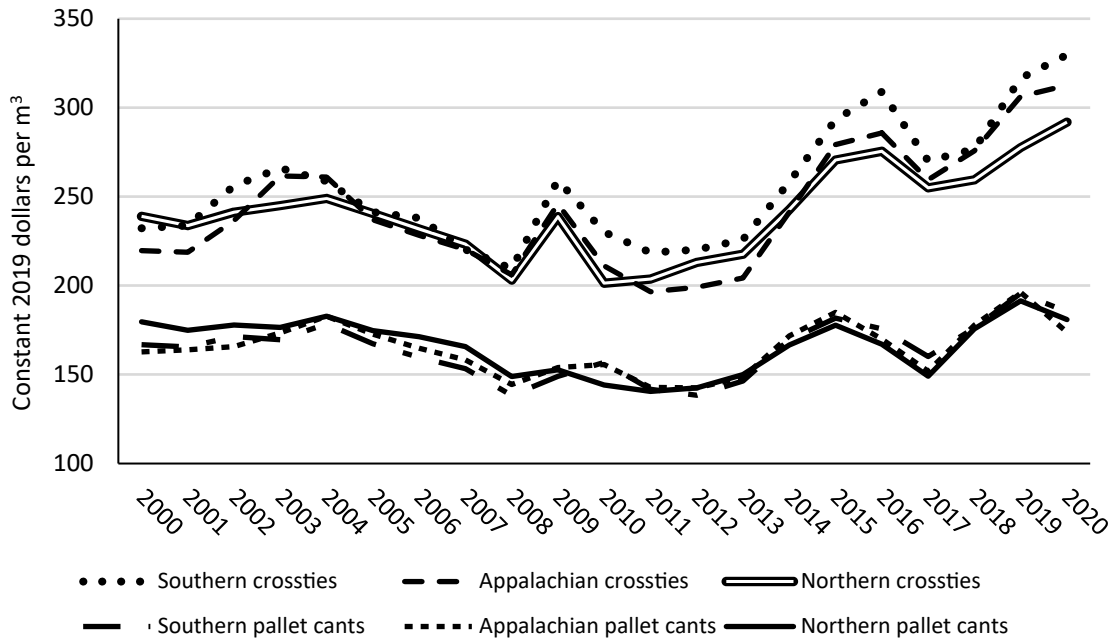


Figure 6. Crosstie and pallet cant prices for the Northern, Appalachian, and Southern reporting areas, 2000 to 2020. Correlation coefficients: Appalachian and Northern pallet cants ($r = 0.89$); Appalachian and Southern pallet cants ($r = 0.95$); Appalachian and Northern crossties ($r = 0.96$); Appalachian and Southern crossties ($r = 0.97$).

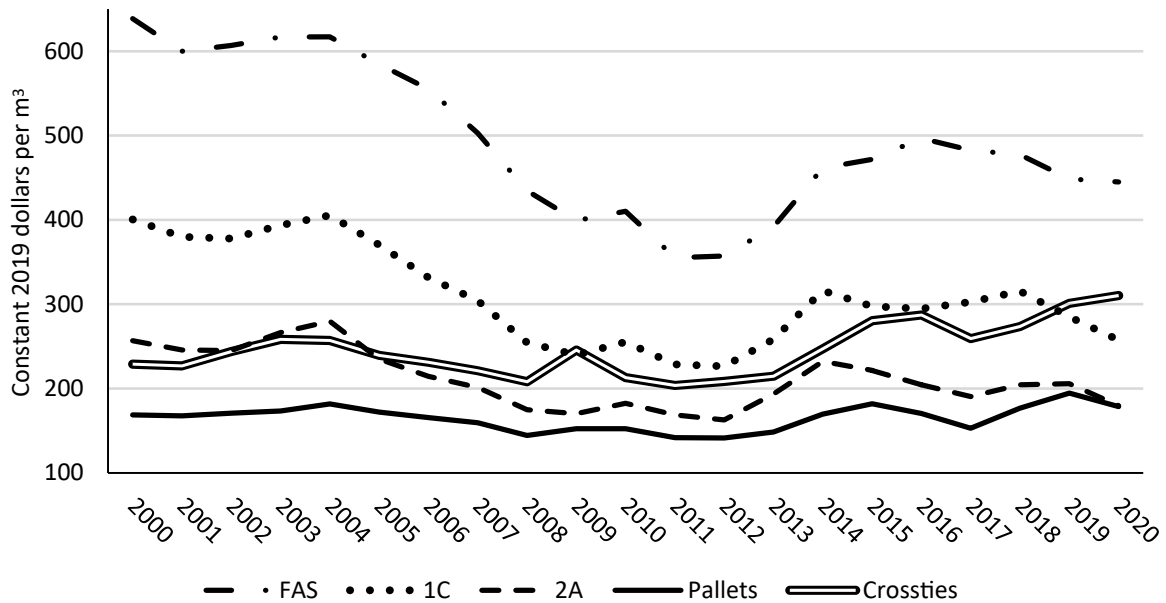


Figure 7. Resource volume-weighted aggregate eastwide FAS, 1C and 2A green lumber prices compared to pallet cant and crossties prices, 2000 to 2020.

Table 5. Correlation coefficients (r) for eastwide prices of FAS lumber, 1C lumber, 2A lumber, pallet cants, and crossties.

	FAS price	1C price	2A price	Crosstie price
FAS price	—			0.15
1C price	0.98	—		0.13
2A price	0.91	0.96	—	0.18
Cant price	0.54	0.55	0.62	0.80

While pallet cants had a higher correlation with 2A lumber ($r = 0.62$) the price paths of these products differed. Eastwide pallet cant price was 34% below that of 2A lumber in 2000. While both 2A lumber and pallet cant prices trended downward between 2004 and 2012, the difference between the two price series declined to 13% in 2012. Between 2012 and 2018, aggregate eastwide 2A price remained above the pallet cant price. In 2020, eastwide pallet cant prices and aggregate 2A lumber prices were nearly identical. When examining the individual species used to develop the aggregate 2A price, pallet cant prices exceeded 2A lumber prices for most species in 2020, with the exception of red oak, white oak, hard maple, and walnut (HMR 2020).

In 2000, the aggregate price of 1C lumber exceeded crosstie price by 43%. Between 2004 and 2009, 1C prices declined by 41%, while crosstie prices declined by 4%. In 2009 and 2016, crosstie prices were similar to 1C prices, but were below 1C prices for the years between these two points. Crosstie prices remained below 1C prices in 2017 and 2018, but exceeded 1C price by 21% in 2020. These divergent paths for 1C and crosstie prices resulted in low correlation ($r = 0.13$).

4 Discussion

The differences in the relative levels of aggregate regional FAS, 1C, and 2A lumber prices are the result of differences in species composition. The fact that these series also were highly correlated indicates that the overall impact of changes in domestic and international markets for hardwood lumber have been similar across regions. Four patterns are consistent across Figures 3, 4, and 5: the declines between 2004 and 2009, the continued low relative prices until 2012, the rapid upward movement in 2013 and 2014, and the flat to downward-trending prices since 2014. In these respects, aggregate regional prices of the different lumber grades have moved in a similar manner; however, the size of the decline varied among regions.

As discussed in Luppold et al. (2014), the decline in lumber prices between 2004 and 2009 was the result of declines in domestic and international demand for lumber used in appearance applications. The downward trend between 2009 and 2012 also was influenced by the liquidation of lumber inventories by primary and secondary manufactures being forced out of business due to poor market conditions. The increase in prices after

2012 was the result of relatively low domestic production (Luppold & Bumgardner 2017) and increased exports, with most of the increase in exports going to China and Vietnam (Luppold & Bumgardner 2016). Quesada et al. (2019) also noted that exports have become a dominant market for hardwood lumber. The declines in FAS and 1C prices that began in 2018 also were associated with large declines in exports to China (USDA FAS 2020). These changes also seem to have influenced 2A prices, as eastwide 2A prices were highly correlated with 1C and FAS prices (Table 5).

Another pattern exhibited in Figures 3, 4, and 5 was the increasing relative position of aggregate prices in the Central region from 2017 to 2020, compared to the other regions. In the lumber market, white oak and walnut were the only species to have higher prices for grades FAS in 2020 than in 2000 (HMR 2000 to 2020). The 1C price of white oak has also declined by a considerably lower amount than the 1C price of red oak (Table 4). The Central region had the largest compositional weights associated with white oak and is the only region with significant volumes of walnut (Table 2). High quality white oak lumber prices have increased as demand for logs by the stave industry has increased (relative to supply) in conjunction with increased demand for aged whiskeys (Schweitzer et al. 2019). Walnut prices have increased as a result of a tenfold increase in walnut lumber exports since 2000 (USDA FAS 2020).

The differences between aggregate regional lumber prices have become smaller (converged) for the three lumber grades examined. The convergence of lumber prices among regions is the result of the declines in prices of higher value species being larger than the declines in prices of lower value species. The three species with the highest 1C lumber prices in 2000 (Table 4) — black cherry, red oak, and hard maple — had price declines of \$506, \$341, and \$262 per m^3 , respectively, between 2000 and 2020. The three compositionally important but lower value species — yellow poplar, sweetgum, and aspen — had 1C price declines of \$122, \$72, and \$48 per m^3 , respectively, during the same period.

Regional prices of 2A lumber differed from FAS and 1C lumber in the magnitude of the 2004 and 2014 price spikes, and the magnitude of the decline in 2A price after 2014. Both price peaks primarily were the result of 2A red oak prices, and to a lesser extent 2A white oak price. These increases were influenced by increased 2A

oak lumber purchases by the wood flooring industry (Johnson 2020). The decline in 2A price after 2014 was influenced by increased use of wood substitutes in flooring products. The demand for residential oak flooring and hard maple basketball court flooring appear to be the principle factors that have caused 2A oak and hard maple prices to remain higher than pallet cants prices.

The relationship between crosstie and 1C lumber prices, and between 2A lumber and pallet cants prices (Figure 7) is indicative of the domestic markets for these products. With the possible exception of staves, crossties have been the only sawn hardwood product with stable domestic consumption over the past 20 years (Luppold & Bumgardner 2016). While consumption of hardwood lumber by the pallet industry has declined since 2000, its proportion of total sawn product demand has increased, resulting in higher pallet cant prices (Luppold & Bumgardner 2016). The price of crossties seems to have put a lower limit on how far 1C lumber price can decline, while the price of pallet cants has put a lower limit on aggregate 2A lumber price.

What was not examined in this paper was the potential influence hardwood lumber prices have on log and stumpage prices. Log and stumpage price series often are developed at the state level, but are inconsistent among states and across regions, requiring additional research to resolve these inconsistencies. Another factor that can influence log and stumpage prices are the primary processing industries present in a region. Industry data will become more widely available with the implementation of an eastwide Timber Product Output program currently under development by the USDA Forest Service, Northern and Southern Forest Inventory and Analysis units.

Changes in hardwood prices over the next decade primarily will be a function of market activity, as timber composition and quality are slow to change. The potential impact of improved U.S. and China trade relations on lumber prices cannot be overstated as exports have become a major portion of the overall market (Luppold & Bumgardner 2016). Increased U.S. housing starts also point to greater domestic demand for lumber.

The trends examined in this paper indicate that it will take continual increases in total demand (domestic plus international) to enable lumber prices to recover to 2000 levels. However, the largest impact of low lumber prices over the last two decades may be the effect prolonged low prices might have on expected returns

to timber management, as well as the money available for such investments.

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