

THE EFFECTS OF SPOTTED OWL LITIGATION ON  
NATIONAL LUMBER MARKETS

by

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## ABSTRACT

Spotted Owl litigation has led to substantial fluctuations in Pacific Northwest public timber availability from 1987 to the present. A theoretical and two distinct empirical models using monthly data are developed to understand and test the potential of this litigation to affect the national market for lumber. The results of an econometric framework indicate that Northwest public timber fluctuations have affected the Northwest lumber industry, but provide no evidence that the effects are felt in other regions of the United States. A time-series approach indicates that the Northwest lumber market is affected by these timber fluctuations, and that regional lumber markets are interdependent, but again, there is no direct evidence that Northwest public timber fluctuations have affected the lumber markets of other regions. Using each of these empirical frameworks, intervention analysis is performed to test the significance of *individual* litigation events on regional lumber markets. Econometric-model intervention results provide no evidence to suggest that individual litigation events have influenced these markets, but time-series intervention results suggest that lumber prices may have been influenced by some of the litigation in question.

## 1. INTRODUCTION

Since the late 1980's, litigation efforts on behalf of the Northern Spotted Owl have led to sharp fluctuations and reductions in timber availability from federal lands in the Pacific Northwest. By early 1991, judicial injunctions had virtually halted all federal timber sales in Spotted Owl habitat west of the Cascade Crest. During this same period, prices of high-volume softwood lumber products *nationwide* have fluctuated widely, and numerous wood products industry sources have placed the blame for this on Spotted Owl litigation results.<sup>1</sup> Given that lumber price fluctuations are highly positively correlated across regions (Uri and Boyd, 1990), if this litigation is in fact the origin of these price fluctuations, it follows that the lumber industries in other regions of the United States are being affected by this litigation as well. The possibility of this result depends on a number of factors, the most important of which are: 1) lumber products from other regions in the U.S. are substitutes for lumber originating in the Pacific Northwest; in other words, regional lumber markets are in competition with each other, 2) Pacific

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<sup>1</sup>In real terms, however, prices have not reached as high as in the mid to late 1970's (Gorte, 1993) This observation is based on the Random Lengths framing lumber composite price series. The "high volume" distinction is made here because some specialty lumber products do not show large price fluctuations. This is not to say that no prices of lower volume lumber products have seen wide fluctuations, because some have. "Lumber" in this thesis refers to softwood lumber unless specified otherwise.

Northwest public timber holds a significant share of the aggregate timber market of that region, such that fluctuations in public timber availability can affect the regional market as a whole, and 3) the Pacific Northwest comprises a significant market share of the national market for lumber, such that the Northwest lumber industry can affect the national market for lumber. The objective of this thesis is to determine through empirical analysis whether it is reasonable to believe that the recent public timber sales fluctuations of the Northwest could be the source of these lumber price fluctuations. Further, because significant lumber price changes can influence lumber production and lumber industry labor markets, the relationships between public timber fluctuations and these market factors are investigated.

Existing empirical research on these questions is discrepant. Consider the findings regarding the influence of Northwest public timber availability on that region's wood products industries. Numerous studies have forecast the costs to the Northwest economy of Spotted Owl preservation in terms of employment, lost Federal timber sales revenues, lost income, and other factors.<sup>2</sup> All of the studies predict positive losses on all counts for the region, though the predictions vary widely.<sup>3</sup> These forecasts, and the fact that public timber has accounted for 40 percent of all Northwest timber harvests for the last two decades, seem to indicate that public timber does in fact play a significant role

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<sup>2</sup>Each of these studies is based on numerous assumptions, and the assumption sets vary widely.

<sup>3</sup>A number of these studies assume no private timber cutbacks related to the Spotted Owl.

in the wood products industries of the Northwest.<sup>4</sup> In addition, various Northwest National Forest timber demand elasticities estimated by Adams (1983) support the hypothesis that public timber fluctuations are influential in the timber market of that region. On the other hand, a time-series analysis by Buongiorno, Bark, and Brannman (1985) finds no evidence that public timber sales fluctuations affect the Northwest wood products industry as a whole.

Existing studies that estimate the potential for Northwest wood products industries to influence national wood products industries are few, and report mixed results. Adams and Haynes (1980) report significant demand elasticities, but Berck (1978) and Lewandrowski, Wohlgenant, and Grennes (1994) find no such evidence.

And finally, regarding the question of interregional competition, structural econometric models in general (such as Berck, 1980, and Lewandrowski, et al., 1994) find no evidence to support the hypothesis of regional market interdependence, but a time-series analysis by Uri and Boyd (1990) finds strong statistical evidence to the contrary.

Given the disparities among results for each of these questions it is clear that further research is warranted. And given these disparities, it also is not surprising that the overall results of the present analysis are mixed. Using monthly data for 1982 through 1993, two empirical approaches are applied: a structural model approach and a time-series approach. The basic structural model produces results that do not always fit well with *a priori* expectations. However, some evidence from this model suggests that

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<sup>4</sup>Percentage calculation generated from the Timber Assessment Market Model Database, courtesy of Darius Adams, University of Montana.

Northwest public timber sales fluctuations are influencing lumber markets; not surprisingly these effects are strongest on the Northwest region itself. The time-series results fit *a priori* expectations somewhat better. Public timber sales fluctuations are shown in general to be significantly correlated to Northwest market indicators (prices, production, employment, and wages), and less significantly correlated with other-region market indicators. On the basis of both the structural and time-series models, Intervention analysis is performed to test the influence of individual litigation decisions on regional lumber markets. This type of analysis has some weaknesses in this context, however. These rulings will have impacts on lumber markets only if they contain new information. Because the existence of these court cases are a matter of public record, lumber market participants can potentially know about and speculate on the nature of the final court ruling before the decision is actually handed down. If market participants are accurate at predicting the outcome of a ruling, the ruling itself will contain no new information. The fact that these are not completely unforeseen events, such as an airplane crash, weakens this analysis. Another weakness of intervention analysis in this context is that even if particular litigation decision dates appear to have affected the lumber market, it is not clear whether it was the litigation itself that led to the market activity, or if it was a different, coincidental event that is related to the market activity. The structural model intervention results provide no evidence that individual litigation decisions have had significant impacts on the lumber markets of any of the three regions. The time-series intervention analysis, like the structural intervention analysis, provides no evidence (with one possible exception) that individual litigation decisions have affected any regional markets. This result may be misleading however, due to problems of

multicollinearity among intervention variables. When only one intervention variable is included in each estimation run (instead of all eight), the significance of the intervention variables in both the structural framework and the time-series framework generally increase, and many of them become significant at the 10 percent level, indicating that although the effects of each litigation decision are difficult to isolate, the cumulative effects may be substantial.

The body of this thesis has the following format. Chapter 2 will begin with a historical overview of the Spotted Owl's relationship with Northwest timber supply, further discussion of the forecasted local economic effects of Spotted Owl preservation, and a review of papers measuring the potential for fluctuations in Northwest public timber supplies to affect the regional market as a whole. The Chapter will continue with additional detail of literature regarding the market relationships already introduced, and a complementary review of existing structural lumber market models and lumber production factor demand relationships. Finally, we will review the time-series and econometric literature upon which the empirical analysis of this thesis is based.

In Chapter 3 a theoretical model will be developed to tie together all of the subtopics introduced in the literature review to justify the hypothesis that public timber supply shocks in one region of the United States are in some way related to prices, production, and employment in other regions.

In Chapter 4, two empirical approaches are used - a structural approach and a time-series approach. Both of these include intervention analyses for eight potentially influential Spotted Owl litigation rulings. Chapter 5 summarizes the empirical results and discusses their implications.

## 2. LITERATURE REVIEW

### **Historical Overview of Related Conservation Efforts and Litigation in the Northwest**

The Northern Spotted Owl began receiving attention from a group of biologists at Oregon State University in the middle to late 1960's. Concern within the national Forest Service and the Fish and Wildlife Service over the viability of the Spotted Owl and its relationship with Pacific Northwest timber supply was first publicly acknowledged in 1972. By 1978, following research efforts by the involved state and federal agencies and the development of various regional habitat conservation standards and guidelines, it had become clear that the preservation of the Spotted Owl would have a significant impact on Pacific Northwest timber harvest levels.<sup>5</sup>

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<sup>5</sup>This discussion of the development of the Spotted Owl issue will draw information primarily from two sources. One of them is "An Historical Perspective on the Evolution of the Spotted Owl Issue and Its Incorporation Into *de facto* Forest Management Policy," an appendix in U.S. Dept. Ag. Forest Service, (1993). This appendix provides a discussion of related legislation and litigation from the perspective of the involved government agencies. The other source is the Environmental Law Reporter, a monthly periodical published by the Environmental Law Institute, Washington, D.C.. Additional sources include the five major newspapers; the Los Angeles Times, the Washington Post, the Wall Street Journal, The New York Times, and the Christian Science Monitor, as well as various wood products industry sources.

See Appendix B for a graph of Northwest Public Timber Sales.

The Endangered Species Act of 1973 did not include the Spotted Owl as either threatened or endangered, and not until 1990 was it listed as threatened throughout its range. Although the act has become a high profile tool for the preservation of threatened species and their habitats and has and will continue to shape legislation affecting the Spotted Owl, most of the Spotted Owl-related litigation has been based not only on the Endangered Species Act, but on other legislation, including the National Forest Management Act of 1976, The National Environmental Policy Act of 1969, the Oregon and California Lands Act, and the Migratory Bird Treaty Act. The National Forest Management Act requires the Forest Service to maintain viable populations of native and "desirable" non-native species within National Forests. This means that "not only [is] the Forest Service directed to not cause any additional species to be listed as threatened or endangered - the agency was directed to not sever portions of a species range. This is an even stronger mandate than that of the Endangered Species Act to maintain individual species."<sup>6</sup> Most importantly for our purposes, by the late 1980's each of these acts in one way or another had incorporated requirements that the involved federal agencies produce and update environmental impact statements in response to new information regarding the management of public lands. It is this requirement that has been the basis for almost all of the litigation against federal agencies that has led to injunctions against the sale or harvest of public timber in Spotted Owl habitat.

The first successful court case of this series, brought by the Portland Audubon Society, was typical of the lawsuits to come. It was filed in October of 1987, alleging

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<sup>6</sup>National Forest Service, 1993



that the Bureau of Land Management's harvesting of old-growth forest violates the National Environmental Policy Act, the Oregon and California Lands Act, the Federal Lands Policy and Management Act, and the Migratory Bird Treaty Act because the agency had not incorporated updated information regarding the Spotted Owl and its habitat needs.<sup>7</sup> The effective result was a May 1988 Ninth U.S. Circuit Court of Appeals decision temporarily enjoining Bureau of Land Management sales of timber over 200 years old [litigation rulings to be included in the empirical analysis of this thesis will be noted. This is RULING #1].<sup>8</sup> Although the direct impact on the timber industry of this decision was not as great as some of the litigation to follow because of the limited volume of harvestable timber it affected, it was the first litigation to restrict public timber harvests to any degree using the Spotted Owl as a figurehead, and therefore may have had an impact on the expectations of lumber market participants regarding future Northwest public timber availability. In January 1989 this decision was reversed by the Ninth Circuit Court, and the injunction was abandoned [RULING #2].

Stepping back briefly to 1984, the U.S. Forest Service, in response to pressure from various environmental groups, was required by the Deputy Assistant Secretary of Agriculture to revise the existing Spotted Owl management guidelines. The resulting

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<sup>7</sup>This successful litigation was an appeal of a decision to dismiss the case basically because the Portland Audubon Society had not given the Bureau of Land Management enough time to incorporate the new information into its environmental impact statement. This decision is based on Section 314 of the 1987 Continuing Budget Resolution, a technicality we shall see again.

<sup>8</sup>This litigation event is tested for significance in the empirical section of this paper because it was the first Spotted Owl related court case to directly affect public timber supply.

guidelines (USDA, 1988) were immediately appealed by the Washington Department of Wildlife, and by timber *and* environmental groups. The timber industry claimed that the guidelines were too restrictive with respect to National Forest timber availability, and environmental groups claimed that the plan violated both the National Environmental Policy Act and the National Forest Management Act. According to a Washington Post article, "scientists later characterize[d] this plan as 'a prescription for the extinction of the owl.'"<sup>9</sup> Although the appeals to the Forest Service were denied by the Assistant Secretary of Agriculture, lawsuits were brought both by a timber industry coalition and environmental groups, beginning a complex series of lawsuits (and often numerous appeals) that continues to date.<sup>10</sup> In March 1989 a U.S. district court enjoined the Forest Service from further timber sales because its 1988 management plan likely violated the National Forest Management Act, and the National Environmental Policy Act.<sup>11</sup> Also in March of that year the Ninth U.S. Circuit Court temporarily enjoined the Bureau of Land Management from proceeding with timber sales affecting Spotted Owl habitat in response to an environmental group's challenge that the Bureau of Land Management existing guidelines did not include new information regarding the Spotted Owl [RULING #3]. The final decision for this lawsuit was handed down two months later (May), withdrawing this injunction based on a technicality regarding "new

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<sup>9</sup>Washington Post, *Fluttering through the Federal System*. April 2, 1993. p. A23.

<sup>10</sup>Due to limited space and time, we will limit the discussion of these litigation events to those believed to have the greatest potential impact on the timber industry. Many of the litigation decisions related to this topic will not even be mentioned.

<sup>11</sup>Seattle Audubon Society Versus Evans, *Environmental Law Reporter*, 19:20545

information", even though the agency was in fact in violation of the National Forest Management Act and the National Environmental Policy Act.<sup>12</sup> During this same time period, the timber industry coalition lawsuit was disallowed.<sup>13</sup>

As a result of this series of litigation, the Hatfield-Adams Amendment (section 318) was attached to the 1990 Department of the Interior appropriations bill. Basically this amendment was a compromise providing for Spotted Owl protection supplementary to the 1988 Forest Service guidelines in an attempt to preclude litigation against Forest Service and Bureau of Land Management timber sales for 1990.<sup>14</sup> Note in figure 1 the spike in National Forest and Bureau of Land Management timber sales for this period. In September of 1990, however, section 318 was found by the Ninth Circuit Court to be unconstitutional because in effect it directed the judicial ruling on specific cases

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<sup>12</sup>The technicality stemmed from section 314 of the 1987 Continuing Budget Resolution (Portland Audubon Society Versus Lujan. Environmental Law Reporter 19:21230). This decision was upheld in September of 1989 (Portland Audubon Society Versus Lujan. Environmental Law Reporter 19:21378)

<sup>13</sup>The timber industry coalition attempted to intervene on behalf of the Bureau of Land Management. This action was rejected by the Ninth Circuit Court (Portland Audubon Society versus Hodel, Environmental Law Reporter 19:20366).

<sup>14</sup> The amendment also required the formation of an interagency committee to develop a comprehensive conservation strategy for the Spotted Owl. In October of 1989 the Interagency Scientific Committee was established, with representatives from four federal agencies ( Forest Service, the Bureau of Land Management, the Fish and Wildlife Service, the National Parks Service), three states (Washington, Oregon, and California), the timber industry, environmental organizations, and academia. In 1990 the committee published its report, "A Conservation Strategy for the Northern Spotted Owl (Thomas, et al. 1990)." This report, which has been widely cited, recommends the reservation of 5.8 million acres of otherwise harvestable Federal forests, which would limit future federal harvests to about half the 1980's harvest levels (Thomas, Raphael, et al., 1993). Of five alternative conservation strategies it was selected as the final environmental impact statement for the Forest Service.

involving the Forest Service and Bureau of Land Management (a separation of powers issue).<sup>15</sup>

In January 1991 the Ninth Circuit Court prohibited the Bureau of Land Management from selling any timber in Spotted Owl habitat until it had prepared an environmental impact statement of its activities on the Spotted Owl [RULING #4]. This decision was based on requirements of the Endangered Species Act, the National Forest Management Act and the National Environmental Policy Act; the "new information" technicality did not hold in this instance. In May of the same year, the U.S. District Court barred the Forest Service from logging in Spotted Owl habitat, as well as from conducting public timber sales from 17 National Forests in Washington, Oregon and Northern California until it prepared an environmental impact statement for the effects of its activities on the Spotted Owl [RULING #5].<sup>16</sup> This decision was upheld by the Ninth Circuit Court in December of the same year [RULING #6].<sup>17</sup> The restrictions on

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<sup>15</sup>Environmental Law Reporter 21:20019-20023. Section 318 was not entirely effective before the ruling that it was unconstitutional. In May 1990 a district court disallowed the sale of timber from Umpqua national Forest in Oregon due to a technicality.

<sup>16</sup>Environmental Law Reporter, 21:21505-21512.

<sup>17</sup>Environmental Law Reporter, 22:20372-20376. It is interesting to note the Forest Service's basis for appeal (resulting in this decision): "In its appeal, the Forest Service's principal contention is that it is no longer required under the [National Forest Management Act] to plan for the future survival of the spotted owl because the Fish and Wildlife Service has declared the owl threatened under the Endangered Species Act...("ESA"). The Forest Service contends that it is required to plan for "viable" species, and that a species declared threatened or endangered under the ESA is no longer viable."

Note that events #6 and #8 are similar in that previous injunctions were upheld and continued.

National Forest logging and timber sales were upheld by a July 1992 ruling requiring revised guidelines regarding Spotted Owl management [RULING #8].<sup>18</sup>

The Bureau of Land Management had been prohibited from selling timber in Spotted Owl territory since January 1991, which essentially halted all timber sales by that agency in western Washington and Oregon.<sup>19</sup> In May of 1992, the Endangered Species Committee allowed the sale of 13 tracts of timber previously withdrawn from sale under the Endangered Species Act [RULING #7].<sup>20</sup>

It should be reiterated that the eight rulings summarized above and included in the empirical analysis of this thesis are not the only cases that could have had an impact on the markets of the three regions under consideration here. The decision whether to include a particular court ruling is based primarily on the potential (as perceived by the author) of a ruling having a significant impact not only on actual public timber sales in the Northwest, but on the expectations of wood product industry economic agents.

Since July of 1992, most of the litigation has resulted in the continuance of logging and timber sales injunctions.<sup>21</sup> The primary exception is a June 1994 decision to lift the ban on logging in the 17 National Forests because it was found that the current

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<sup>18</sup>Environmental Law Reporter, 22:21471-21474.

<sup>19</sup>The January 1991 decision was upheld by the Ninth District Court in February, 1992. Environmental Law Reporter 22:20889-20892.

<sup>20</sup>Further discussion of this complicated event can be found in Thomas, J.W., M.G. Raphael, et al., 1993.

<sup>21</sup>There have been some modifications to these injunctions, however. In March of 1994 for example resulting from an appeal of Seattle Audubon Society Versus Lyons, 24 timber sales were allowed in Spotted Owl habitat. USDA Forest Service, (1994).

National Forest Service environmental impact statement appropriately addresses the conservation concerns for the Spotted Owl specified by the plaintiffs (environmental groups) for this particular case. The district judge hearing the case stated, however, that this particular decision does not address the overall legality of the current conservation plan. Numerous similar court cases are still pending, and the expectations of wood products industry spokespeople for future timber sales in the Northwest continue to be low. "It's nice to see the injunctions being lifted, yet with all the new lawsuits...it may be a short reprieve." This statement by a spokesman for the Western Forest Industries Association is an illustration of the expectations for the near future regarding public timber sales in the Northwest.<sup>22</sup>

### **Intraregional Economic Impact Studies**

Long term impacts of Spotted Owl conservation plans, though they do not have any direct relevance to this study, do affect current expectations of future Northwest timber availability. Therefore a brief discussion of the long run effects of Spotted Owl protection plans is appropriate. To date at least 30 studies from various institutional sources have focused in one way or another on the economic impacts of Northern Spotted Owl preservation efforts on the Pacific Northwest. For expediency, this section will draw to a large extent from Gorte (1992), *Economic Impacts of Protecting Spotted Owls: A comparison and Analysis of Existing Studies*, which focuses on seven of the

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<sup>22</sup>Associated Press, June, 1994.

most extensive and widely cited of these.<sup>23</sup> Almost all studies published subsequent to Gorte's paper consist primarily of minor revisions of prior studies.

The most costly aspect of protecting the Spotted Owl is the withholding of otherwise available timber to protect the species' critical habitat. Average annual Federal timber sales estimates for the next decade reported in the 1994 Supplemental Environmental Impact Statement (U.S. Forest Service, 1994, p. 3&4-264) under the "no action alternative [re: Spotted Owl Protection]" are three to four billion board feet (BBF) for the spotted Owl region. Estimates of harvests under the other ten owl protection plans range from .114 to 1.645 BBF. In percentage terms, this range (using 3.5 BBF as the denominator) is 3.26 to 45.7 percent of the expected harvests under the "no action " plan.<sup>24</sup> Private timber sales in the region are projected to decline approximately 3.3 to 3.8 BBF over the next 15 years.<sup>25</sup> Employment projections for the next decade for the Spotted Owl region, which attempt to account for changes in all wood products industries including paper and pulpwood sectors, show an expected decrease in jobs from the 1990 levels of 144.9 thousand jobs to anywhere from 120.8 (-24.1 thousand jobs; 16.6 percent) to 109.5 (-35.4 thousand jobs; 24.4 percent) for the

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<sup>23</sup>Gorte (1992) reviews and compares seven studies: U.S. Dept. Interior, Fish and Wildlife Service (1992); U.S. Dept. Ag. Forest Service and Dept. Inter. Bureau of Land Management (1990, with updates in 1991 and 1992); Beuter (1990); Olson (1988, with an expanded update, Anderson and Olson, 1991); Mead, et. al. (1990); Greber, et. al. (1990); Lippke, et. al. (1990).

<sup>24</sup>Based on similar (but earlier) harvest projections reported in Gorte (1992), Northwest federal timber prices projections produced in or before 1992 by the Fish and Wildlife, the Forest Service, and Mead (1990) range from \$176 to \$418 - a variance that does not instill confidence.

<sup>25</sup>USDA Forest Service, et al. 1993.

next decade, depending on the management alternative (Forest Service, 1994). These are projected decreases of 16.6 to 24.4 percent for the wood products industry of the Pacific Northwest region. Previous studies reported in Gorte (1992) predict decreases from 8.6 to 20 thousand jobs for the 1990's. Projections for secondary employment impacts (defined variously and reported in Gorte, 1992) range from 9.8 to 24.0 thousand jobs.

The validity of these projections are of little relevance for the questions addressed in this thesis. The existence of these reports are important, however, in understanding the reaction of the wood products industry to the prospect of Spotted Owl and old-growth forest preservation; it is the reactions to these preservation efforts that manifest themselves in the market fluctuations in which we are interested.

### **Structural Softwood Lumber Market Models**

Studies of United States' lumber markets date back at least to 1946, with a paper by L.M. Shames on forecasting lumber demand. I.I. Holland (1955) develops possibly the first structural model for the U.S. lumber market, and within the next decade numerous studies were published with similar focuses.<sup>26</sup> This discussion will begin with a brief overview of a broad econometric study by McKillop (1967) on the markets for forest products. The estimation section of McKillop's paper is preceded by a lengthy theoretical development of the stumpage, sawlog, pulpwood, veneer log, lumber (general), softwood lumber, building paper, and paperboard markets. The theory section is expanded around a profit-maximization framework. Two-Stage-Least-Squares is then

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<sup>26</sup>For a listing of related papers of this period, see McKillop (1967).



performed on models for the lumber, softwood lumber, building paper, paperboard and plywood markets using annual data for 1929-1960. McKillop's results for softwood lumber demand indicate the expected signs on all significant coefficients (eight of eleven independent variables). For softwood lumber supply, four of ten coefficients are significant and of the expected sign.<sup>27</sup> Adequate data were claimed not to be available for the development of wood inputs to the lumber market. McKillop's paper is designed entirely as a structural framework for the major components of the wood products markets, and it is by far the most comprehensive in this respect of any paper found, and provides a solid theoretical framework upon which to build structural econometric market models.

McKillop (1967) is an example of what Adams and Haynes (1980) define as a "nonspatial market model", characterized by 1) the treatment of all involved economic agents as part of one aggregate regional market, absorbing all intraregional activity into one demand and supply function for a commodity, 2) ignoring transportation costs,

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<sup>27</sup> Of McKillop's independent variables in the lumber demand equation, the following were significant at the ten percent level and of the expected sign: lumber price, construction wages, manufacturing production wages, value of construction, ratio of past prices of building board/lumber (building board expected to be a substitute), price of paperboard (substitute), plywood price (substitute). Insignificant coefficients were freight rates, ratio of past prices of plywood/lumber, the ratio of past prices of steel/lumber and the ratio of past prices of clay/lumber.

Significant coefficients (10%) in the lumber supply equation were: exchange rate, lumber tariff, sawmill productivity, and a structural dummy. Lumber price, stumpage prices, sawmill wages, electricity price, petroleum prices, and a trend were insignificant. "Productivity" is defined as production divided by employment levels. Note that interest rates are not included in McKillop's lumber demand equation. The justification given is, in effect, that model simplicity was a factor in deciding which variables to exclude.

except for inclusion as supply shifters; and 3) holding demand and supply prices equal.<sup>28</sup>

Along with his definition of nonspatial models, Adams and Haynes (1980) define a

"quasi-spatial market model" and a "spatial [market] model." Quasi-spatial models are

"similar in most respects to nonspatial forms except that supplies from and (in some cases) demand for end products are disaggregated on a regional basis. Supply equations in models of this class explain product flows from a given supply region to only one demand region or destination. Thus the structure of transportation is greatly simplified. Transportation costs are ignored, and prices in supply and demand equations are identical."<sup>29</sup>

The most important point for the purposes of this thesis is that the demand region is not disaggregated spatially. Robinson (1974), described below, is an example of this class of models. The spatial market model, as one might infer, takes spatial disaggregation the furthest of the three. It incorporates separate regions for both the supply and demand of a commodity, and by accounting for transportation costs attempts to compute equilibrium prices in all markets, given any explicit assumptions, such as perfect competition.<sup>30</sup> The Softwood Timber Assessment Market Model (TAMM) developed in Adams and Haynes (1980), also briefly described below, is a spatial model.

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<sup>28</sup>Adams and Haynes (1980) cite the following additional examples as nonspatial model specifications: McKillop (1969), Gregory (1960, 1965), Adams and Blackwell (1973), Leuschner (1973), Adams (1974), and Simpson and Halter (1963).

<sup>29</sup>Adams (1980) cites the following as additional examples of quasi-spatial models: McKillop (1973), and Adams (1975, 1977).

<sup>30</sup>This concept is credited to Samuelson (1952). For a more complete discussion of this concept, see Judge (1963). Adams cites numerous examples of such analyses applied to forest products industries, including Judge (1963) and Holley, Haynes, and Kaiser (1975).

This thesis is concerned primarily with interregional effects of supply shocks. Given this purpose, we have a functional interest only in total demand for each regionally produced commodity. For example, in developing our structural models, we are interested in accounting for the *total* demand for Southern Pine and the *total* demand for Douglas Fir. To disaggregate lumber demand into separate regional demand functions (as in Adams and Haynes 1980) would be superfluous for our purposes, so this review will focus on quasi-spatial models, or the relevant aspects of spatial models, as will be the case for the discussion of the TAMM.

Robinson (1974) develops a quasi-spatial econometric model for Douglas Fir and Southern Pine lumber and stumpage markets using annual data for 1947-1967.<sup>31</sup> For the Douglas Fir Market, Robinson estimated the demand as a function of Douglas Fir price, Southern Pine price, freight rates, exchange rates, and the value of current construction. Each of the coefficients was of the expected sign, and significant at the five percent level. Domestic Douglas Fir lumber supply was modelled as a function of the price of Douglas Fir, the exchange rate, and the productivity level.<sup>32</sup> In estimating the Southern Pine markets, preliminary results included insignificant coefficients (at the 10% level) on output prices in both the lumber and stumpage markets, "implying that the demand for Southern Pine lumber was infinitely inelastic and suggesting that the quantity of southern

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<sup>31</sup>Interestingly, the motivation for the paper was to make recommendations for the nations "housing goal" for the following decade.

<sup>32</sup>"Most" of the "raw data" for Robinson's paper were obtained from Hair and Ulrich (1971). "Productivity" was not defined explicitly, but McKillop (1967) defined it as production divided by employment levels -- Average Product of Labor.

pine lumber should be treated as a predetermined variable."<sup>33</sup> Robinson continued; "Several studies suggest that quality and in-place costs, rather than price, were the primary considerations for seeking ... substitute materials (King, 1954; Robinson, 1966; Taylor and Thompson, 1967).<sup>34</sup> Hence , a predetermined demand for southern pine appeared plausible." Because of this, his model for the Southern Pine sector collapses into a "price relation" for lumber and stumpage, with price as the dependent variable. Lumber price is modelled as a function of Southern Pine Stumpage Price, Southern Pine lumber production, and productivity. The stumpage price is found to be a function of Southern Pine lumber production, and the quantity of Southern Pine chips.<sup>35</sup> Again, each of the associated coefficients was of the expected a priori sign, and significant at the five percent level.

As mentioned earlier, Adams and Haynes (1980) TAMM would be categorized as a spatial model, primarily because of the way it models commodity demands. Although this aspect of the paper has no direct relationship to this thesis, the modelling approach to the supply side of the commodity markets is of interest primarily because of its uniqueness in the context of the previously reviewed papers. The supply equations have

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<sup>33</sup>"Stumpage" is a term used for standing timber; stumpage prices are the value of standing timber.

<sup>34</sup>"In-place costs" were not defined by Robinson.

<sup>35</sup>Robinson does not discuss why Southern Pine chips are included in the inverse demand equation for Southern Pine Lumber Supply. It is presumed that chips are used in the production of plywood or paper.

the general form (using the same notation as Adams and Haynes, and replicating variable descriptions):

$$S_{jt}^1 = \alpha_0 + \alpha_1 \left[ P_{jt}^1 - W_{jt}^1 (C_{jt}^1 + p_{jt}) \right] + \alpha_2 S_{jt-1}^1$$

Where

$S_{jt}^1$  is the production of product 1 (lumber or plywood) in region  $j$  in year  $t$ ;

$P_{jt}^1$  is the regional average mill level product price (measured in dollars per unit of output);

$C_{jt}^1$  is the regional average "stump to car" production cost including logging, log transportation, and milling costs (measured in dollars per MBF, log scale, Scribner);

$W_{jt}^1$  is regional average "overrun" factor (measured in MBF, log scale, Scribner per MBF, lumber tally or MSF, surface measure, 3/8-inch basis); and

$p_{jt}$  is regional average stumpage price (measured in dollars per MBF, log scale, Scribner).

In effect, current output is a function of the profit margin per unit of output this period and output last period.<sup>36</sup> Note that this formulation includes the basic ingredients of most other structural models (product price, factor costs, and productivity), but additional structure is added, resulting in the general form presented here. The primary justification for the additional structure is to reduce multicollinearity.<sup>37</sup> The results of the estimation process, then, are coefficients for two right-hand-side variables -- *margin*, and *past production*. Using two-stage-least-squares or iterative-two-stage-least-squares where

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<sup>36</sup>A discussion of the variable "regional average overrun factor" can be found on page 19, Adams and Haynes (1980).

<sup>37</sup>The other two justifications they give are "i) all costs are explicitly incorporated, and ii) The costs are specific to the region and industry under analysis...". Because these objectives can be accomplished with other structural forms, it is not clear that these are legitimate justifications in this case.

appropriate, coefficients on *margin* for all seven regions are positive (though the Rocky Mountain and South Central region coefficients are insignificant at the 10% level), and *past production* coefficients are all positive (though the Pacific Southwest and Southeast coefficients are insignificant at 10%). All other coefficients are significant with p-values below .05.

It is important to note that the above review is not a comprehensive list of all previous work on the general market specification of wood products industries. It is meant to present research representative of the different theoretical and empirical directions taken in past work.

### **The Influence of National Forest Timber in Aggregate Timber and Lumber Markets**

The sharp fluctuations in public timber sales of the Pacific Northwest resulting from Spotted Owl litigation and legislation is a clear indication that the volume of timber sold from public lands is not a reflection of market conditions at the time of the sale. But inasmuch as the level of public timber sales affects the amount of timber available on the market at any given time and price, one might expect from a theoretical standpoint that public timber sales will affect the timber and lumber markets as a whole. The validity of this assumption, however, depends on the elasticity of the demand function for public timber. While assuming that public and private timber are perfect substitutes and the market share of all national forests in a region is small, Hamilton (1970) and U.S. Department of Agriculture (1969) argue they are justified in their assumption that the demand for National Forest timber is highly elastic. Note that if this

were the case, even extreme fluctuations in National Forest timber availability would have little or no effect on timber and lumber prices as a whole. Note also that with the inclusion of Bureau of Land Management timber sales, the market share for public timber is higher than that of the Forest Service alone, which is the focus of the previously cited papers.<sup>38</sup>

Several econometric studies have estimated National Forest timber demand elasticities for various species-delineated regions and various National Forests in the Pacific Northwest. Adams (1983) reports the results of these studies, as well as results of his own.<sup>39</sup> Research previous to Adams (1983) report demand elasticities ranging from -1.6 to -333.3; all greater than unity. Adams (1983) reports elasticities for individual National Forests and for three Pacific Northwest regions (Western Washington, Northwest Oregon, and Southwest Oregon) for three time periods.<sup>40</sup> Elasticities for individual National Forests range from -15.0 to -1.4. For the three regions, elasticities range from -.7 to -3.0. In every case, however, the elasticities of the individual National Forests were larger in absolute value than those of the regions of which they are a part. This is in fact the *a priori* expectation because the region as a

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<sup>38</sup>BLM harvests account for 19 percent of all federal Northwest timber harvests for the last decade, and 7.6 percent of total Northwest timber harvests. Calculated with data from: U.S. Forest Service, *Production, Prices, Employment, and Trade in Northwest Forest Industries*, various issues.

<sup>39</sup>Results from other papers reported by Adams are taken from Frazier (1967), Adams (1974), Schreuder, et al. (1976), U.S. Dept. of Agriculture (1979), Adams and Haynes (1980) and Walker (1980). These studies used quarterly or annual data for various time periods ranging from 1951 to 1980.

<sup>40</sup>Adams (1983) used annual data for three time periods: 1953-1959, 1960-1969, and 1970-1979.

whole represents a larger share of total timber supply; this fact lends some credibility to the overall results. The evidence from these studies suggests that National Forest demand schedules are not perfectly elastic, but may nonetheless be quite responsive to public timber sale volumes. It would be expected that public timber in general, making up an even greater share of the market than just National Forest timber, would face even more inelastic demand schedules.

A time-series analysis by Buorgiorno, Bark, and Brannman (1985), however, found no evidence that the volume of National Forest timber offered for sale affects the overall prices of timber and lumber. The technique used in this analysis is in essence identical to that introduced by Granger (1969), further developed by Pierce and Haugh (1977, 1979), and applied to the question of regional lumber market interdependence by Uri and Boyd (1990). Incidentally, Buorgiorno, Bark, and Brannman (1985) also tested whether the prevailing stumpage price level affects public timber sales levels, and found no evidence to support this hypothesis. This technique will be used in the empirical section of this paper, so further discussion will be reserved for that Chapter. Note that no studies to date have studied the effects of public timber in one region on the wood products industries of other regions. This, in effect, is the basic task of this thesis.

### **Regionality of the United States Lumber Industry**

Four published structural models address the issue of regional interdependence, i.e., whether economic activity in one region of the U.S. lumber industry affects other regions in that industry. Two of them report no evidence regarding regional



interrelationships.<sup>41</sup> Robinson (1974) presents one significant t-statistic that indicated interregional substitution of lumber products, but that is the extent of this paper's contribution to this subject.

The latest of the four structural models (Lewandrowski et al., 1994), lists testing for regional interdependence as one of its primary objectives. Using monthly data they find no evidence to support regional relationships in the lumber industry.

"The implication is that lumber markets respond quickly to market disturbances, but that responses are limited primarily to the region in which the disturbance occurs. Absences of cross-price effects suggests that policies can be designed to assist producers in one region without negatively impacting producers in other areas."[p.92]

Regional interdependence in the lumber industry has been addressed using time series techniques as well, supporting much different conclusions than those of Lewandrowski et al. (1994). Using annual data, Uri and Boyd (1990) specify Autoregressive Integrated Moving Average (ARIMA) models for each of four U.S. regions and then examine correlations between the filtered errors of each region, theorizing that significant correlation among the contemporaneous (white noise) residuals from any two regions provides evidence that regional markets are interdependent. The results of their analysis suggests that such interdependence exists. Part of the empirical analysis presented later in this thesis will closely parallel the methods used by Uri and Boyd (1990), so further development of these methods will be undertaken then.

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<sup>41</sup>Adams and Haynes (1980) and Adams, Haynes, and Homayounfarrokh (1986) distinguish between regions, but due to the nature of their models no evidence supporting or refuting regional interdependence is presented.

### The Lumber Market in the Short Run

One objective of this paper is to isolate the impacts, in the lumber and labor market, of specific events - in this case timber supply shocks. As recent lumber price fluctuations have shown, the lumber market can show significant flux from one month to the next. Using monthly data therefore seems appropriate for the question at hand. With short observation lengths such as these, however, estimation problems arising from dynamics likely will follow. Two papers have been published that estimate lumber market structural models with monthly data and discuss dynamics.<sup>42</sup>

The first, by Buongiorno, Chou, and Stone (1979) focuses on lumber imports, a subset of total demand for domestic lumber. Each of the static structural models they initially estimate (with monthly data from January 1965 to December 1977) show significant autocorrelation. The authors include a lagged dependent variable on the right-hand-side (implying infinite lags on each of the other independent variables), and the serial correlation coefficients ( $\rho$ ) for these equations are insignificant.

The second paper to use monthly data and address the short run in modelling the lumber market is by Lewandrowski, Wohlgenant, and Grennes (1994).<sup>43</sup> Their primary

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<sup>42</sup> In their paper on competition among wood products and substitute structural products, McKillop, Stuart, and Geissler (1980) used some distributed-lag formulations in estimating structural models with annual data. The estimated coefficient for every *lagged* variable in the lumber consumption reduced form equation and in the structural lumber supply and demand equations was insignificant at the ten percent level.

<sup>43</sup> Two aspects of this paper are relevant with respect to this thesis. One is the fact that they attempt to model the lumber markets with monthly data, and the other is that they address the national lumber industry as having interrelated regions, as this thesis will. This aspect of the paper will be discussed in a subsequent section of this Chapter.

mode of dealing with short-run behavior is the inclusion of price expectations and finished product inventories in the supply and production equations.<sup>44</sup> The demand equations are estimated as static. Using nonlinear Three-Stage-Least-Squares, they report estimates from a non-restricted and a restricted model where the restriction is that Southern Pine, Douglas Fir, and the Western Pine conglomeration are constrained to be either substitutes or complements for each other. The authors argue that Southern Pine and Douglas Fir are substitutes in construction for one another, but Western Pine is a complement in construction to both of the other species.

### **The Relationship Between Wood Inputs and Labor in Lumber Production**

Numerous studies of the lumber industry have produced derived demand estimates for sawlogs and labor. Some studies, such as Haynes (1977) assume fixed labor-sawlog input proportions, but relatively few have explicitly measured the nature of the relationship between these two production factors. Three studies attempting to measure the relationships between sawlogs and labor as inputs into the production of lumber will be reviewed here.

The first of these, Steir (1980), uses an estimated lumber industry cost function and reports estimates of cross-price elasticities among three inputs; labor, sawlogs, and capital. He found elasticities of substitution for each combination of these three inputs to be statistically significant. The short run sawlog price elasticity of labor ( $\% \Delta \text{Labor} / \% \Delta P^{\text{sawlogs}}$ ) is -.040, and the labor wage elasticity of sawlogs

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<sup>44</sup>They also include two explicit lags on stumpage prices.

$(\% \Delta \text{Sawlogs} / \% \Delta \text{Wage})$  is  $-.070$ . Though these elasticities are small, they do not support the assumption of fixed input proportions, as noted by Steir.

Merrifield and Haynes (1984) report cross-price elasticity estimates for relationships between labor wages and stumpage  $(\% \Delta \text{Stumpage} / \% \Delta \text{Wage})$ , and employment levels to stumpage inventories  $(\% \Delta \text{Employment} / \% \Delta \text{Inventories})$ , National Forest timber sale volumes  $(\% \Delta \text{Employment} / \% \Delta \text{Sales})$ , and National Forest stumpage prices  $(\% \Delta \text{Employment} / \% \Delta P^{\text{stumpage}})$ . Of particular interest are the effects of changes in timber volume sold and stumpage price on labor employment. Using a structural model based on a profit-maximization framework they report that changes in both stumpage price and National Forest timber sales will lead to changes in the proportions of labor and sawlogs utilized in the production process, with a stumpage price elasticity with respect to employment of  $.1709$  (holding stumpage harvests constant) and an elasticity of National Forest timber volume sold with respect to employment of  $-.7181$  (holding stumpage price constant). These results indicate that sawlogs and labor are not necessarily employed in fixed proportions.

Finally, Abt (1987) reports findings for three geographic regions. Using an estimated cost function as did Steir (1980), he reports negative cross-price elasticities of demand for labor and sawlogs that are significant at the 10% level for two of the three regions.

These studies suggest in all but one instance that labor and sawlogs are complements in the lumber production process, but that the assumption of fixed proportions (perfect complementarity) between these two inputs may not hold. It follows

that fluctuations in stumpage prices may not have as strong of an effect on employment levels as would be the case if the two inputs were perfect complements.

### **Intervention Analysis**

Throughout the 1990's the lumber industry has seen sharp fluctuations in lumber prices. A number of wood products industry sources have claimed that these fluctuations stem primarily from the fluctuations in Pacific Northwest public timber availability and uncertainty regarding future public timber availability from that region. One objective of this thesis is to test whether the litigation decisions leading to the timber supply fluctuations have in fact had measurable short-run impacts on the regional markets of the United States.

The majority of intervention analyses have focused on the response of futures and stock markets to new information. This appears to be the case for a number of reasons. First, these markets tend to clear quickly in response to new information; secondly, price data for these markets are readily available; and thirdly, government reports of supply conditions for particular commodities are announced at regular intervals; an example of this is the U.S. Department of Agriculture Hogs and Pigs Report, which provides various porcine information in March, June, September, and December each year.<sup>45</sup>

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<sup>45</sup>Currently there exists only one futures market for lumber. Because we are considering various interregional effects of timber supply shocks, we cannot apply the futures price series to the question at hand.

The basic model used in most of these studies begins with the transformation of the price series into terms of percentage change (Colling and Irwin 1990; Barnhart, 1989; Sumner and Mueller, 1989; and Miller, 1979, among others), though the raw price series also has been used (Aradhyula, Kesavan, and Holt, 1993), as well as constructed rates of return indexes (Robenstein and Thurman, 1993).

The most basic models then measure in the following manner whether the price changes for observations after information events are significantly greater than price changes for other observations (following Pearce and Roley, 1985);

$$P_t^* = \alpha + \beta X_t^u + \gamma X_t^e + \sum_{i=1}^m \delta X_{t-i}^u + \varepsilon_t \quad (2)$$

where

$P_t^*$  is some transformation of a price series (percent change, for example),

$X_t^u$  is the vector of unexpected components of an information event just before period  $t$ ,<sup>46</sup>

$X_t^e$  is the vector of event components that were expected by market participants just before the event occurred,

$X_{t-i}^u$  is the vector of unexpected components of past information events, and  
 $\varepsilon_t$  is an error term

In the context of this thesis, an "unexpected component" might be the difference between the volume of timber expected by the lumber industry to be taken off the market and the volume of timber that actually was taken off the market. If the market

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<sup>46</sup>It is often the case that new information regarding commodities markets is presented after closing on a particular day (say day  $t-1$ ), so the market effects are not realized until the following day,  $t$ .

adjusts instantaneously, then all past information, both expected and unexpected, will already be incorporated into the current price, so this model simplifies to

$$P_t^* = \alpha + \beta X_t^u + \varepsilon_t. \quad (3)$$

This is the basic model of most intervention analysis, where  $\beta$  is the measure of the effect on a series of an information event.

This general model can be applied in numerous ways. It can be incorporated into structural models that attempt to account for all price fluctuation not related to the news event in question. Similarly, it can be incorporated into time-series models through which systematic error structures (unrelated to the events) can be filtered out. In an ARIMA framework, Aradhyula, Kesavan, and Holt (1993) account for both fluctuations in means and variances on hog prices resulting from information events. And as implied in equation (2), the adjustment process after information events can be modelled where adjustment is not complete in one period. Robenstein and Thurman (1993), modelling the effects of news about the link between cholesterol levels and heart disease, is an illustration of this type of modelling. Not only did they include a dummy variable for the period immediately following the event, but they included dummy variables for a number of periods after the news event to account for any lagged effects. Further, they included dummy variables for a number of periods before the event to account for possible leaks of information.

Additions to the general intervention model such as this will prove useful for the questions at hand, and will be discussed further in the theory and empirical sections of this thesis.

### 3. THEORETICAL RELATIONSHIPS BETWEEN TIMBER HARVESTS AND LUMBER INDUSTRY EMPLOYMENT

A theoretical framework for understanding the potential effects of timber supply reductions on the lumber industry is developed in this Chapter. We will begin with a general static illustration of the model. The presentation of the general model is followed by more in-depth discussion of each of the primary points of interest. Numerous assumptions will be made about the nature of the markets of interest to simplify the initial discussion. The validity of the most important of these assumptions will be considered in later sections of this Chapter as well as in the empirical analysis (Chapter 4). Two assumptions central to this analysis are:

- 1) Softwood lumber produced in each of the three regions under consideration are substitutes for each other in end use, although they need not be perfect substitutes.<sup>47</sup>

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<sup>47</sup> Uri and Boyd (1990) suggest that lumber products from different regions are related in some way, and numerous structural models have been developed under the assumption that they are substitutes. Lewandrowski, et. al. (1994) on the other hand began their study by assuming that softwood lumber from one of these regions (the Rocky Mountain region) is a complement to softwood lumber from the other two regions (the Northwest and the Southeast) because of their belief that the Western Pine conglomeration is used for nonstructural construction purposes. Their empirical results suggest that the regional markets are unrelated.



2) As inputs to lumber production, wood inputs and labor are complements.<sup>48</sup>

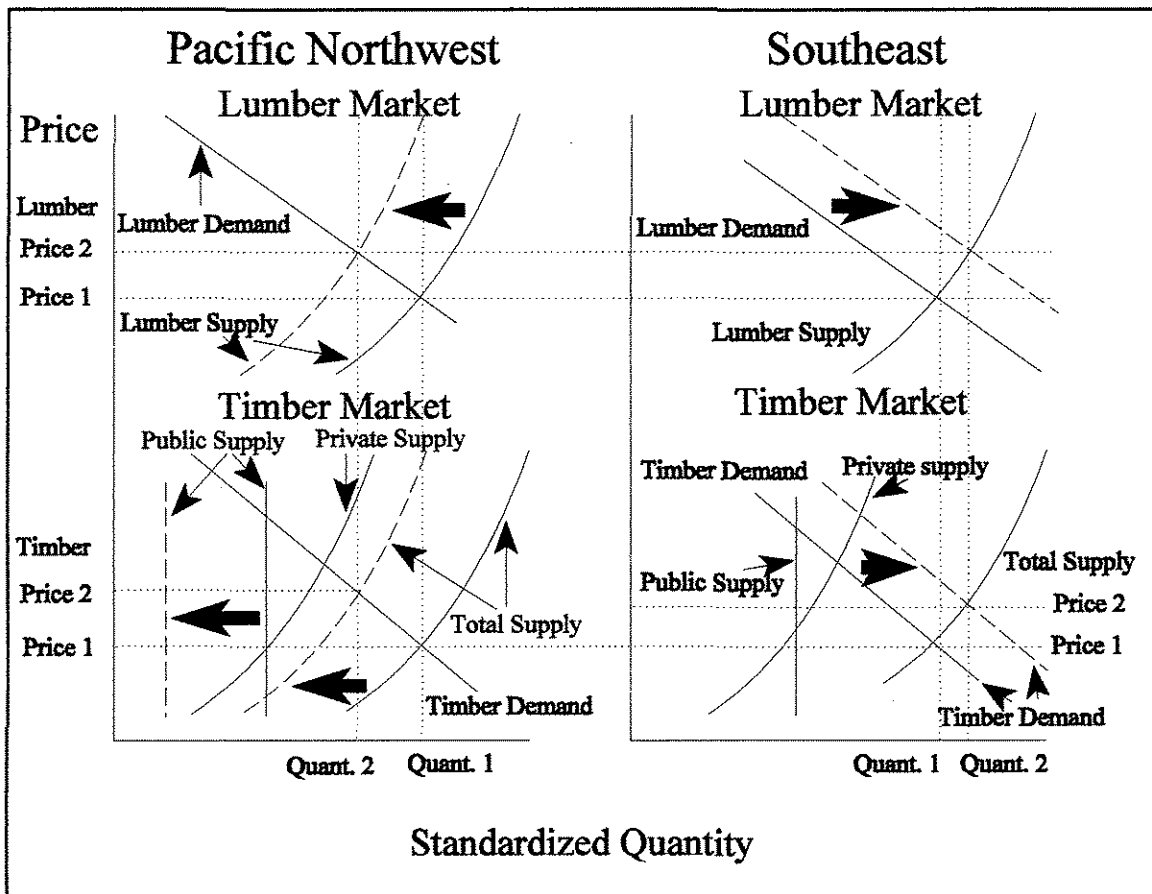
Consider two geographically distinct timber and lumber producing regions - the Pacific Northwest, which primarily produces Douglas Fir, and the Southeast, which primarily produces Southern Pine.<sup>49</sup> Suppose that litigation resulting from preservation attempts on behalf of the Northern Spotted Owl leads to a ban on the (previously expected) harvest of a significant quantity of public timber in the Northwest. The expected Northwest public-timber harvest levels immediately drops by the amount of the disallowed harvest, indicated in Figure 1 by a leftward shift of the public timber supply curve.<sup>50</sup> Though by assumption this does not directly affect the private timber supply, the region's total timber supply (public plus private, horizontally summed) shifts back by

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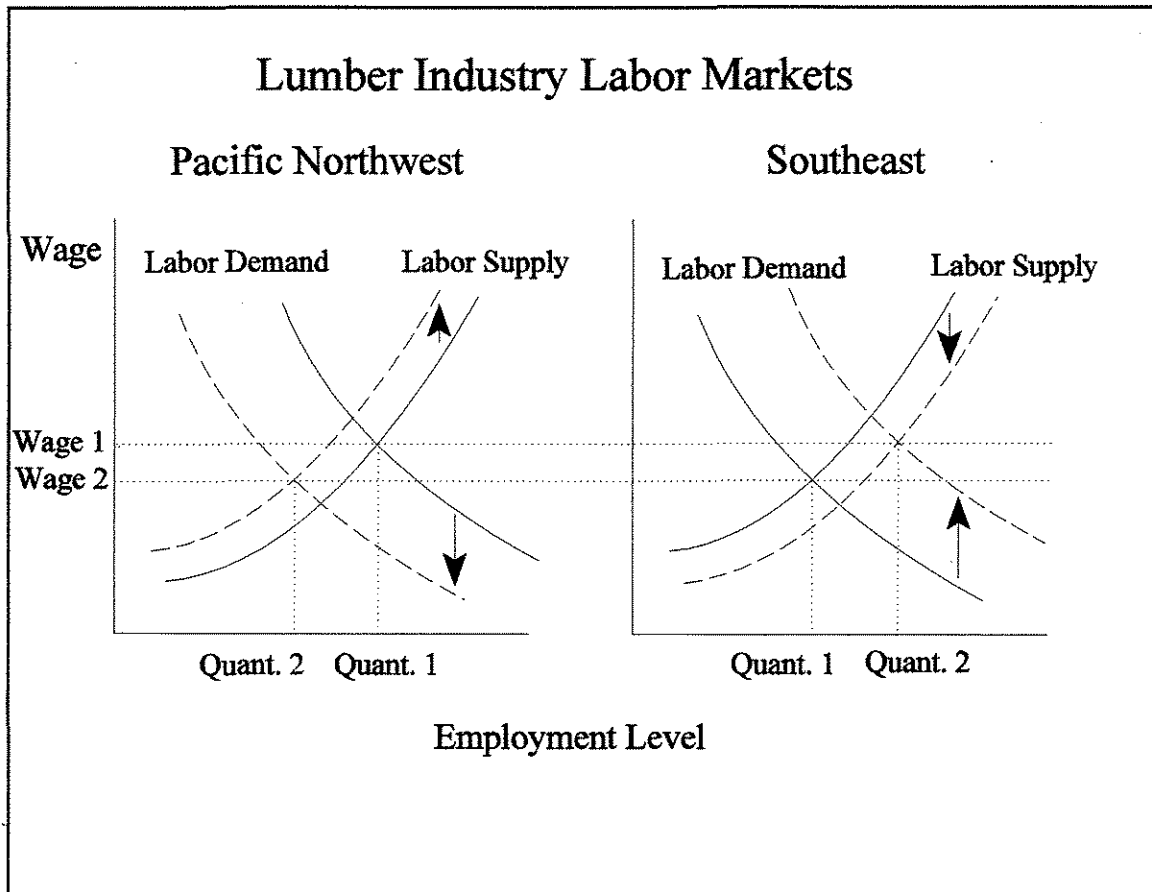
<sup>48</sup>As noted in Chapter 2, many previous studies of the lumber industry have assumed that labor and sawlog are used in fixed proportion; that they are perfect complements in production. At least three studies have found that the fixed proportions assumption does not hold, though their analyses suggest that the two inputs are in general complementary.

<sup>49</sup>Note that although we will consider three regions in our empirical analysis, we will limit this discussion to two for clarity.

<sup>50</sup>Public Timber sales levels are assumed to be decided irrespective of timber price levels, hence a perfectly inelastic Public Timber Supply curve. Given the nature of the recent public timber sales fluctuations in the Northwest, this is considered reasonable. Boungiorno, Bark, and Brannman (1985) report evidence to support this assumption.



**Figure 1.** Regional Timber and Lumber market reactions to a leftward shift in Northwest Public Timber Supply.



**Figure 2.** Regional lumber-industry labor market reactions to a leftward shift in Northwest Public Timber Supply.

the amount of the harvest reduction.<sup>51</sup> As a result, the total timber output for that region decreases, and the equilibrium price is bid up from *Price 1* to *Price 2*.<sup>52</sup>

Timber is a primary input for lumber production, so with an increase in the price of timber, the supply of lumber in the Northwest will shift leftward, leading to a lower output level and a higher price at equilibrium (Figure 1, upper left).<sup>53</sup>

Recall the assumption that the lumber products of the two regions are at least to some extent substitutable. In response to the higher price of Northwest lumber, some consumers on the margin will switch from using Douglas Fir to using Southern Pine, implying an outward shift in the demand for Southeast lumber, and an accompanying shift in the derived demand for Southeast timber.<sup>54</sup> As the demand for Southern Pine shifts rightward, the equilibrium price and quantity of lumber and timber in the Southeast will increase (Figure 1, right).

Given that timber and labor are complements in the production of lumber (assumption 2, above), we can infer the employment effects for these two regions (Figure 2). In the Northwest, where the supply curves for timber and lumber are shifting leftward, the lumber industry labor demand curve is expected to shift leftward as well, leading to lower wages and lower employment levels. In the Southeast, following a

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<sup>51</sup>Adams (1983) presents a similar model for the National Forest timber market.

<sup>52</sup>Note that the quantity of timber supplied by private timber owners increases as the market price is bid up.

<sup>53</sup>Uri and Boyd (1990) show that the lumber supply function is neither perfectly elastic nor perfectly inelastic.

<sup>54</sup>Implicit in Figure 1 is that timber is a normal input into production. Given the physical relationship between logs and lumber, this is likely.

rightward shift in lumber demand, labor demand will shift to the right, leading to higher employment levels and, *ceteris paribus*, higher wages.

Consider another possible result of decreases in the Northwest lumber industry employment. For some of the laid-off Northwest workers, particularly those with lumber-mill-specific skills, their next best alternative to employment in a Northwest lumber mill may be employment in the lumber industry of the Southeast.<sup>55</sup> Lumber mill labor migration from the Northwest to the Southeast would lead to a shift in the supply curve for labor in both the Northwest (leftward) and Southeast (rightward).<sup>56</sup> Note that with both the supply and demand curves shifting out in the Southeast, wages may increase, decrease, or remain the same depending on the relative size of the shifts.

In this fashion, given the assumptions presented above, decreases in public timber availability in the Northwest can potentially lead to increases in lumber production and labor employment in the Southeast. The above analysis is presented with the implicit assumption of instantaneous adjustment. It is reasonable to expect lags in any of the adjustments, especially those across regions, and most notably, those relating to the labor market. Having modelled the basic static structure for the relevant markets, supplementary discussion follows for critical aspects of the above discussion.

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<sup>55</sup>Though layoffs are the most obvious reasons to find employment elsewhere, even Northwest workers who find themselves with lower wages and/or fewer working hours might seek work in the Southeast if the present value of the expected benefits of such a move outweighs the expected costs, which would include their foregone wages from another Northwest job.

<sup>56</sup>Wages are assumed flexible here, although union activity probably dampens this effect.

### The Market for Public Timber

For public timber supply shocks in the Northwest to have any effect on regional or national lumber markets, the public timber demand schedule for that region must be less than perfectly elastic, such that the quantities of public timber supplied affect the overall market price for timber. In this section we will derive the elasticity of demand for public timber and its relationship with total regional demand using the idea of a residual demand for public timber.<sup>57</sup> Begin by assuming that public and private timber from the Pacific Northwest are perfect substitutes. The residual demand curve for public timber is defined as the demand for timber that is not met by the private sector,

$$R^{pub}(P) = D(P) - S^{priv}(P) \quad (4)$$

where  $S^{priv}(P)$  is the supply function for the private sector. Differentiating (1) with respect to  $P$  gives

$$\frac{\partial R^{pub}}{\partial P} = \frac{\partial D}{\partial P} - \frac{\partial S^{priv}}{\partial P} \quad (5)$$

Given equilibrium levels for the total quantity of timber demanded ( $Q_d$ ), the quantity supplied by the private sector ( $Q_s^{priv}$ ), the [residual] quantity of public timber demanded ( $Q_d^{pub}$ ), and the price ( $P$ ), we can multiply (2) by  $P/Q_d^{pub}$ , and the first and second right-hand side terms of (2) by  $Q_d/Q_d$  and  $Q_s^{priv}/Q_s^{priv}$  respectively to get

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<sup>57</sup>The derivation of general input demand functions will be covered in a subsequent section.

The framework developed in this section draws from Carlton and Perloff (1990).

$$\left( \frac{\partial R^{pub}}{\partial P} \frac{P}{Q_d^{pub}} \right) = \left( \frac{\partial D}{\partial P} \frac{P}{Q_d} \right) \frac{Q_d}{Q_d^{pub}} - \left( \frac{\partial S^{priv}}{\partial P} \frac{P}{Q_s^{priv}} \right) \frac{Q_s^{priv}}{Q_d^{pub}} \quad (6)$$

where the elasticity of demand for public timber, the elasticity of total demand, and the elasticity of private supply are in parenthesis from left to right. It can be seen in (6) that when the market share of public timber decreases (increases) the elasticity of demand for public timber becomes larger (smaller) in absolute value. In the context of this thesis, a change in public timber availability will have a larger effect on timber prices if public timber holds a larger share of the total regional market. Public timber harvests historically have accounted for about 40 percent of total regional harvests from the Northwest.<sup>58</sup> Although this seems to be a significant market share, existing evidence regarding the influence of public timber on the aggregate Northwest timber market is mixed. Adams (1983) report demand elasticities for National Forest timber from western Washington, and western Oregon ranging from -.7 to -3.0. On the other hand, Boungiorno, Bark, and Brannman (1985) find no evidence that public timber harvests have any effect on stumpage prices for that region.

### Interdependence of Geographically Distinct Markets

Although timber prices will affect lumber prices in a particular region, sawlogs are not transported across regions to the extent that lumber is. Therefore, it is through the covariance of regional lumber prices that a timber supply shock in one region can

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<sup>58</sup>Calculated from harvest series from the TAMM database, curtesy Darius Adams.

affect the lumber market of another. What can lead to such covariance? To begin with, the commodities must have some form of relationship with each other. In other words, they must be either substitutes or complements in consumption or production. Douglas Fir and Southern Pine, for example, are generally considered substitutes; they are both used widely as structural material for construction.<sup>59</sup> If this is the case, then when the price of Douglas Fir increases due to a supply shock in the Pacific Northwest it is reasonable to expect that the marginal consumers of Douglas Fir will instead use the lower priced Southern Pine products. This outward shift in Southern Pine demand will then lead to higher prices for Southern Pine. It is through this equilibrating process that prices are expected to fluctuate together. The covariances and dynamics of regional price series will be studied further in Chapter 4 using time-series techniques.

### **General Model of a Lumber Producing Firm**

A comparative statics analysis of lumber supply and factor demand, to be developed in this section, will provide a framework for discussing the relationship between lumber industry labor and timber markets.<sup>60</sup> Consider a strictly concave production function (over the relevant region) for lumber with three inputs,

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<sup>59</sup>It has been hypothesized by Lewandrowski (1994) however, that the Western Pine conglomeration is actually a complement to these other two species because it is primarily used for nonstructural construction purposes.

<sup>60</sup>See Beattie and Taylor (1993), Chapter 3 for a general development of this particular production setting. The model developed in this section also follows Abt (1987) in some respects.



$$Y = f(S, L, K) \quad (7)$$

where  $Y$  represents lumber output,  $S$  represents sawlogs,  $L$  represents labor, and  $K$  represents the capital stock. The variable for capital stock has been explicitly included to emphasize that capital and technology in this industry have changed significantly for the time period of interest. In a competitive lumber market with competitive input markets, the mill will attempt to maximize profit, given by

$$\pi = Pf(S, L, K) - (W_S S + W_L L + W_K K) \quad (8)$$

where  $P$  is the output price  $W_S$ ,  $W_L$ , and  $W_K$ , are variable factor wages for sawlogs, labor, and variable capital inputs.

First order conditions for profit maximization are

$$\begin{aligned} P \frac{\partial f}{\partial S} &= W_S \\ P \frac{\partial f}{\partial L} &= W_L \\ P \frac{\partial f}{\partial K} &= W_K, \end{aligned} \quad (9)$$

indicating that for each input, its wage (marginal cost) will be equal to the value of its marginal product at equilibrium.

Assuming the implicit function theorem holds, and given (from the assumption of a strictly concave production function and linear input costs, i.e. a concave primal profit function) that the second order conditions hold for a maximum, we have the input demand functions

$$\begin{aligned}
Y &= f(S^*, L^*, K^*) \equiv Y^*(P, W_S, W_L, W_K) \\
S &= S^*(P, W_S, W_L, W_K) \\
L &= L^*(P, W_S, W_L, W_K) \\
K &= K^*(P, W_S, W_L, W_K)
\end{aligned} \tag{10}$$

where  $Y^*$  is the competitive firm's supply function, and  $S^*$ ,  $L^*$ , and  $K^*$  are demand functions for each input - all of which are functions of the output price and the wage rates of all inputs.

Invoking the Envelope Theorem we have

$$\frac{\partial^2 \pi^*}{\partial P^2} = \frac{\partial Y^*}{\partial P} > 0 \tag{11}$$

Given linear input costs and a concave production function over the relevant range (implying diminishing returns), if the price of lumber increases in the Southeast, for example, we would expect an increase in lumber output for the representative mill, and for that region as a whole. For a change in output ( $Y$ ) with respect to a change in input prices, from Young's Theorem we know

$$\frac{\partial^2 \pi^*}{\partial P \partial W_i} = \frac{\partial^2 \pi^*}{\partial W_i \partial P} = \frac{\partial Y^*}{\partial W_i} = -\frac{\partial X_i^*}{\partial P} < 0 \tag{12}$$

If input  $i$  is a normal input for production over the relevant range (which is a reasonable assumption given the nature of the physical relationship between sawlogs and lumber), output will *ceteris paribus* decrease with an increase in the price of that input. We also know

$$\frac{\partial^2 \pi^*}{\partial W_i \partial W_j} = \frac{\partial^2 \pi^*}{\partial W_j \partial W_i} \Rightarrow \frac{\partial X_i^*}{\partial W_j} = \frac{\partial X_j^*}{\partial W_i} < 0 \quad (13)$$

If two inputs are complements in production, these values will be negative. In a lumber industry context, if sawlogs and labor are complements in the production of lumber and sawlogs are a normal input, then an increase in the price of sawlogs (resulting, for example, from a constriction in the Pacific Northwest timber supply) would *ceteris paribus* lead to a decrease in labor demand in that region.

### The Dynamics of Labor Demand

The above comparative statics model dealt in part with labor demand in a static framework. It provides a starting point for discussing the dynamics of labor demand.

In a competitive labor market in a world without labor force adjustment costs, each employee of a lumber mill would receive a wage equal to his or her marginal revenue product,

$$P \frac{\partial f}{\partial L} = W_L \quad (14)$$

With the inclusion of adjustment costs this equality of an employee's wage and marginal revenue product no longer holds. Using a dynamic profit-maximization framework and assuming linear adjustment costs, Nickell (1986) shows that marginal labor will be hired such that

$$P_t \left( \frac{\partial Y^*}{\partial L_t} \right) = W_t + \alpha r_t \quad (15)$$

where  $\alpha$  is the hiring rate and  $r_t$  is the real interest rate at time  $t$ . This indicates that the firm will hire marginal labor until the value of the marginal labor product is equal to the wage plus the opportunity cost of hiring that labor.<sup>61</sup>

A firm will fire employees to the point where the costs over time of keeping labor equal the opportunity costs of firing:

$$P_t \left( \frac{\partial Y^*}{\partial L_t} \right) = W_t - \beta r_t \quad (16)$$

where  $\beta$  represents firing costs. The assumption of a strictly concave production function implies a decreasing marginal product of labor. As a result, if labor adjustment costs are positive, when non-labor input supply and output demand fluctuations call for the hiring (firing) of labor, the firm will hire (fire) fewer laborers than it would if adjustment costs are zero. This leads to a dampening of employment fluctuations resulting from supply and demand shocks in the lumber and labor markets.<sup>62</sup>

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<sup>61</sup>Nickell (1986) accounts for a voluntary quit rate. For simplicity this was assumed zero here.

<sup>62</sup> This model with linear adjustment costs implies a peculiar adjustment process at the level of the individual firm, with segments of the cycle showing no labor adjustments. As noted by Anderson (1993), differences among firms will lead to smooth aggregate fluctuations, as are usually seen in employment time-series.

The salient point of this discussion on the dynamics of labor demand is that in an empirical study, it is reasonable to expect less fluctuation in employment levels than might be expected for prices, outputs or more cheaply adjustable inputs.

### **Labor Migration**

Timber harvest reductions in the Northwest are expected to lead to employment reductions in that region. If the Northwest lumber market is in competition with the Southeast lumber market, one would expect that as lumber prices increase, Southeast lumber mills will increase production, and as a result, hire more labor. A worker laid off from a Northwest lumber mill has two general options, assuming that a job in a different firm is preferable to unemployment; he could stay in the Northwest and find a job in a different industry (because the lumber industry as a whole is contracting in that region), or he could move to a region such as the Southeast where the probability of getting a job in the lumber industry might be better.

Many factors are involved in making such a decision. It may be that an ex-Northwest-lumber-mill worker could earn more due to industry-specific skills in a Southeast lumber mill than in, for example, the manufacturing sector of the Northwest.<sup>63</sup>

In addition to possible wage differentials, there are costs involved in migrating as well.<sup>64</sup>

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<sup>63</sup> Due to accumulated experience, even in equilibrium, the value of the marginal product of a lumber-mill worker working in a lumber mill is likely to be higher than the value of the marginal product of a lumber-mill worker working in a steel mill.

<sup>64</sup>For a discussion of the possible monetary and non-monetary costs incurred from migration, see Sjaastad (1971).

Consider an individual who, after being laid-off from a Northwest lumber mill job, must decide whether to find a job in a different sector in the Northwest, or a lumber mill job in a different region. Although it is likely that an individual might prefer working and living in a particular part of the country over another part of the country at a given wage level, for simplicity we will ignore this aspect of the problem by assuming that the individual is indifferent between living and working in either region. The assumption allows us to approach the question using a wealth-maximization framework; where the individual's future wealth is denoted as  $W = f(\text{wage}^i, \text{wage}^j, C)$ , where  $\text{wage}^i$  is the wage he could receive in region  $i$ ,  $\text{wage}^j$  is the wage he could receive in region  $j$  (both are in real terms, accounting for inflation and cost of living differences), and  $C$  is the income he would spend moving (because he would move right away, no discounting is necessary). Because moving to a different region for employment is an all or nothing proposition, the worker will want to maximize the present value over his working life of his potential utility from taking a job in a different industry but the same region or taking a job in the same industry but a different region:

$$\text{Max} \left[ \begin{array}{l} \left( \int_{t_0}^{\tau} e^{-r_t} W_t (\text{wage}_t^i) dt \right) \\ \left( \int_{t_1}^{\tau} e^{-r_t} W_t (\text{wage}_t^j) dt - C_t \right) \end{array} \right]$$

where  $r$  is his discount rate,  $(t_0 - t)$  is the time it would take to find a job in region  $i$ , and  $(t_j - t)$  is the time it would take to move and find a job.<sup>65</sup> If the individual chooses to stay in region  $i$  he will not incur moving costs, but he will not receive any wage from the other region. If we are discussing an individual who has not lost his job, but is facing a lowered wage, the decision is essentially the same, but the top integral (which in this case represents his current job) begins at  $t$  instead of  $t_0$ . One can see from this model that marginal workers might migrate 1) if wages in the Northwest decrease and/or wages in the Southeast increase for some significant period of time and/or 2) if wages in another sector decrease due to a shift in labor supply (from workers coming out of wood products industries of that region).<sup>66</sup> This type of one-directional migration is expected to shift the labor supply curve of the Northwest leftward, and the labor supply curves of other regions rightward.

### The Demand for Lumber

Approximately 80 percent of softwood lumber is used in residential construction (U.S. Industrial Outlook, 1993), and a substantial part of this is used for new construction. Therefore, the determinants of lumber demand can to a large extent be derived from a profit-maximization model for construction firms. Because a general

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<sup>65</sup>Note that we are implicitly assuming that the individual has no potential for income between periods  $i$  and  $j$ , and that the costs of finding a job are expected to be the same for each region, and that  $i < j$ .

<sup>66</sup>The model presented here is deterministic in nature. It would become more realistic (and more cluttered) if we incorporate the probabilities associated with finding or not finding jobs of a given wage in a particular region.

profit-maximization model has been developed in the previous section, we will not repeat the process. But as in lumber production, this theoretical framework demonstrates that it is the prices of inputs to production of construction projects and the output price of these projects that determine the supply curve for a construction firm in a competitive market. Approximately 20 percent of softwood lumber is purchased by final consumers.<sup>67</sup> This then calls for a utility-maximization framework for deriving the determinants of non-construction lumber demand.<sup>68</sup> Consider a constrained utility-maximization equation in lagrangian form,

$$\mathcal{L} = U\left(\sum_{i=1}^n x_i\right) + \lambda\left(M - \sum_{i=1}^n p_i x_i\right)$$

where  $x_i$  is a series of consumer goods,  $p_i$  are the corresponding prices of those goods, and  $M$  is income. The first order conditions are

$$\begin{aligned}\mathcal{L}_1 &= U_1 - \lambda p_1 = 0 \\ &\vdots \\ \mathcal{L}_n &= U_n - \lambda p_n = 0 \\ \mathcal{L}_\lambda &= M - \sum_{i=1}^n p_i x_i = 0\end{aligned}$$

Given that the first order conditions hold, the implicit function theorem holds, and the second-order conditions hold for a maximum,  $\lambda$  and the choice variables  $(x_i)$  can be written as a function of prices and income

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<sup>67</sup>Lewandowski, Wohlgenant, and Grennes, 1994.

<sup>68</sup>See Silberberg (1990) for a detailed discussion of consumer demand theory.



$$\begin{aligned}
 x_1 &= X_1^*(p_1 \dots p_n, M) \\
 &\vdots \\
 x_n &= X_n^*(p_1 \dots p_n, M) \\
 \lambda &= \lambda^*(p_1 \dots p_n, M)
 \end{aligned}$$

where  $x_i^*$  are the Marshallian demand functions for consumer goods. So, though the non-construction share of total lumber demand is relatively small (not more than 20 percent), income and the prices of substitutes are candidates as variables for an empirical study.

### **Characteristics of an Economic "Event"**

Any political decision leading to a different volume of available public timber has the potential to affect the market in some way. Even in the long run, if a political decision to reduce public timber harvests stands indefinitely and timber prices increase as a result, it is likely that a different equilibrium price and quantity of timber, and similarly lumber, will result.

In the short run, expectations regarding the event come into play. These litigation decisions can be considered "events" in the sense that they could potentially contain new information regarding changes in the availability of Northwest public timber; information that might lead to market reactions. It is helpful to consider two extreme cases. Suppose that in January 1991 a judge prohibits further harvests and sales of timber from a particular tract of public land, and the amount of timber affected is a significant percentage of the timber volume that would otherwise be on the market. Suppose also that every market participant learned exactly three months beforehand with 100 percent certainty that the prohibition was inevitable, and knew the amount of timber

to be withheld. One would expect the market participants to begin the adjustment process not on the date of the judicial decision, but three months before when the information was acquired. In expectation of higher timber prices due to the expected shift in supply, lumber mills will attempt to stock up on sawlogs before the price increases, and private timber suppliers will begin to raise prices immediately in expectation of this increased demand. In a world of zero transaction and information costs, prices and output levels would instantaneously adjust three months prior to the ruling. Furthermore, the ruling itself will provide no new information, and will have no further effect on these markets.

The other extreme possibility is that no industry participant is aware that the decision is even being *considered* until the decision is handed down, a situation analogous to an airplane crash in that it is completely unexpected. If this were the case, there of course would be no prior speculation about the outcome of the ruling, implying universal expectations of no shock. One would expect a discontinuity in market behavior at the time the final decision is publicized if the decision changes market expectations. In this scenario, market participants will begin to react to a litigation decision as soon as the decision is publicized, but not before.

Neither of these extreme cases is likely for the litigation decisions we are considering here. These litigation decisions are not like an airplane crash. Information regarding lawsuits filed is a matter of public record, and the judicial decision process is not instantaneous. This sets the scene for speculation about the decision that could manifest itself in market fluctuations. On the other hand, market participants will likely not be able to predict with much certainty the outcome of the litigation being brought on

behalf of the Spotted Owl, because the litigation is often based on a confusing set of legislation, and the outcome of the decision is affected by a larger, even more confusing set of legislation. This is illustrated by the regularity with which cases are overturned on appeal due to apparent errors on the part of lower courts (this was the case for at least three cases relating to the spotted Owl). It is also an indication of the inescapable subjectivity of the legislation interpretation process. Therefore, for each of the lawsuits of interest here, there will undoubtedly be some level of uncertainty, and there is a likelihood that the ruling will contain unforeseen information regarding the ruling — information that could significantly affect the expectations of lumber market participants and therefore could affect lumber markets. The potential effects on markets of new information are illustrated by a number of studies applied the live hog futures and other commodity markets, which show that announcements containing new information can have significant market impacts.<sup>69</sup>

The direction or existence of market adjustments to these court rulings depends on people's expectations of the outcome relative to the actual outcome. Therefore, unlike an airplane crash, we do not have any *a priori* expectations regarding the effects of the rulings. For example, consider a court case in which the judge could have potentially withdrawn from sale anywhere from 1 to 2 million board feet of timber, and the final decision was to withdraw the sale of 1.5 million board feet. If the wood products industry as a whole had expected the judge to withdraw 1 million, the expected supply of timber decreases as a result of this decision, and an increase in timber and

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<sup>69</sup>See Barnhart (1989), Colling and Irwin (1990) and Miller (1979) for examples.

lumber prices would result. If on the other hand the wood products industry had expected the judge to withdraw the full 2 million board feet, the expected supply of timber increases, and prices would decline. Similarly, there would be no market reaction if the expectations of the decision exactly matched the results of the decision itself, assuming the market had already adjusted to the potentiality of the decision. In summary, significant (otherwise unexplained) market activity during or shortly after a court ruling may be an indication that the litigation outcome was in some way different than market participants expected it to be, whereas if the ruling appears to have no effect on lumber markets, it may be inferred that the outcome of the ruling was accurately predicted by market participants, or that the ruling affected such a small segment of the market that it had no significant impact.

#### 4. EMPIRICAL METHODS AND RESULTS

The extent of regional lumber market interdependence and the effects of Spotted Owl litigation on the lumber industry are examined using two empirical approaches. First, a structural model is developed for the lumber and labor markets of the Pacific Northwest, the Southeast, and the Northern Rocky Mountain regions.<sup>70</sup> The extent and significance of interregional market relationships is examined in this model with cross-region price coefficients, and the significance of individual litigation decisions is examined using intervention analysis techniques. To complement this structural analysis, a time-series approach first developed by Pierce and Haugh (1977) is then performed to examine regional interdependence and evidence of Spotted Owl related shocks, again including intervention analysis for specific rulings.

##### **Structural Model of Regional Lumber and Lumber Industry Labor Markets**

The structural model of each market is based primarily on the general theory of

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<sup>70</sup> Ideally, a model for the timber market would be included in this framework. The relevant data, however, were available only in period lengths too long (many of them 5-year periods) to be useful in a monthly analysis. Furthermore, due to poor preliminary results of full-information 3SLS estimation results, limited-information procedures have been chosen for this analysis. Because each equation in a limited-information framework is estimated separately, this allows the exclusion of timber market equations.

profit-maximizing firms developed in Chapter 3.<sup>71</sup> The general model was developed under the assumption of instantaneous adjustment. This is not a realistic assumption, however, as lumber mill managers must make plans for future period production based on expected input and output prices. The structural model developed in this section uses a distributed lag framework, where decisions made for the current period are based on past values of explanatory variables.

#### Lumber Supply and the Demand for Lumber Inputs

Assuming a general distributed lag model, where current period production and input use are dependent on past prices, the parameters upon which a profit-maximizing lumber mill operator will base production decisions are:

$$\pi = \pi^*(P_{t-k}, W_{t-k}^S, W_{t-k}^L, W_{t-k}^K, W_{t-k}^X) \quad (21)$$

where

$P$  = output price,

$W_S$  = the price of sawlogs,

$W_L$  = labor wages,

$W_K$  = rental rate for capital,

$W_X$  = prices of other inputs, and

the number of explicit lags,  $k \geq 1$ , is not necessarily the same for all variables, and generally more than one lag is included for each variable; the notation is simplified here for clarity, and will be further developed later.

Comparative statics results indicate that the lumber supply and input demand functions (labor, for our purposes) for this firm are also a function of the above parameters. Because we are interested specifically in the effects of Northwest public

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<sup>71</sup>The labor supply equations are not drawn from a profit-maximization framework, but from a utility-maximization framework.

timber sale fluctuations, we replace the sawlog prices with the Northwest public timber sales variable. *Ceteris paribus* we cannot expect sawlog prices to remain constant as timber sales change; the exclusion of the sawlog price series allows sawlog prices to fluctuate freely as we examine the effects of public timber sales fluctuations.

The next consideration is data selection. First consider the lumber mill output price. There are numerous lumber products, varying in size and shape, the quality standards to which they are subject, and production volume. Two important lumber products, 2x4 Standard and Better #2 Dimension, and 2x4 Stud Grade deserve consideration; the former because it is produced in the highest volume of any lumber product, and the latter because it is a lumber product used almost entirely in residential construction. Preliminary regressions including one series, the other, or a weighted composite of both (as well as a visual inspection of these series) indicated that it matters little which one is used.<sup>72</sup> The dimension series were used for the final estimation. Douglas Fir is used to represent the Pacific Northwest lumber market, because it is the species used for 55 to 60 percent of all lumber produced in that region (Western Wood Products Association, 1991).<sup>73</sup> Southern Pine, which constitutes about 85 percent of all lumber products of the Southeast is the proxy

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<sup>72</sup>The simple correlation coefficients between the composite (of deflated dimension and stud prices) for each region range from .93 to .98, and there is no significant upward trend in any of the deflated price series.

<sup>73</sup>Seven other species comprise the rest of the timber inputs for the Pacific Northwest.

chosen for this region.<sup>74</sup> For the northern Rocky Mountain region, the Random Lengths composite price for Spruce, Pine and Fir is used. This conglomeration of species (referred to as "Western Pine" by the Bureau of the Census, Survey of Current Business Statistics) accounts for about 75 percent of all lumber production in Montana and Idaho.<sup>75</sup> Each of these price series is deflated by a producer price index for intermediate materials.

The practice of holding inventories is not costless for a mill. The space used for storage could be used for the production process itself. Further, the opportunity cost of holding inventory, be it in the form of sawlogs or finished lumber, is the foregone income the mill operator could receive by selling the inventory and reinvesting the income. Therefore interest rates on 91-day treasury bills are included in the lumber supply and input demand equations to represent the opportunity cost of inventory storage.<sup>76</sup>

Wood Products Industry Average Hourly Earnings from the Bureau of Labor Statistics are used as a proxy for lumber mill labor wages and is deflated by a producer price index.

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<sup>74</sup>Calculated from the Timber Assessment Market Model (TAMM) database. This data set was provided by Darius Adams, University of Montana.

<sup>75</sup>Percentage estimate calculated from Western Wood Products Association, 1991.

<sup>76</sup>One additional note regarding price series. Although stumpage prices are replaced by public timber sales in the structural equations, stumpage prices were included in preliminary regressions for completeness; their estimated coefficients are reported in footnotes later. National Forest stumpage prices as reported in quarterly form in *Production, Prices, Employment, and Trade in Northwest Forest Industries*, are used here.



To account for changes in the capital stock over time, the net value of Wood Products Industry capital stock (Bureau of Economic Analysis) is used as a proxy for the price of capital. The *net* value is defined to be the gross value of capital stock minus depreciation. This series is deflated with a producer price index.

Because most lumber mill machinery is powered by electricity, regional electricity prices are included (representative of "other input prices",  $\underline{X}$ ). These data were received in annual form, by state, from the department of Energy.

#### The Demand for Lumber

Because approximately 80 percent of softwood lumber is used in the construction industry (U.S. industrial Outlook, D.O.C., 1993), the lumber demand equations are based on input demand functions from a profit-maximization framework for a representative construction firm, which in general form is

$$\text{Lumber Demand} = f(P_{t-k}^C, P_{t-k}^i, \underline{P}_{t-k}^j, \underline{P}_{t-k}^X) \quad (22)$$

where  $P^C$  represents the output price of construction projects,  $P^i$  and  $\underline{P}^j$  are lumber prices in region  $i$  (for the demand equation for region  $i$ ) and a vector of lumber prices from all other regions.<sup>77</sup> Note that it is the statistical significance of other-region lumber prices that will indicate whether or not geographically distinct lumber markets are interdependent. Finally, construction industry demand for lumber depends also on the prices of other construction inputs.

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<sup>77</sup>Again, the number of lags  $k$  is not the same for all variables

Housing starts are included as a proxy for the output price of construction and the prices for all other construction inputs,  $P_x$ .<sup>78</sup> Other studies that include housing starts in place of the output price of housing include Buongiorno, Chou, and Stone (1979), Adams and Haynes (1980) and Robinson (1974), Spelter (1985), Lewandrowski, et al. (1994), among others. Because the housing starts variable accounts only for new units started, personal disposable income is included as a proxy for consumers' propensity to invest in housing improvements. United States population is included to account for a 10.9 percent population increase (from 231.37 million to 259.74 million) between 1982 and 1993.

#### Wood Products Industry Labor Supply

A labor supply equation appropriate in this context should include the potential opportunity costs of working in a particular industry and/or region. As represented below, the labor supply specification used in this study contains wage levels for lumber industries in different regions, as well as wage levels for different industries.

$$\text{Labor Supply} = f\left(W_{t-k}^i(wp), \underline{W}_{t-k}^j(wp), \underline{W}_{t-k}^i(ind), \underline{E}_{t-k}^j(wp)\right) \quad (23)$$

where

$W^{i(lumber)}$  = lumber industry labor wages in region  $i$ ,

$\underline{W}^{j(lumber)}$  = a vector of other-region lumber industry labor wages,

$\underline{W}^{i(industry)}$  = a vector of labor wages in other industries in region  $i$ ,

$\underline{E}^{j(lumber)}$  = a vector of employment levels in other regions.

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<sup>78</sup>The average value of housing has been used as a variable in a small number of lumber demand analyses using annual data, but the results are generally not as strong as those in which housing starts are used.

The decision to accept a lumber-industry-related job in region  $i$  is based on the lumber industry wage levels in that region, lumber industry wage levels in other regions, wages in other industries, and lumber industry employment levels in other regions. Bureau of Labor Statistics data on average hourly earnings are used to represent wage rates of each industry and region. The employment level variable is included to capture any evidence of wood products industry labor migration away from the Pacific Northwest and into other regions, as discussed in Chapter 3. Finally, seasonal dummy variables are included in all supply and demand equations to account for otherwise unexplained seasonal employment fluctuations.

#### Specification of the Dynamic Structure of the Lumber and Labor Markets

Though numerous studies of U.S. lumber markets have used a static framework with annual data, preliminary regression results using monthly data indicated the presence of dynamic processes in each of the lumber and labor markets being considered.<sup>79</sup> Therefore, specification of these dynamics is necessary. Numerous distributed lag specifications were attempted, including explicit lags of varying orders on the explanatory variables, Almon lags, Koyck-Nerlove specifications of various orders, and various Rational Lag specifications (following Jorgenson, 1966).<sup>80</sup> A first order Koyck transformation, a first order Rational Lag (with explicit

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<sup>79</sup>Recall that two other studies have used monthly data; Buongiorno, Chuo, and Stone (1979) and Lewandowski, Wohlgenant, and Grennes (1994). A discussion of the dynamic specifications used in these studies is provided in Chapter 2.

<sup>80</sup>See Pindyck and Rubinfeld (1991) and Judge, Griffiths, Hill, and Lee (1980) for discussions of each of these dynamic specifications.

lags on a number of the explanatory variables), and a model with free-formed lags and no lagged dependent variable explained the dynamics equally well for each market model. The Koyck-Nerlove and the Jorgenson models constrain the dynamic processes of each explanatory variable to be the same. There is no reason to believe that this is justifiable, so a model with free-formed lags and no lagged dependent variable is used for this study. Also, distributed lag models such as the Koyck-Nerlove and Jorgenson models often are used to save degrees of freedom. Because each series used here has 141 observations and the lag processes for the independent variables rarely extend past three periods, the degrees-of-freedom problem is considered not to be extreme. The model takes the general form

$$Y_t = \alpha + \sum_{i=1}^I \sum_{k=0}^K \beta_{ik} X_{i,t-k} + \epsilon_t$$

where

$Y$  is the dependent variable,  $\alpha$  is a constant,  
 $X_{i,t-k}$  is one of  $i$  explanatory variables lagged  $k$  periods, and  
 $\beta_{ik}$  is the coefficient corresponding to  $X_{i,t-k}$ .

The exact lag lengths for each variable were determined in an *ad hoc* fashion based on the significance level of the coefficient for each lag. The statistical significance tended to die out by the second or third lag for most variables, but occasionally longer lags were included.

### Model Estimation

From a theoretical standpoint, when the current-period dependent variable is a function of past-period explanatory variables, endogeneity is precluded (as long as serial correlation is absent) because past values cannot be affected by current values.

But serial correlation was present in each equation when OLS was applied. This indicates that for explanatory variables whose current-period observations are correlated with the error term (indicating endogeneity), their past-period observations will be correlated with the error as well. If this is the case, OLS estimates will be inconsistent. Furthermore, serial correlation leads to inefficient OLS estimators for finite sample sizes. Therefore an autoregressive specification is called for; the autoregressive form of order one [AR(1)] is assumed for these equations. Further discussion of an autoregressive model is presented in the time-series section of this Chapter.

In addition to serial correlation, cross-correlation of errors between supply and demand equations for each market was present to varying degrees, even after correcting for serial correlation which implies Seemingly-Unrelated-Regression problems.<sup>81</sup> This result implies the need for the use of a full-information technique in order to retrieve asymptotically unbiased, consistent, and efficient estimators. Three Stage Least Squares (3SLS) was performed for each pair of supply and demand equations, but the results were unacceptable in each case; the mean-squared-errors increased substantially in all cases, and t-statistics on the coefficients generally dropped substantially.<sup>82</sup> 3SLS as an estimation technique was therefore discarded in

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<sup>81</sup>In actuality, even with serial correlation corrections, the null hypothesis of no serial correlation is rejected for two of the labor demand equations.

<sup>82</sup>As noted below, serial correlation is a problem in each of the equations estimated. 3SLS was attempted both before and after accounting for serial correlation, and results were poor in both cases.

favor of less sensitive single equation estimation techniques. Although the accuracy of the estimates suffers, precision is retained.<sup>83</sup>

#### Testing for Regional Interdependence in the Context of a Structural Model

Recall that lumber prices of all regions are included in each regional lumber demand equation. They are included as potential substitutes for each other (given our hypothesis as developed in Chapter 3). If the price of Pacific Northwest Douglas Fir increases, marginal consumers of Pacific Northwest lumber will attempt to substitute lumber from other regions to lower their input costs. If this is indeed the case, one would expect significant cross-price elasticities for lumber. In the context of this model, this will be considered evidence supporting the existence of regional interdependence. In addition to lumber price effects, labor supply in one region may be affected by market shocks in another region. As discussed in the previous Chapter, if employment levels significantly decrease in the Pacific Northwest due to a decrease in labor demand for that region, the lumber industry labor markets of other regions may see an increase in labor supply resulting from migration.

#### Estimation of Litigation Effects

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<sup>83</sup>Although this model, which technically has no endogenous explanatory variables, does not call for Two Stage Least Squares estimation, two stage least squares was run on regressions that included current-period explanatory variables. As with 3SLS, efficiency suffered a great deal.

This efficiency problem probably stems from poor fits for instrumental variables generated in the 2SLS and 3SLS routines. Instrumental variables were generated manually by regressing each endogenous variable on all exogenous variables, and the  $R^2$ s ranged from .65 to .85.

The following general model is used to test the effects of Spotted Owl litigation on the relevant supply and demand equations for each of the three regions.<sup>84</sup> For the Northwest this includes lumber supply and both labor supply and demand. For the Southeast and the Rocky Mountains, the lumber and labor demand and labor supply equations are of interest:

$$Y_t = \alpha + \beta'X_t + \sum_{i=1}^8 \delta_i E_i + \epsilon_t \quad (25)$$

where  $Y_t$  is the dependent variable,  $X_t$  is the vector of (non-dummy) explanatory variables in the equation (as described previously), and  $E$  is equal to 1 beginning on the month after the litigation decision date and thereafter.<sup>85</sup> Recall that the intervention models reviewed in Chapter 2 included intervention dummy variables that equalled one only on the ruling date, and reverted back to zero afterward. This is generally the case because these models use first-differenced data series instead of non-differenced data. Differenced data provides information about the size of the change between periods; if the market reacts to a litigation decision in one period, the change will be seen in that period only. With non-differenced data the result will be a

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<sup>84</sup>For further discussion of intervention analysis see Box and Tiao (1975) and Mills (1990)

<sup>85</sup>Dummy variables for the periods before the ruling were considered, but it is hypothesized that expectations regarding the upcoming ruling will change gradually over time, and that there is no reason to believe that a sudden aggregate change in expectations would occur prior to (and as a result of) the upcoming litigation, given the nature of the litigation process.

once and for all level shift. This level shift implies the need for the dummy variable structure described in equation (5).

### Structural Model Results

In order to determine the extent of the effects of public timber sales reductions and litigation decisions, we will begin by examining the Northwest itself. If there is evidence of market effects at all, one would expect them to be strongest for the region in which the shocks are occurring. Recall from prior discussion that Generalized Least Squares is used to account for serial correlation in estimating these models.

Table 1. Northwest Lumber Supply: Dependent Variable = Northwest Douglas Fir Shipments			
$R^2 = .6150$	$\text{Rho} = .53558$	$\text{Durbin Watson} = 2.1158$	
Variable Name	Sum of Lag Coefficients	LR Expected Sign	T-Ratio
Northwest Lumber Price <sub>(t-1, t-2)</sub>	.0711	+	.1877
Northwest Lumber Wage <sub>(t-1, t-2)</sub>	-20.055	-	-.32265
Northwest Electricity Price <sub>(t-1, t-2)</sub>	62.752	-	2.0251
Value of Capital Stock	-142.72	?	-3.627
Winter	24.275	-	1.141
Government Bonds <sub>(t, t-1, t-2)</sub>	31.625	+	1.945
Northwest Public Timber Sales <sub>(lags 1-5)</sub>	.0012	+	2.444
Constant	2577.8	?	4.370

The overall results for the Northwest lumber supply equation (table 1) are not very good. It should be reiterated that numerous dynamic specifications and numerous



combinations of variables were considered (for this and all subsequent equations); all produced results comparable to those reported here.

The coefficient of particular interest, that for public timber sales, is strongly significant. From these results it appears that Northwest lumber production is affected by public timber sales in the region.<sup>86</sup>

Table 2. Northwest Lumber Demand: Dependent Variable = Northwest Douglas Fir Shipments			
$R^2 = .6322$	Rho = .5653	Durbin Watson = 2.1785	
Variable Name	Sum of Lag Coefficients	LR Expected Sign	T-Ratio
Northwest Lumber Price <sub>(t-1, t-2)</sub>	-.3300	-	-.4537
Southeast Lumber Price <sub>(t-1, t-2)</sub>	.65105	+	.6193
Rocky Mountain Lumber Price <sub>(t-1, t-2)</sub>	.0956	+	.11961
Housing Starts <sub>(t-1, t-2)</sub>	2.1165	+	1.8762
Per Capita Disposable Personal Income <sub>(t-1, t-2)</sub>	.13813	+	1.782
Population	-.0052	+	-.5384
Winter	24.984	-	1.224
Government Bonds <sub>(t, t-1, t-2)</sub>	-2.5693	-	-.21134
Constant	-28.318	?	-.0850
*Signs based on the assumption that lumber from different regions are substitutes; Also, to reduce collinearity problems, each other-region lumber price coefficient was estimated while excluding the other other-region lumber price from the equation.			

<sup>86</sup>When the Northwest timber sales variable is replaced with a National Forest stumpage price series, the coefficient on that variable is of the expected sign (negative) with a t-statistic of -1.5512.

Although all lumber price coefficients in table 2 are of the expected sign, none of the other-region prices appears to be significantly correlated to the quantity supplied of Northwest lumber. From this, regional lumber markets appear not to be interdependent. This result is consistent with the results of the structural models developed by Lewandrowski et al. (1994) and others.

Table 3. Northwest Labor Demand: Dependent Variable = Northwest Lumber Employment			
$R^2 = .9606$	$\text{Rho} = .97300$	$\text{Durbin Watson} = .9561$	
Variable name	Sum of Lag Coefficients	LR Expected Sign	T-Ratio
Northwest Lumber Wage <sub>(t-1, t-2)</sub>	9.1106	-	2.1198
Northwest Lumber Price <sub>(t-1, t-2)</sub>	.0559	+	2.729
Northwest Electricity Price <sub>(t-1, t-2)</sub>	3.004	-*	-8.597
Value of Capital Stocks	-9.5110	-\$	-1.705
Winter	-2.3128	-	-3.262
Government Bonds <sub>(t-1, t-2)</sub>	2.3802	+	2.4009
NW Public Timber Sales <sub>(lags 1 through 5)</sub>	.0001	+	2.5285
Constant	172.67	?	1.634
*Signs based on the assumption of complementarity with labor in production.			
§Based on the assumption that capital and labor are long run substitutes.			

Although the overall results in table 3 are weak, the coefficient on public timber sales is significant and of the expected sign.<sup>87</sup>

From the above results, Northwest public timber sales fluctuations appear to influence the lumber market and lumber industry labor market of the Northwest region.

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<sup>87</sup>If the public timber sales variable is replaced with the stumpage price series, the t-statistic is .30933.

### Regional Interdependence

Regional relationships can be seen through cross-price effects in lumber demand, lumber industry labor demand, or through evidence of labor migration. Again, the Northwest lumber supply and demand equations show no indication of regional interdependence. Now consider the results from the other two regions.

Table 4. Southeast Lumber Demand: Dependent Variable = Southern Pine Shipments			
$R^2 = .8316$	$\text{Rho} = .46736$	$\text{Durbin Watson} = 2.0033$	
Variable name	Sum of Lag Coefficients	LR Expected Sign	T-Ratio
Southeast Lumber Price <sub>(t-1, t-2)</sub>	-.2688	-	-.3043
Northwest Lumber Price <sub>(t-1, t-2)</sub>	.8263	+ <sup>§</sup>	.5833
Rocky Mountain Lumber Price <sub>(t-1, t-2)</sub>	-.4944	+ <sup>§</sup>	-.4666
Housing Starts <sub>(t, t-1)</sub>	.4793	+	.3508
Per Capita Disposable Personal Income <sub>(t, t-1, t-2)</sub>	.2048	+	2.1565
Population	.0072	+	.5480
Government Bonds <sub>(t, t-1, t-2)</sub>	-12.437	-	-.864
Winter	62.704	-	2.229
Northwest Public Timber Sales <sub>(lags 1-5)</sub>	-.00019	-	-.2826
Constant	-3412.8	?	-1.473
<sup>§</sup> Based on the assumption that the lumber of different regions are substitutes; Also, to reduce collinearity problems, each other-region lumber price coefficient was estimated while excluding the other other-region lumber price from the equation.			

It is through price effects that we expect the Northwest timber shocks to affect the demand for lumber in the Southeast. As with the results for the Northwest, however, results for the Southeast do not support this expectation; the cross-region price coefficients are both insignificant. Insignificant price coefficients are a common

problem in lumber market modelling literature. Adams and Haynes (1980), Berck (1979), Lewandrowski, Wohlgenant and Grennes (1994), and Robinson (1974) among others report similar results. The Northwest timber sales variable is explicitly included in this equation. There is weak evidence that a relationship (of the expected sign) between Northwest public timber sales and Southeast lumber demand may hold.

Consider now the Southeast labor demand and supply equations.

Table 5. Southeast Labor Demand: Dependent Variable = Southeast Wood Products industry employment			
$R^2 = .9799$	Rho = .9728	Durbin Watson = 1.4877	
Variable name	Sum of Lag Coefficients	LR Expected Sign	T-Ratio
Southeast lumber wage <sub>(t-1, t-2)</sub>	9.3998	-	1.7213
Southeast Lumber Price <sub>(t-1, t-2, t-3)</sub>	.0214	+	1.7213
Southeast Timber Price <sub>(t-1, t-2)</sub>	.0750	-\$	1.1840
Southeast Electricity Prices <sub>(t-1, t-2)</sub>	2.7043	-\$	1.1998
Government Bonds <sub>(t-1, t-2)</sub>	1.7275	+	2.7086
Winter	-1.1148	-	-3.032
Value of Capital	1.9906	-\$*	3.033
Northwest Public Timber Sales <sub>(lags 0-3)</sub>	.6371E-4	-	3.4067
Constant	-36.609	?	0.7537
§Based on the assumption that this input is complementary with labor inputs. *Based on the assumption that capital and labor are long-run substitutes			

Table 6. Southeast Labor Supply: Dependent Variable = Southeast Wood Products industry employment			
$R^2 = .9788$	Rho = .97447	Durbin Watson = 1.6574	
Variable name	Sum of Lag Coefficients	LR Expected Sign	T-Ratio
Southeast Lumber industry Wage <sub>(t-1, t-2)</sub>	7.9392	+	1.3964
Southeast Manufacturing Wage <sub>(t-2, t-3)</sub>	13.355	-	2.1548
Northwest Lumber Employment <sub>(t-2, t-3)</sub>	.12506	-	1.8270
Rocky Mountain Lum. Employ. <sub>(t-1, t-2)</sub>	-.3983	-	-1.0464
Winter	-1.0256	-	-2.640
Northwest Public Timber Sales <sub>(t-2, t-3)</sub>	.2096E-4	-	1.9442
Constant	-2.1974	?	-.0475

Clearly the labor supply and demand equations for the Southeast are not satisfactorily specified, but results that better fit *a priori* expectations were not found. The results are similar if the Northwest public timber sales variable is excluded. No substantial evidence of expected regional market relationships for the Southeast follow from this model. No existing studies report results with respect to lumber industry labor supply, and only two studies report labor demand elasticities. Using annual data from 1950 to 1976, Merrifield and Haynes (1984) report a labor demand elasticity of the expected sign (negative), but report no significance level for the estimate. Abt (1987), using annual data from 1963 to 1978 reports significant labor demand coefficients of the expected sign for two of the three regions he considers. No studies using monthly data report results for the lumber industry labor market.

Let us now examine the results from the model of the Rocky Mountain regional markets.

Table 7. Rocky Mountain Lumber Demand: Dependent Variable = Western Pine Shipments			
$R^2 = .7054$	Rho = .58612	Durbin Watson = 2.1892	
Variable name	Sum of Lag Coefficients	LR Expected Sign	T-Ratio
Rocky Mountain Lumber Price <sub>(t-1, t-2)</sub>	.20774	-	.24835
Southeast Lumber Price <sub>(t-1, t-2)</sub>	-.55327	+ <sup>§</sup>	-.7753
Northwest Lumber Price <sub>(t-1, t-2)</sub>	-.50112	+ <sup>§</sup>	-.6737
Housing Starts <sub>(t-1, t-2)</sub>	1.2820	+	1.2389
Per Capita Disposable Personal Income <sub>(t-1, t-2)</sub>	.21394	+	2.674
Government Bonds <sub>(t, t-1)</sub>	-1.919	-	-1.695
Population	-.0084	+	-.8428
Winter	4.5514	-	.2178
Northwest Public Timber Sales <sub>(lags 1-5)</sub>	.0003	-	.7375
Constant	-140.35	?	-.085
<sup>§</sup> Based on the assumption that the lumber of different regions are substitutes; Also, to reduce collinearity problems, each other-region lumber price coefficient was estimated while excluding the other other-region lumber price from the equation.			

Table 8. Rocky Mountain Labor Demand: Dependent Variable = Rocky Mountain Wood Products Industry Employment			
$R^2 = .7745$	Rho = .86812	Durbin Watson = .8552	
Variable name	Sum of Lag Coefficients	LR Expected Sign	T-Ratio
Rocky Mountain Lumber Wage <sub>(t-2, t-3)</sub>	-.63430	-	-2.767
Rocky Mountain Lumber Price <sub>(t-2, t-3)</sub>	.0082	+	1.9029
Rocky Mountain Timber Price <sub>(t-1, t-2)</sub>	-.0056	-\$	-1.3624
Rocky Mountain Electricity Prices <sub>(t-1, t-2)</sub>	-.7790	-\$	-8.525
Government Bonds <sub>(t-1, t-2, t-3)</sub>	.2396	+	1.2415
Winter	-.037	-	-2.582
Value of Capital Stock	-1.021	-*	-1.767
Northwest Public Timber Sales <sub>(t-1, t-2, t-3)</sub>	.979E-6	-	.2025
Constant	45.82	?	4.167
<p>§Based on the assumption that this input is a complementary with labor inputs.          *Based on the assumption that capital and labor are long-run substitutes</p>			

Table 9. Rocky Mountain Labor Supply: Dependent Variable = Rocky Mountain Wood Products Industry Employment			
$R^2 = .8746$	Rho = .97867	Durbin Watson = 1.6820	
Variable name	Sum of Lag Coefficients	LR Expected Sign	T-Ratio
Rocky Mountain Lum. Wage <sub>(t-1, t-2)</sub>	.0223	+	.1111
Manufacturing Wage <sub>(t-2, t-3)</sub>	1.0329	-	1.0197
Southeast Lumber Employment <sub>(t-2, t-3)</sub>	.0418	-	1.045
Northwest Lum. Employ <sub>(t-1, t-2)</sub>	.10954	-	5.2844
Population	.787E-4	+	.6745
Winter	-.1397	-	-1.352
Northwest Public Timber Sales <sub>(t-2, t-3)</sub>	-.308E-5	-	-1.0483
Constant	-39.158	?	-1.399

Again, there is little evidence from the Rocky Mountain Results to suggest regional market interdependence. Further, the coefficients on Northwest public timber sales are insignificant and do not have the expected sign. The structural model results, though often inconsistent with economic theory, are generally consistent with the results of earlier research.

#### Structural Model Intervention Analysis Results

Information events considered for this analysis are limited to litigation decisions; legislation decisions related to the Spotted Owl issue are excluded. The justification for this is based on the differences between the legislative and judicial processes. Legislative decisions are developed, and often publicized, over relatively long periods of time, giving economic agents (the wood products industry) the opportunity to digest and act on the proposed legislation before it is in fact enacted; in other words, enactment of the legislation is unlikely to include any new information on the actual enactment date. Although speculation about the potential outcome of a ruling is probable because the filing of lawsuits is no secret, it is probable that few people will know the details of the judicial decision until the decision is handed down. It is more likely that these judicial decisions will contain "news".

Eight Spotted Owl related litigation decisions were chosen for this study based on the potential effects on the supply of timber from the Pacific Northwest. All of the decisions were handed down between May 1988 and July 1992. The following tables summarize the effects and statistical significance of each ruling on the supply of



lumber and demand for labor in the Pacific Northwest, and on the demand for lumber and labor in the Southeast and Rocky Mountain regions. Additionally, inverse supply and demand relationships were estimated to test for the effects of these rulings on lumber prices and wages.

The underlying market equations are identical to those for which results were reported in tables 1 through 9. To each of these equations, all eight dummy variables (corresponding to the court rulings described in Chapter 2) were added. Because we are looking for level changes corresponding to the decision dates, the dummy variables take the value of zero until the month of the ruling, and take the value of one thereafter (recall that we are measuring the effects assuming a one month lag). Due to the variability of the exact day within the month that each ruling was made, and the fact that these models do not fully adjust in one month's time, the coefficients for the month *after* the ruling are reported here; for rulings that occur early in the month, this implicitly assumes a one month lag.

Table 10a. Structural Model Intervention Results: Northwest Region. t-statistics in parenthesis under estimated coefficient								
Market Equation	May 1988	Jan. 1989	March 1989	Jan. 1991	May 1991	Dec. 1991	May 1992	July 1992
Northwest Lumber Supply inverse (lumb. pr. dep. var)	.0132 (.3323)	-.0001 (-.0045)	-.0147 (-.4793)	-.0159 (-.7949)	.0220 (1.341)	.0118 (.8489)	-.0128 (-1.295)	.0007 (.0839)
Northwest Lumber Supply	-.0192 (-.4770)	-.0154 (-.3982)	.0095 (.2795)	-.0247 (-1.246)	<b>-.0308</b> <b>(-1.653)</b>	-.0011 (-.0729)	-.0085 (-.6996)	.0056 (.5198)
Northwest Labor Demand	.0005 (.0503)	.0090 (1.085)	<b>.0166</b> <b>(2.176)</b>	-.0011 (-.2410)	.0008 (.1954)	-.0044 (-1.343)	.0025 (1.088)	-.0018 (-.8699)
Northwest Labor Wage	-.0014 (-.3130)	.0005 (.1121)	.0008 (.2169)	-.0011 (-.4500)	.0024 (1.192)	.0015 (.9708)	-.0005 (-.4680)	-.0009 (-.8947)

Table 10b. Structural Model Intervention Results: Southeast Region. t-statistics in parenthesis under estimated coefficient								
Market Equation	May 1988	Jan. 1989	March 1989	Jan. 1991	May 1991	Dec. 1991	May 1992	July 1992
Southeast Lumber demand inverse (lumb. pr. dep. var)	<b>.0615</b> (1.940)	.0078 (.2266)	-.0089 (-.2956)	.0113 (.5602)	.0042 (.2454)	<b>.0220</b> (1.741)	-.0007 (-.0647)	.0087 (.9765)
Southeast Lumber demand	-.0087 (-.2115)	-.0057 (-.1362)	-.0467 (-1.290)	.0141 (.5963)	-.0343 (-1.591)	<b>.0267</b> (1.844)	.0122 (1.010)	<b>-.0242</b> (-2.366)
Southeast Labor Demand	.0070 (1.596)	.0036 (.9365)	.0037 (1.042)	<b>-.0072</b> (-3.137)	.0009 (.4455)	.0004 (.2600)	.0007 (.6410)	.0007 (.7698)
Southeast Labor Wage	.0011 (.4291)	-.0015 (-.6440)	-.0003 (-.1503)	-.0014 (-.9667)	-.0002 (-.2162)	-.0005 (-.5693)	-.0003 (-.5030)	-.0002 (-.2916)

Table 10c. Structural Model Intervention Results: Rocky Mountain Region. t-statistics in parenthesis under estimated coefficient								
Market Equation	May 1988	Jan. 1989	March 1989	Jan. 1991	May 1991	Dec. 1991	May 1992	July 1992
Rocky Mountain Lumber demand inverse (lumb. pr. dep. var)	.0378 (1.251)	-.0065 (-.2377)	.0123 (.4859)	.0047 (.2695)	.0217 (1.569)	.0145 (1.390)	-.0075 (-.9171)	.0071 (1.017)
Rocky Mountain Lumber demand	-.0352 (-1.023)	.0147 (.4230)	-.0132 (-.4209)	-.0259 (-1.272)	-.0076 (-.4459)	-.0133 (-1.082)	-.0018 (-.1646)	-.0059 (-.6560)
Rocky Mountain Labor Demand	<b>.0364</b> (1.784)	-.0198 (-1.118)	<b>.0434</b> (2.608)	<b>-.0264</b> (-2.625)	.0125 (1.432)	.0002 (.0259)	.0059 (1.194)	.0055 (1.234)
Rocky Mountain Labor Wage	.0179 (1.600)	-.0138 (-1.250)	<b>.0245</b> (2.410)	-.0083 (-1.347)	.0055 (1.041)	-.0008 (-.2087)	-.0029 (-.8499)	<b>.0034</b> (1.767)

Results that are significant at  $\alpha \leq .10$  are in bold type. Given that there are a total of 72 intervention coefficients reported, one would expect between seven and eight of these coefficients to be significant even if all parameters were in fact zero. As reported here, only 12 coefficients are significant at  $\alpha \leq .10$ . These are not strong results. There are, however, serious problems with this model given the nature of the data. This is illustrated by the fact that if each of these intervention dummies is estimated alone (only one dummy variable per regression instead of eight), a much

larger number of these coefficients become significant at the 10 percent level - on the order of 50 to 60 percent of all coefficients. This is probably a result primarily of multicollinearity among intervention dummies. The correlation coefficients among these variables range from .36 to .95, indicating that the results of a particular court ruling will sometimes be difficult to distinguish from the effects of another. Also, intervention coefficients are probably picking up on dynamics in the data, rather than the effects of specific court rulings.<sup>88</sup>

One weakness of intervention analysis should be noted. Even though we are considering these court rulings to be exogenous to the markets in question, we cannot directly infer that significant intervention coefficients are the direct result of, or even directly related to, the litigation decisions themselves. It is possible, especially in markets as volatile as wood products industry markets have been during the time period being considered, that the coefficients are picking up information from market activity that is not tied to the litigation of interest here. For example, although this

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<sup>88</sup> Although the results presented above are weak, note that for four of the eight intervention dummy variables, the coefficients on all three regional lumber prices are of the same sign, a characteristic that would be expected given that lumber from different regions are substitutes. The significance of this result can be tested using a binomial distribution as follows. For three random time-series, the probability (p) of obtaining three positive *or* three negative signs (x=3) is  $p = (.5)^3(2) = .25$ . If we randomly select eight observations (representing eight intervention dummies: n=8), on average we would expect  $(.25)(8) = 2$  observations to have three identical signs. The variance of x [ $V(x) = np(1-p)$ ] is  $2(1-.25) = 1.5$ , and the standard deviation is 1.2247 (the square root of the variance). A significance test in the form of

$$\frac{(\text{observed} - \text{expected})}{\text{Standard Deviation}} = \frac{4 - 1}{1.2247} = 2.449 \text{ indicates that with seven}$$

degrees of freedom, the result of four out of eight observations is significantly different that one out of eight at the 5 percent level. This result suggests that lumber prices are positively correlated.

thesis is limited to the national lumber markets, it could be that lumber import and export activity not captured in this model are leading in part to the United States lumber price volatility.

### **Time Series Analysis of Lumber Prices, Lumber Production and Employment**

We will now perform a time-series analysis of the relationships between Northwest public timber sales and regional market indicators.

Applying time series techniques to lumber prices of different regions, Uri and Boyd (1990) conclude that lumber markets of different regions are in fact in competition with each other. As shown by Uri and Rifkin (1985), these techniques can also be useful in studying the price effects of structural shifts such as might be occurring in response to the Spotted owl litigation of the Northwest. Such an analysis is now applied to monthly lumber price data, lumber output data, employment and wage data for the Pacific Northwest, the Southeast, and the Northern Rockies, in a search for regional market interdependence and potential market effects of Northwest public timber sales fluctuations.

One simple but potentially misleading technique for measuring interdependence of markets is simple correlation analysis, as done recently by Stigler and Sherwin (1983) and Horowitz (1981), and as a sideline by Uri and Boyd (1990). With respect to lumber prices of four U.S regions, Uri and Boyd (1990) found deflated annual prices to have positive correlation coefficients of .98 or above, indicating a strong positive relationship. But as noted above, comparing simple price correlations can be

misleading when studying market interdependence through price relationships, as argued by Price (1979). Consider two price series with strong, similar trends. The existence of these trends in itself could produce a large (positive) correlation coefficient, even if the prices tend to fluctuate about this trend in directions opposite each other at any given time (which by itself implies negative correlation). Another problem, as Uri and Boyd (1990) point out, is that simple correlation analysis does not detect any *relative* changes in these trends over time, such as might be expected in related markets after a shock.

Now consider the methods used by Uri and Boyd (1990) and Uri and Rifkin (1985) that attempt to account for these problems. Autocorrelation often exists in time series data, especially when dealing with relatively short time periods between observations. If the contemporaneous prices of two competing markets are correlated, one would expect *lags* of one price series ( $P_{i,t-j}$ ) to be correlated with the other market's price in the current period simply because of this autocorrelation. In other words, if two contemporaneous prices are correlated and if one (or both) of these prices is systematically correlated with its own past prices, it follows that the past prices in one price series are correlated with the current price of the other series. To extract unbiased results when examining two contemporaneous price correlations, these systematic temporal correlations must be removed from the time series.

In comparing two autocorrelated price series, they can be written in matrix form as

$$\begin{bmatrix} F(B) & 0 \\ 0 & G(B) \end{bmatrix} \begin{bmatrix} P_{1t} \\ P_{2t} \end{bmatrix} = \begin{bmatrix} u_t \\ v_t \end{bmatrix} \quad (26)$$

where  $P_{1t}$  and  $P_{2t}$  are the original price series,  $F(B)$  and  $G(B)$  are lag series in lag operator form, and  $u_t$ ,  $v_t$  are residuals. The lag structure imposed on each price series is specified (as an ARIMA model) such that  $u_t$  and  $v_t$  are white noise residuals.<sup>89</sup> If the ARIMA model is specified correctly, then for each of the individual time-series there will be no systematic relationship between the error in one period and the error in any other period. This being the case, we can examine the nature of the relationship between the two time series. If the two markets are interdependent, market shocks affecting one market will elicit a response in the other market. Therefore one would expect that the filtered errors of the two series would be correlated in some way. Given the correct ARIMA specification, this relationship can be tested using OLS in the following manner:

$$v_t = \sum_{i=0}^I (-\alpha_i) u_{t-i} + \epsilon_{1t}$$

$$u_t = \sum_{j=0}^J (-\beta_j) v_{t-j} + \epsilon_{2t}$$

If all market adjustments occur within one period, one would expect only the estimated coefficients on the contemporaneous residuals ( $\alpha_0$  and  $\beta_0$ ) to be significant, with all the lagged coefficients insignificant; Uri and Boyd (1990) obtained this result using annual lumber price data. It is possible, however (and in fact the case for the

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<sup>89</sup>See Mills (1990) and Nelson (1973) for detailed discussions of the identification and specification of ARIMA models.

results presented below) that dynamics exist in the system, and that past residuals from one time series affect the current residuals of the other even though all systematic autocorrelation of errors has been removed from each series.

### Time Series Identification Process

The first task is to develop ARIMA filters that reduce the residuals of each series to white noise.

Three time series characteristics must be addressed for correct model specification; the autoregressive process involved, the moving average error process involved, and the appropriate degree of differencing (be it seasonal or not). An autoregressive process of order  $n$  takes the general form

$$x_t = \rho_1 x_{t-1} + \rho_2 x_{t-2} + \dots + \rho_n x_{t-n} + \varepsilon_t,$$

or in lag operator form

$$(1 - \rho_1 B - \rho_2 B^2 - \dots - \rho_n B^n) x_t = \varepsilon_t$$

where  $B^i x_t = x_{t-i}$ . Note that for the time-series to be stationary (i.e. it has a constant mean) the characteristic roots must all lie outside the unit circle.<sup>90</sup> For a second order autoregressive process, for example, the necessary conditions are

$$(\rho_1 + \rho_2) < 1; (\rho_1 - \rho_2) < 1; |\rho_2| < 1. \text{ With monthly data, then, an autoregressive}$$

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<sup>90</sup>For a discussion of the implications of this, see Mills (1990) or Nelson (1973).

pattern of order one implies that January 1991 is correlated to adjacent months (December 1990 and February 1991). It is also possible to have a seasonal relationship, such that the observation for January of 1990 is correlated to that for January 1991, rather than an adjacent month. This seasonal relationship takes on the form  $x_t = \rho_{12}x_{t-12} + \varepsilon_t$  or  $(1 - \rho_{12}B^{12})x_t = \varepsilon_t$ .<sup>91</sup> Given the nature of the time-series we are considering, and the fact we are using monthly data it is reasonable to expect seasonality to be present. That is, not only might we expect adjacent observations to be correlated (a non-seasonal relationship), but we might also expect observations of a particular month of the year to be correlated with the same month of succeeding years.

Now consider another form of serial correlation, the moving average error (MA), which takes the form

$$X_t = \varepsilon_t + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} \dots + \theta_m \varepsilon_{t-m}$$

or in lag operator form,

$$x_t = (1 - \theta_1 B - \theta_2 B^2 - \dots - \theta_m B^m) \varepsilon_t$$

where  $m$  is the largest order of the moving average specification. As with the AR process the characteristic roots must lie outside the unit circle, and the requirements for a second order MA process are similar to those for the AR(2) shown above. A

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<sup>91</sup>There are two types of seasonal ARIMA models - the multiplicative (restricted) and the non-multiplicative (unrestricted) models. The non-multiplicative model is used here. See Mills (1990) for a further discussion of these.



seasonal moving average of order 1 [SMA(1)], similar to the seasonal autoregressive process for monthly data is described by  $x_t = (1 - \theta_{12}B^{12})\epsilon_t$ .

When both AR and MA processes are present in a series (called an ARMA specification) the model takes the lag operator form

$$x_t(1 - \rho_1 B - \rho_2 B^2 - \dots - \rho_n B^n) = (1 - \theta_1 B - \theta_2 B^2 - \dots - \theta_m B^m)\epsilon_t$$

and the filter (the lag specification itself) can be expressed as

$$(1 - \theta_1 B - \theta_2 B^2 - \dots - \theta_m B^m)(1 - \rho_1 B - \rho_2 B^2 - \dots - \rho_n B^n)^{-1}$$

The correct specification of the above processes requires the time series in question to have a constant mean and a constant variance (i.e. the series has no trend).<sup>92</sup> If the original series does contain a trend, differencing of the data to some degree is generally called for. This is done by subtracting  $x_t$  from  $x_{t-1}$  for all observations (except the first). We are then left with what were (in the original series) the fluctuations about that trend. In this fashion, mean stationarity is enforced. If the variance of the fluctuations about the trend in the original series is changing over time, this implies that there will also be a trend present in the first-differenced series. If this were the case, second-differencing  $[(x_t - x_{t-1}) - (x_{t-1} - x_{t-2})]$  would be required. For

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<sup>92</sup>We will limit our discussion to these two moments, given that our data only requires first differencing.

expediency in reporting results, non-seasonal differencing to the  $i^{th}$  degree will be denoted  $\nabla^i$ .<sup>93</sup>

Once the data have been non-seasonally differenced to the appropriate degree, there may be a need for seasonal differencing. Although the characteristics of seasonal non-stationarity are less easily envisioned in the time series itself, an indication of the need for seasonal differencing of monthly data is the presence of correlation coefficients for the 12<sup>th</sup>, 24<sup>th</sup>, 36<sup>th</sup>, etc. lags that are diminishing in size and significance very slowly. Seasonal differencing (for monthly) data will be denoted  $\nabla_{12}^i$

Once the necessary differencing is complete for a data set, analysis of the AR and MA processes present in the differenced data can be undertaken as discussed above.

### **Time Series Identification and Estimation Results**

The specifications and estimation results for each time-series of interest are listed in the following table. All ARIMA specifications were modelled using 141 observations dating from January 1982 to September 1993.

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<sup>93</sup>Note that  $\nabla^1 = \nabla$  for first differencing.

Table 11. ARIMA Identification Specification Results	
Series	Estimated filter in lag operator form, t-statistics below coefficient
$\nabla\nabla_{12}$ Northwest Public Timber Sales	$(1 + .0987B - .0420B^2 - .9236B^3)(1 - .8207B^{12})(1 - .7358B)^{-1}$ (-2.778) (1.217) (38.96) (20.75) (11.07)
Northwest Lumber price	$(1 + .3500B)(1 - .8748B)^{-1}(1 - .2422B^{12} - .3305B^{24})^{-1}$ (-3.429) (19.43) (2.147) (3.096)
$\nabla\nabla_{12}$ Northwest Lumber Production	$(1 - .3158B - .2490B^2)(1 - .9204B^{12})$ (3.633) (2.865) (33.62)
$\nabla\nabla_{12}$ Northwest Lumber Employment	$(1 - .9080B^{12})(1 - .2869B)^{-1}$ (33.97) (3.352)
$\nabla$ Northwest Labor Wage	$(1 + .0793B^{12})(1 + .1830B)^{-1}$ (-2.179) (-2.657)
Southeast Lumber Price	$(1 + .43706B)(1 - .81100B)^{-1}$ (-4.657) (15.05)
$\nabla$ Southeast Lumber Production	$(1 + .5660B^{12} + .5675B^{24})(1 + .57706B + .27931B^2)^{-1}$ (-1.058) (-8.381) (-6.971) (-3.378)
$\nabla\nabla_{12}$ Southeast Lumber Employment	$(1 - .5866B - .9159B^{12})(1 - .8488B)^{-1}$ (9.535) (4.312) (32.00)
$\nabla$ Southeast Labor Wage	$(1 - .2557B^{12} + .1856B^{24})$ (2.977) (-2.147)
Rocky Mountain Lumber Price	$(1 + .4233B)(1 + .1925B^{12})(1 - .7243B)^{-1}$ (-4.427) (-2.042) (10.50)
$\nabla$ Rocky Mountain Lumber Production	$(1 - .305B - .171B^2)(1 - .886B^{12})(1 - .733B^{12} - .2654B^{24})^{-1}$ (3.593) (2.017) (24.66) (8.763) (3.119)
$\nabla\nabla_{12}$ Rocky Mountain Lumber Employment	$(1 - .85533B^{12})$ (26.70)
$\nabla_{12}$ Rocky Mountain Labor Wages	$(1 - .5196B^{12} - .3556B^{24})(1 - .5690B)^{-1}$ (6.811) (4.681) (7.771)
$\nabla$ = first difference indicator $(X_t - X_{t-1})$ $\nabla_{12}$ = Seasonal first difference indicator $(X_t - X_{t-12})$ $\nabla\nabla_{12}$ = both of the above $[(X_t - X_{t-1}) - (X_{t-12} - X_{t-13})]$ Lag operator $B^i = X_{t-i} / X_t$ or $B^i X_t = X_{t-i}$	

### **Instantaneous Correlations Among Time Series**

To understand the nature of the relationships among the data sets of interest, we must now compare the filtered residuals from each data set. Recall again that the above ARIMA specification process is necessary to rid the data of any systematic correlation of errors within a series. This will allow us to view any relationships between different series as being free of the effects of correlations from other time periods within either of these series. Recall again that this would not be the case if we were considering simple correlation coefficients.

We will first focus on the correlation between the filtered Northwest public timber series and the lumber market of the Northwest itself. Filtered residuals of lumber prices, lumber production, employment and wages are regressed on contemporaneous observations and 12 lags of the public timber sales variable. Initial OLS regressions including all 141 residuals resulted in insignificant results for many of the comparisons. Because public timber supply shocks occur only in the latter part of each time series, it was hypothesized that the first half of the series was dampening the results. OLS coefficients therefore were estimated using the last 100 observations (of the white noise residuals filtered with ARIMA specifications based on 141 observations). In general, the results (table 12) suggest that the relationships among the variables of interest take more than one period to fully adjust. Therefore the sum of estimates for the lagged coefficients (along with the t-statistics for the sums of

coefficients) are reported, rather than each coefficient.<sup>94</sup> Given that we are looking for evidence of exogenous shocks (public timber sales fluctuations resulting from Spotted Owl litigation), we will report and discuss only the regressions with public timber sales as the independent variable.

If fluctuations in public timber sales are going to be correlated with any market indicators, one might expect the relationship to be the strongest in the region in which the public sales are occurring. Let us therefore first examine the relationships between Northwest public timber sales and the market variables of interest for the Northwest itself.

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<sup>94</sup>The sum of the coefficients reported is  $\sum_{i=0}^{12} \alpha_i$ , and the variance of the sum of lags is

$$V\left(\sum_{i=0}^{12} \hat{\alpha}_i\right) = \sum_{i=0}^{12} V(\hat{\alpha}_i) + 2 \sum_{i < j} \text{COV}(\hat{\alpha}_i, \hat{\alpha}_j).$$

The standard error of the sum of coefficients is the square root of this value, and the t-statistic is the sum of coefficients divided by the standard error.

Table 12. Time-series residuals Correlations: Public Timber Sales - Northwest Lumber Market Independent Variable - Northwest Public Timber Sales, lags 0 through 12.		
Dependent Variable: Filtered Residuals for	Sum of Lag Coefficients	t - statistic
Northwest Lumber Price	.2885E-3	1.1017
Northwest Lumber Production	.2147E-2	1.8442
Northwest Lumber Employment	-.4741E-4	-1.9716
Northwest Labor Wage	.2170E-5	1.5790

There is little evidence to suggest that fluctuations in Northwest public timber sales influences the prices for Northwest Douglas Fir lumber. This is the conclusion arrived at by Buongiorno, Bark, and Brannman (1985) as well, applying the same techniques on quarterly data from 1960 to 1982. The relationship between public timber harvests and production and employment are much stronger. This result may reflect both the physical relationship between timber and lumber and the complementarity of labor and stumpage in the production process. It may also be indicative of long-run timber supply expectations as well. The sign differences are puzzling, however. One would expect the residuals between timber harvests and employment to be positively correlated, rather than negatively correlated.

Given that fluctuations in Northwest public timber sales affect the lumber markets of that region, the next question is whether they affect markets in other regions. We will begin by testing for interregional price correlations as done by Uri and Boyd (1990). Again, because the price relationships do not equilibrate within one period, the sum of the coefficients and its corresponding t-statistic are reported. It

should be noted that in all cases the contemporaneous prices had by far the largest coefficients and were most significant, with t-statistics ranging from 17.78 to 10.95.

Table 13. Cross-Region Correlations of Lumber Price Residuals.		
Dependent Var ← Independent Variable	Sum of lag Coefficients	t - statistic
Southeast ← Northwest	1.1394	5.9328
Rocky Mountains ← Northwest	.81010	3.1110
Northwest ← Southeast	.58053	3.3759
Rocky Mountains ← Southeast	.57090	2.4507
Northwest ← Rocky Mountains	.79566	3.1342
Southeast ← Rocky Mountains	1.2022	4.3902

The coefficients in table 13 can be interpreted as the change in price residual of one region (dependent variable) with respect to a change in the price residual of another region (independent variable). Clearly, there are strong regional price correlations. This supports Uri and Boyd (1990) conclusion of regional market interdependence. It is also interesting to note that the western regions tend to affect Southeast prices more than Southeast prices affect western prices.

Given that there is evidence to suggest interregional market relationships, we can now examine the effects of Northwest public timber supply on the Rocky Mountain and Southeast regions.

Table 14. Instantaneous Correlations: Public Timber Sales - Southeast and Rocky Mountain Lumber Markets Independent Variable - Northwest Public Timber Sales, lags 0 through 12.		
Dependent Variable	Sum of Lag Coefficients	t - statistic
Southeast Lumber Price	.3574E-3	1.1927
Southeast Lumber Production	.5414E-3	.4989
Southeast Lumber Employment	-.1914E-4	-1.314
Southeast labor Wage	.4387E-6	.8255
Rocky Mountain Lumber Price	.2653E-3	1.0519
Rocky Mountain Lumber Production	.9423E-3	.96951
Rocky Mountain Lumber Employment	-.5554E-5	-1.3763
Rocky Mountain labor Wage	.1682E-5	.51929

The relationships between Northwest public timber fluctuations and market indicators of other regions are quite similar to those for the Northwest. The signs follow the same pattern. The primary difference is that the coefficient on Northwest lumber production is significant at the ten percent level (table 12), but other-region production is not (table 14). This is not surprising given that the Northwest lumber industry draws timber inputs primarily from within the Northwest region, whereas it is hypothesized (*ex ante*) that the lumber markets of the other two regions are affected by Northwest public timber supply shocks through lumber price effects alone.

#### ARIMA Intervention Analysis Results

The procedure for intervention analysis in this section is identical to that applied to the structural equations. The reported coefficients correspond to the month



after the actual ruling for the same reasons outlined in the previous section, and the structure of the dummy variables is the same; they take the value zero through the ruling date, and take a value of one beginning the month after the ruling.

The nature of the underlying data sets in this section is different than those of the previous analysis, however. In correctly applying an ARIMA framework, we are assured that each observation in the filtered time series is not systematically correlated with any other observation, which in effect provides us with white noise residuals. In applying econometric techniques, we are relying on proper specification of a structural market model through the inclusion of explanatory variables. Even if the structural model successfully reduces the regression residuals to white noise, this series of residuals will undoubtedly be different from the series of residual resulting from time-series techniques.

Table 15a. ARIMA Intervention Results: Lumber Prices. t-statistics in parenthesis below coefficient estimate.								
Time-Series Name	May 88	Jan. 89	March 1989	Jan. 1991	May 1991	Dec. 1991	May 1992	July 1992
Northwest Price	8.998 (0.69)	4.919 (.035)	-.0593 (-0.00)	6.442 (0.45)	<b>31.039</b> <b>(2.12)</b>	5.915 (0.40)	5.405 (0.36)	8.553 (0.57)
Southeast Price	11.623 (0.96)	-3.58 (-0.24)	-2.27 (-0.16)	-2.85 (-0.20)	<b>34.81</b> <b>(2.34)</b>	13.474 (0.89)	10.757 (0.68)	20.14 (1.30)
Rocky Mountain Price	7.807 (0.63)	0.453 (0.03)	1.728 (0.13)	-7.213 (-0.51)	<b>42.83</b> <b>(3.01)</b>	12.32 (0.86)	-5.12 (-0.33)	-6.67 (-0.43)

Table 15b. ARIMA Intervention Results: Lumber Production. t-statistics in parenthesis below coefficient estimate.

Time-Series Name	May 88	Jan. 89	March 1989	Jan. 1991	May 1991	Dec. 1991	May 1992	July 1992
Northwest Lumber Production	6.67 (0.07)	82.08 (0.88)	136.76 (1.43)	136.33 (1.44)	-112.61 (-1.15)	57.62 (0.60)	62.32 (0.62)	36.22 (0.37)
Southeast Lumber Production	7.663 (0.12)	-53.68 (-0.88)	72.62 (1.14)	-50.90 (-0.81)	40.124 (0.61)	<b>-118.17</b> <b>(-1.81)</b>	-67.33 (-0.99)	59.39 (0.90)
Rocky Mountain Lumber Production	<b>-144.76</b> <b>(-2.81)</b>	-1.60 (-0.03)	63.57 (1.17)	11.15 (0.20)	48.53 (0.86)	16.95 (0.31)	44.84 (0.74)	-9.89 (-0.17)

Table 15c. ARIMA Intervention Results: Labor Employment. t-statistics in parenthesis below coefficient estimate.

Time-Series Name	May 1988	Jan. 1989	March 1989	Jan. 1991	May 1991	Dec. 1991	May 1992	July 1992
Northwest Employment	-1.52 (-0.88)	2.65 (1.54)	<b>4.43</b> <b>(2.52)</b>	2.300 (1.31)	0.185 (0.10)	-0.915 (-0.51)	-0.979 (-0.53)	-1.77 (-1.01)
Southeast Employment	1.677 (1.36)	0.64 (0.54)	0.94 (0.76)	<b>-3.05</b> <b>(-2.46)</b>	-0.237 (-0.19)	2.144 (1.71)	-0.45 (-0.35)	-0.37 (-0.30)
Rocky Mountain Employment	0.217 (0.72)	0.247 (0.82)	<b>0.567</b> <b>(1.84)</b>	-0.400 (-1.29)	0.37 (1.16)	0.36 (1.13)	0.068 (0.21)	0.166 (0.53)

Table 15d. ARIMA Intervention Results: Labor Wage. t-statistics in parenthesis below coefficient estimate.

Time-Series Name	May 88	Jan. 89	March 89	Jan. 91	May 91	Dec. 91	May 92	July 92
Northwest Wage	.004 (0.04)	.092 (0.95)	.116 (1.17)	-.038 (-0.39)	.1511 (1.53)	.1408 (1.46)	.0082 (0.08)	-0.104 (-1.09)
Southeast Wage	.0205 (.54)	-.0498 (-1.37)	-.0364 (-0.97)	-0.052 (-1.45)	0.009 0.24	-0.051 (-1.39)	<b>-0.064</b> <b>(-1.72)</b>	-0.017 (-0.48)
Rocky Mountain Wage	0.176 (1.11)	0.221 (1.12)	0.036 (0.19)	-0.032 (-0.18)	-0.059 (-0.30)	0.191 (0.98)	<b>-0.369</b> <b>(1.67)</b>	0.104 (0.51)

The same problems and *caveats* discussed for the structural intervention results hold. As with the intervention results from the structural model, the results in tables 15a to 15d suggest that individual litigation rulings are not significantly affecting

lumber markets of any region.<sup>95</sup> Again, multicollinearity among intervention dummy variables is likely affecting the statistical significance of each litigation decision. This is suggested by the fact that when only one of the eight intervention variables is included in each estimation procedure, the significance of that dummy variable generally increases, as shown in table 15e with the lumber price series.

Table 15e. ARIMA Intervention Results including one intervention variable per estimation run: Lumber Prices. t-statistics in parenthesis below coefficient estimate.								
Time-Series Name	May 88	Jan. 89	March 1989	Jan. 1991	May 1991	Dec. 1991	May 1992	July 1992
Northwest Price	9.08 (.65)	12.70 (.90)	18.72 (1.33)	5.20 (0.34)	<b>27.49</b> <b>(1.94)</b>	<b>25.94</b> <b>(1.80)</b>	10.74 (0.69)	14.47 (0.92)
Southeast Price	17.80 (1.50)	<b>24.82</b> <b>(2.12)</b>	<b>24.90</b> <b>(2.12)</b>	<b>36.33</b> <b>(3.13)</b>	<b>36.62</b> <b>(3.03)</b>	<b>49.58</b> <b>(4.22)</b>	<b>13.10</b> <b>(3.96)</b>	17.63 (1.09)
Rocky Mountain Price	13.44 (1.24)	13.86 (1.25)	<b>20.51</b> <b>(1.89)</b>	<b>23.52</b> <b>(2.13)</b>	17.79 (1.47)	<b>27.41</b> <b>(2.29)</b>	21.40 (1.62)	<b>25.23</b> <b>(1.93)</b>

The fact that all 24 coefficients are positive is probably an indication that, although we cannot statistically reject that each complete filtered price series is stationary (as a result of our ARIMA filtering process), there still may be an upward trend in each of them near the end of the series (where these litigation rulings are taking place) that the filter is not fully capturing. This may lead to positive coefficients as seen in table 15e.

The differences between the results in table 15a and those in 15e indicate that, although multicollinearity probably is making it difficult to isolate the effects of

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<sup>95</sup>For three rulings, the coefficients on the intervention variables for all three lumber price series are the same. Following the test presented previously, three same-sign observations is not significantly different than two (the expected number of same-sign observations) at the 10 percent level, with a t-statistic of 1.64 and seven degrees of freedom.

individual litigation decisions, the cumulative effects of this series of litigation may be substantial.<sup>96</sup>

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<sup>96</sup>Again, note that all coefficients in each column of table 15a are of the same sign, supporting previous results suggesting that these regional price series are correlated.

## 5. CONCLUSIONS

The primary objective of this thesis is to examine whether it is reasonable to believe that public timber fluctuations in the Pacific Northwest resulting from Spotted Owl litigation and legislation can affect the United States lumber industry as a whole. The two empirical frameworks applied to this question lead to results quite different from each other, and suggest different implications.

For Northwest public timber sales levels to affect the national lumber markets, it is presumed that they must influence the lumber market for that region in particular. Both the structural and the time-series models suggest that changes in the levels of Pacific Northwest public timber sales do influence the lumber market of that region (tables 1-3 and 12). This result is supported by a number of existing econometric studies. The apparent insignificance of public timber on lumber prices shown by the time-series results is also supported by the time-series analysis by Buongiorno, Bark, and Branmann (1985). The intervention analyses based on both the econometric and the time-series models indicate that, although the effects of individual litigation decisions are difficult to isolate, the cumulative effects (particularly on prices) may be substantial.

Regardless of public timber's influence on the lumber market of the Northwest itself, geographically distinct markets must be in competition with each other for Northwest public timber to have effects on these other markets. Regarding this question, the structural and time-series results are contradictory. The structural model shows no evidence that regional U.S. markets are related through price effects (tables 2, 4, and 7). At least four previous econometric studies report similar results. The time-series analysis, on the other hand, shows that regional market prices are highly correlated, a relationship hypothesized to be an indicator of competition among markets (table 13). A study using the same framework as that used here reports similar results (Uri and Boyd, 1990). Additionally, Northwest and Rocky Mountain lumber prices appear to have a stronger influence on prices of the Southeast than vice-versa.

Lastly, econometric and time-series attempts at directly measuring the relationship between Northwest public timber fluctuations and other-region markets provide no convincing evidence of Northwest public timber influence (tables 4-9, and 14).

Several points should be noted regarding the estimation procedures used here. First, many of the estimated coefficients estimated in the structural model do not match *a priori* expectations. If we are to assume that classical production theory provides a framework that approximates the activity of the United States lumber market, the market specifications applied here are questionable, though in many ways

they provide results similar to previous work. Further work is therefore indicated for this area of study.

Overall, the time-series estimation process provides the fewest peculiar results. This impression probably stems from the fact that it is purely a statistical technique. An econometric model requires the inclusion of various data in the attempt to reduce the regression residuals to white noise; a time series model does not. The relative ease with which white-noise residuals can be obtained for a data series (given contemporary computer software) makes time-series techniques useful tools, especially for problems difficult to model econometrically, such as those considered here.

Intervention analysis may be rightly applicable in other settings, but the results of the intervention analysis as applied here to lumber and labor markets are not robust. This problem most likely arises from the fact that there are dynamics involved in these markets when using monthly data. As a result, there are difficulties in temporally isolating the effects of a particular litigation ruling. Furthermore, as the specification difficulties indicate, there are numerous factors, some difficult to model, that potentially could have large effects on lumber markets. Even if many of the intervention coefficients had been significant, there is a reasonable possibility that the significance might have been a result of other market factors not properly specified in the model. Given the difficulties associated with intervention analysis using monthly prices, further intervention analysis with respect to Spotted Owl litigation might be more successfully applied to lumber futures prices.

In summary, the results of this study indicate that Northwest public timber availability is influential in the lumber market of the Northwest. Further, there is some evidence to suggest that regional lumber markets are interdependent, but no direct evidence was found that suggests Northwest public timber fluctuations affect lumber markets of other regions. This thesis provides only indirect evidence that the Northwest public timber fluctuations could have an impact on the lumber markets of the Northern Rocky Mountains or the Southeast.



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## LITERATURE CITED

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APPENDICES

#### A. DATA DESCRIPTIONS AND SOURCES

**National Forest timber stumpage prices** used for this study are reported in quarterly form in *Production, Prices, Employment, and Trade in Northwest Forest Industries*, [Third Quarter, 1981 to third Quarter, 1993]. Resource Bull. PNW-RB-188. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. Various pagination.

The data is interpolated linearly between quarterly observations to arrive at monthly observations using the equations  $X_{t+i} = (X_{t+3} - X_t)/3 + X_t$  for  $i = 1, 2$ .

**Northwest Public Timber Sales** are from *Production, Prices, Employment, and Trade in Northwest Forest Industries* as well, and interpolated in a similar fashion. This series is the sum of National Forest and BLM sales. State and other public sources are not included.

**Labor wages for the wood products industry** SIC 324002, monthly, by state were received directly via e-mail from the Bureau of Labor Statistics. Regional wages are the sum of each states wage weighted by the percent of total regional employment that state represents;

$$\sum_{i=1}^k (\text{Wage}^i) (\text{Employment}^i / \text{Total Regional employment})$$

for states  $i$  through  $k$  in each region. For consistency labor wages in every case were deflated by the consumer price index listed in this appendix, though it could be argued that all wage series but that in the labor supply equation should be deflated by a producer price index.

**Electricity prices** are from the Department of Energy, series DOE/EIA-0214(91), and were received as annual data from 1980 to 1991 and interpolated in a fashion similar to that discussed above with respect to stumpage prices. The years 1992 and 1993 are not readily available; therefore a simple average of the previous two years was used for these two years, since there is no strong trend in those two years.

**The price of lumber** for each region is the 2x4 #2 dimension (kiln dried) price series for the dominant species of each region. For the Pacific Northwest, Douglas Fir is used (p. 34, Random Lengths, 1992), for the Southeast, Southern Pine (p. 91, 1992), and for the Northern Rockies, Western Spruce-Pine-Fir (p. 61, 1992). Data for 1993 were taken from the same time series, Random Lengths Yearbook, 1993. Random Lengths Publications, Inc., Eugene, OR.

**Quantity of lumber supplied** is from the U.S. Department of Commerce, Bureau of Economic Analysis, Business Statistics (SUDOC # c 59.11/3: ). The data series are listed in terms of species (Douglas Fir, Western Pine, and Southern Pine), though the Douglas Fir and Western Pine series are based on total regional output. For a mill,  $\text{Production} - \Delta \text{Inventories} = \text{Shipments}$ ; and the BEA series representing inventories is calculated by the difference in production and shipments (adjusted to fit actual mill reports). Therefore, for the structural model the *Shipments* data series is used to represent the quantity of lumber supplied. For the time series analysis the lumber production series is used since we are not specifically trying to model a supply function. These data also can be found in computer readable format in the National Economic, Social, and Environmental Databank, beginning with Item I.D. # EA Bustat s13012.

**Housing starts** data (not seasonally adjusted) are available in monthly form from the U.S. Department of Commerce Bureau of Economic Analysis, Current Business Statistics, and is in computer readable format on the National Social and Environmental Data Bank ( Item ID number EA Bustat s03004).

**Disposable Personal Income** is available in quarterly form from the U.S. Department of Commerce, Bureau of Economic Analysis National Income and Product Accounts. These data also can be found in computer readable format in the National Economic, Social, and Environmental Databank, Item I.D. EA BUSTAT S01019. This series is deflated with the consumer price index listed in this appendix.

**Population** is from the USDOC Bureau of Economic Analysis, and is available in computer readable format in the National Economic, Social, and Environmental Databank, Item I.D. EA NIPA 802-016.

**91-day Government Bonds** are from the U.S. Department of Commerce, Bureau of Economic Analysis Business Cycle indicators in monthly form and is in computer readable format on the National Social and Environmental Data Bank ( Item ID number EA CYCIND U0M114).

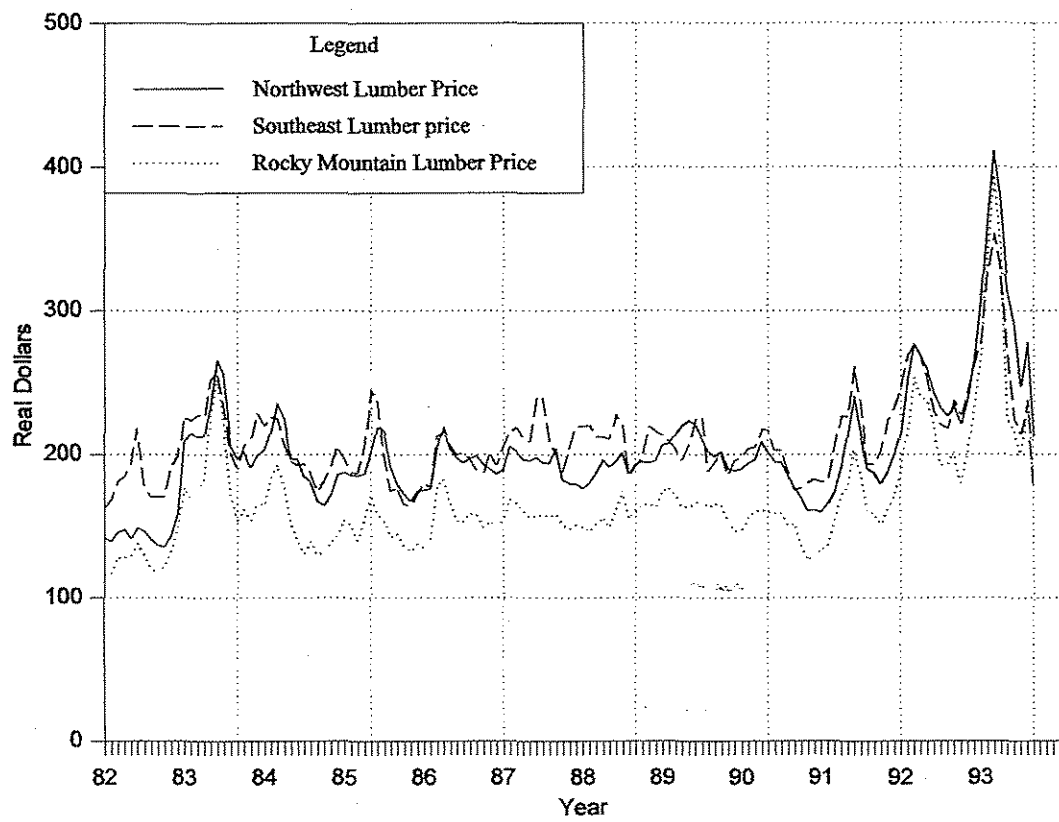
**Value of Net Capital Stock** for the Wood Products Industry is reported by the U.S. Department of Commerce, Bureau of Economic Analysis, and is available in computer readable format in the National Economic, Social, and Environmental Databank, Item I.D. EA WEALTH COGSFPC03014. "Net stock" is defined as gross stock minus depreciation. Depreciation estimates are based on the straight-line formula. Gross stock is defined as gross investment (value of capital purchases) minus retired capital. A complete description of these data can be found in USDOC Bureau of Economic Analysis (1993a). The series is deflated by the producer price index listed in this appendix.

**Producer Price index for Intermediate Goods**, (not seasonally adjusted) is used to deflate all price series except labor wages (for which a CPI is used). This producer price index is in monthly form from the U.S. Department of Commerce Bureau of Economic Analysis, Current Business Statistics, and is in computer readable format on the National Social and Environmental Data Bank ( Item ID number EA Bustat 502056).

**Consumer Price Index** (not seasonally adjusted) is in monthly form from the U.S. Department of Commerce Bureau of Economic Analysis, Current Business Statistics, and is in computer readable format on the National Social and Environmental Data Bank ( Item ID number EA Bustat s02016).

## B. GRAPHS OF SELECTED DATA SERIES

## Regional Lumber Prices (Deflated)

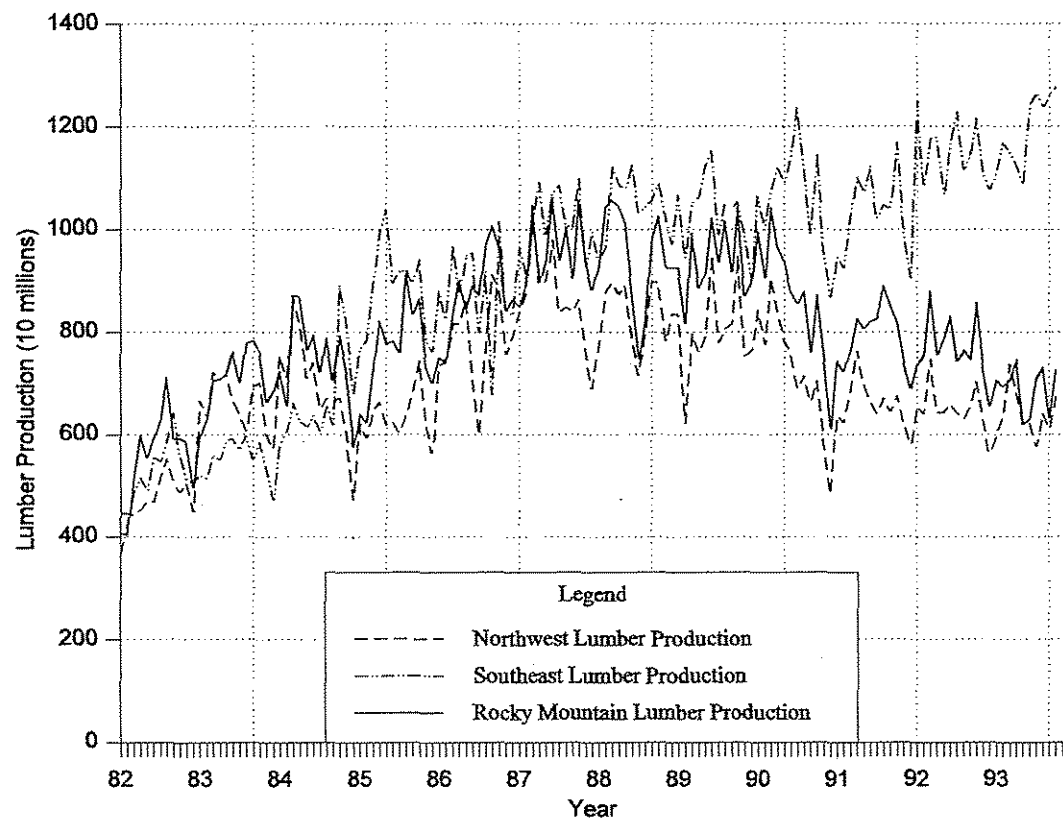




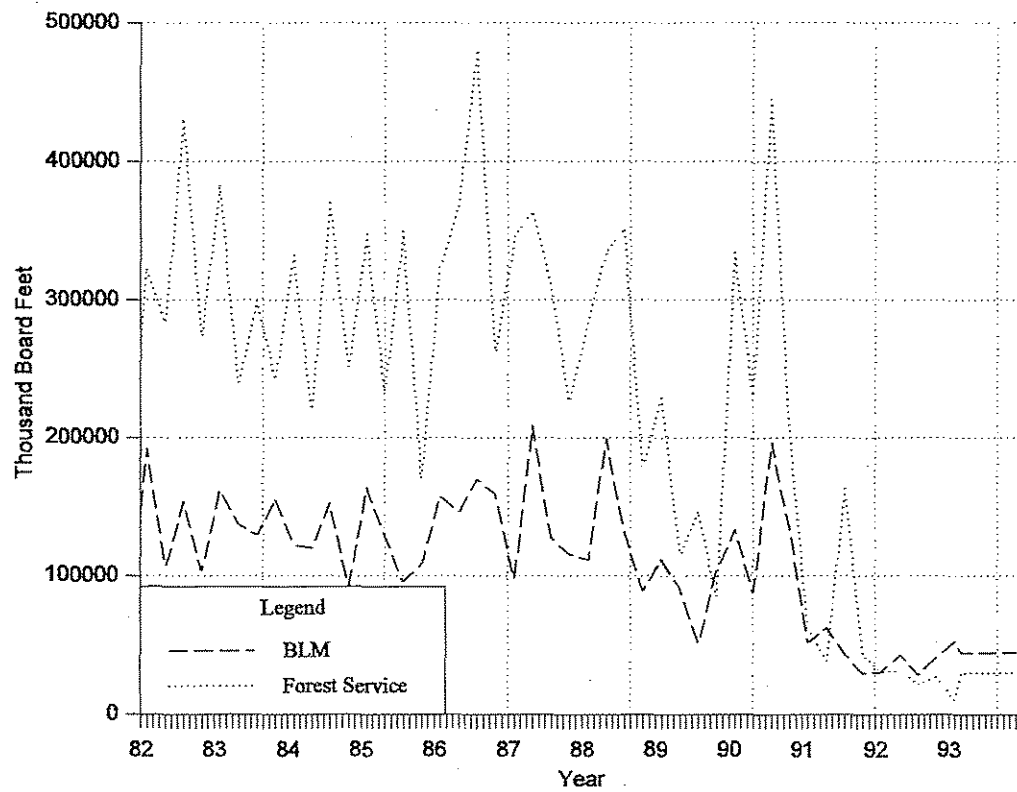
## New Housing Units Started



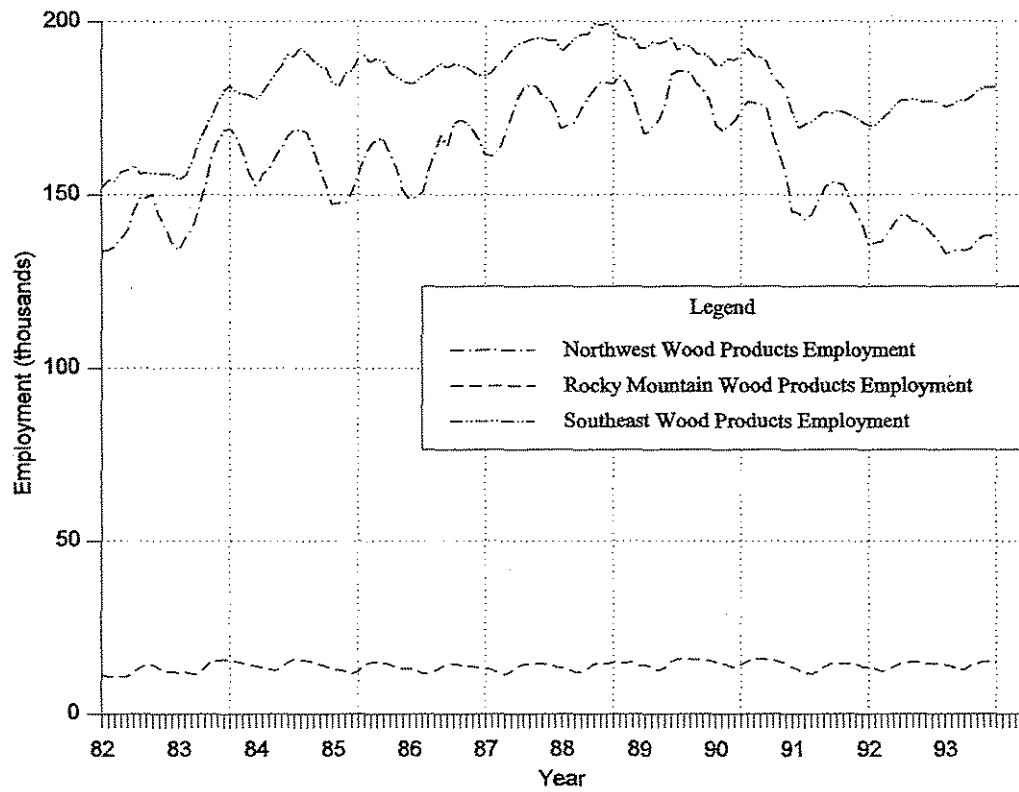
## Regional Lumber Production



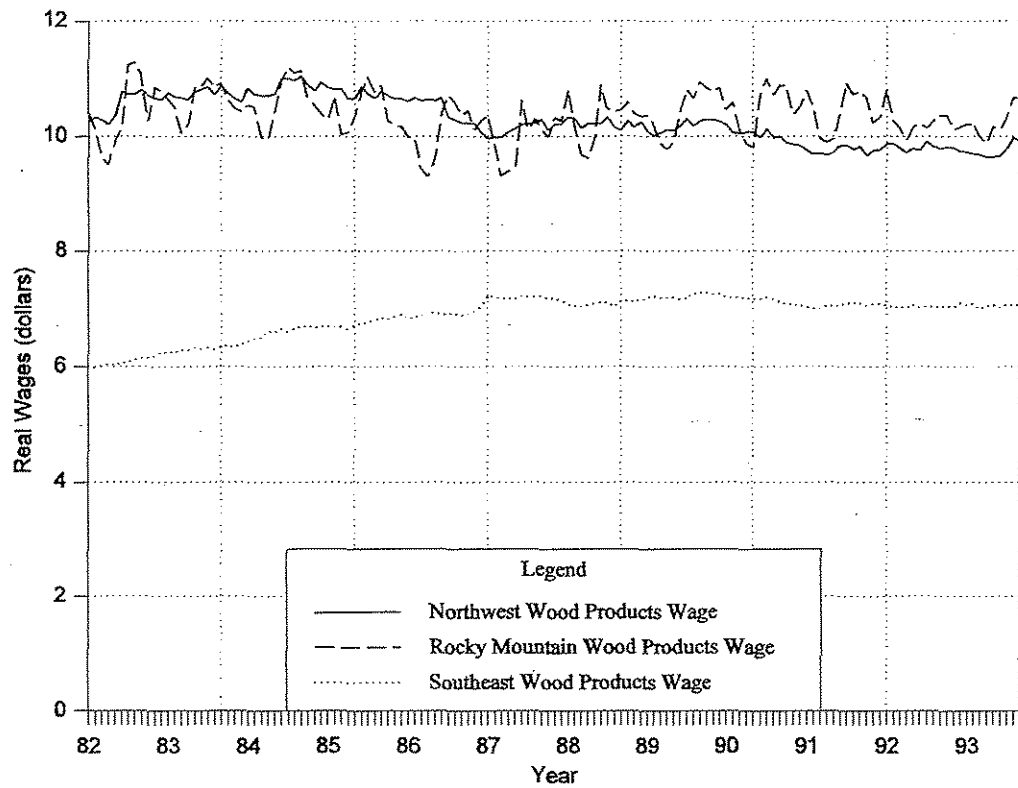
## National Forest and Bureau of Land Management Timber Sales for the Pacific Northwest



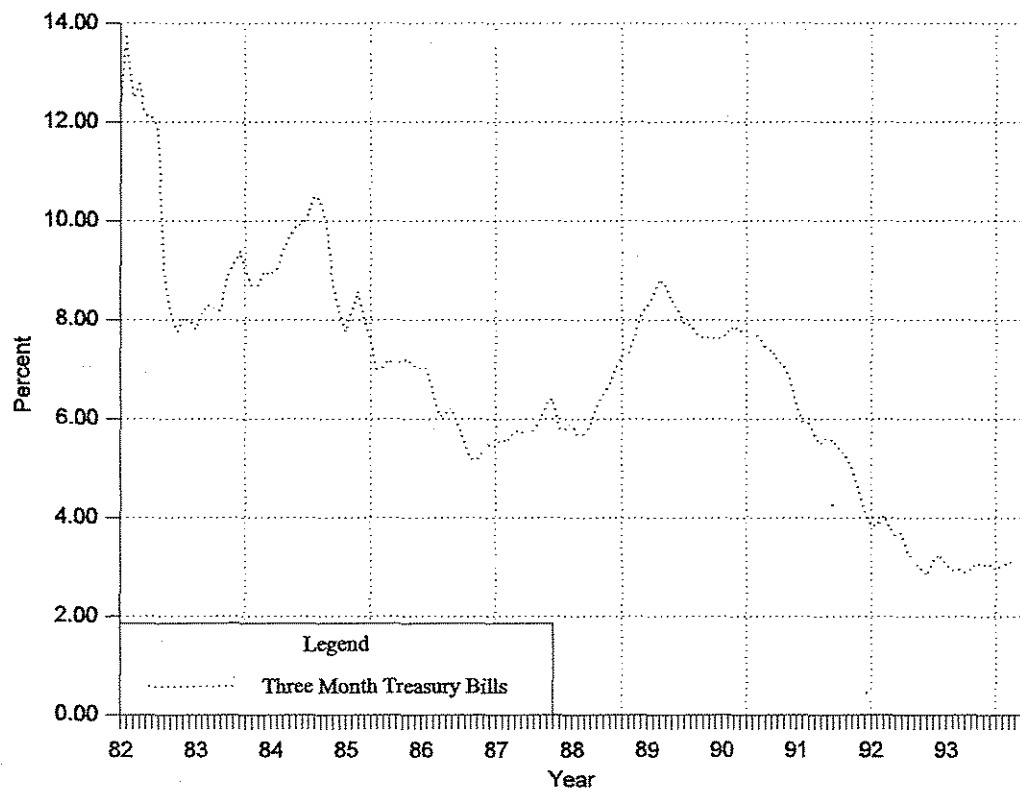
## Regional Wood Products Industry Employment



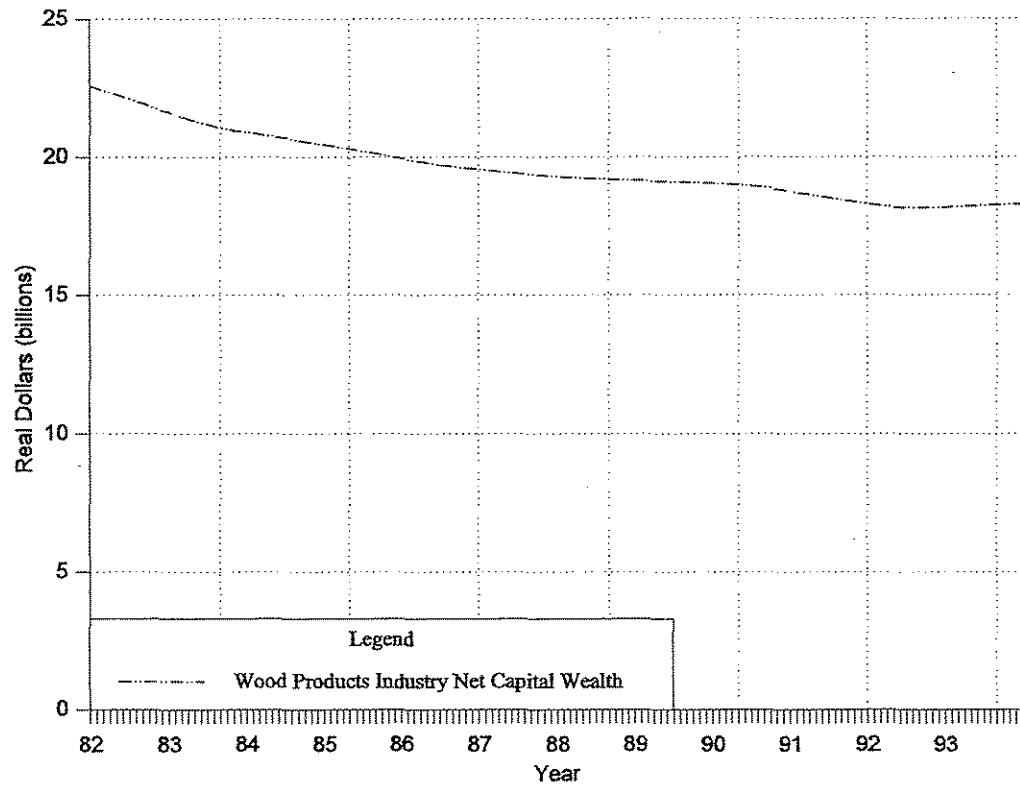
## Regional Wood Products Industry Average Hourly Earnings



## Interest Rate on 91-Day Treasury Bills



## Wood Products Industry Net Capital Wealth



## Per Capita Personal Disposable Income

