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Economic Impacts of the Southern Pine Beetle

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Abstract

This paper provides an overview of the timber economic impacts of the southern pine beetle (SPB). Although we anticipate that SPB outbreaks cause substantial economic losses to households that consume the nonmarket economic services provided by healthy forests, we have narrowly focused our attention here on changes in values to timber growers and wood-products consumers. Thus, the economic values reported here represent a lower-bound to the total economic impacts of SPB in pine-dominated forests. A theoretical framework for measuring economic impacts on individual forest landowners is described. This framework is then linked with a model of the timber market impacts of the SPB that allows us to estimate separate impacts for timber producers and wood-using firms. The salvage of timber killed by the SPB during large outbreaks creates a surge in the volume of pine timber entering the market that, in turn, decreases the timber market price faced by all timber sellers. This short-run impact decreases the economic welfare of timber producers while increasing the economic welfare of wood-using firms that can obtain timber at lower prices. Over longer periods of time, large SPB epidemics can reduce the volume of standing timber inventories, causing a smaller, but important, increase in the price of timber due to increased timber scarcity. Estimates of the short-run and long-run changes in economic welfare are computed using an empirical model. During the 28 years for which we have data, estimates of short-run impacts indicate that timber producers have lost about $1.2 billion to the SPB, or about $43 million per year, and wood-using firms have gained about $837 million or about $30 million per year due to SPB outbreaks. Because the broadscale effects of accelerated harvesting impact all timber owners in the affected areas, governments may play a role in reducing the negative impacts on timber producers. Strategies include: 1. holding SPB-killed timber on public forests off the market in order to limit the short-run price depression, 2. temporarily adjusting weight restrictions on public roads to help facilitate timber salvage on private forests, and 3. advising forest landowners with healthy forests to forego timber harvesting until the pulse of beetle-killed timber clears the market and prices return to more normal levels.

14.1. INTRODUCTION

Southern pine beetle (*Dendroctonus frontalis* Zimmermann) (SPB), epidemics periodically cause widespread mortality in pine-dominated forests in the Southern United States and induce a variety of economic impacts. The SPB is native to the Southern United States and plays an ecological role, along with wildfire, in the recycling of nutrients in forest ecosystems. Despite its evolutionary role, the SPB disrupts the flow of economic goods and services demanded by modern society. The spectrum of contemporary economic impacts includes the loss of timber values to forest landowners and a loss of aesthetic and recreational values to a complement of resource consumers (Leuschner 1980). During catastrophic SPB outbreaks, aggregate markets for goods and services are affected, and economic impacts are transmitted across a broad complement of consumers and producers.

Estimating the economic impacts of a forest insect epidemic is not a simple matter. In contrast to agricultural systems, forests are long lived so that the economic impacts of current forest mortality are distributed over many years. Insect epidemics may suddenly terminate decades of productive forest growth and reduce stocks of commercially available timber for years to come. In addition, pine-dominated forests provide an array of ecosystem services, so that nonmarket economic damages need to be considered. Estimates of the total impacts of SPB damage, while difficult to approximate, are crucial data for evaluating the risk profile of forest investment decisions, optimal approaches to pest management, and government policies for responding to epidemics.

The exclusive focus of our analysis here is the effect of SPB epidemics on the returns to timber production in the South. Economic impacts to timber producers and wood-products firms are essential to consider because the SPB causes extensive mortality in forests that have high commercial value in a region with the most active timber market in the world (Prestemon and Abt 2002). We first consider the effects of localized tree mortality on individual landowners. We then examine how broadscale tree mortality affects markets and consumers and producers of timber in both the short and long runs.

14.1.1. Theory of Landowner Impacts

When the SPB kills a landowner's trees, changes in the plans for forest management result. Assuming that these plans represent the high-value course of action for the landowner, unanticipated mortality will lead to some loss of value. How are these losses defined? First the landowner faces an immediate decision regarding the treatment of the killed timber. Options may include: 1. A salvage harvest, 2. A sanitation cut to mitigate further damage, or 3. Nothing. All three options imply costs, both the costs of conducting the treatments and opportunities foregone associated with altering the schedule of forest management activities. For example, the landowner will suffer losses associated with harvesting timber earlier than planned—that is, losing the returns to additional years of tree growth. Prices for damaged timber will likely be lower than prices for undamaged timber, leading to even greater losses. In addition, higher costs are likely to be incurred for salvage harvests because they involve smaller stems and overall harvest volumes, and require extra measures to mitigate the hazards associated with cutting dead and damaged timber.

When a landowner decides to conduct a salvage harvest there are several factors that contribute to the total costs of the mortality. They can be derived by contrasting the net returns of management following the epidemic with the value that would have been derived from managing an undamaged stand (a precise mathematical derivation of these impacts can be found in Appendix A). There are five factors influencing this change in value:

1. Reduction in the price paid for the damaged vs. undamaged timber
2. The loss of volume that would have accrued in subsequent years (depends on the current age of the stand)
3. The higher costs of harvesting damaged vs. undamaged timber
4. Accelerated cost schedules; e.g., regeneration costs are incurred sooner, rather than later
5. Changes in value associated with harvesting the next crop of trees sooner

The first factor is very likely to be negative; the second, third, and fourth terms are unambiguously negative; and the fifth term is positive. Because of the effect of discounting in all cases we can envision, the negative terms far outweigh the small positive impact in the fifth term. Overall, the economic impacts of the epidemic for the owner with damaged timber are associated with: 1. harvesting timber sooner than planned, 2. the price penalty for the damaged timber, and 3. changes in the timing of management costs and subsequent timber harvests.

14.1.2. Theory of Market Impacts

When the SPB reaches epidemic conditions, so much salvage harvesting can be generated that it changes the overall market for timber. During the epidemic, for any given price, much more timber enters the market due to salvage harvests. Because the demand for timber is unaffected by the SPB, this surge in timber supply results in the reduction of timber prices and spreads the impacts of the epidemic beyond the landowners, with damaged timber to include all participants in timber markets:

1. *Owners of damaged timber:* Price reductions amplify the damages described above for these individuals. Because of rapid decomposition of dead logs, they have little opportunity to defer their harvests to await the return of higher prices.
2. *Owners of undamaged timber:* Price reductions harm all timber producers, either through the receipt of lower prices for their harvested timber or through the costly deferral of timber harvesting to later dates.
3. *Purchasers of timber:* Timber purchasers receive an economic gain from paying less for their timber. That is, they purchase more timber and at a lower price than would have ordinarily been the case.

So in the short run, SPB epidemics cause a surge in supply with a concomitant reduction in timber price, and result in losses to all timber producers and gains to timber consumers (Holmes 1991). In the language of welfare economics (Just and others 1982), the total return to timber producers is called Producer Surplus, referring to the difference between the revenue achieved in selling timber and the cost of delivering the timber. The surge in supply yields a smaller Producer Surplus. The total benefits accruing to the consumers of timber are called Consumer Surplus, and refers to the difference between the price paid and the value of the timber in the production of wood products. Surges in supply yield higher consumption and lower prices, and therefore a net gain in consumer benefits will result.

Economic impacts of an SPB epidemic may extend beyond its physical duration. Damage from the epidemic could be extensive enough to reduce the stock of standing timber available for harvest in future periods. If this happens, the long-run market will adjust to yield effects opposite to the short-run impact. Timber supply contracts, so that less is harvested at a given price and, *ceteris paribus*, timber prices increase. As a result, timber producers in these out-years will reap benefits (Producer Surplus increases), while timber consumers lose benefits (Consumer Surplus shrinks). In practice, these longer run impacts are much smaller than the short-run impacts. However, because impacts are spread across many years, they represent an important component of the total costs of a major SPB epidemic.

In the next section, we provide a summary of historical SPB activity in the South. We start with a rough estimate of the volume of timber killed by SPB on an annual basis and calculate the value of timber revenue foregone. Because we cannot estimate changes in the opportunity costs of individual landowners, this approach may underestimate the total damage suffered by individual landowners. We next evaluate the market impact of the epidemics as it provides a reliable index of direct damages. We estimate the effect of SPB mortality on timber prices, but our primary focus is on measuring changes in Producer and Consumer Surpluses for the timber markets in the South. We estimate the impacts of SPB using a model that accounts for both the short- and the long-run effects and provide insights into the impact of this insect through both endemic and epidemic periods over the past 30 years.

14.2. MORTALITY AND SALVAGE ESTIMATES

Southern pine beetle populations and associated timber damage exhibit dramatic swings even when aggregated across the South. The volume of timber killed by SPB from 1973 through 2004 has ranged from 3 to 417 million cubic feet (Figure 14.1). Eight outbreaks of varying intensity are apparent, each spanning only portions of the region.

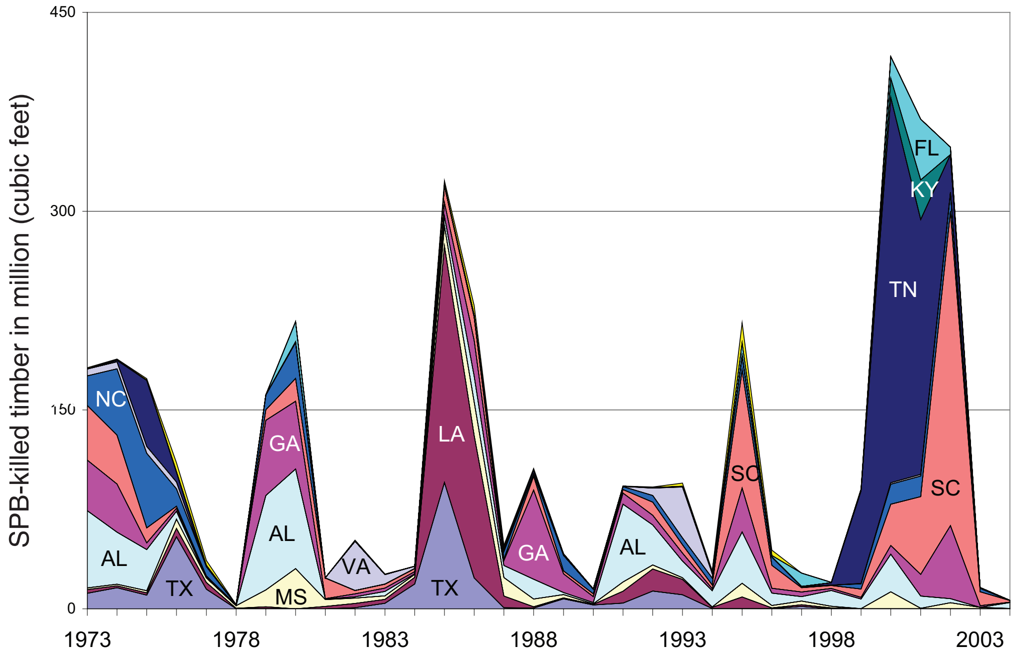

Figure 14.1—SPB-induced timber mortality by year and State.

The largest Southwide SPB outbreak was also the most recent, running from 2000 through 2002 and causing timber mortality exceeding a billion cubic feet. Damage in each year of this outbreak exceeded timber mortality in any other year of the historical record. Nearly half the total damage was reported in Tennessee.

The first 4 years of this record (1973–76) evidenced the second largest Southwide outbreak, which spanned most of the southeastern portion of the South. Damages were augmented during the final year of the outbreak by a geographically separate epidemic in Texas.

Nearly as large as the 1973–76 epidemic was the outbreak of 1984–86, which principally affected Texas and Louisiana. Other notable outbreaks include the 1979–80 outbreak in the Deep South, the 1995 outbreak in the Southeast, the 1988 outbreak in Georgia, the 1991–92 outbreak in Alabama, and the 1982 outbreak in Virginia.

In short, southern pine forests periodically experience a large SPB outbreak somewhere in the region on relatively short cycles. Although Southwide damages did not exceed 8 percent of typical sawtimber or pulpwood harvests in any given year, the concentration of mortality to subregions suggests that impacts to local timber markets would be more severe.

As described in the Theory of Market Impacts section above, the impacts of mortality include both short-term effects of timber salvage on timber harvest volumes, and longer term effects of mortality on timber inventory. Figure 14.2 plots both these factors for individual states and years. More specifically, the horizontal axis shows reported salvage amounts expressed as a share of typical softwood harvests during that year. The vertical axis shows the amount of timber killed by SPB expressed as a share of softwood inventories. All measures are for softwood sawtimber, and are annual and statewide.

In most years and in most States, damages and consequent salvage levels are low, hence the cluster of points near the origin. Extreme events are found away from the origin—only the most extreme are labeled. The wide scatter of points reflects the different character of outbreaks in particular states. Outbreaks such as experienced in Kentucky during 2001 and Louisiana in 1985 induced salvage levels amounting to more than a third of typical statewide harvest levels. These amounts would likely cause substantial short-term depression of stumpage prices.

Conversely, the outbreak in South Carolina in 2002 evidenced very low salvage amounts, relative to typical harvest levels. However, the mortality from southern pine beetle accounted for more than 2 percent of softwood inventories in that State. Such reductions in timber inventories are expected to result in longer term increases in local and statewide stumpage prices.

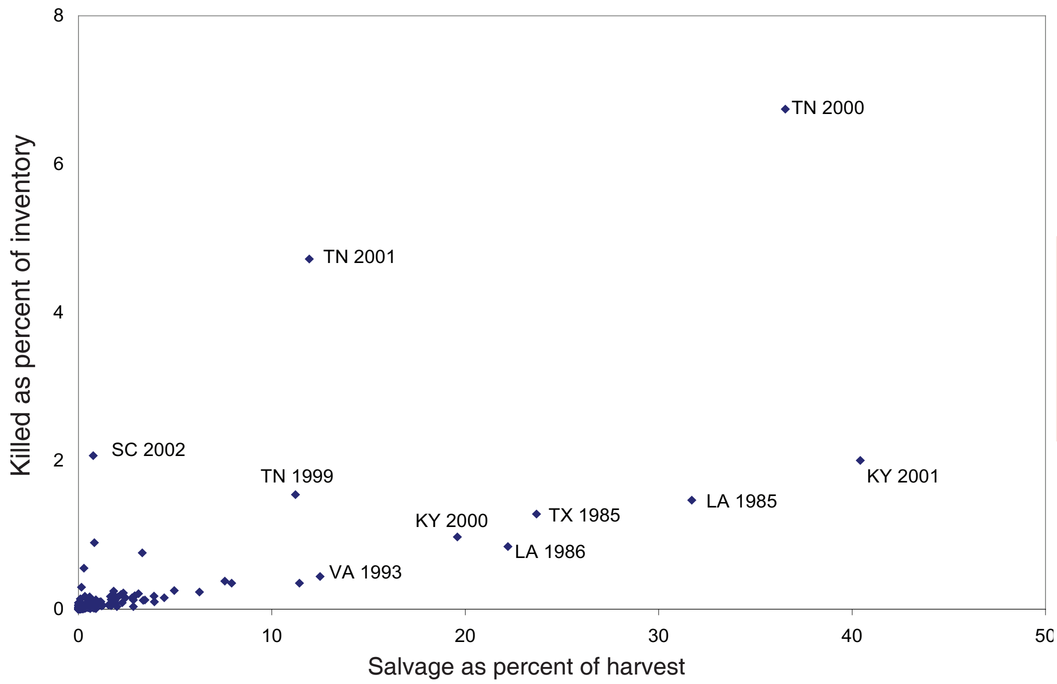

Figure 14.2—Annual salvage and mortality from SPB relative to harvest and inventory levels, key factors in short-term and long-term market impacts.

14.3. ECONOMIC DAMAGE ESTIMATES

As discussed in the preceding section, the salvage activity and broader timber mortality associated with SPB outbreaks have both near term and delayed effects on timber markets. These have differential effects on various participants in these markets. Assumptions used in this analysis are found in Appendix B.

14.3.1. Short-Run Aggregate Impacts

The short-run economic impacts of SPB outbreaks on timber markets in the South are large, and result primarily from the effect of salvaged timber on market prices. During the period for which economic data are available, 1977–2004, the SPB was estimated to cause a net, short-run economic loss to southern timber markets of about $375 million (in constant 2004 dollars). Dividing the total market impact by the total number of years included in the data record, the average net annual loss was roughly $13 million. However, annual damage estimates can be misleading in understanding the economic impacts of the SPB. Although SPB kills timber somewhere in its range every year (Figure 14.1), most economic impacts occur during a small number of large outbreaks. These catastrophic outbreaks have occurred every 5-10 years in southern forests during the past 3 decades (Figure 14.3).

Catastrophic timber market impacts caused by SPB epidemics are both episodic and geographically dispersed. For example, roughly a third of the timber market losses in 3 decades of outbreaks occurred during just 3 years (1984–86), accounting for $133 million in losses. Most of these losses were in Texas and Louisiana. The second-worst outbreak occurred during 2000–02 and caused timber market losses of about $110 million, largely in Tennessee and Kentucky. The third-worst outbreak occurred during 1979–80, caused losses of about $48 million, and was particularly severe in Alabama and Georgia. Finally, a relatively short epidemic occurred in 1995, causing timber market losses of about $25 million. This epidemic differed from the other catastrophic outbreaks in that it was geographically widespread and created major losses in Arkansas, Louisiana, Florida, Georgia, North Carolina, and South Carolina. Taken together, these four large outbreaks occurred in 10 states, with large outbreaks occurring twice in Louisiana and Georgia, and accounted for roughly 84 percent of the total losses.

14.3.2. Short-Run Winners and Losers

Our discussion of the net economic impacts of the SPB up to this point disguises the fact that SPB outbreaks have very different impacts on different timber market participants. As discussed above, during an SPB

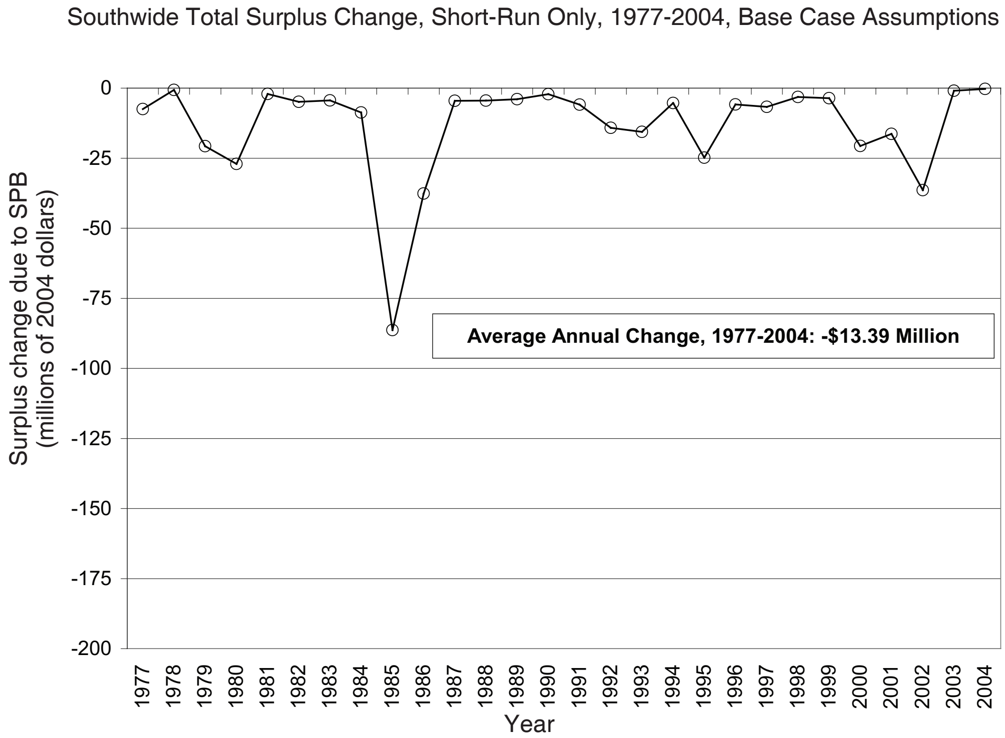

Figure 14.3—Southwide net short-run timber market impacts from SPB, 1977–2004.

outbreak, timber producers often try to limit their losses by harvesting and selling damaged trees to local mills. Live, undamaged buffer trees are also harvested and sold in an attempt to control the growth of SPB spots. The resulting pulse of salvaged and green timber depresses timber prices as local timber markets become saturated.

The pulse of salvaged timber, and lower-than-normal market prices, has a quite different effect on mills purchasing timber. Much of the value lost by timber owners who sell timber during the salvage period is transferred to wood-using mills, causing the aggregate short-run impacts described above to be potentially misleading. For example, although the aggregate short-run timber market losses occurring during the 1984–86 epidemic totaled about $133 million (Figure 14.3), the losses experienced by timber owners—due to the price depression—was approximately $429 million (Figure 14.4). A large share, but not all, of the short-run losses experienced by timber owners was transferred to wood-using firms in the form of low-priced timber. We estimated that, during this epidemic, wood-using firms gained roughly $296 million due to the availability of low-priced timber (Figure 14.5). During the 28 years for which we have data, timber producers have lost about $1.2 billion to the SPB, or about $43 million per year, and wood-using firms have gained about $837 million or about $30 million per year due to SPB outbreaks.

14.3.3. Long-Run Aggregate Impacts

As described above, the reduction in standing inventory due to SPB outbreaks causes a long-term shift in the amount of timber that is available for harvest during the subsequent rotation. A smaller volume of timber available for harvest creates a price increase in local timber markets, assuming the level of demand doesn't change from preoutbreak levels. As the timber inventory regrows during the subsequent rotation, prices gradually subside to precatastrophe equilibrium levels. Until then, the scarcity-induced, higher-than-normal price levels provide benefits to timber owners who hold stands of undamaged timber. Conversely, the higher prices reduce profits for wood-using mills that must pay a higher-than-normal price for timber.

The long-run impact of timber shortages caused by SPB epidemics, as a proportion of annual timber market benefits, is substantial and varies by state and year (Figure 14.6). For example, the epidemic of 1984–86 was severe enough to cause a long-run loss roughly equivalent to an entire year of timber market benefits in Louisiana and roughly 7 months (62 percent) of timber market benefits in Texas. While attributable to just a few years of

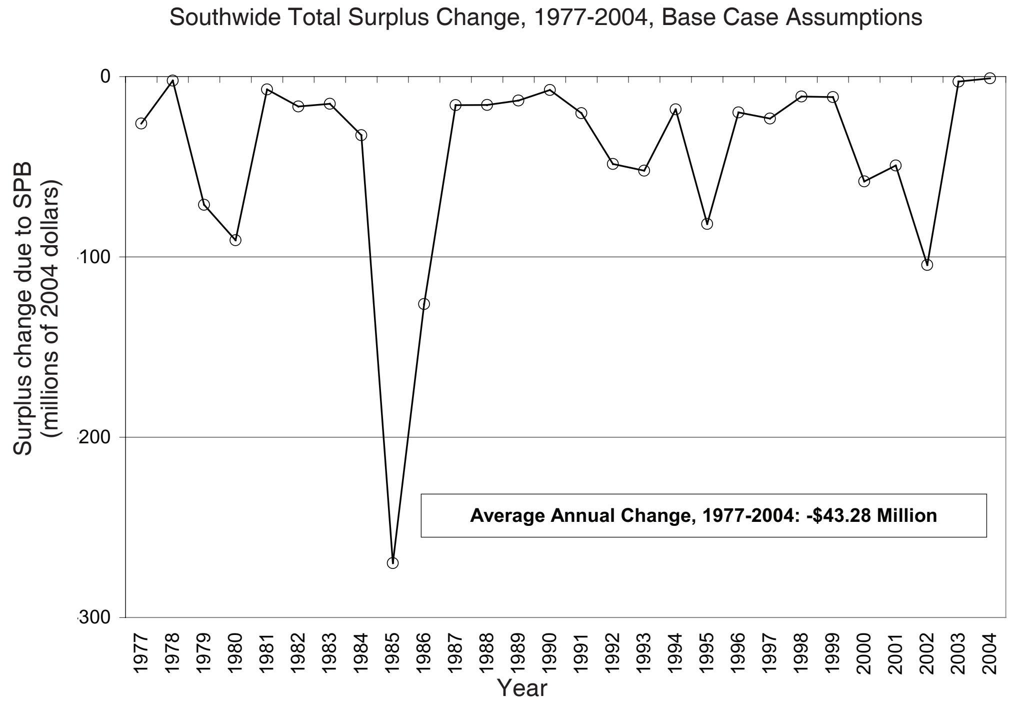

Figure 14.4—Southwide short-run losses to timber owners from SPB, 1977-2004.

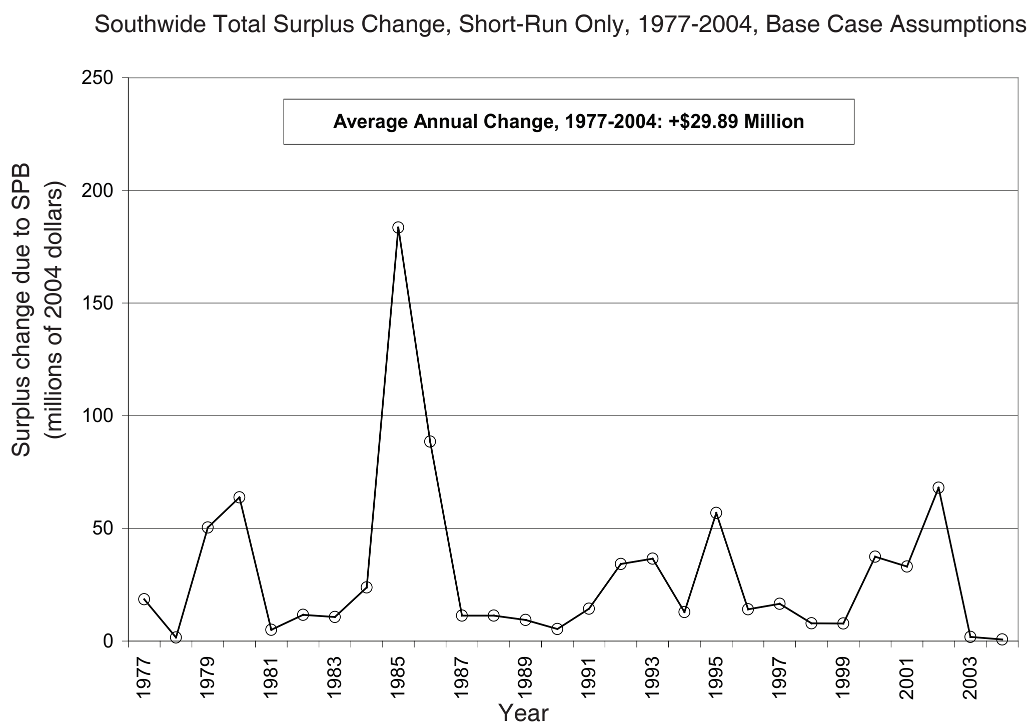

Figure 14.5—Southwide short-run gains to wood-using mills from SPB, 1977-2004.

outbreak, these long-run impacts are in practice spread across decades, and should diminish most quickly for pulpwood markets and only later for sawtimber markets.

14.4. DISCUSSION

Timber growing involves the risk of losses from a variety of disturbances including hurricanes, wildfires, and forest insects and diseases. Forestry is a capital-intensive activity because the factory (the growing forest) is also the output, such as wood products, recreational settings, wildlife habitat, or other ecosystem services. Mortality caused by disturbances such as the SPB disrupts the flow of goods and services provided by healthy forests. The loss of the productive capacity of capital invested in pine-dominated forests causes economic losses to the owners of that capital investment, such as the owners of productive timber land. The loss of the productive forest capacity also causes losses to the consumers of the outputs provided by healthy forests.

alter their production plans. By eliminating the possibility of future value growth on productive timber stands, SPB-induced timber mortality rapidly reduces the opportunity cost on the capital invested in timber production to zero. Thus, timber owners may try to salvage their beetle-killed timber to recover some economic value before it is lost.

In cases where SPB-induced mortality is widespread, such as during epidemics, many timber owners may attempt to salvage their

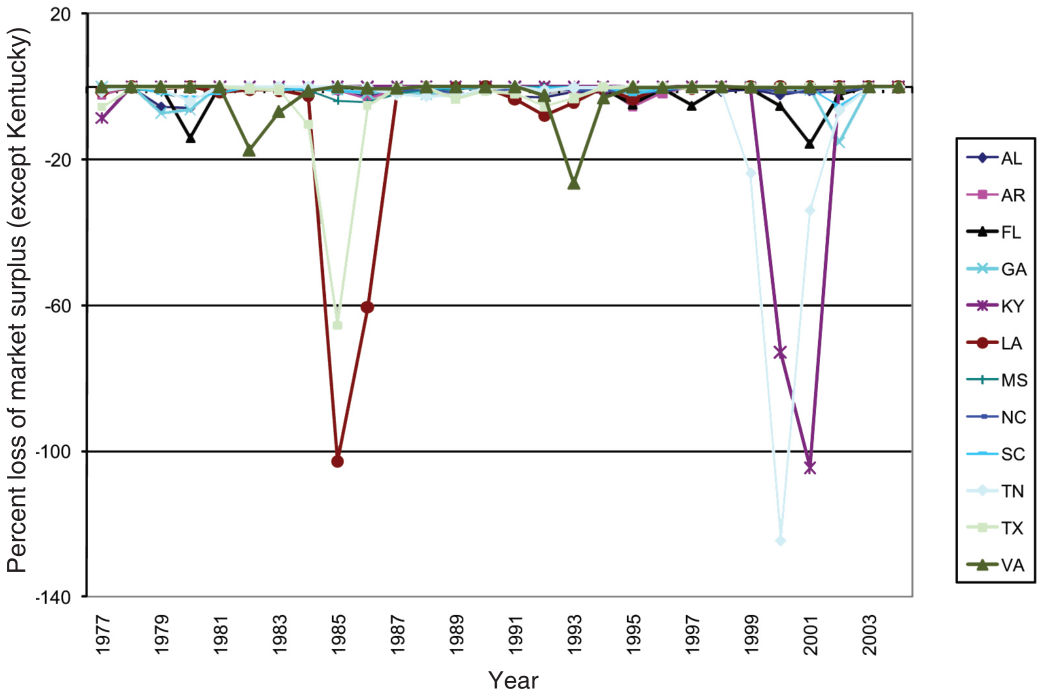

Figure 14.6—Southwide long-run losses to timber owners and wood-using mills from SPB, 1977–2004, as a percentage of annual market benefits.

timber or perhaps harvest healthy timber before it is attacked. In aggregate, this accelerated harvest of timber affects its overall supply. The pulse of timber entering the market during epidemic conditions reduces market prices for all timber owners. However, due to the loss in timber inventory, timber supply may shrink for many years following epidemic conditions.

Although we anticipate that SPB outbreaks cause substantial economic losses to households that consume the nonmarket economic services provided by healthy forests, we have narrowly focused our attention here on changes in values to timber growers and wood-products consumers. Thus, the economic values reported here represent a lower-bound to the total economic impacts of SPB in pine-dominated forests. A complete accounting of the total economic damages from SPB would require new research to estimate the economic impacts of the disruption caused by the SPB on recreational users of forests, on the production of aesthetic values on private and public landscapes, and on the changes in the risk of wildfires.

Because SPB outbreaks disrupt the timing of timber production activities, they have a negative impact on individual timber growers who must

Because the broadscale effects of accelerated harvesting impact all timber owners in the affected areas, governments may play a role in reducing the negative impacts on timber producers. If government-held forest lands are affected by an SPB epidemic, one action public forest managers can take is to withhold their beetle-killed timber from the market so that timber prices are not further depressed. To assist private landowners who wish to salvage beetle-killed timber, governments may aid the salvage process by temporarily adjusting weight restrictions on public roads. Governments may also advise forest landowners with healthy forests to forego timber harvesting until the pulse of beetle-killed timber clears the market and prices return to more normal levels.

14.5. APPENDIX A: ECONOMIC IMPACTS OF A SALVAGE HARVEST

In equation form, the landowner expects to reap a discounted or present value from managing the forest stand prior to the outbreak:

$$NPV^U = [p_U V_T - c_U]\, d^{-(T-a)} - Rd^{-(T-a)} + [p_U V_T - c_U]\, d^{-(2T-a)} - Rd^{-(2T-a)} + Zd^{-(2T-a)}$$

where NPV^u is the net present value anticipated for future management of the undamaged stand. The first term in brackets refers to the revenue (price [p] times volume harvested [V]) and costs (c) associated with harvesting at the planned rotation age (T=a+n) equal to the current age (a) plus n more years. The d variables are discounting terms that translate costs and revenues in the future to today's dollar value. Regeneration costs (R) are incurred following harvest. The next bracketed term in the equation refers to revenues and costs accruing to the second harvest rotation, and Z refers to the returns of subsequent rotations discounted from the time of the second harvest.

The net present value anticipated for the damaged stand (NPV^D), assuming that timber is salvaged, is defined as:

$$NPV^D = [p_D V_a - c_D] - R + [p_U V_T - c_U] d^{-T} - Rd^{-T} + Zd^{-T}$$

Here, the price received is the price for damaged timber ($p_D < p_U$) and the harvest volume is the volume for a stand of age a ($V_a = V_T - \Delta V$, where ΔV is the difference between standing volume and the volume expected at the planned harvest age).

To evaluate the change in value associated with the salvage harvest, we subtract the value of managing the undamaged stand from the value of managing the damaged stand. The result is the net present value of the economic damage associated with the mortality.

$$\Delta NPV = [(p_D - p_U d^n)V_a] - [p_U \Delta V d^n] - [c_D - c_U d^n] - [R(1+d^n)] - [(p_U V_T - c_U - R + Z)(d^{-T} - d^{-(2T-a)})]$$

The five terms in brackets describe the various costs associated with the SPB damage:

$$[(p_D - p_U d^n)V_a]$$

is the difference in value of harvesting the current standing volume today rather than at the optimal time in the future. Note that this term could be negative or positive depending on the difference between the price of damaged and undamaged timber and the value of the discount factor, but given the deep discount applied to damaged timber, it is likely to be negative.

$$[p_U \Delta V d^n]$$

is the difference in value associated with the loss of growth between today and the optimal harvest age. This leads to an unambiguous loss in value.

$$[c_D - c_U d^n]$$

is the difference between harvest costs for damaged and undamaged stands. This leads to a loss in value since costs are incurred sooner and the harvest costs for damaged stands are likely to be higher.

$$[R(1+d^n)]$$

is the difference in the cost of regeneration associated with moving up the regeneration date. This leads to a loss in value.

$$[(p_U V_T - c_U - R + Z)(d^{-T} - d^{-(2T-a)})]$$

represents the change in value associated with the change in timing for the second and subsequent harvests. This contributes a positive offset as subsequent harvests are now scheduled for nearer dates.

The first term above is very likely to be negative; the second, third, and fourth terms are unambiguously negative; and the fifth term is positive. Because of the effect of discounting in all cases we can envision, the negative terms far outweigh the small positive impact in the fifth term. Overall, the economic impacts of the epidemic are associated with: 1. harvesting timber sooner than planned, 2. the price penalty for the damaged timber, and 3. changes in the timing of management costs and subsequent timber harvests.

14.6. APPENDIX B: ASSUMPTIONS USED IN WELFARE ANALYSIS

Estimates of salvage and mortality are taken from www.srs.fs.usda.gov/econ/data/spb/. At that site are also found harvest and inventory estimates abstracted from Forest Inventory and Analysis reports.

Elasticities of supply and demand come from published sources. These are shown in Table 14.1.

In our simulations, we adapted the findings from Holmes (1991) to identify the elasticity of the price change of standing timber with respect to the volume of salvage entering the market. This figure was -0.73, where each percentage of salvage volume as a share of regular (pre-outbreak) harvest volume yielded a 0.73 percent decrease in price.

We also established a multiplier that would be used to compute the long-run consumer surplus impacts deriving from timber mortality. This multiplier was found through a simulation of actual inventory regrowth at varying growth rates, computed price effects due to the inventory losses at assumed elasticities (Table 14.1), and alternative discount rates. At our assumed discount rate (7 percent), growth rates, and elasticities (Table 14.1), the welfare multiplier was found to be 4.40. Applied to each economic measure (consumer surplus, undamaged producer surplus), the current year outbreak's effects on these are multiplied by 4.40 to arrive at the long-run impact, after salvage is exhausted. The simulation employed ordinary least squares and generated a model with an R^2 of 0.98, based on 280 simulated combinations of inventory regrowth and discount rates. In a separate analysis, not reported in our paper, we varied the discount rate, the regrowth rate, and elasticities to evaluate how our economic impact measures would be affected by uncertainties. The long-run multiplier was therefore adjusted to accommodate those variations in discount rate and regrowth using the estimated OLS parameters (Table 14.2).

14.6.1. Kentucky Special Assumptions

The Kentucky volume killed and salvaged for 1999–2001 were based on reported spot numbers for Kentucky. The volumes killed and salvaged were based on the average volumes killed per spot and the average salvaged rate per spot observed in Tennessee, 1995–2004.

Table 14.1—Key elasticities used in the southern pine beetle economic impact assessment

Elasticity	Value	Source
Pulpwood demand elasticity with respect to price	-0.425	(Abt and others 2000)
Pulpwood supply elasticity with respect to price	0.23	(Abt and others 2000)
Pulpwood supply elasticity with respect to inventory	1.00	(Adams and Haynes 1996)
Sawtimber demand elasticity with respect to price	-0.57	(Abt and others 2000)
Sawtimber supply elasticity with respect to price	0.55	(Abt and others 2000)
Sawtimber supply elasticity with respect to inventory	1.00	(Adams and Haynes 1996)
Pulpwood annual regrowth rate	0.05	(Smith and others 2004, p. 71, 110, 114)
Sawtimber annual regrowth rate	0.05	(Smith and others 2004) p. 71, 110, 114.

Table 14.2—Ordinary least squares estimates of the long-run surplus impacts of inventory losses as a proportion of the short-run effects found in the first year immediately following the exhaustion of timber salvage

	Coefficients	Standard Error	t Stat
Intercept	2.44	0.01	242.04
Discount Rate/100	-2.63	0.10	-26.42
Growth Rate	-20.46	0.34	-59.38
Growth Rate squared	98.08	3.05	32.12