Economic Impacts of Hurricanes on Forest Owners

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Abstract

We present a conceptual model of the economic impacts of hurricanes on timber producers and consumers, offer a framework indicating how welfare impacts can be estimated using econometric estimates of timber price dynamics, and illustrate the advantages of using a welfare theoretic model, which includes (1) welfare estimates that are consistent with neo-classical economic theory, and (2) wealth transfers among various market participants that can be evaluated. Timber producers in the Southern United States are faced with the regular risk of damages from intense hurricanes. Individual events can kill several million cubic feet of standing timber, with attendant losses for forest owners. One result of using a welfare theoretic model that is not apparent using simpler models is that timber producers with undamaged timber suffer economic losses in the short term because of a price depression, and they may be compensated in the long term by an enhancement of market prices owing to the loss of standing inventory. Catastrophic storms induce losses to timber producers holding damaged timber owing to quality degrade, price depression, and the inability to salvage all of the damaged timber. To minimize decay-related losses, owners of damaged timber should salvage as quickly as possible and favor salvage of higher value trees. Owners of undamaged timber should delay harvesting until salvage wood is exhausted from the market. Evidence suggests that timberland investors under hurricane threat could benefit by diversifying their holdings geographically, favoring areas far enough from coastal counties to minimize catastrophic losses from such storms but close enough to benefit from market-level price enhancements resulting from regional inventory losses.

Keywords: Economic welfare, Hurricane Hugo, Hurricane Katrina, timber salvage, tropical cyclone.

Introduction

This paper provides a description of the hurricane process in the United States in the context of economic impacts on forest land owners, presents the welfare theoretic model used to quantify timber market impacts, describes and compares the impacts of a few large and recent hurricanes on timber markets in the South, and concludes with some recommendations for landowners based on the research. This section focuses on measurement of catastrophic storm impacts on landowners.

More than 150 hurricanes have struck the U.S. Atlantic and Gulf of Mexico coasts during the past century, and these storms have caused economic damages totaling billions of dollars (Blake and others 2007). Human loss of life and suffering, destruction of housing, and disruptions in economic activities are the most obvious impacts of catastrophic storms, and recent, large hurricanes are proof of their ability to economically and politically transform affected regions. States vulnerable to the most intense storms include Florida, Texas, North Carolina, and South Carolina, but all States in the South and some States in the mid-Atlantic region and the Northeastern United States are also vulnerable to hurricanes.

Less appreciated, perhaps, are the effects that catastrophic storms have on forests and the people who own them. The effects of hurricanes on landowners are a complex function of many factors, including storm severity (windspeeds), prior rainfall activity (whose effect in turn is modified partially by soils), the strength of the timber market, tree species affected, and timber decay rates. Overall effects on landowners from hurricanes depend on hurricane frequencies and intensities. Given these variables affecting damages, the long-term effect of hurricanes will depend on long-term trends in climate and the timber market.

Research has shown that individual storms can create forest damages into the billions of dollars, and those damages create widespread wealth redistributions. The timing, scale, and implications of these losses and benefits have been the subject of research by the authors of this paper and by others. We have learned that measuring the impacts

Table 1—Hurricane landfalls, 1851–2006, and timber growing-stock volumes and production, 2002

State	All categories (1-5)	Major hurricanes (3-5)	Standing growing-stock volume, 2002	Timber, production 2002
			Million ft^3	*Thousand ft^3*
Florida	113	37	15,366	560,475
Texas	60	19	12,939	769,501
Louisiana	52	20	18,844	958,981
North Carolina	50	12	32,742	957,675
South Carolina	30	6	17,702	682,901
Alabama	26	6	27,847	1,298,533
Georgia	23	3	31,704	1,447,941
Mississippi	16	9	20,611	1,149,880
Virginia	10	1	26,487	654,829
New York	12	5	21,831	141,068
Connecticut	11	3	3,192	11,691
Massachusetts	11	3	5,732	26,437
Rhode Island	9	4	496	1,742
Maine	6	0	20,891	441,729
Maryland	2	0	5,092	40,507
Delaware	2	0	695	7,654
New Jersey	2	0	2,819	10,549
New Hampshire	2	0	9,015	140,282
Pennsylvania	1	0	24,903	215,912

Note: State-by-State information about the number and intensity ranges of hurricanes, where they made landfall (1851–2006), and the total current (nondamaged) amount of growing stock and timber production by State (for 2002) are given. Hurricane intensities are represented using Saffir-Simpson categories.

Sources: Blake and others (2007, p. 18); Smith and others (2004).

on landowners can be accomplished using standard economic concepts of supply and demand in combination with econometric analysis of timber price dynamics following a catastrophic event. This approach is consistent with welfare economic methods described by Just and others (1982) and as applied to forest impacts by Holmes (1991). These concepts have been used by the authors to measure the effects of Hurricane Hugo on prices, producers, and consumers (Prestemon and Holmes 2000, 2004). These techniques have also been used to quantify the timber market impacts of large-scale fires (e.g., Butry and others 2001, Prestemon and others 2006). The implications of these findings suggest that landowners can take steps before and after such events to reduce exposure to the risk process and to mitigate damages when subjected to it.

The Biophysical Risk Process of Atlantic Basin Hurricanes in the United States

This section provides a discussion of biophysical risk processes associated with timberland ownership in the Eastern and Southern States of the United States. Atlantic hurricane arrival rates are available from the National Oceanic and Atmospheric Administration, which are reported here to provide the scope of the issue for forest landowners. Table 1 and Figure 1 show the number of hurricanes, by Saffir-Simpson scale category, striking each State in the Atlantic Basin of the United States, 1851-2004. Table 1 can be used to infer the probability of a hurricane striking a specific State by dividing the number of years represented by the number of landfalls (although a spatially weighted probability listing would look different). This table shows that there is a coincidence of high hurricane frequency and high timber volumes. This coincidence is apparent when the

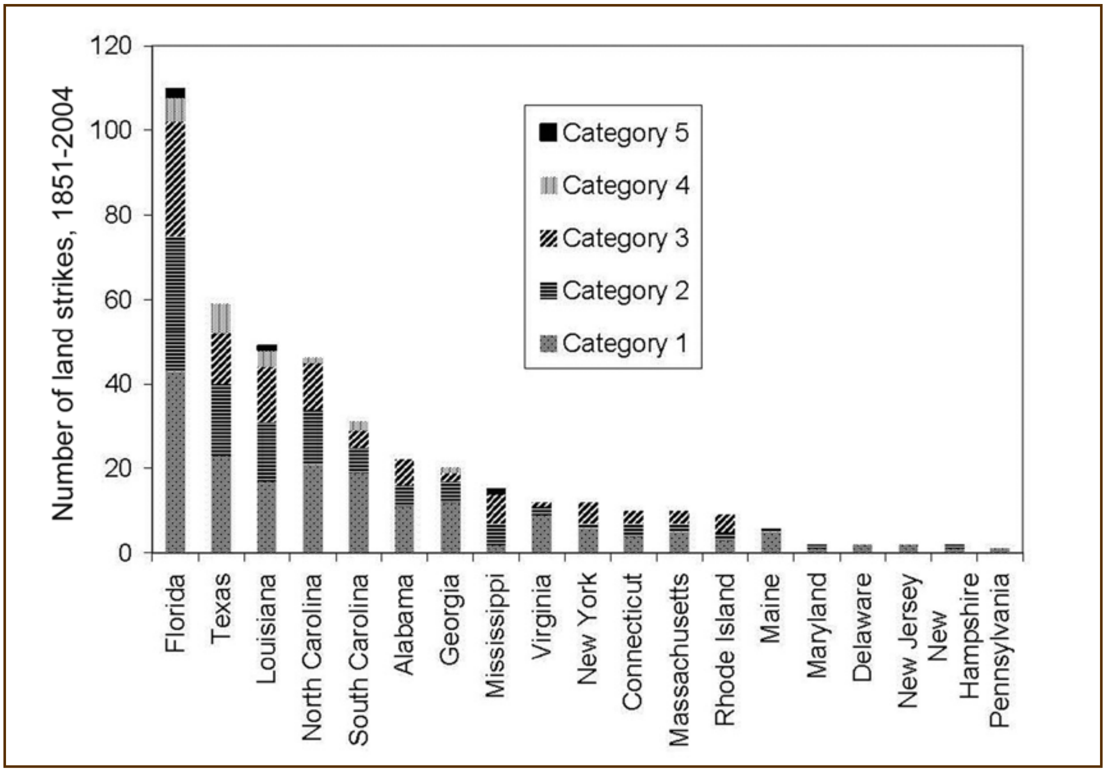

Figure 1—Atlantic hurricane strikes, 1851–2004, by State by Saffir-Simpson Category. Source: National Oceanic and Atmospheric Administration (2006).

States are ranked by hurricane landfall. The States with the greatest number of hurricanes are Florida, Texas, Louisiana, and, then, North and South Carolina. The strongest timber markets are found along the gulf coast, so the southern timber resource is particularly threatened by severe losses from large-scale wind events. In other words, timber owners in these high-frequency States are at particularly high risk of timber loss. See Stanturf and others (2007) for additional details about timber and hurricane frequencies and the United States Department of Commerce, National Hurricane Center (2007) for information on hurricane return intervals.

Data from the National Oceanic and Atmospheric Administration (2006) show that the number of hurricanes in the United States has recently demonstrated an upward trend. These data are consistent with Emanuel (2005) who indicated that hurricane intensities in many parts of the world appear to have risen over the past several decades. Both of these trends are consistent with some predictions of anticipated effects of climate change (e.g., Knutson and Tuleya 2004) and with recent global ocean temperature rises (Barnett and others 2001). Whether or not the recent increase in hurricane activity is due to climate change (Gray 1984a, 1984b; Gray and others 1996) or primarily associated with multidecadal Atlantic Ocean sea surface temperature oscillations is still being debated. What is clear is that the Southern United States is facing a period in which substantial damage to timber resources from hurricanes can be anticipated, along with the associated consequences for forest landowners.

Timber Market Dynamics Following Hurricanes

This section provides information on (1) timber market shifts following natural disturbances, (2) resulting timber price movements through time, (3) welfare movements through time, and (4) salvage recovery values following natural disturbances. This will provide the reader with an overall picture of timber market behaviors and offer intuition about expected price movements and production

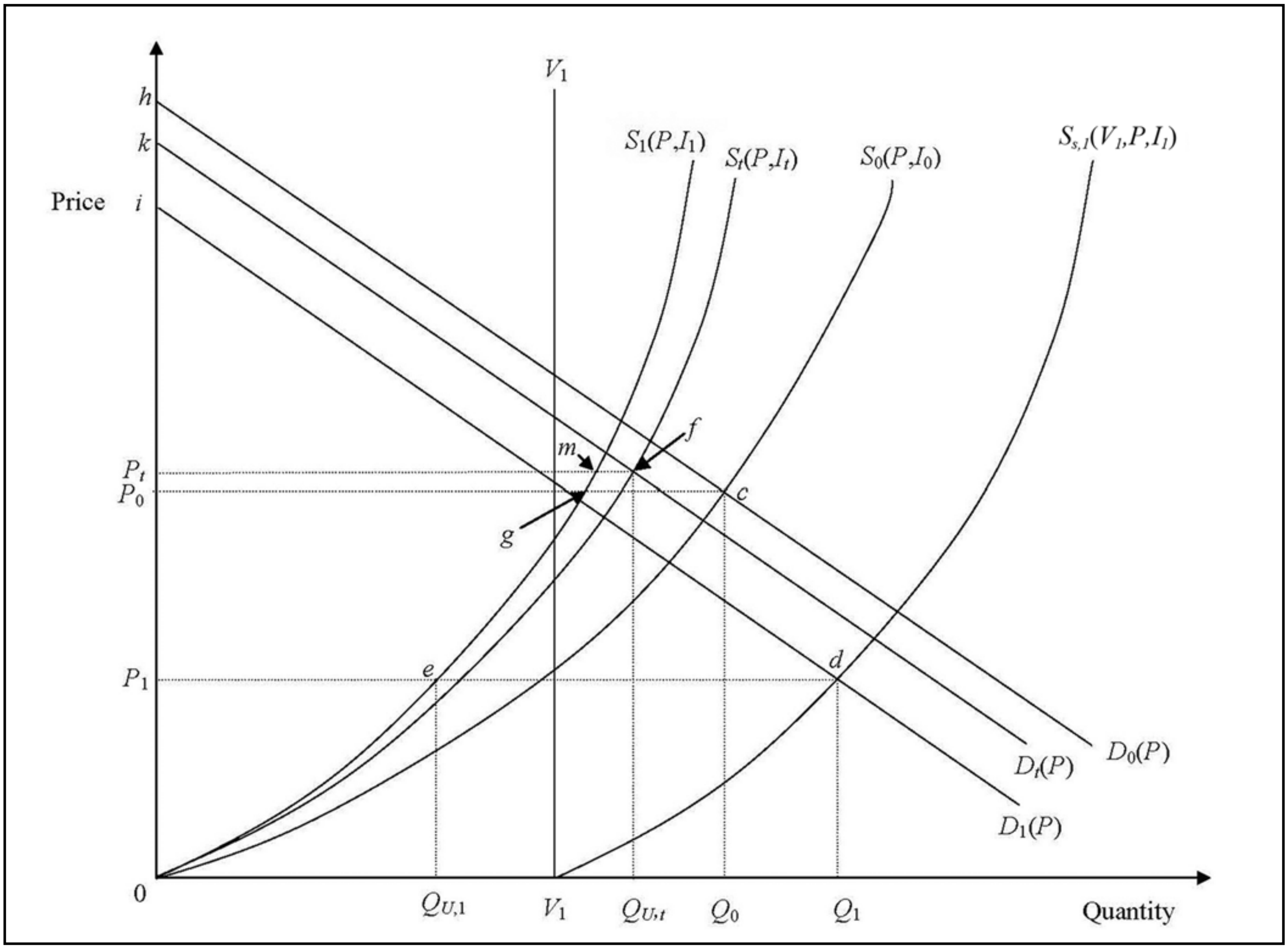

Figure 2—A representation of the timber market following a natural disaster such as a hurricane. The primary effect of hurricane damage to timber is to temporarily shift supply outward (from S_0 to $S_{s,1}$) during salvage and then shift back to S_1 due to salvage exhaustion and inventory loss. As inventory (I) regrows, supply shifts outward toward S_0, and an intermediate position may be S_t. Demand, initially at D_0, may shift backward to D_1 because of mill closures and higher market prices; intermediate demand level is at D_t, during inventory regrowth. Price paths over time can be traced to these market shifts. Lower-case letters have been added at intersection points to facilitate detailed discussion in the text.

shifts in the aftermath of large-scale catastrophes affecting timber.

Graphical Overview of Market Shifts

Following a large hurricane (or any natural disaster), a timber market may undergo substantial changes in supply and demand. In Figure 2, supply of timber is represented as S_0 initially and is a function of price (P) and available inventory (I_0). Demand, also a function of price, is the curve sloping down from the left, and initial levels are represented by the curve D_0. The initial (prestorm) price is designated as P_0, and quantity is Q_0. Following the storm, the timber supply curve shifts inward to S1 due to a reduction in available standing live inventory of undamaged timber (I_1). However, in the immediate aftermath of the storm, a pulse of timber salvage, V_1, enters the market. This supply is zero when price is zero—i.e., it is a single point—but jumps to a large positive amount when price exceeds zero (Holmes 1991; Prestemon and Holmes 2000, 2004). In other words, the supply curve parallels the horizontal axis between 0 and the quantity V_1. Any stand with fatally damaged timber with nonzero stumpage value is part of salvage supply. The combination of the inventory effect and the salvage effect is to create a total market supply of $S_{s,1}$. Again, as in the case of the salvage supply, $S_{s,1}$ consists of a single point at (0,0) but jumps to V_1 when price slightly exceeds zero. During this salvage period, the equilibrium price is P_1, lower than the prestorm price. When the pulse of salvaged timber is exhausted, the supply curve reverts to S_1, with a higher price (P_t) than prior to the storm. As inventory grows over time, the supply curve gradually shifts back out to the original position of S_0, achieving the original price and quantity at equilibrium. At that point, assuming no investment shifts owing to the storm, the effects of the hurricane disappear from the market.

In addition to impacts on timber supply, hurricanes might also impact timber demand. Many mills were closed because of either hurricane damage to mill facilities or anticipated long-term timber shortages following salvage operations after the passage of Hurricane Hugo. Syme and Saucier (1992) uncovered some evidence of short-term mill closures. In that case, demand might shift back (to D_1), as capital is reallocated to other, undamaged regions or out of the wood processing sector. The degree of backward shift in demand identified by Prestemon and Holmes (2004) was slight. Such a backward demand shift tended to dampen any price swings following Hugo. However, it could be that, with time, demand expands in response to timber inventory regrowth, allowing for prices that are not as low (e.g., P_t) as they would be if demand did not respond.

Timber Price Movements Through Time

Timber prices following a hurricane proceed through three phases: (1) price depression, (2) price enhancement, and (3) the gradual return of timber prices to prestorm levels, as implied by the discussion of the graphical representation of the hurricane's impact on a timber market. First, immediately following the storm, a price depression occurs, as was identified by Yin and Newman (1999) and Prestemon and Holmes (2000) following Hurricane Hugo. The finding of a price depression is consistent with what Holmes (1991) found in the case of southern pine beetle (*Dendroctonus frontalis* Zimmermann), and in all cases it is due to timber salvage activity, which drives down the market price owing to the supply expansion.

Prestemon and Holmes (2000) also found that there was a second stage involving a higher set of prices for timber products owing to the shortage of timber inventory following Hugo's destruction. This is the enhancement effect identified by them statistically, consistent with theory and with local markets where timber is expensive to move. Such an effect has been observed in other circumstances, as well (Berck and Bentley 1997, Olson and others 1988). In the third stage, timber returns to the prestorm level, when the inventory returns to normal levels.

Figure 3 illustrates timber price dynamics following a large-scale natural catastrophe. This figure shows a brief, negative price spike for timber because of salvage, a longer term price enhancement owing to inventory shortages, and then a gradual price reduction to precatastrophe levels as inventory regrows. Both a timber price index (where the precatastrophe timber is normalized at an index value of 100) and a timber inventory index (where the precatastrophe inventory volume is normalized at an index value of 1.00) are shown, indicating that 25 percent of timber inventory is killed. The figure is built upon assumptions of a constant demand elasticity with respect to timber price of –0.5 and constant supply elasticities with respect to price and inventory of 0.3 and 1.0, respectively. (These elasticities represent the percentage change in timber supplied to the market, given a 1-percent change in price or inventory volume, respectively). It also assumes that (1) 30 percent of timber killed is salvaged, (2) it takes 4 quarters (a quarter is 3 consecutive months) to exhaust the salvage, (3) the salvage quantity is highest immediately following the event and tapers off linearly following the event, and (4) the salvage quality discount factor is 5 (i.e., a unit of salvage timber has a quality discount of 80 percent).

Prestemon and Holmes (2000) conducted an intervention analysis of southern pine sawtimber and pulpwood stumpage (timber) prices, modeled after a similar analysis conducted by Holmes (1991). The approach was to model timber prices as autoregressive-integrated-moving average processes, including an intervention component that captured the effect of the hurricane on South Carolina timber prices. Comparison of the South Carolina price processes to price processes for the same product in other locations

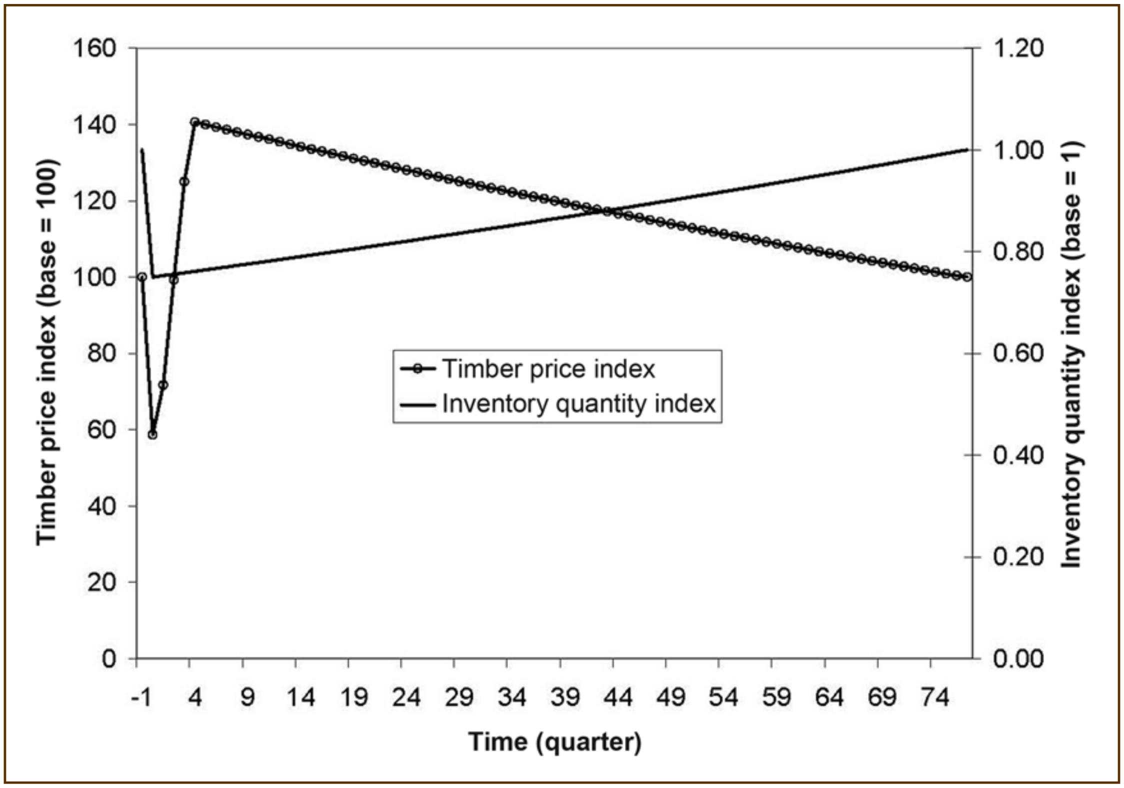

Figure 3—A hypothetical price path over time for timber following a large-scale natural catastrophe. In this figure, prices in the quarter immediately preceding the catastrophe (quarter -1) are at 100 and inventory is at 1.00. In the quarter of the catastrophe, inventory drops to about 0.75 and prices fall to 60 as salvage volume moves into the timber market. With salvage exhaustion, the inventory shortage effect is felt in timber prices, as they are temporarily elevated to as high as about 140. With time, prices recover to their original level as inventory returns to its initial volume.

in the South allowed identification of the full price effect of the storm, in both the short and long terms. As Holmes (1991) pointed out, statistical identification of the market price effects of such an event requires a sufficiently long series before and after the modeled event in order to identify derivative patterns in the prices owing to the event. Prestemon and Holmes (2000) found in their intervention analysis that salvage induced an average 30-percent decline in green (undamaged) pine pulpwood and pine sawtimber stumpage prices during the salvage period and that the inventory loss induced a persistent 10- to 30-percent enhancement (increase) in those prices after salvage was exhausted. This finding relied on tests that confirmed the nonstationarity of timber prices in South Carolina and identification of significant co-integration relations between South Carolina prices and those of other States. Nonstationarity of the State's timber prices has been also confirmed using longer time series, inclusion and exclusion of time trends, alternative deflation methods, and alternative tests of stationarity by Prestemon and others (2004). Using a different approach that relied on an assumption of trend-stationary timber prices in South Carolina, Yin and Newman (1999) identified no long-run price enhancement in South Carolina.

Welfare Movements through Time

This section describes how timber damages, salvage, and price shifts result in effects on different segments of the timber market. Results from published research are used to illustrate these shifts. Prestemon and Holmes (2004) traced out the economic equity (welfare, or economic surplus) impacts of hurricanes and similar large-scale catastrophes in an analysis that is based on methods applied by Holmes (1991) and those of Just and others (1982). Thurman and Easley (1992) showed how, when an event occurs in a

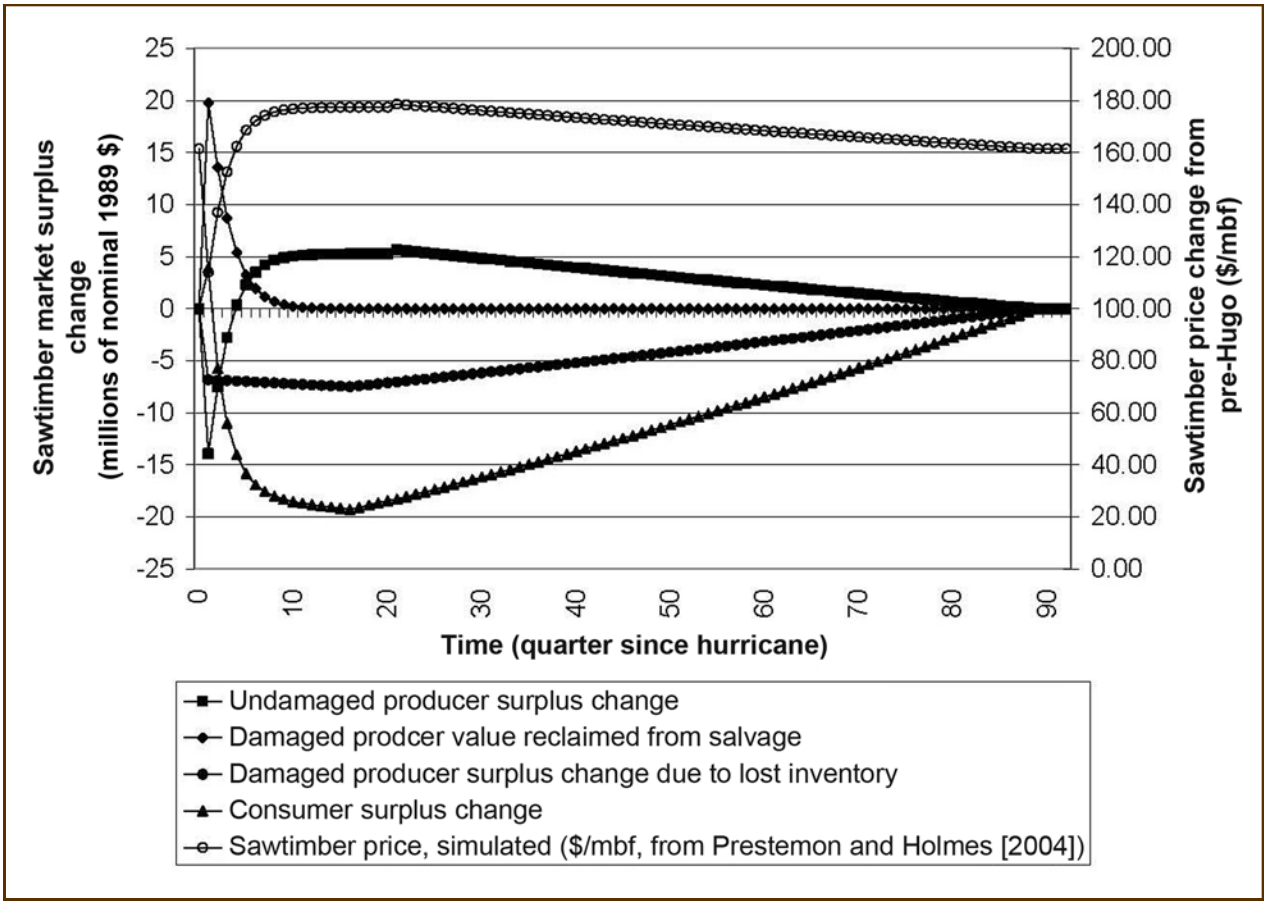

Figure 4—Identified price and welfare shifts in the Timber Mart-South (Norris Foundation, 2004–2006) Region 2 market, South Carolina, immediately before and after Hurricane Hugo, for southern pine sawtimber, by quarter. Figure based on the base case scenario data from Prestemon and Holmes (2004). [mbf = million board feet].

primary product market (such as timber), a welfare analysis of the economic impacts of the event on the primary market will capture the effects on all higher levels of processing deriving from that market. Given this, in our study, the full timber market economic impacts can be partitioned across owners of damaged timber, owners of undamaged timber, and timber consumers. This requires definition, however. Consumer surplus is defined, in Figure 2, as the area below the demand curve, above the equilibrium market price, and to the left of the equilibrium quantity supplied to the market. For example, before the hurricane, the consumer surplus is area P_0ch, while in the immediate aftermath of the storm, it was area P_1di. Producer surplus of undamaged producers is the area above and to the left of the supply curve and below price. Before the storm, producer surplus was P_0c0. In the immediate aftermath of the storm, producers of undamaged timber receive surplus represented by the area P_1e0, but as timber salvage is exhausted, say in period t, this subset of producers actually gains, with their surplus valued as 0fmP_t. The producer surplus gained by damaged producers upon salvage of their timber by the storm is equivalent to salvage volume (e.g., V_1) times the price received during the salvage period (P_1). This is the area represented by the rectangle P_1d$Q_1$0. In the immediate aftermath of the storm, then, these undamaged producers, because they cannot produce undamaged timber, also lose an area represented by a curved shape bounded by 0, S_1, S_0, and demand curve, D_1, the shape represented by the shape 0cg.

Figure 4 illustrates how changes in southern pine timber market economic surplus, salvage revenues, and timber price varied over time following hurricane Hugo, as identified by Prestemon and Holmes (2004). In their simulations, inventory regrowth is projected, based on Forest Inventory and Analysis surveys in 1993 and 1999 in South Carolina. The rate of regrowth is a key determinant of the quantity and timing of post-hurricane welfare impacts. The figure shows that consumer welfare increased briefly following the hurricane because of lower prices and greater quantity consumed. Undamaged producers were briefly harmed from this salvage, but damaged producers captured some value for a few quarters. Consumers were harmed over the long term, undamaged producers gained over the long term, and damaged producers lost in the long term. In this figure, prices were determined to return to prestorm levels in the sawtimber market by 2012, about 90 quarters (23 years) after the storm. A similar price and welfare path was also traced out by Prestemon and Holmes (2004) for the southern pine pulpwood market there.

As shown, all of these losses and gains proceed into the future until the timber inventory returns to the prestorm inventory volume and timber production and price levels. The long-term discounted economic surplus lost and gained by the various market participants is tracked by tallying these changes for all periods into the future, discounting the values using an economic discount rate to the present. In a later section, we describe those changes for Hurricane Hugo in a table.

Salvage

This section describes how the value of salvage is calculated and some of the factors influencing the value recovered by salvaging timber. Readers interested in more detail about the economics of the salvage decision should review Haight and others (1996), whereas those interested in operational aspects of salvage should see Stanturf and others (2007). Our research and research conducted by others (e.g., Lowell and others 1992), indicate that the value of salvage depends on several factors: (1) the severity of initial damage (function of wind, prestorm rain); (2) the amount of timber decay, which is a function of tree species, the post-event ambient air temperature, the post-event ambient humidity, the dimensions of the materials, and time; (3) the aggregate volume of salvage entering the timber market; and (4) market supply and demand sensitivities with respect to price and market supply sensitivity with respect to inventory. The species, temperature, humidity, log dimension, and time all govern the current value of the salvage discount factor, *K*. *K* is used to translate the salvage volume into a value-equivalent "green" timber volume for market valuation purposes (see Holmes 1991):

$$Q^s = Q^D K^{-1},$$

where Q^D is the raw quantity damaged or killed and Q^S is the value-equivalent of the timber in "green" timber volume. As *K* increases, the value-equivalent reduction in timber volume increases.

What the research implies is that hurricanes (which occur generally in warm, humid areas of the United States and cause a great amount of physical damage to the internal log structure from wind) produce values of *K* that are large. Prestemon and Holmes (2004) found that *K* likely averaged about 4.5 for southern pine sawtimber following Hugo and 6.6 for southern pine pulpwood. Events such as fires (e.g., Lowell and others 1992) and southern pine beetle outbreaks (e.g., de Steiguer and others 1987) produce smaller values for *K* (in the range of 1.1 to 1.5 in the months immediately following the event).

Forest and Timber Impacts of Recent Hurricanes

The need for landowners and policymakers to plan for effects of increased hurricane activity is discussed in this section, and comparative information about damage levels of recent vs. older hurricanes is provided. Recent hurricanes, including Ivan and Frances in 2004, and Katrina and Rita in 2005, provide evidence of the timber market impacts of these events, including their impacts on landowners. These can also be compared with the impacts of older hurricanes, such as Hugo in 1989 and Camille in 1969, to help us understand how changes in timber prices as well as volumes affected may be leading to rising economic impacts. Below, we focus on the kinds of losses experienced by owners of timber in terms of hardwood and softwood, pulpwood, and sawtimber-product categories.

Table 2—Timber damage volume and dollar impacts from six severe hurricanes affecting selected States in the United States Atlantic Basin

	Units	Camille, 1969[1]	Hugo, 1989[1]	Frances, 2004[2]	Ivan, 2004[2]	Katrina, 2005[1]	Rita, 2005[2]
Softwood timber mortality							
South Carolina	million ft^3		1,008				
Florida	million ft^3			87	208		
Mississippi	million ft^3	216				619	
Louisiana	million ft^3					287	296
Alabama	million ft^3				603	126	
Texas	million ft^3						239
Hardwood timber mortality							
South Carolina	million ft^3		319				
Florida	million ft^3			58	94		
Mississippi	million ft^3	74				426	
Louisiana	million ft^3					193	177
Alabama	million ft^3				414	91	
Texas	million ft^3						293
Total timber mortality							
South Carolina	million ft^3		1,327				
Florida	million ft^3			145	302		
Mississippi	million ft^3	290				1,044	
Louisiana	million ft^3					480	473
Alabama	million ft^3				1,017	216	
Texas	million ft^3						532
Total, measured affected States, all species	million ft^3	290	1,327	145	1,319	1,740	1,005
Softwood portion of damaged volume	Percentage	74	76	60	61	54	53
Timber value damaged (price × quantity)							
Sawtimber value lost	Millions of 2005 dollars	177	494[3]	153	2,094	1,600	504
Pulpwood value lost	Millions of 2005 dollars	25	136[3]	9	83	113	32
All products	Millions of 2005 dollars	202	630[3]	162	2,177	1,713	536
Timber economic surplus							
Producer surplus lost, all owners and periods	Millions of 2005 dollars		121[3]				
Consumer surplus lost, all periods	Millions of 2005 dollars		1,402[3]				
All market groups	Millions of 2005 dollars		1,523[3]				

[1] Final USDA Forest Service Forest Inventory and Analysis estimates of volumes of timber mortality. Economic impacts in dollars based on these final estimates.

[2] Initial USDA Forest Service Forest Inventory and Analysis estimates of volumes of timber mortality. Economic impacts in dollars based on these initial estimates.

[3] Dollar values shown for Hurricane Hugo are for softwood timber only.

Sources: Surplus values for Hurricane Hugo are from Prestemon and Holmes (2004); volumes for Camille are from Van Hooser and Hedlund (1969); pine values are from Mississippi Forestry and Agricultural Experiment Station (2006); baldcypress and hardwood values are from and Louisiana Department of Agriculture (1969); volumes for Frances, Ivan, Katrina, and Rita are from USDA Forest Service Forest Inventory and Analysis (2004a, 2004b, 2005a, 2005b), respectively; and values are from Norris Foundation (2005–2006).

The 2005 hurricane season was the worst, in terms of timber damages, in a generation—much bigger than the largest in the last two decades, Hurricane Hugo (Table 2) (USDA Forest Service, Forest Inventory and Analysis 2005a, 2005b). Hurricane Katrina damaged 1.74 billion cubic feet of timber, and about 41 percent of the volume was hardwood. Other estimates, not reported here, put long-term damages much higher than this. Hurricane Rita added to those damages, so when combined, these two storms damaged at least twice as much timber in the affected States of Alabama, Louisiana, Mississippi, and Texas as was damaged by Hugo in South Carolina in 1989 (although those South Carolina damages exclude damages in North Carolina, another affected State).

The market value of these timber inventory losses for Katrina and Rita was quantified in a special report provided to the Forest Service, expressed in terms of 2005 dollars to account for inflation. For this review, we also quantified the same values for Hurricane Frances (which affected Florida) and Hurricane Ivan (which affected both Florida and Alabama) in 2004. These economic effects are reported at the bottom of Table 2, principally in market-value terms. In Table 2, we also include the economic effects of two other large Hurricanes, Camille (1969) and Hugo (1989). At the bottom of Table 2, we include information for Hurricane Hugo, addressing both market value and economic surplus, as calculated by Prestemon and Holmes (2004). Market values can be termed timber value losses, whereas economic surpluses can be termed economic losses. We note that the welfare impacts for softwood calculated by Prestemon and Holmes (2004) depend on assumptions regarding market supply and demand parameters and timber regrowth rates, and they depend on the validity of the price paths identified by Prestemon and Holmes (2000). Prestemon and Holmes (2004) conducted Monte Carlo and sensitivity analyses on these damages, which report ranges of possible impacts. The welfare amounts shown in Table 2 for Hugo are average estimates.

Hurricane Frances is the smallest hurricane impact shown in the table, with 145 million cubic feet of damage. Camille damaged twice as much timber as Frances, but it still is small compared to the rest of the hurricanes shown in the table. For example, Hurricane Ivan created timber damages that are comparable to those measured for Hugo. Rita created damages that totaled a billion cubic feet, about 75 percent the size of Hugo. The amount of softwood lost in these storms varied, mainly according to the amount of pre-existing softwood in the timber inventory. In the South, the amount generally exceeds 50 percent.

The values of timber damaged or killed in the storm are variable, as documented in Table 2. One surprising finding from this comparison is that Ivan's timber damages exceed the value of those found for Katrina. This is explained by the substantially higher timber prices in effect in Florida and Alabama prior to the hurricane, in comparison with the timber mainly damaged in Mississippi and Louisiana. It is also partially explained by the former hurricane's higher proportion of damage to softwood and sawtimber-sized trees. Still, when Rita's damages, which totaled over $536 million, are added to those of Katrina, those two storms damaged volumes that are more than twice those of Hugo or Ivan.

Hugo's timber value lost in the southern pine market, measured as price times quantity, was $630 million. The analysis by Prestemon and Holmes (2004) showed, however, that the market impacts in welfare terms were 2.4 times larger. This magnitude of difference between market value and welfare impact should be viewed with caution when attempting to translate between market-value losses to welfare losses for other storms or catastrophic events. Even for Hugo, this translation depended on many assumptions, especially regarding (1) timber salvage rates, market supply and demand sensitivities; (2) rates of timber inventory regrowth; (3) the reality of a long-term inventory-induced price enhancement; and (4) the scale of timber market demand and supply. Nonetheless, a rough calculation could be attempted that would suggest the economic surplus impacts of those other storms are much larger—maybe two to three times larger—than the timber value impacts shown. In short, recent hurricanes have created market losses totaling into the many billions of dollars. As Prestemon and Holmes (2004) and Holmes (1991) pointed out, these losses represent a net redistribution of wealth in the market, in favor of undamaged producers and to the detriment of consumers and damaged producers.

There are obviously other potential outcomes of hurricanes on the broader economy as they relate to the timber market. Structure (e.g., housing) losses are quite high when large events such as Hurricane Katrina sweep through heavily populated areas. The National Oceanic and Atmospheric Administration (2006) indicated that hurricanes Katrina, Rita, and Wilma in 2005 combined to create nearly 2.8 million insurance claims, totaling $40 billion in insured losses. Data provided by the American Red Cross, as cited by the National Association of Home Builders (2005), compiled preliminary estimates indicating that Hurricane Katrina damaged 275,000 homes in the Gulf States of Louisiana, Mississippi, and Alabama, 10 times the second-largest loss in homes, which was caused by Andrew in 1992 in south Florida. The National Association of Home Builders (2005) report stated that Katrina, coupled with Rita and Wilma (in Florida), would drive up prices for southern pine framing lumber, plywood, and other sheathing products. This price effect on forest products should filter back to the timberland, helping to support prices in the Southern United States during the reconstruction phase. The implication here is that landowners whose timber was unaffected by the storms should enjoy some price support, increasing the chances for a post-hurricane price enhancement, even if that enhancement does not emanate directly from lost timber inventory in the region.

Management Implications

We now discuss the future of hurricane activity in the United States and the implications of the existence of hurricane risk on land management strategies, with a focus on timber salvage. What we can glean from the previous discussion is that the impacts of hurricanes on landowners will be partitioned according to the location of the timberland. Hence, owners closer to the impact zone—typically, closer to the ocean—will face a higher likelihood of timber damages and long-term negative impacts. Those farther from the coast may face lower impacts and a greater chance that they could enjoy a long-term price enhancement owing to timber inventory losses and, potentially, output effects on the construction market. Due at least partly to the species mixes and particular species vulnerabilities, it appears also that owners of softwood timber may face greater economic risks than owners of hardwood timber, but this is a hypothesis that remains to be tested in the literature. Hardwood damages frequently occur as degrade, rendering the stand lower in value in the long term and potentially vulnerable to a higher rate of mortality (Sheffield and Thompson 1992).

As we appear to be in a period (or riding a trend) of higher hurricane activity, we might expect that the frequency and magnitude of large-scale catastrophic hurricanes will increase or remain high for several years or decades. In response to damage, timberland owners would do well to prepare for such storms by assessing the value of the timber before the storm. Creditable casualty losses require that the current basis of affected timber be assessed. Following such storms, timberland owners whose timber is unaffected would benefit from withholding their mature timber from the timber market until after salvage material has been recovered from damaged forests and then consumed at area mills. As well, owners of damaged timber should endeavor to quickly arrange for the salvage of their timber, owing to the high likelihood of timber decay for killed timber. Here, some colloquial evidence suggests that hardwoods should receive lower priority, as they may remain alive and hence valuable for a longer period, compared to softwoods, which are more likely to die following a storm (Sheffield and Thompson 1992). Because of the rapid decay rate of killed timber, then, it is especially beneficial to quickly salvage such timber following the event, especially timber stocks with the least amount of damage, to justify salvage.

Government actions following catastrophic windstorms may have an effect on the value of salvaged timber. For example, timber salvage on publicly owned lands has a negative impact on private landowners but a positive impact on consumer welfare (Prestemon and others 2006). There are, however, government actions that can produce broader benefits. Governments can facilitate salvage activities by (1) rapidly clearing roads, (2) relaxing weight limits on roads to allow logging trucks to carry heavier loads, (3) permitting larger than normal log storage volumes at mills,

(4) subsidizing or providing tax breaks for mills to produce water storage facilities for logs, (5) aiding in post-hurricane damage assessment, and (6) assisting private landowners and nongovernmental organizations with salvage planning (Freeman 1996, Lupold 1996). However, we would caution that research is currently not available to help evaluate either the form or the scale of public interventions that would be economically or socially optimal.

Research Needs

We conclude our synthesis of the impacts of hurricanes on forest landowners with a discussion of the research needed to further advance our understanding of these impacts and to identify alternative strategies for coping with these storms. This assessment reveals a long list of potential research needs. A primary need in all timber market assessments of hurricanes is up-to-date and precise information on green timber supply, salvage supply, and demand function parameters. Our results for Hurricane Hugo depend critically on assumed market sensitivities, and conclusions about the ultimate economic (especially welfare) impacts of other events depend on similar assumptions that need to be evaluated. We would note that for published salvage studies (starting with Holmes 1991), assumptions were made about the perfect inelasticity of the salvage supply function. This function is unlikely to be perfectly inelastic (unresponsive to prices). Although sensitivity analysis is useful for establishing plausible bounds on potential economic impacts, up-to-date studies of southern pine supply and demand functions would reduce the need for making assumptions regarding market conditions. Additionally, new studies are needed to identify how hurricanes affect markets for products other than southern pine. A large component of total timber impact results from damages to hardwoods, yet hardwood markets are notoriously under-researched. Such studies could reveal not only the hardwood market economic impacts but also potentially identify new and innovative strategies that owners of hardwoods could apply before and after hurricanes and other catastrophic events.

Timber salvage is a means of recovering value following such storms, yet little is known about how various factors affect the size of the timber salvage discount, particularly how it varies over time and among species. Such studies could provide valuable information regarding optimal salvage strategies following major hurricanes. Our economic calculations—and, hence, recommended salvage strategies—could be improved and changed with better information on this segment of the post-hurricane timber market.

Other analysts in these proceedings provide evaluations of the timber management consequences of holding timber assets that are subject to large-scale natural disturbances. However, research to date has not addressed whether long-term price enhancements emanating from a hurricane or other large natural disturbance can generate expected profits that are, in aggregate, greater than those expected in regions without such events. Timber losses occur in a subset of the timber market—consumers and damaged producers—but the gains could be significant for some landowners. Identifying the circumstances under which timberland owners gain, in aggregate, from these storms is an area worthy of further study.

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