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National Forest Timber Supply and Stumpage Markets in the Western United States

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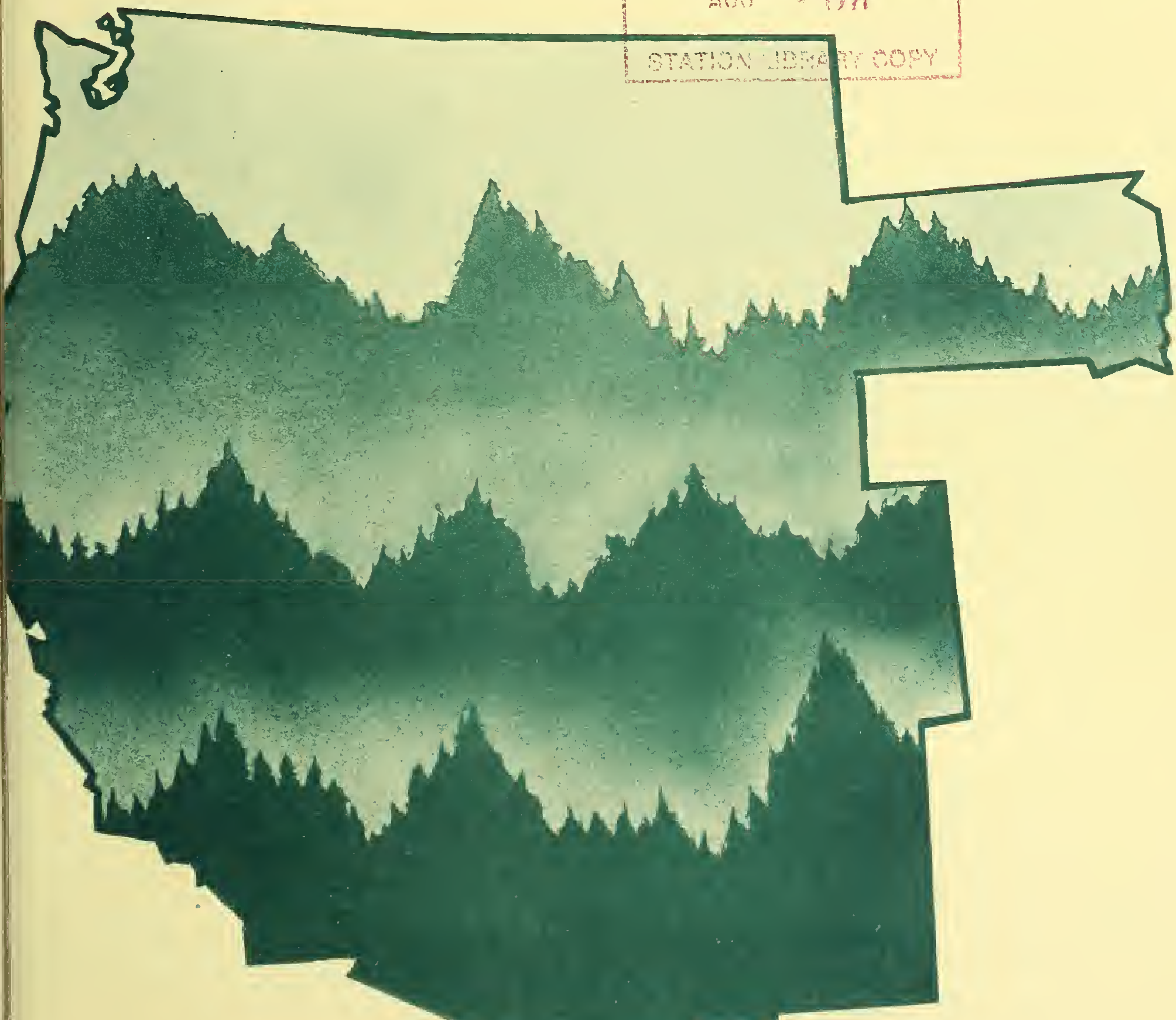

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Abstract

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This paper presents an aggregate regional model of the National Forest timber supply process and the interaction of National Forest and non-National Forest supply in determining regional stumpage prices and harvest volumes. Model simulations track actual behavior in the Douglas-fir regional stumpage market with reasonable accuracy; projections for the next two decades suggest that little real appreciation in stumpage prices will occur, that cut and bid prices will fluctuate around each other, and that the ratio of uncut volume to sold volume will gradually decline and stabilize at somewhat lower levels than were observed during the 1960s and 1970s.

Keywords: Market model, timber supply, National Forest timber sales, bidding, forecasting, econometrics.

Summary

This paper presents an aggregate regional model of the National Forest timber supply process and the interaction of National Forest and non-National Forest supply in determining regional stumpage prices and harvest volumes. Endogenous elements of National Forest supply include establishment of the appraised price, bid price, volumes sold and unsold, the uncut volume under contract, volumes harvested, and harvest price. Components of the model describe the distribution of volumes sold and harvested by bid-price and contract-duration classes. Estimation results for bid-price relations in several Western regions indicate that prices bid for stumpage depend on a short (1-year) distributed lag in product prices and production costs. Application of the full model in the Douglas-fir region suggests that short-term National Forest supply may be more elastic in harvest price than is industrial private supply. Model simulations track actual behavior in the Douglas-fir regional stumpage market with reasonable accuracy; projections for the next two decades suggest that little real appreciation in stumpage prices will occur, that cut and bid prices will fluctuate around each other, and that the ratio of uncut volume to sold volume will gradually decline and stabilize at somewhat lower levels than were observed during the 1960s and 1970s.

Contents

Introduction

In the Western United States, National Forests provide nearly 36 percent of total softwood timber harvest. Because of this significant supply, the auction process through which the rights to harvest National Forest timber are transferred to private firms has received extensive study in the economics and forestry literature. In the context of regional timber supply, however, the timber sale is only the first of several steps in the movement of National Forest timber from woods to mill. A comprehensive understanding of the functioning of regional timber markets and the role of National Forests in a region's timber supply requires some explanation of the disposition of the sold timber, the rates at which the timber is harvested, and the interaction between National Forest and other ownerships resulting from harvest decisions. These post-sale elements of National Forest supply have received only limited attention in past research.

This paper presents a theory and model of the National Forest timber supply process, from sale to harvest, and the integration of National Forest with non-National Forest elements in the aggregate timber supply of a region. The explanatory power of the model is tested by using historical data from the Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) region of western Oregon and Washington. After a review of past work, the several components of the National Forest supply process are examined and models developed. Results of an empirical test for the Douglas-fir region are presented together with a simulation of future market development. A final section summarizes the findings and offers some generalizations and suggestions for further research.

This study focused on the Western United States including the contiguous States west of the Rocky Mountains, but excluding Alaska and Hawaii. This area is subdivided into four regions: the Douglas-fir or Pacific Northwest-west side (PNWW), the ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) or Pacific Northwest-east side (PNWE), Pacific Southwest or California (PSW), and the Rocky Mountain (Rockies) (fig. 1). Among these regions, National Forest harvest shares are higher in the interior pine (PNWE and Rockies) and California regions (53 percent and 42 percent, respectively) and somewhat lower in the Douglas-fir region (25 percent), which reflects different concentrations of land ownership.

Previous Work

Virtually all existing research about the National Forest timber supply process focuses on bidding and uses individual sale data in empirical analyses. Though studies differ markedly in their theoretical foundations and statistical methodology, they generally explain bid prices on individual sales as functions of sale volume, spot (or current) product or stumpage prices, price expectations, physical sale characteristics, number of bidders, and contract provisions. Four studies (those developing explicit theories of bidder decisions and bidding strategies to derive testable hypotheses) merit detailed consideration.

Figure 1—Regional division of the Western United States: PNWW = the Douglas-fir subregion; PNWE = ponderosa pine subregion; PSW = California; and Rocky Mountains = the remaining Western States.

Johnson (1977) uses a theoretic approach to demonstrate conditions under which sealed and oral bidding can be expected to produce equivalent or disparate bids. As in most such approaches (see, for example, the survey of bidding studies by Englebrecht-Wiggins [1980] and a more recent summary by McAfee and McMillan [1987]), individual bids are presumed to differ with the bidder's estimate of the value of the object being sold, which may be a random variable. Determination of the equilibrium bid price resulting from the auction requires further specification of the bidding environment; that is the bidding strategies of participants, the existence of collusion or cooperation, and the relative availability of information on the object for sale to classes of bidders. Under various conditions, the expected high bid generally depends on the expected value of the object and the number of bidders.

Though Johnson's analysis generates expectations for bid-price behavior, it does not produce an explicit functional form to be estimated. This is derived by appeal to hedonic pricing analysis[1] and to standard notions of future pricing. His final formulation explains bid price as a function of product price and expected price growth (from consideration of the future pricing nature of the sale), physical sale characteristics and appraisal estimates of production costs (from hedonic price analysis), number of bidders, and dummy variables to represent sale and contract conditions (oral versus sealed bidding, price escalation clauses). In a related approach, Hansen (1984) developed a more specific theory to distinguish between behavior in oral and

[1] Hedonic price analysis attempts to value the variations in quality characteristics of a given commodity.

sealed-bid auctions. His final empirical formulation nonetheless relates bid price to potential number of bidders, actual bidders, and an array of price, cost, and sale characteristics similar to Johnson's.

Alden (1984) takes a different approach by deriving a bid-price relation from basic concepts of future commodity contract pricing and elements of the capital asset pricing model. Her basic theory argues that observed bid prices are comprised of three elements: current spot price of stumpage, plus the expected appreciation in spot price at the (expected) time of harvest, less a premium required by risk-averse buyers to hold a fixed-price contract with uncertain conditions at harvest time and imperfect options for hedging. This basic structure is modified to reflect specific sale and contract characteristics (for example, bid deposits, escalation, road costs) possibly influencing the latter two elements. Alden's empirical relations use past lumber prices as the basis for estimating future price appreciation and terms in the variance of lumber prices and the covariance of lumber prices and returns on investments in nonforest products as measures of risk.

The model developed by Rucker (1984) departs from the above studies by explicitly incorporating the full array of sale-termination options open to the buyer in his decision process at the time of bidding. Bidders, who want to maximize expected revenues, offer bid prices that reflect potential returns (or losses) from actual harvest of the sale at termination, default (with penalty), or extension (at some cost) of the contract. As in the Johnson (1977) and Hansen (1984) studies, the theoretical model merely suggests hypotheses. The empirical relations for testing are established by analogy with the theoretical results. Bid price is expressed as a function of product prices, expected price growth, sales characteristics, dummies representing contract provisions, and terms in the variance of stumpage and product prices to represent the stochastic elements of the theoretical model. Number of bidders is also added, though this was not a part of the theoretical development.

Bidding studies in the forestry literature have generally resulted from concern over competition for sales (Haynes 1980, Mead 1967, Mead and Hamilton 1968), the effects of different auction methods (Haynes 1980, Mead 1967), and the method and accuracy of National Forest timber appraisals (Berck and Bible 1985, Buongiorno and Young 1984, Huang and Buongiorno 1986, Jackson and McQuillan 1979). Exceptions are the bid-price relations reported by Cardellichio and Veltkamp (1981) used in the delivered-wood cost calculations of the FORSIM model and those by Frazier (1967) used in a profit-based model of the California pine lumber industry. These studies generally have not developed explicit optimizing theories of the bidding process or bidding strategies. Empirical relations have been constructed from considerations of hedonic pricing analysis and principles of forward commodity contracting or from assumptions that bidders use some form of residual-value appraisal.[2] Explanatory variables commonly used are similar to those cited for the Johnson (1977), Hansen (1984), and Rucker (1984) studies.

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[2] Residual value appraisal is a common appraisal system used for National Forest timber where the appraised price is the residual left after deducting all costs from the expected selling value of products made from that timber.

Considerable difference occurs across studies in the specific form of the dependent variable, in the inclusion of certain variables (appraised price and number of bidders appear in only about half of the studies reviewed), in the treatment of inflation (only two studies used deflated data, though all deal with multiple years), and in the form of the data set used (all have been censored by deleting observations in different ways). Productive comparisons of numerical results are practically impossible. Apart from the work by Cardellichio and Veltkamp (1981) and Berck and Bible (1985), bidding studies have not explicitly incorporated representations of expected future (timber or product) price appreciation that are such integral parts of the four theoretical studies reviewed above. This would seem to be important, even in studies designed to yield appraisal estimates of current harvest value, because historical bidding data presumably do include these effects.

Finally, a study by Adams (1974) illustrates an attempt to model elements of the National Forest supply process beyond bidding. Relations are developed to explain both the volume harvested from National Forests and the influence of public harvests on regional log prices (which in turn affect private harvesting decisions). The study fails to distinguish, however, between bid and cut prices (though these were virtually identical in the period analyzed), nor does it represent the uncut volume inventory in a way allowing for consideration of the effects of price escalation or contract extensions.

Elements of National Forest Supply

For this study, the National Forest supply process was subdivided into four key elements: determining volume offered and appraised price, bidding and sale, determining uncut volume under contract, and determining harvest volume and cut price. The volume offered depends on the allowable cut as given in the management plans of the various National Forests and on funding available to prepare and sell harvest units. It has been customary to accept volume offered as it is established by forces outside the market system. Both timber purchasers and nonindustry groups may influence the volume offered, however, via the USDA Forest Service's budgetary process. The appraisal process establishes the lower bound, or refusal price, below which a sale will not be sold. The bidding process establishes both the future harvest price (or base for escalation) and the volume of timber actually sold. Sold volume enters the inventory of uncut volume. While it resides in this inventory, its price or other characteristics may be modified by contract provisions or other actions. The uncut volume also forms the base from which actual harvest volumes are selected. It is at this stage that interaction between National Forest and non-National Forest supply occurs, as timber processors determine the mix of harvests across ownerships and their average stumpage cost.

An Overview of the Model

The following sections treat each of the elements in the supply process in detail, with first a look at past behavior and the operational mechanics and then a description of model development.

The model is based on annual data aggregated across all sales and does not distinguish among National Forests in a given region. Computations proceed on an annual cycle in roughly the following order:

1. The average bid price for all sales is determined as a function of expected future spot stumpage price. The latter price is estimated as a distributed lag in current and past product prices and nonwood production costs.

2. The volume that is not sold (as a fraction of the total volume offered) is determined as a function of bid and appraised prices and sale quality characteristics.

3. The distribution of sold volume by bid-price class and sale-duration (contract length) category is determined as a function of the average bid for all sales and agency decisions on the proportion of sales by contract-duration class.

4. The sold volume as distributed in (3) is combined with the residual uncut volume under contract from sales in previous periods. This composite uncut volume is then adjusted for any applicable price escalation and sale-duration extensions.

5. The effective supply function for National Forest timber is constructed by accumulation of the uncut volume under contract at successively higher bid price categories. The aggregation of this (price sensitive) National Forest supply and supplies from private and other public owners comprises total regional stumpage supply. Total regional supply interacts with total regional stumpage demand to determine the current regional spot price for stumpage and the volumes harvested from each ownership.

6. The distribution of National Forest harvest by price, sale-duration, and sale-date classes is partially determined by current spot-stumpage price. This distribution is removed from the uncut volume under contract, and the cycle is begun again at step (1).

The regional stumpage demand and private supply framework needed to make this National Forest model operational were taken from the TAMM model (Adams and Haynes 1980).

Volume Offered

In broad terms, the volumes of National Forest timber offered for sale during the last decade have been set as part of the long-term planning process mandated by the 1974 Forest and Rangeland Renewable Resources Planning Act (RPA [U.S. Laws, Statutes 1974]; as amended by the National Forest Management Act of 1976 [U.S. Laws, Statutes 1976]). Within the RPA structure, the Forest Service sets goals for managing National Forest resources and proposes programs (Agency activities) to achieve these goals (Shands 1986). As originally conceived, programs were translated into management actions through the budgetary process (Wolf 1982). In the 1980 RPA process, conflicting pressures from external industry and environmental interests and budgetary concerns within the Reagan Administration precluded the development of a single timber program proposal. As a consequence, the Forest Service transmitted to Congress a range of proposed harvest levels (a high bound and a low bound program). The lower bound level was roughly consistent with a constant timber management budget. The upper bound level, generally preferred by the Forest Service, called for an expansion of harvest and budget. The rationale for the upper bound was derived from the 1979 RPA Timber Assessment (USDA Forest Service 1982), which projected strong continued growth in both domestic and international markets during the 1980s and did not anticipate the sharp recession of 1980-82.

Proposed high and low bound sales volumes and actual funded sales levels since 1981 are summarized in table 1 for the National Forest System. Funded offerings have generally fallen within the proposed RPA bounds. Year-to-year variation derives from the counterpoising political pressures of the Agency's various client groups and the vicissitudes of the Congressional budgetary process. The sharp drop in offerings beginning in 1982 reflected the large buildup of high-cost uncut sales and Agency and Congressional uncertainty over the ultimate disposition of these volumes. Some 9.75 billion board feet of this timber was never cut and eventually was reconveyed to the Forest Service under provisions of the Federal Timber Contract Modification Act (U.S. Laws, Statutes 1984).

Table 1—Volumes of National Forest timber offered for sale: proposed high and low levels from 1980 RPA planning process and actual authorized sales levels

Fiscal year	Low bound	High bound	Actual sales level
	– – – Billion board feet – – –		
1981	11.0	11.9	12.2
1982	11.0	11.9	11.1
1983	11.0	12.1	11.3
1984	11.0	12.2	11.9
1985	11.0	12.5	11.5
1986	11.0	12.9	11.7

Source: USDA Forest Service annual reports.

Timber Appraisal

The Forest Service, by both law and administrative regulation, offers timber for sale for not less than its appraised value. In practice, the objective of the appraisal is to estimate fair market value, defined roughly as a price agreeable to both a willing buyer and seller. In the West, a residual value appraisal approach is used. This section summarizes the major elements of the appraisal system (for additional discussion of the appraisal system, see Beuter 1984, 1985).

For nearly 80 years, the Forest Service has been appraising National Forest timber in the West by using the residual value approach. The method is outlined in the Secretary's regulation (36 CFR 223.60):

> ...The basic procedure will be analytical appraisal under which stumpage value is a residual value determined by subtracting from the selling value of the products normally manufactured from the timber the sum of estimated operating costs, including costs to the purchaser for construction of roads or other developments needed by the purchaser for the removal of the timber and margins for profit and risk. Costs and product values under the residual value method shall be those of an operator of average efficiency and related to the operating difficulties and to size and quality of timber.

Though details differ substantially from sale to sale, the general appraisal procedure described above can be summarized in mathematical terms as follows.

The product selling value in its original units (for example, dollars per thousand board feet lumber tally or dollars per thousand square feet 3/8-inch basis for plywood) is converted to a log scale basis by means of a product overrun factor:

$$PSV_{LS} = PSV * POR \, , \qquad (1)$$

where

PSV_{LS} = product selling value in log scale,
PSV = is product selling value in original product units, and,
POR = the average product overrun factor, which is a ratio of product output units per unit of log scale processed.

An initial estimate of stumpage value is obtained by subtracting all costs from the product selling value on a log scale basis. This estimate is called the "indicated net stumpage" and is computed as:

$$INS = PSV_{LS} - MC - LC - RC - P\&R \, , \qquad (2)$$

where

MC = is an estimate of log pond-to-railcar manufacturing costs,
LC = is an estimate of stump-to-log pond logging and hauling costs,
RC = are the costs of specified or system roads that are to be built as part of the sale for which the agency will reimburse the contractor, and
P&R = an allowance of profit and risk.

The profit and risk allowance is computed as a percentage of, or markup on, total costs including the costs of stumpage:

$$P\&R = p(MC + LC + RC + INS) \ , \tag{3}$$

where

p = the percentage of profit and risk allowance.

By substituting (3) in (2), the indicated net stumpage can be written as:

$$INS = [1/(1+p)]PSV_{LS} - MC - LC - RC \ . \tag{4}$$

And by substituting (4) in (2), the allowance for profit and risk is shown to be simply a fraction of product selling value because it is taken as a mark-up on all costs, that is:

$$P\&R = [p/(1+p)]PSV_{LS} \ . \tag{5}$$

Finally, because the contractor will be reimbursed for the estimated costs of building the specified roads, RC, the appraised price is taken as the sum of the indicated net stumpage and road costs:

$$AP = INS + RC \ ; \tag{6}$$

or by substituting (4) in (6):

$$AP = [1/(1+p)]PSV_{LS}\ POR - MC - LC \ . \tag{7}$$

Equation (7) illustrates that under the standard Forest Service residual value appraisal system, stumpage values are estimated as if the specified roads were in place.

In the computation of PSVs, all products are generally included—lumber, plywood, chips, and bark. Where several major products, such as lumber and plywood, may be produced from logs on a given sale, the PSV represents a weighted average of the values of potential product yields. By-product values are added to the returns from major products. Product selling values are adjusted to the time of appraisal, usually 3 months.

Estimates of product yields (by grade) and the volume of product resulting from a given volume of logs processed—the overrun or POR—are derived from recovery studies of milling operations within a given administrative region or appraisal zone. Data may be drawn from independent agency studies or from historical records of operators. Like PSVs, POR estimates are updated periodically to reflect current operating conditions.

Estimates of MC in the appraisal are derived from the cost experience of actual mills operating in the region or appraisal zone and may differ by individual species. This approach allows a reflection of cost differences due to manufacturing method, log size, and seasoning practices. In some areas, costs are adjusted to the average diameter of timber in the sale parcel. Logging costs (LC) may be derived similarly for standard practices, such as specific types of tractor or cable yarding, or they may be derived by using engineering costing methods based on equipment, materials, and labor inputs. Logging costs are commonly adjusted for differences between conditions for the appraised timber and the average conditions characterizing the basic data for such factors as volume per acre, average size of timber, and steepness of terrain. Estimates of RC are commonly based on unit construction estimates derived from public works contracts with adjustments for differences in labor costs. All cost data, such as selling values, are updated as near to the period of appraisal as possible.

The margin for profit and risk (p) is intended to provide an allowance for a normal return to the operator, interest on borrowed capital, income taxes, and risk resulting from uncertain markets and sale quality characteristics and costs. In most Western U.S. regions, it has commonly ranged from 10 to 15. The Agency periodically adjusts (p) for changes in interest rates, taxes, profit levels, and levels of risk associated with certain types of sales.

Nearly all National Forest timber offerings in the West include two or more species of different value. Some offerings include more than five species. All the included timber must be removed and paid for under the terms of the timber sale contract. In recognition that each offering is an undivided package, it is appraised as a whole, though appraised prices are developed for each species. Under Agency policy, advertised appraised prices for each species must exceed so-called base rates, generally defined as some minimum rate plus an allowance for costs of regeneration. To meet this constraint, appraisal rates for highly-valued species appraised alone may be reduced as necessary to offset appraisals below the base rate for low-value timber. These adjustments take place after the computations illustrated in equations (1) through (7). Where such adjustments are necessary, sales are said to be offered with lower than normal allowances for profit and risk and on the presumption that augmentation of the prices of low-value timber come from the P&R margin. As a consequence of these adjustments, advertised rates for a given species in contemporaneous offerings of timber of the same size, quality, and operating conditions may differ because of the differences in value of other timber included in the sales.

The result of the appraisal process is a price for timber that reflects resource and market conditions near the time of offering. This advertised price may be increased to provide a minimum rate of cash receipts and to assure sufficient funds for reforestation. As noted above, the actual advertised rates where bidding begins are calculated as if permanent roads were in place. Road costs are estimated separately to determine the amount of purchaser credit the contract holder will receive as the road work is completed. Such credit is used in partial payment for the timber.

Outside of Alaska, most Forest Service timber sale contracts now being offered in the West include provisions for adjusting stumpage rates actually paid by the purchasers for changes in PSVs. This process is termed "stumpage rate adjustment" or "price escalation." Adjustments in stumpage prices mostly commonly are linked to changes in percentage in some index of lumber prices between the purchase date and the actual date of harvest. The rate and extent of adjustment differs with species (not all species are included) and between rising and falling markets. Adjustments upward are generally less than the percentage of rise in the selling value index; reductions are usually equal to the full percentage of decline in the index. The rates paid for most National Forest timber in the West differ to some extent from the rates bid at the time the sale is sold. National Forest timber in the West has been priced in this manner for over two decades. The only exception has been in the Pacific Northwest west side, where stumpage rate adjustment was dropped in the mid-1960s and reinstituted in the early 1980s.

Volumes Sold and Unsold

Historical behavior—Not all National Forest timber offered in any given period is actually sold. Conditions in product markets and the physical characteristics of particular sales (as these influence production costs) combine to make some sales seem unprofitable to potential purchasers. Identification of the volume of unsold offerings is difficult at the aggregate regional level owing to the nature of, and changes in, conventions of Forest Service record keeping.[3] What data are available suggest that the occurrence of unsold volume differs markedly across regions in the West. Over the past decade, the Rocky Mountain and PNWE regions have experienced the highest fractions of unsold volume at roughly 10 percent and 5 percent, respectively, of the annual volume offered. In the PNWW and PSW, the unsold portions have averaged about 3 percent and 2.5 percent, respectively.

Causes of regional variation in unsold volume have received limited attention from researchers. A review of historical studies of the bidding process suggests, however, that the hypothesis on frequency and level of unsold volume may be linked to the degree of competition for National Forest sales. Haynes (1980) for example, examines the extent of competition for National Forest sales in the West as measured by the size of overbid (the difference or ratio of bid and appraised prices), the traditional measure of competition for timber sales (see, for example, Mead and Hamilton 1968). Noncompetitive sales were defined as those with small differences between bid and appraised prices, or bid-appraisal ratios close to one. Haynes found a pattern of competitiveness across western regions that closely parallels the percentage of unsold volume as noted above; the Rockies and PNWE regions had the lowest fractions of sales occurring under apparently competitive conditions, and the PNWW and PSW regions had the highest fractions of competitive sales.

[3] Accurate estimates of unsold volume require examination of individual sales reports (Form 2400-17) retained at the Forest level. Before 1973, reports of unsold volume to the regional level were incomplete. In later years, regional accounting has been more comprehensive but Agency definitions of unsold have varied markedly over time. Of particular concern is the treatment of sales that are initially sold but later cancelled. The present data include these volumes.

The link between the degree of competition for National Forest timber and unsold volume may derive from the relation between the level of National Forest offerings and the processing capacity of local industries. In regions where timber volumes available from public sources are large relative to processing capacity, bid-appraisal differences may be low as firms have some latitude to purchase only the most desirable or potentially profitable sales. Offerings with large volumes of undesirable species, adverse logging conditions or low merchantable volumes per acre would not attract many bidders. These conditions are not static. As capacity expands relative to timber supply, or as the quality characteristics of available supplies decline, competitive pressure increases. Entry of low cost firms or adoption of new technology to process previously undesirable timber will reduce the unsold volume and expand bid-appraisal differences. An example of this evolution is seen in some areas of the Rockies, where the advent of efficient small-log processing capabilities has markedly increased the salability of lodgepole pine (*Pinus contorta* Dougl. ex Loud.) from the National Forests.

Within a given region, unsold volume can vary substantially over time. Figure 2 illustrates unsold volume (expressed as a percentage of the total volume offered) for the PNWW and PNWE regions. The general patterns in unsold volume roughly follow broad trends in forest products markets. In both regions, the unsold fraction gradually declined from 1973 through 1980, except in 1977. This was a period of considerable strength in forest products markets when bid and product prices rose sharply. After 1980, with both product and stumpage prices low and relatively stable, the unsold fraction gradually rose. The 1975 recession apparently was not accompanied by an increase in the unsold fraction in either region. Further, the unsold fraction during parts of the 1970s was as large as (or in some years larger than) levels observed during the early 1980s, while real bid prices in the former period averaged nearly twice those in the latter.

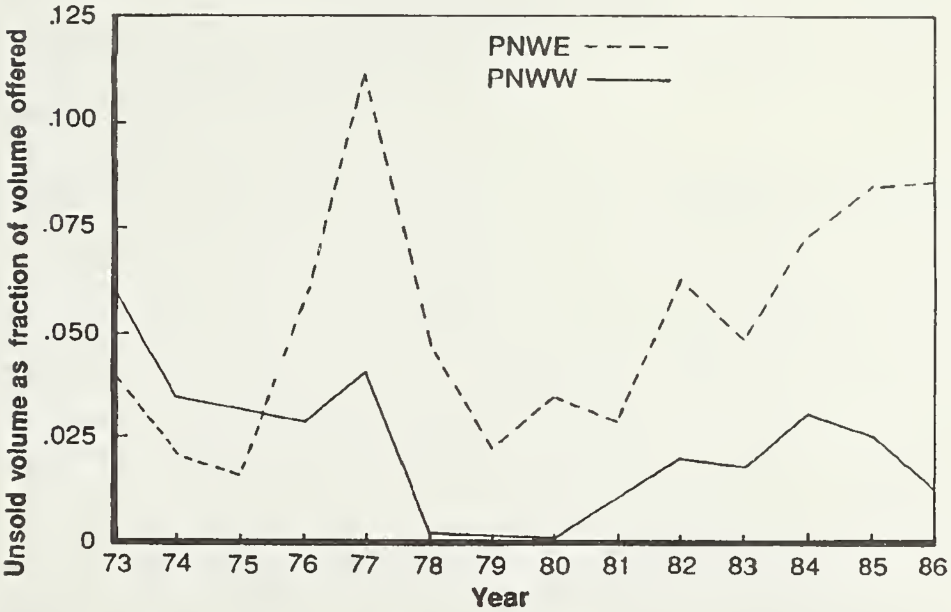

Figure 2—Unsold volume as a fraction of volume offered from National Forests in the PNWW and PNWE regions.

Unsold volume model—For a single timber sale, unsold volume is zero if a bid is submitted that is at least as large as the appraised price and equal to the volume offered otherwise. Thus at the individual sale level, a model of bid-price behavior (given knowledge of appraised prices) would also yield estimates of the volumes of timber sold and unsold. Huang and Buongiorno (1986) have incorporated this notion in a model of bidding for the Chequamegon National Forest in Wisconsin. In their approach, the market value of a sale is taken as a function of the physical characteristics of the parcel and the prices of products. The actual market value is observed, however, only when a sale is sold (a bid at least as large as the appraisal is tendered), in which case bid and market value are assumed to be equal. Otherwise, the sale is unsold, and the apparent market value is less than the appraisal. In light of the censored nature of the bid-price (market-value) data, Huang and Buongiorno (1986) use a Tobit model[4] to estimate the parameters of the market-value function. For a given sale, they demonstrate that the probability of that sale remaining unsold rises as the difference between the appraised value and the market value declines.

In the aggregate regional context of the present study, a direct application of this approach to explain the volume of timber unsold, though desirable, is not possible: the number of individual sales is simply too large. At the same time, a consistent method to aggregate Huang and Buongiorno's model both over time and across sales in a region could not be found. We therefore have constructed an aggregate model as an analogy to their basic behavioral result. Specifically, the fraction of volume unsold in a period is expressed as:

$$U_t = f(AP_t / BP_t , Z_t) , \qquad (8)$$

where

U_t = is the ratio of the volume unsold to the total volume offered in period t,

AP_t / BP_t = is the ratio of regional average appraised price to the average bid price in period t, and

Z_t = is a vector of sale quality characteristics.

We expect (by analogy with the Huang and Buongiorno model) that as the appraisal-bid ratio rises, the fraction of unsold volume will rise.[5] The set of sale quality characteristics, Z_t, includes sale size, method of sale (sealed versus oral bidding), and road construction costs. Consistent with past studies (see, for example, Haynes 1980), we expect that smaller sales and those with higher road costs will have reduced apparent sale values and increases in the fraction of volume unsold. The method of sale, though it has been found to have ambiguous impacts on average bid price, may in fact reduce the desirability of otherwise marginal sales. Recognizing that sales of

[4] A Tobit model is a type of linear probability model where the dependent variable is a dummy or binary variable and is expressed as a linear function of the independent variables.

[5] See also Adams (1974) for a roughly similar model of unsold volume in which the absolute level of unsold volume is related to the difference between bid and appraised prices, sale, and market characteristics.

lesser quality entail greater risks of low profitability and that a higher bid may be required to ensure success under sealed bidding, firms often may fail to submit bids on such sales under sealed bidding requirements. Thus, we expect that expansion of sealed bid sales, as took place in 1977, will lead to higher unsold volumes. Other characteristics, such as average log haul distance, species composition, a dummy for salvage sales, and so forth, have not been incorporated in this analysis. Although normally included in individual sale studies, these attributes show only limited variation over time at the aggregate level.

Results of the application of this model to the Pacific Northwest and its two subregions are given in table 2. In this analysis, the sale method dummy had a nonzero value only in 1977. Under provisions of the National Forest Management Act of 1976, the use of sealed bidding was markedly expanded beginning in 1977. Subsequent repeal of this provision of the Act returned the mix of sealed and oral bids in 1978 and subsequent years to roughly its position before the Act was passed. Sale size is also represented by a dummy having a value of one in 1981 and, in later years, a value corresponding to the major reduction in average sale duration and size that began in that year (see further discussion in the next section).

The regression results indicate that the unsold fraction is more sensitive to changes in the appraisal-bid ratio in the PNWW than in the PNWE, with elasticities[6] of 1.4 and 0.6, respectively. Although the average unsold fraction in the PNWW is smaller, it is more volatile in the face of equivalent changes in the appraisal-bid ratio than its counterpart in the PNWE (note the standard deviation-mean ratios in table 2). At the same time, the shift in sale size and the brief expansion in sealed bidding during 1977 significantly increased the unsold fraction in the PNWE but not in the PNWW. For sale size, Haynes (1980) found that sales with appraisal-bid ratios of 1.0 in the PNWE typically contain less than half the volume of sales with appraisal-bid ratios greater than 1.0. No such difference was found in similarly classified sales in the PNWW. The sealed bidding result also lends some support to our conjecture that more marginal sales may go unsold under sealed bidding, at least in the PNWE. Average road cost did not enter significantly in any of the regressions.

Bid Prices

Historical bid price behavior—Average real (deflated) National Forest bid prices for four Western regions are shown in figure 3. The results of previous theoretical and empirical studies of the bidding process led to the expectation that movements in current bid prices and the spot prices of products will be closely correlated. A close linkage also reflects the effects of arbitrage in the spot market for stumpage. If current bids did not rise commensurately with product prices, purchasers of current sales could harvest their timber immediately (regardless of contract length) and earn extra profits. In a falling market, bids must drop at least as fast as spot prices or purchasers would face continuous losses. Similarities in the time paths of real softwood lumber prices, also shown in figure 3, and the four bid-price series are consistent with these expectations. The regional bid series differ substantially in their absolute levels, in the amplitude of their changes as product price rises and falls, and with regard to the timing of peaks and troughs relative to the product price series.

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[6] A measure of the percentage of change in one varaible with respect to a percentage of change in another variable.

Table 2—Parameter estimates for National Forest unsold volume relations in the Pacific Northwest and subregions[a]

Variable	Region PNW	PNWW	PNWE
Constant	−0.00891 (.01053)	−0.00881 (.01565)	8M-0.00058 (.01700)
Appraisal/bid ratio	.07599 (.02094)	.07362 (.03610)	.05742 (.02636)
Sale size	.01322 (.00555)	NS[b]	.03225 (.00905)
Sealed bidding	.02552 (.01095)	NS	.07224 (.01748)
Adj R^2	.64	.48	.68
DW	2.03	1.87[c]	1.86
Mean unsold percentage	3.4	2.3	5.2
Ratio of standard deviation to mean of unsold/offered ratio	.49	.73	.54

[a] Data sample 1973 through 1986. Figures in parentheses below coefficients are estimated standard errors.
[b] Coefficient was not significantly different from 0 at the 0.2 level. Variable deleted from regression.
[c] Adjusted for first order autocorrelation.

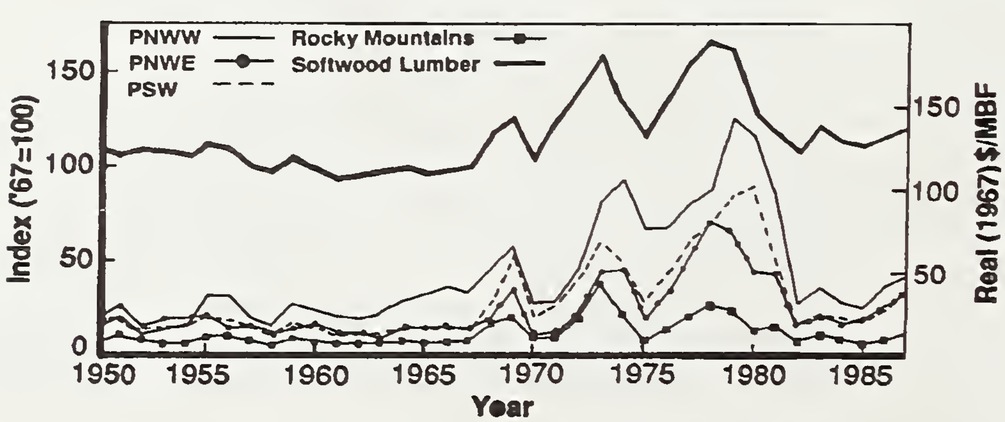

Figure 3—Real National Forest bid prices for four Western regions and real softwood lumber producer price index (deflated by the all-commodity producer price index 1967=1.0).

In a time series context, the four bid-price series are all strongly autocorrelated,[7] as indicated by the gradually decaying correlograms in figure 4. The order of this autocorrelation is limited, however. This is seen in the partial autocorrelations of the absolute series and in the insignificant positive partial autocorrelations of the first differenced series (negative autocorrelations appear significant in some cases but there is no ready interpretation of this result). In the spirit of the efficient markets theory (see, for example, Fama 1970, Mishkin 1978, Kanniainen and Kuuluvainen 1984), these results suggest that bid prices are fairly flexible in their response to changes in underlying determinants (such as product prices). Whatever forces cause bid prices to move, their effects are rapidly reflected in bids. Changes 2 or more years ago would likely have little influence on current bids.

Given that National Forest sale contracts average 3 years in length, it might be anticipated that adjustments in bid price would be gradual (and hence their order of autocorrelation would increase). Expectations of future market conditions at time of harvest, to the extent that the expectations are derived from information on past market activity, might involve lengthy distributed lags. Past studies of the bidding process provide some support, however, for a hypothesis of fairly rapid response. In most of the single-sale bidding studies previously reviewed, only current prices and costs were used in the empirical analyses. This could mean that these relations were misspecified or that the expectational processes are simple.

In studies where detailed attention was given to the structure of expectations, similar results were obtained. In all cases, expectational representations were developed by using lumber prices alone. Production costs, which would presumably influence future spot log and stumpage prices, were ignored. Rucker (1984) and Alden (1984) found that relatively simple time-series models using quarterly lumber prices are adequate to simulate expected price formation. Adams (1974) uses at most a two-quarter distributed lag in lumber prices to model Forest Service and Bureau of Land Management bid prices. Cardellichio and Veltkamp (1980) use a three-quarter lag in lumber prices.

The aggregate bid-price series shown in figure 3 represents in a simple way the considerable variation in prices among individual sales observed in each year. Much of this variation derives from the diversity of timber quality and operating characteristics across sales, which influence the value of the sale to buyers (for example, sale size, species mix, road costs, logging costs). Indeed, a substantial portion of the explanatory ability of past single-sale studies resulted from explicit representation of these characteristics in the regression analyses. Some portion of this variation in single-sale bids also arises from differences in buyers' expectations for market conditions at time of harvest. Bids for sales with longer contract lengths differ from bids for those having shorter contract lengths. And during a given year, bids for identical sales sold at the start of the year differ from those sold at the end of the year as expectations change.

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[7] The error term is correlated with its own past values indicating some systematic influence has been omitted from the equation.

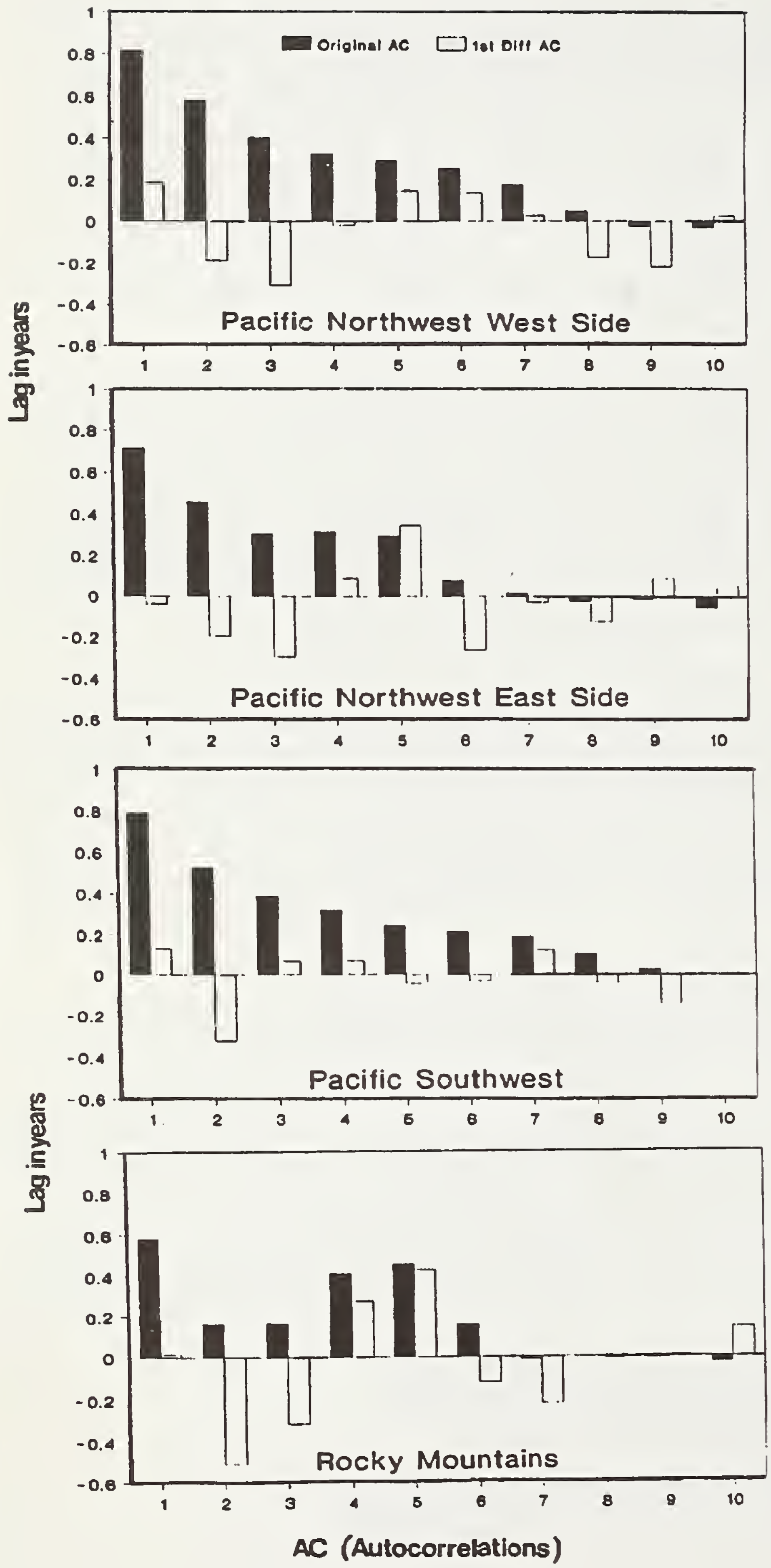

Figure 4—Correlograms and partial correlograms for original and first differenced real bid prices for four Western regions.

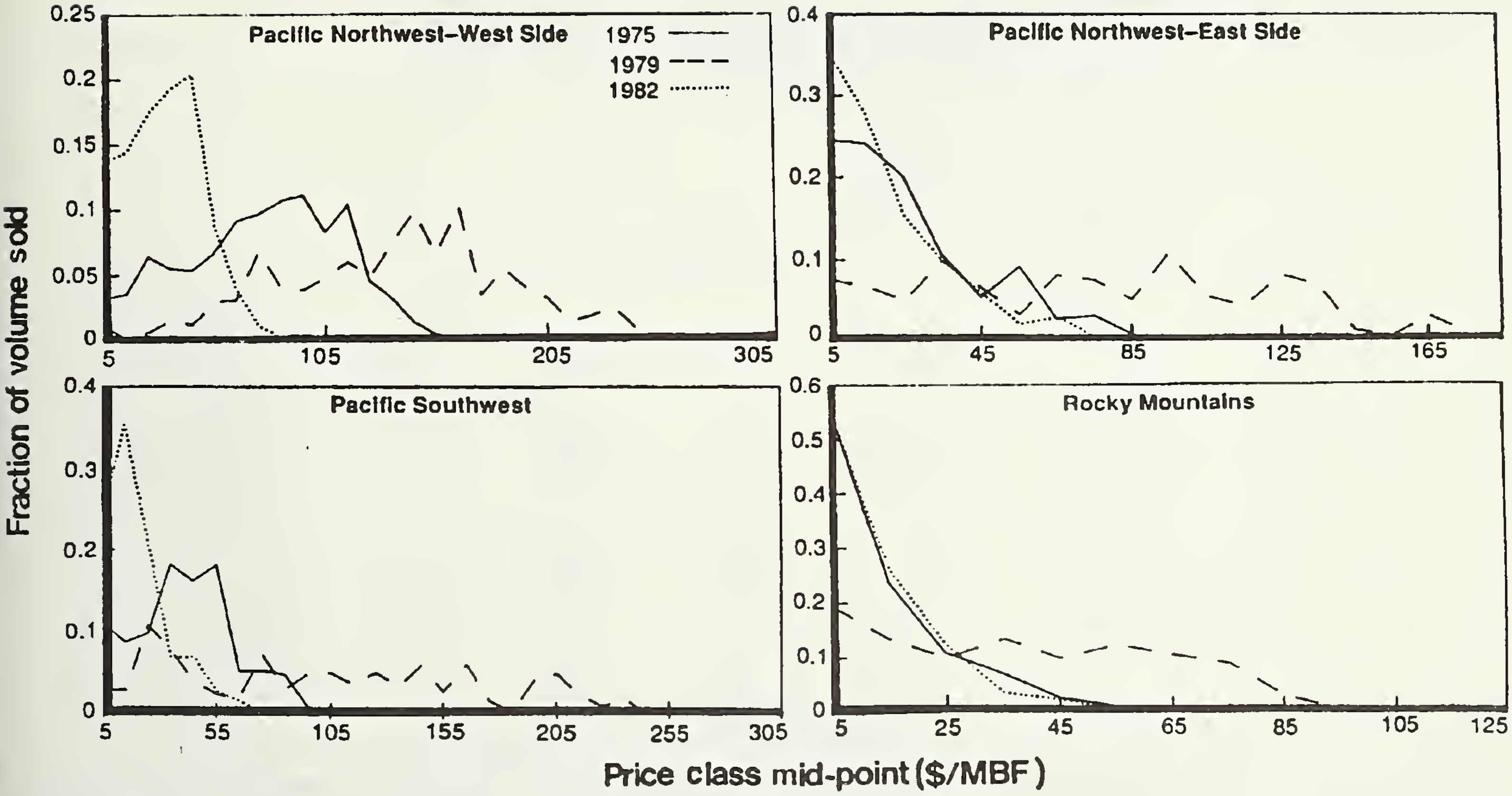

Figure 5—Distribution of real bid prices by bid-price class ($20 classes), f(b), for National Forest sales in four Western regions: 1975, 1979, and 1982.

Figure 5 illustrates the distribution of real bids by bid-price class for four Western regions in 1975, 1979, and 1982. The first year, 1975, was a recessionary trough. Product prices and housing activity had dropped dramatically from the 1973 peak, but demographics suggested the possibility of a strong recovery. In 1979, the peak of the last forest products price cycle occurred. Housing construction fell from its high in 1978, and the outlook was generally for a continued drop in the near term but a significant long-term recovery, again based primarily on demographic considerations. An immediate end to strong general inflation and real growth in forest products prices was not expected. The final year, 1982, was the trough of the last recession. Housing starts were at their lowest point since World War II, economy-wide inflation had been sharply curbed, real interest rates were at record levels, and the outlook for future housing activity was highly uncertain.

Bid distributions shifted directly with current-period product prices, moving to the right in 1979 and sharply to the left in 1982 (fig. 5, table 3). The ratio of mean bid to standard deviation (see table 3) rises modestly between 1975 and 1979 in three of the four regions and falls in all regions between 1979 and 1982. This suggests that despite the sharp price rise between 1975 and 1979 (and the considerable uncertainty surrounding prices beyond 1979), the relative dispersion of bids did not rise in 1979 and may actually have been reduced.

Table 3—Mean real bid prices and standard deviations (SD) of National Forest timber sales in four Western regions, 1975, 1979, and 1982

Region	Mean and standard deviation	1975	1979	1982
		1967 dollars/mbf, log scale		
PNWW	MEAN	78	138	33
	SD	37	55	19
PNWE	MEAN	26	75	20
	SD	19	45	16
PSW	MEAN	42	106	22
	SD	23	67	16
Rockies	MEAN	14	38	13
	SD	11	28	10

Within a given year, bid prices would be expected to differ depending on the duration of the sales contracts being sold. If buyers generally expect spot product and stumpage prices to rise in the future, they should be willing to bid higher prices for sales of longer duration. Buyers would anticipate holding sales until near their termination dates to realize the most gain. If buyers anticipate stable or declining future spot prices, bid prices should be nearly equal for both near- and- far-term contracts, but they should not decline with longer duration. Competition will force bids to the highest anticipated level over the life of the contract, even if the maximum is in the period of sale.

These considerations do not preclude the possibility of the average price bid for National Forest timber in a given period falling below the average price of timber harvested from the National Forests in this same period.[8] For given conditions of regional timber demand and non-National Forest timber supply, average harvest price depends on the full array of sales available to purchasers, both current sales and uncut volume from past sales. Thus the equilibrium harvest price is partially determined by prices already set in earlier periods. If spot prices are declining, the average price of the mix of sales actually harvested may well be above the average price of sales recently bid with recent (low-bid) sales comprising a larger portion of the total harvest.

The data in table 4 illustrate some of the points raised above. In 1975 and 1979, bids rose unevenly as contract duration increased. Instances of reductions in average bid from one duration category to the next may be a reflection of differences in sale

[8] See, for example, plots of average bid and harvest prices in figure 11.

Table 4—Mean real bid prices and standard deviations (SD) for National Forest sales in the PNWW region by sale duration and average price of timber harvested, 1975, 1979, and 1982

Year	Mean and standard deviation	Sale duration (years) 1	2	3	4	5+	All sales	Harvest price
		1967 dollars/mbf. log scale						
1975	MEAN	44	63	74	82	81	78	41
	SD	34	50	33	35	36	37	
1979	MEAN	89	117	145	140	154	138	60
	SD	49	46	49	55	58	55	
1982	MEAN	32	31	35	32	35	33	29
	SD	18	18	20	19	14	19	

quality characteristics among categories. In both years, ratios of the mean and standard deviation rise abruptly for sales of 2 to 3 years duration and longer but show no consistent pattern after this jump. Shorter term sales thus appear to have the greatest bid dispersion, a result possibly reflecting greater heterogeneity in the quality characteristics of these sales. In the recessionary trough year of 1982, when there was a relatively pessimistic outlook for future price recovery, the bid-price structure by duration category is nearly flat. Ratios of the mean and standard deviation rise only in the longest duration class and are smaller than 1979 levels for all classes save the shortest.

Bid-price model for average bid—The basic model of bid-price determination adopted in the present study derives directly from the primary result of previous theoretical and empirical studies. We hypothesize that current-period average bid price is a function of expected spot stumpage price at time of harvest. Because we use aggregate time series data on bid prices for all sales in a region, our analysis departs in several ways from methods commonly employed in single-sale (cross-sectional) studies. The effects of variation in the degree of competition, usually represented in single-sale studies by the number of bidders, is not considered.[9] Our

[9] Single sale studies have generally found that bid price varies directly with the number of firms submitting bids for a given sale. An analysis of time series data on the average number of bidders on all sales in Region 6, however, reveals an inverse pattern. Average number of bidders per sale declined during the cyclical price peaks in 1972 and 1978-79 and rose as prices fell in 1973-75 and after 1979 (see, for example, Mead and others 1983). Although a variety of reasonable explanations for these countercyclical movements may be adduced, their existence casts some doubt on the utility of incorporating number of bidders as a measure of competition in an aggregate model in simple analogy with single sale studies.

development presumes that buyers view themselves in a fully competitive environment in establishing future spot-price expectations. Further, we assume that the mix of products made from National Forest timber is identical to those made from the volumes harvested from all other ownerships and that all product processing costs are identical across owners in the region. Thus we do not include variables to represent differences in the quality characteristics of sales.

In developing expectations of spot stumpage prices at time of harvest, we assumed that buyers consider the prospective demand for National Forest timber, as influenced by future product prices, production costs and potential supplies from non-National Forest lands, and the likely supply of National Forest timber. For the last case, buyers are hypothesized to recognize that the prices bid for National Forest timber today will influence the cost structure of their harvest options tomorrow. Specifically, the volume of National Forest timber available for harvest at a future time is comprised of the current uncut volume under contract plus the volumes added to this inventory as a result of current sales. The price structure of the current uncut volume under contract has been established by past bidding activity and is essentially fixed (save, of course, for escalation and related adjustments). The prices of current sales have yet to be determined, however. If they are high relative to those in the current uncut volume, the average price structure of volumes available for harvest in the future will be drawn up and vice versa if they are relatively low. This suggests the possibility of some feedback between current bidding decisions and anticipated future spot prices.

The development of the model for bid prices starts with the assumption that all timber is offered for sale only at the start of each period. At that point, buyers have some uncut volume under contract that is the residual from past sales less past harvests (call this the presale uncut volume). Buyers must then decide what to bid for timber currently being auctioned. In doing so, they consider potential market conditions in the forthcoming period.

The actual derivation of the bid price model is explained in appendix 1. The model can be summarized as:

$$BP = BP(X, S)\ , \tag{9}$$

where

BP = average bid price of all volume sold,
X = the vector of buyer's expectations for future product prices and costs, and
S = total volume sold.

Buyers implicitly solve equation (9) to determine both p and BP as functions of market price and cost conditions (X) and the volume of timber sold (S). We would expect that both p and BP would rise as X (again interpreted as a single variable, such as product price less nonstumpage costs) rises and to fall as S increases. The development of equation (9) does not lead to unambiguous expectations about the signs for the total derivatives of either BP or p with respect to X and S. It is possible to determine the signs of these derivatives only with the benefit of some empirical information. An illustrative analysis for the PNWW region is given in appendix 2. The results suggest that our expectations hold under a reasonable set of assumptions, at least for the PNWW.

Estimation of equation (9) requires some specification of the composition of X, future product prices, and nonstumpage production costs and of the expectational structure. With all the solid wood products industries in the Western United States being purchasers of National Forest timber, the number of variables potentially involved in X is quite large. To reduce the number of variables (and the problem of interdependence among them) while limiting the loss of information, we incorporated the several price and cost variables that should theoretically comprise X in a single weighted-average residual stumpage variable defined as:

$$DC = \sum_i V_i \, DC_i \ , \qquad (10)$$

where

V_i = is the fraction of total timber harvest consumed by industry i, and

$$DC_i = o_i \, [(1 + m)^{-1} \, (P_i + R_i) - M_i \,] - L \ , \qquad (11)$$

where

o_i = the average overrun (product output/log input) of industry i;
M_i = average (pond-to-car) manufacturing cost per unit output in industry i;
P_i = is the average product price for output of industry i;
R_i = average residue revenue per unit of output in industry i;
L = average (stump-to-pond) log and haul cost (expressed on a log-scale basis); assumed to be identical for all industries; and
m = a fraction of total costs (stumpage + manufacturing + logging) reserved by purchasers as an allowance for profit and fixed costs.

The DC_i terms are simply a residual value estimate of stumpage with an allowance for profit and fixed costs. The allowance for profit and fixed costs will vary over time and across industries depending on financial and market conditions. In the absence of any information on these determinants, we have taken m as fixed. The DC_i for each industry is weighted by the industry's share of total regional timber harvest (V_i) to determine a regional average.

Given the similarity of this approach to the standard National Forest appraisal procedures, why is it not reasonable to use National Forest appraised values rather than construct DC? Apart from obvious differences in estimates of costs, residue values, and profit allowance (M, L, R, and m), our variable DC will depart from National Forest appraised values in several ways. The product prices incorporated in DC are current period values, and prices used in appraisals unavoidably involve some time lag. Buyers have knowledge of current price developments in the markets for their products and presumably incorporate this information in their bids. The weighting of stumpage estimates by industry (the V_i) varies in DC according to actual changes in the composition of log consumption. In National Forest appraisals, selling values assume some fixed split of log use across industries that is updated over time, but only with some lag.

Finally, for regions where it is of significance, we explicitly consider the log export industry in the computation of DC. This is, of course, not the case in National Forest appraisals. Even though exportation of National Forest logs has been banned or sharply limited since the 1960s, arbitrage in the log market will force prices of public stumpage prices to reflect product values in both domestic and export uses. Any price differential between public (nonexportable) and private (exportable) stumpage not based on quality or cost differences between domestic and export uses could be exploited by domestic (nonexporting) processors to reduce their wood costs.

In the empirical specification of the bid-price relation, we have taken the expected future value of X to be a distributed lag in DC. If a linear structure is assumed, then the estimation form of equation (9) is:

$$BP_t = a_o + \sum_{j=1}^{n} w_j DC_{t-j} + a_1 S_t + u_t . \qquad (12)$$

From the foregoing discussion of historical bid-price behavior (especially the time series results of figure 4), we expect that National Forest markets are relatively efficient in their use of information affecting timber value. Bid prices should respond rapidly to changes in their determinants. As a consequence, the lag weights (w_j) in equation (12) are likely to be greatest for recent values of DC, and the maximum lag (n) should be relatively short. We employ an Almon polynomial lag structure[10] to estimate the w_j. In the analysis of figure 4, the undifferenced bid-prices series all showed strong autocorrelation owing to trend effects. This same behavior is observed in the DC series for all regions. High autocorrelation in the series will confound efforts to identify the appropriate lag structure and will almost surely lead to problems of autocorrelated errors. As a consequence, we have estimated equation (12) in first difference form.

[10] A distributed lag formulation where the weights on successive values of the lagged variable follows a pattern dictated by a polynomial.

Estimation results are shown in table 5. A simple linear lag structure with a 1-year maximum lag was found to be appropriate for the residual stumpage variable (DC) in all regions. Systematic investigation of longer maximum lags and higher order polynomials yielded insignificant results in all cases. As anticipated, DC_t has the highest lag weight, but the relative values of w_0 and w_1 vary across regions. The volume of timber sold (S) enters the relations in all regions with the expected negative sign but is not significant at usual levels in each instance. Even though the consistently negative sign is supportive of our theory, its insignificance is perplexing and suggests that buyers give only limited attention to the effects of current bids on future harvest options. It may be that their estimates of harvest prices are dominated by the much larger presale uncut volume with known prices and volumes, while the impacts of current sales volumes are simply too small to detect. These findings, though only partly consistent with our theory of bid price, are broadly similar to the empirical results of Buongiorno and others (1985). In that study, the authors examine the causal relation between bid prices and the volume of timber offered for sale on National Forests in the Pacific Northwest Region. They conclude that offerings do not influence bid prices. Our results suggest that similar findings may be obtained in other Western regions as well.

When the insignificant sale volume terms are dropped, the regression statistics of the simplified relations appear satisfactory. The explanatory power of the first difference forms is reasonable and the correlation of actual and forecast bid price levels (R^2_L) remain high, except in the Pacific Southwest region. Here, the level forecasts fail to track the timing of the major downturn in bid price between 1978 and 1982. Because the equations lack an intercept, Durbin-Watson tests for first-order serial correlation must be modified (Farebrother 1980). The tests suggest that serial correlation of errors can be rejected at the 1- and 5-percent levels, except in the PNWW where the test just misses the bound at the 1-percent level. An AR(1) correction was applied in this case.

A limited analysis of the stability of the regression coefficient over subsets of the estimation period was undertaken. As shown in figure 3, bid prices in all regions rose dramatically beginning in 1970 and display far wider cyclical movements in the ensuing 15 years than was the case before 1970. To examine the stability of the regression between the periods 1955-69 and 1970-85, we split the estimation sample and conducted the usual F-test for equality of coefficients across the two subsamples. Resulting F-ratios were 0.219, 0.709, 0.291, and 2.614 for the PNWW, PNWE, PSW, and Rockies equations, respectively. Critical F-values for 2 and 25 degrees of freedom (there are two polynomial distributed lag terms in the regression) are 5.49 at the 1-percent level and 3.35 at the 5-percent level; this allows acceptance of the unchanged structure hypothesis in all cases.

Table 5—Regression results for bid price equations in Western regions

Region	Distributed lag in DC			Sold volume	R^{2a}	R^2_L [b]	Intercept[c]	DW[d]
	w_i	w_1	w_2					
PNWW	1.496 (.176)	0.815 (.125)	0.681 (.124)	–0.000420 (.00314)	0.723	NC	NC	2.654
	1.520 (.140)	.838 (.112)	.683 (.112)		.722	0.884	–25.72	1.879[e]
PNWE	1.119 (.127)	.758 (.083)	.361 (.086)	–.003870 (.00504)	.769	NC	NC	2.327
	1.104 (.125)	.762 (.082)	.342 (.082)		.764	.832	–18.31	2.316
PSW	1.295 (.196)	.812 (.133)	.483 (.139)	–.00382 (.00380)	.634	NC	NC	1.606
	1.267 (.194)	.827 (.132)	.439 (.132)		.624	.433	3.296	1.718
Rockies	.699 (.068)	.548 (.046)	.151 (.042)	–.00200 (.00132)	.851	NC	NC	1.882
	.662 (.064)	.519 (.043)	.143 (.043)		.840	.731	–6.338	1.967

[a] R^2 is computed with allowance for 0 intercept.
[b] R^2_L is squared correlation of actual and predicted level of bid.
[c] Intercept computed from mean sample period value of $BP_t - w_0DC_t - w_1DC_{t-1}$.
[d] Durbin-Watson statistic. Note that normal bounds do not apply in cases with no intercept.
[e] After AR(1) adjustment.

Bid-price model and bid dispersion—The total volume available to purchasers for harvest in a given period is the sum of the presale uncut volume and the current volume sold. In the present model, uncut volume is disaggregated by bid-price and contract-duration classes (denoted by b and d, respectively). To aggregate presale uncut and current sale volumes, the volume sold (S), and the average bid price of all sales (BP) established in the preceding sections must be translated into a distribution of sold volume by bid and duration classes. This distribution is denoted f(b,d), and has the usual properties:

$$\Sigma_b \Sigma_d f(b,d) = 1 ; \quad (13)$$

$$\Sigma_b \Sigma_d f(b,d)BP(b,d) = BP , \quad (14)$$

where BP(b,d) is the average bid price in bid class b and duration class d;

$$\Sigma_d df(b,d) = f(b) , \quad (15)$$

which is the marginal distribution of bids across all duration classes as illustrated by the distributions in figure 5; and

$$\sum_b bf(b,d) = f(d) \; , \qquad (16)$$

which is the marginal distribution of sales by duration class.

Our interest here is in deriving a reasonable approximation of f(b,d) in a parsimonious fashion. Because the model provides only an estimate of the average bid price for all sales (BP), the approach to estimating f(b,d) must be sufficiently simple so that we can derive its parameters from BP and whatever regularities may exist in the behavior of f(b,d) as indicated by historical data. For each year an estimate of f(b,d) is obtained by a three-step process.

1. **The marginal distribution of sales by bid class, f(b), is modeled as a function of the average bid price of all sales, BP.**

Examination of the f(b) distributions in figure 5 indicates that as BP rises and falls over the sample years, the distributions shift from J-shaped to a modal form (or the modes shift directly with BP) and the ranges of the distributions expand and contract. To capture the full extent of these changes, we employ a two-parameter Weibull distribution fit to the historical data (1975, 1979, and 1982) by using a maximum likelihood method (Schreuder and others 1978). Let bb_t and cc_t be the estimated Weibull parameters for the various time points, where bb is termed the "scale" parameter and cc the "shape" parameter. If the range of variation of cc is relatively limited across the samples, it may be possible to approximate bb as a linear function of the distribution mean value (that is BP). The relation of cc and the distribution mean may be more complex. Depending on the regularity of shifts in the distributions from period to period, the relation may be linear, quadratic, or a higher order polynomial. Results for the PNWW and PNWE regions, where both bb and cc are closely approximated as linear functions of the mean, are illustrated in figure 6. The relations employed to estimate the two parameters may be written as:

$$bb_t = bb_0 + bb_1 \, BP_t \text{ , and} \qquad (17)$$

$$cc_t = cc_0 + cc_1 \, BP_t \; . \qquad (18)$$

2. **An estimate of the conditional distribution of sales by bid-price class for each sale-duration class is generated by using information on average bids by duration class and Weibull parameter equations for f(b).**

The data in table 4 provided an illustration of the historical relation between average bid prices by sale duration and the average bid for all sales (BP). At historically low levels of BP, prices by duration class have been stable to slightly rising with longer durations; at high levels of BP, prices by duration rise rapidly, though at a decreasing rate. To estimate average bids by duration class, we use data of the sort presented in table 4 in the relation:

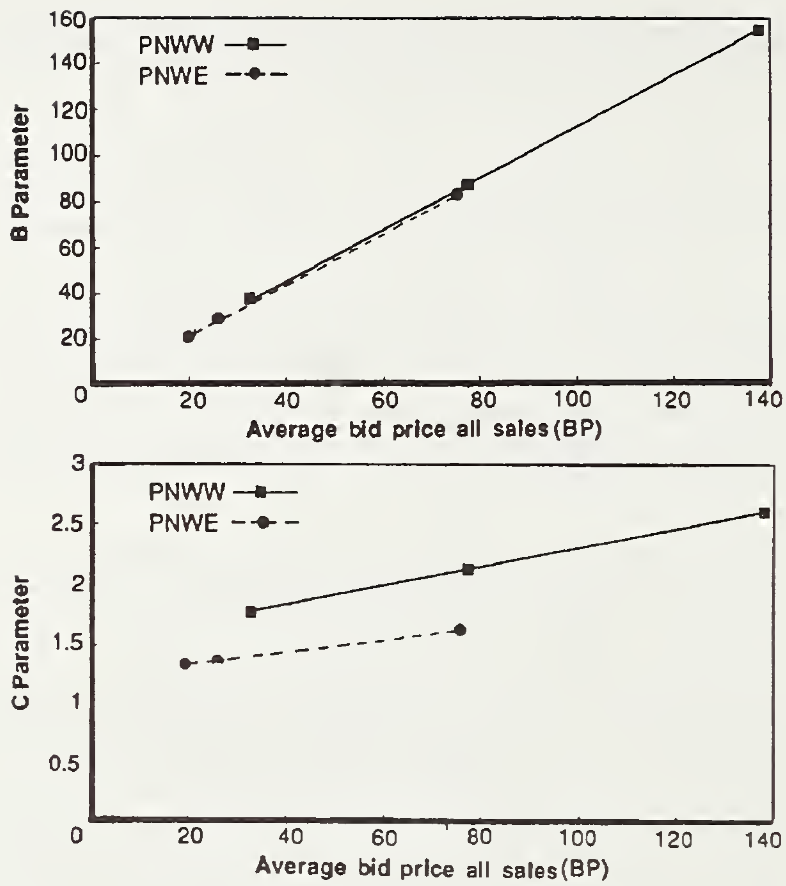

Figure 6—Relation of Weibull bb (scale) and cc (shape) parameter estimates to mean real bid prices for all sales in PNWW and PNWE regions.

$$\ln(BP_{d,t}) = a_o + a_1 \ln(d) + a_2 \ln(BP_t) , \qquad (19)$$

where

$BP_{d,t}$ = the average bid for duration class d in period t, and
d = is the duration class of sales in years.

From examination of historical data, we expect both a_1 and a_2 to be less than 1. Although this approach may capture the historical relation between $BP_{d,t}$ and BP_t, it has definite limitations. For example, if stumpage prices were to rise to (historically) high levels and then stabilize with no expectations of further increases, equation (19) would continue to estimate a rising bid structure by duration.

To develop an estimate of the conditional distribution of sales by bid class for a given duration class, which can be denoted f(b|d), we use the values of $BP_{d,t}$ derived above for each duration class in the Weibull parameter equations (17) and (18) from step 1. This assumes that f(b|d) responds to the mean bid price within the duration class in the same way that the marginal distribution f(b) responds to the all-sale average bid. Analysis of the behavior of historical bid distributions gives qualitative support to this approach, but clearly this is a strong assumption.

3. **The desired f(b,d) is estimated as the product f(b|d)f(d), where f(d) is the marginal distribution of sales by duration class.**

The marginal distribution f(d) is set by administrative policy and has varied markedly over time. In the most recent major shift in 1981, the Forest Service sharply reduced the proportion of sales offered having durations longer than 3 years. In the PNWW region, for example, the mix of sales by duration changed as indicated in the following tabulation:

	Fraction of sales	
Duration	**Before 1981**	**1981 and later**
Years	*- - - - Percent - - - -*	
1	5	22
2	10	29
3	20	32
4	42	15
5+	23	3

The initial product of f(b|d) as derived in step 2 and f(d) will satisfy equation (16) but will not, in general, meet the conditions in equation (15). The final estimate of f(b,d) is obtained by an iterative process of row and column operations on f(b|d)f(d) until both (15) and (16) are satisfied.

The results of the process described in steps 1-3 are illustrated for the PNWW for the extreme years 1979 and 1982 in figure 7. The charts present cross-sections through the f(b,d) surfaces in the bid-price plane. The estimates do not reproduce the erratic movements in the actual distributions but capture the shifts in modes, the spread of bids across price classes, and the relative amplitudes by duration classes.

Uncut Volume Under Contract

The uncut volume under contract is the inventory the buyers draw timber from for current harvest. It is generally comprised of a broad distribution of sales by bid-price and termination classes can fluctuate markedly from year to year in response to differences in levels of sales and cut. During the late 1960s and early 1970s, cut and sold volumes fluctuated around roughly the same mean value from year to year, and the uncut volume inventory bore a relatively stable relation to these flows. This is illustrated in figure 8 for the Northern, Pacific Southwest, and Pacific Northwest Regions of the Forest Service. For the Pacific Northwest Region, uncut volume averaged roughly twice the annual level of sold and cut. The ratio was somewhat higher in the Pacific Southwest Region, averaging about 3:1, while in the Northern Region it averaged about 2.75:1. With the sharp decline in product and stumpage prices beginning in 1980, harvest volumes dropped and remained below the level of sales for 3-4 years. As a result the ratio of uncut to sold volume rose dramatically in Western regions reaching 4:1 to 4.5:1 (see fig. 8). Timber sales contract-relief legislation in late 1985 excused purchasers from nearly half the outstanding uncut volume, and by mid-1986 the ratio of uncut to sold volume had returned to earlier levels.

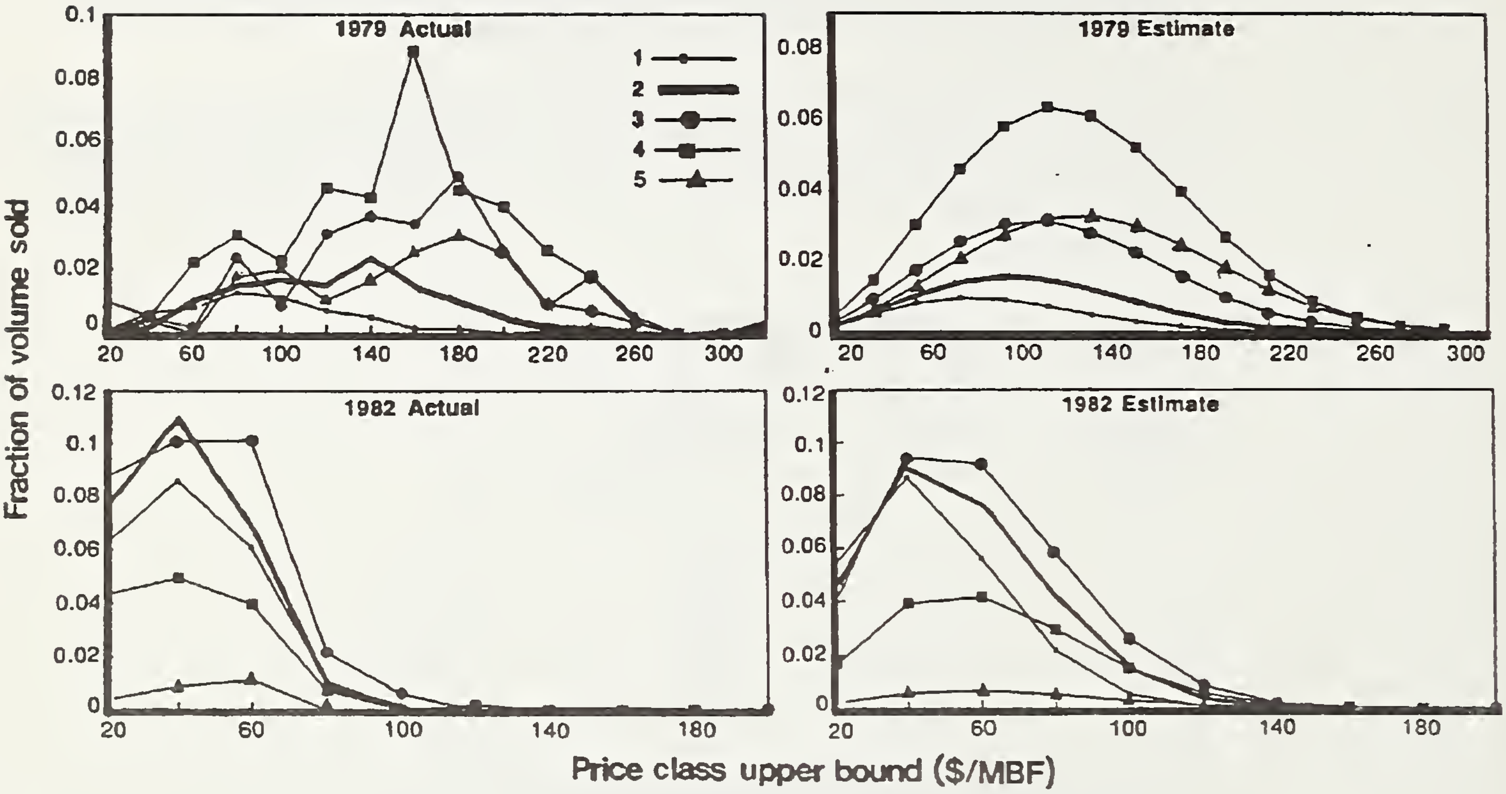

Figure 7—Actual and estimated distributions of bid prices by bid price and sale duration classes for PNWW region in 1979 and 1982.

The cumulative distribution of uncut volume by bid price class is illustrated for the PNWW in figure 9 for 1977, 1979, 1983, and 1986 (adjusted for the effects of relief legislation). The curves in the figure are plots of the function NFS from equation (25) appendix 1. Between 1977 and 1979, nearly 1 billion board feet were added to the inventory; most of it was sold at real prices above $150 mbf. Although bid prices and harvest volume began to drop in late 1979, substantial volumes were still sold at prices in excess of 80 real dollars per mbf in 1980 and 1981. The shift to the right of the 1983 uncut volume curve reflects the larger volumes sold at lower prices in 1983 and the deferral of harvest of high-cost sales. Despite relief legislation, nearly 2 billion board feet of timber remains in the inventory at prices of 50 real dollars/mbf and higher, more than 50 percent above recent (1986-87) average bid and cut prices.

From 1977 through 1986, annual National Forest harvest in the PNWW ranged around the 3-billion-board-foot level. In the neighborhood of this volume level, all the cumulative uncut volume curves in figure 9 appear relatively price responsive. Arc estimates of the elasticity of cumulative uncut volume, with respect to price, range from 1.0 for 1986 to 1.6 for 1979.

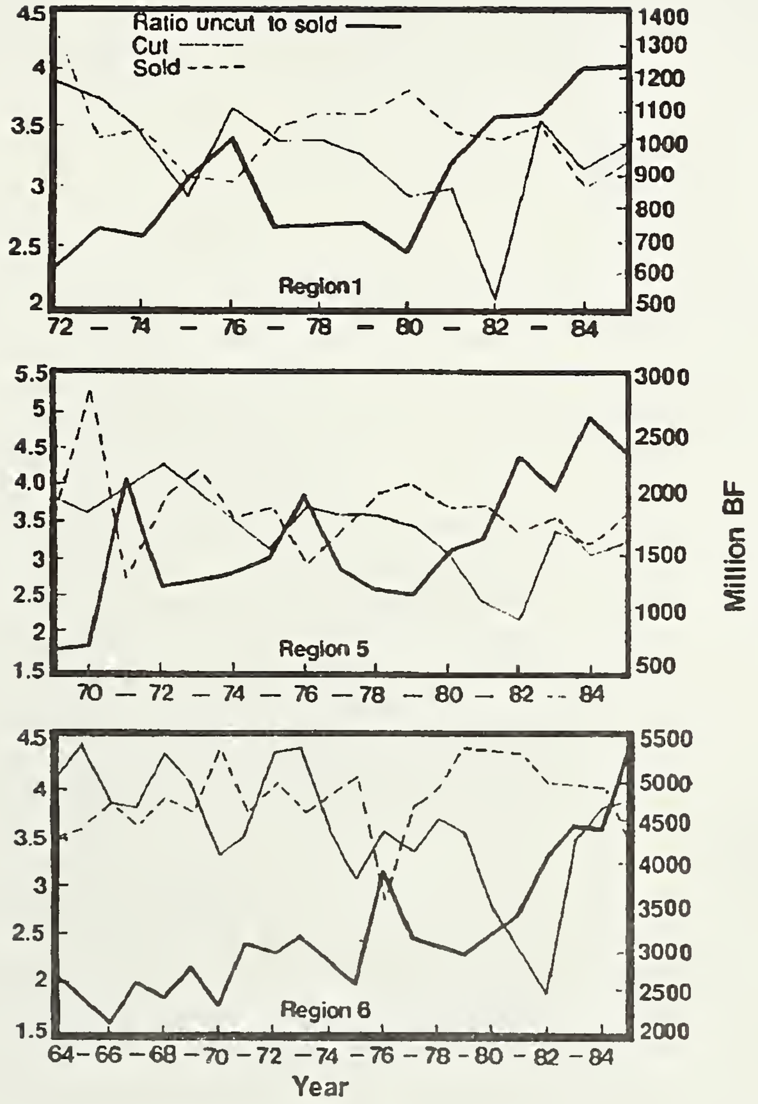

Figure 8—Ratios of uncut and sold volume and volumes cut and sold on National Forests in Regions 1, 5, and 6.

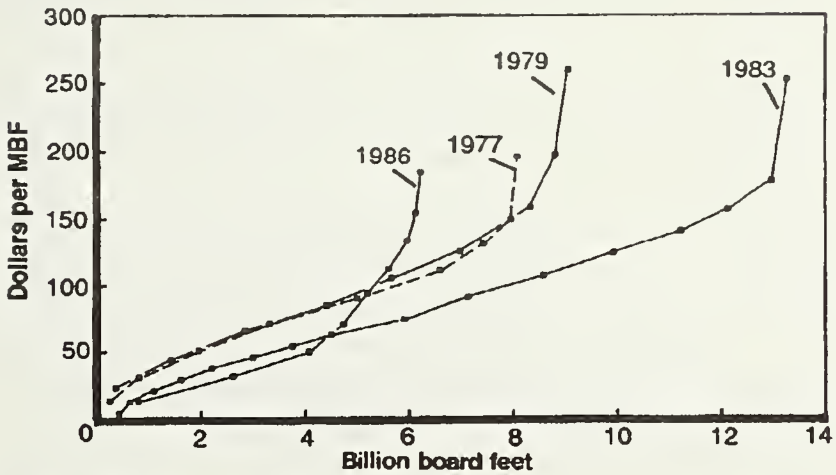

Figure 9—Cumulative uncut volume under contract by bid-price class in PNWW region: 1977, 1979, 1983, and 1986 (after adjustments resulting from the Federal Timber Contract Modification Act).

As an inventory, levels of the uncut volume under contract over time should follow the simple inventory identity: uncut volume(t) = uncut volume(t-1) + sales(t) - cut(t). Published data on uncut, sold, and cut volumes do not, however, conform to this identity. In the PNWW, for example, differences between the reported change in uncut volume (uncut volume[t] - uncut volume[t-1]) and the apparent net addition to the inventory (sold[t] - cut[t]) range as high as 1.5 billion board feet in some years. There are at least two reasons for this discrepancy. First, National Forest statistics on uncut volume generally include only sawtimber (or material measured directly in board feet); timber sold on a per-acre basis, pulpwood, and other nonsawtimber volumes are not included. Reports on cut and sold include all material, however. Nonsawtimber volume may account for 10 percent or more of the total sold volume in some Western regions. Second, differences occur between the estimated sold volumes derived from presale cruises and actual volumes harvested from the sales. In an analysis of PNWW National Forest sales completed between the third quarter of 1979 and the first quarter of 1983, Mead and others (1983) found average absolute percentage differences in volume between the cruise and actual harvest ranging from 15 to 29 percent. The extent of the difference varied nonsystematically over the years in which the sales were actually sold (range in their sample, 1969 to 1983). Lumping all sales together (over the 15 quarters) and recognizing the algebraic sign of the discrepancy, however, Mead and others (1983) found that from an estimated sold volume of 9.551 billion board feet, some 9.294 billion board feet were actually harvested. With both positive and negative discrepancies in the cruises, the net error is just less than 3 percent of the cruise volume.

The terms and conditions of sales may be adjusted in ways significantly affecting their harvestability while the sales are waiting to be harvested. The most obvious adjustment is via price-escalation mechanisms for sales subject to this treatment (see earlier discussion). This will influence the shape (slope and elasticity) of the curves in figure 9 over time quite apart from the addition of new sales and the deduction of harvested volumes. The proximity of sales to termination may also be changed by granting extensions or by special administrative actions of the Forest Service. Detailed data on sale extensions are not regularly reported by the Forest Service, and conditions for extension eligibility have varied over time. It is clear, however, that sale extensions have played an important role in shaping National Forest supply in the past.

During the relatively stable years of the late 1960s and early 1970s, extensions were frequently sought and granted. For example, in a study of timber sales in western Washington between 1965 and 1976, Rucker (1984) found that nearly 20 percent of the sales in his sample had received extensions. Extensions were also widely used to cope with the high-cost sales problem after 1979, before contract relief legislation was passed. In the Pacific Northwest Region, for example 1-year extensions were granted in 1980, and a (cumulative) 2-year extension was granted in 1981 for sales sold during the late 1970s and in 1980. A further 5-year extension was granted for the same sales in 1983. These policies virtually eliminated defaults that might otherwise have been numerous during this period.

Timber Harvest and Current Stumpage Price

In our study, current (harvest) stumpage price was determined by supply and demand. The supply-demand balance can be expressed symbolically as:

$$S_{FI}(P) + S_{OP}(P) + NFS(P) + S_{og} = k_L O_L(P) + k_V O_V(P) + k_{MP} O_{MP} + O_{LE}\,, \qquad (20)$$

where

S_{FI} = price-sensitive private forest industry stumpage supply;
P = current-period sawtimber stumpage price;
S_{OP} = price-sensitive other private supply;
NFS = the uncut volume under contract cumulated by price class;
S_{OG} = harvest from non-National Forest public lands, taken as exogenous
O_l where l = L, V, MP, and LE. These are supplies of lumber, plywood, miscellaneous products, and log exports, respectively, where only the first two products are modeled as price sensitive; and
k_i where i = L, V, and MP. These are exogenous recovery factors converting product output to stumpage equivalents.

Stumpage price in this model refers only to sawtimber. Prices and volumes of pulpwood and fuelwood are not included. The model assumes price equality across owners and, hence, that stumpage quality is identical regardless of owner. Empirically, National Forest cut price—the average price of National Forest timber harvested—is taken as the price measure.

Some justification for the use of National Forest cut price as a measure of current regional price may be because of the confusion evident in the literature over the measurement of spot stumpage prices. Our basic theoretical argument turns on opportunities for arbitrage in the current stumpage market. The most troubling situation seems to occur when stumpage prices fall relative to a past cyclical high. Why should the holder of National Forest timber sales harvest some mix of his or her uncut volume at a higher average price than comparable timber available from private or other public lands? The answer of course is that the holder will not, or at least will not for very long and remain solvent. Sale contracts are generally of sufficient length to allow postponement of harvest until current prices rise enough to make harvest attractive. In the interim, buyers will harvest from existing low-price sales, buy and harvest new sales at currently low prices, or procure wood on the open market.

This was the situation in the West in the early 1980s. If the price depression is lengthy and contract extensions and other means of escaping contract requirements fail, firms will default. The notion of mixing, where some high-cost public timber is mixed with lower cost private timber, although it has some currency in discussion, also seems an unlikely outcome. In this case, the producer clearly would be better off to harvest an equivalent quantity of private timber alone. Mixing assumes, in effect, that private owners assign something other than the current market price as the opportunity cost of their timber.

Under the reverse circumstances, where prices are high relative to historical levels, is there any possibility that buyers of National Forest timber will harvest a mix of timber with an average price consistently lower than the going price of private timber? Again, the answer is no. Opportunities to increase profits at the margin will push production up, together with the average cost of timber harvested from the uncut volume, until prices are equal.

A test of the conjecture that market forces bring about equality of stumpage prices across owners requires data on private stumpage transactions that unfortunately are not available in the Western regions. Two reports of log prices are available, however, for western Washington from the Washington Crop Reporting Service, and for the northern portion of the Douglas-fir region from the Industrial Forestry Association (IFA) (Warren 1986). The western Washington data are derived from mill quotations for delivered logs of various species. The IFA series is based on sales receipts for logs traded in domestic markets by firms reporting to the association. Neither series is based on a statistical sample; further, the actual number of price quotes (for the western Washington data) and the volume of log trade reported (for the IFA data) are extremely small relative to the total market in the respective regions. Nonetheless, these series represent the best available indicators of the prices paid for domestic logs regardless of their ownership or origin.

Estimates of stumpage price were derived from the log-price series by deducting costs of timber harvest and log haul for the appropriate geographic region. Figure 10 compares the results with National Forest harvest prices for western Washington and for the Douglas-fir region. To provide some statistical basis for gauging the differences between the two pairs of series, we estimated simple regressions of the derived stumpage price series on the appropriate National Forest harvest price. In both cases, the intercept terms were not significantly different from zero, and the slope terms were not significantly different from one. Residuals from the regressions showed no significant first-order autocorrelation. Q-tests (Box and Jenkins 1976) of the residuals from these regressions, using both 5- and 10-year lag intervals, could not reject the hypothesis that they were essentially white noise at the 0.70 level (less than a 70 percent chance that the residuals were in fact not white noise). Mean values of the differences between the two pairs of series were not significantly different from zero. Q-tests of the difference series could not reject the white noise hypothesis at the 0.50 level. These results suggest that even though the two pairs of series do not have identical values in all periods, the differences between them may result from random errors in their collection or estimation. From this analysis, we conclude that the available price evidence lends some support to our argument that National Forest harvest prices are representative of stumpage prices across all ownerships.

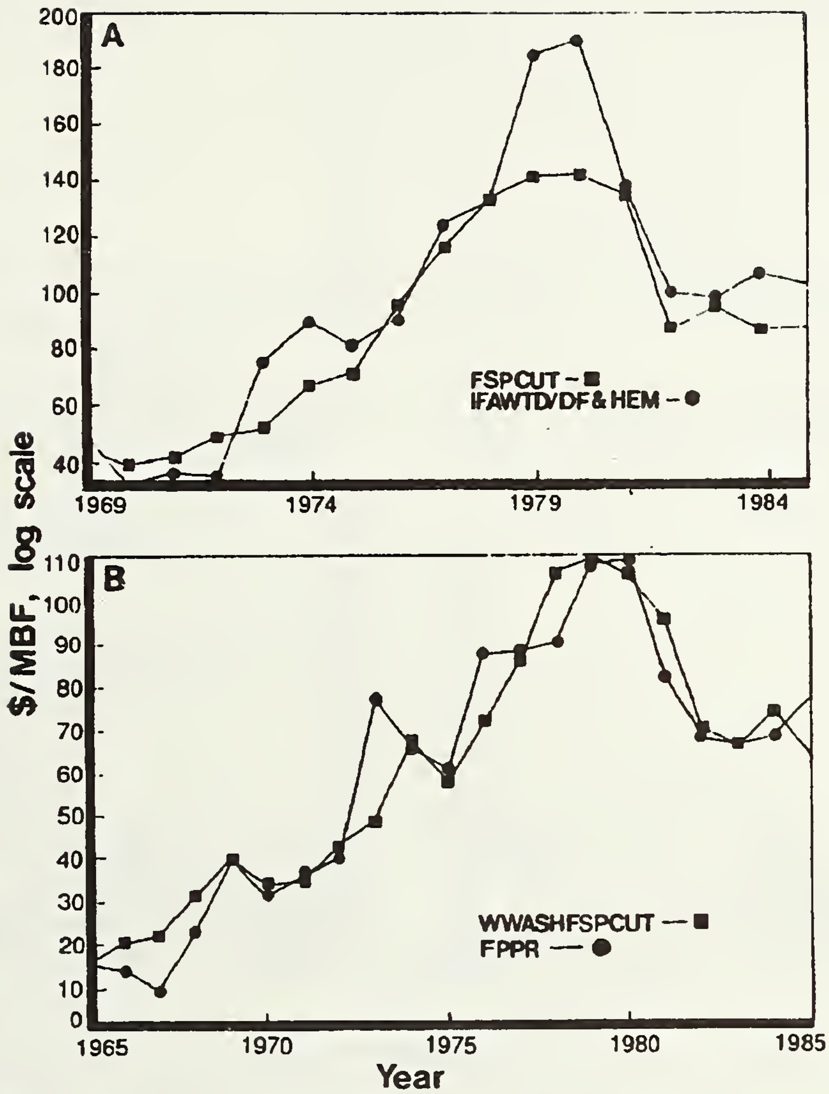

Figure 10—Average harvest price (A) for National Forests in western Washington and estimated stumpage price (B) derived from Washington Forest Products Price Report log prices. National Forest average harvest price for the PNWW and estimated stumpage price derived from IFA log price data.

The market equilibrium expression in equation (20) differs from similar relations in TAMM (Adams and Haynes 1980) and other models only by a price-sensitive National Forest component of stumpage supply. Qualitatively, however, the inclusion of NFS(P) with a non-zero price elasticity yields two important differences in both price and volume behavior of the model. First, it is commonly observed that bid prices are sometimes far more volatile than spot (cut) prices. Plots of bid and cut prices in figure 11 illustrate the differences for the four Western regions. In the common modeling approach treating National Forest supply as a fixed volume, this behavior is difficult to replicate. Aggregate stumpage demand and non-National Forest supply are both generally thought to be quite inelastic in Western regions. As a consequence, relatively small demand or supply shifts yield large price movements. The addition of a price-sensitive National Forest component moderates spot-price variability. This effect may be substantial if National Forest supply (cumulative uncut volume under contract) is as elastic as was found in the preceding examples for the PNWW (see fig. 9 and associated discussion).

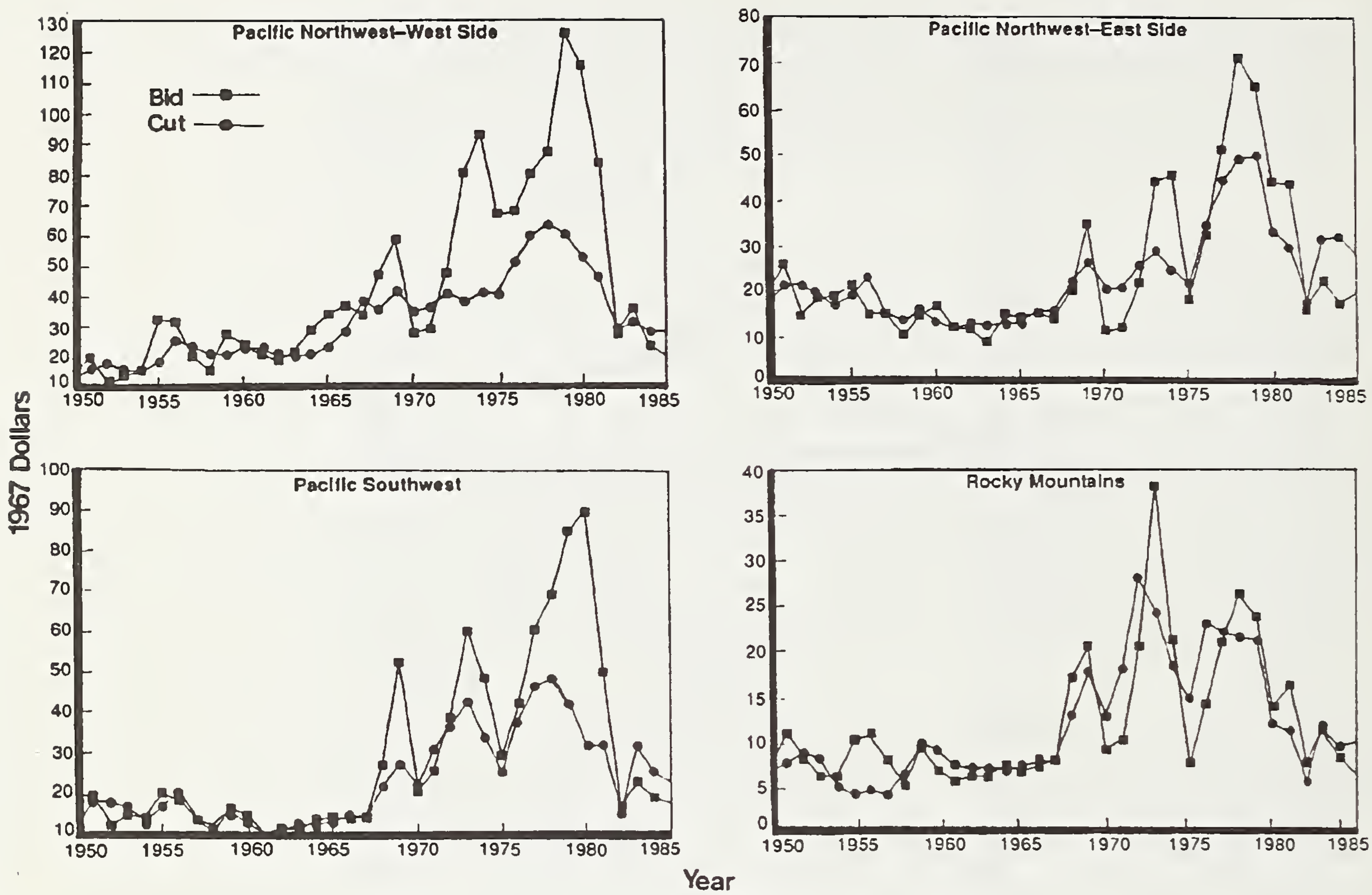

Figure 11—Average real bid and cut prices on National Forests in (A) PNWW, (B) PNWE, (C) PSW, and (D) Rocky Mountain regions, 1950-85.

Second, price-sensitive National Forest supply offers an explanation for short-term shifts in the mix of harvest by owner group over time. Figure 12 illustrates harvest share by owner group for the four Western regions. In all cases, National Forest and forest industry shares show opposing cyclical movements. When the demand and price for forest products decline (as in 1971, 1975, and 1982), the share of private harvest rises and the National Forest share declines. When prices move toward cyclical peaks (1970, 1975, and 1979), private shares decline and National Forest shares rise. Changes of the sort observed would be consistent with a market where National Forest supply were more elastic than industrial supply. Given past findings on the inelasticity of private stumpage supply and the data presented above on the elasticity of uncut volume, this may well be the case in most Western regions.

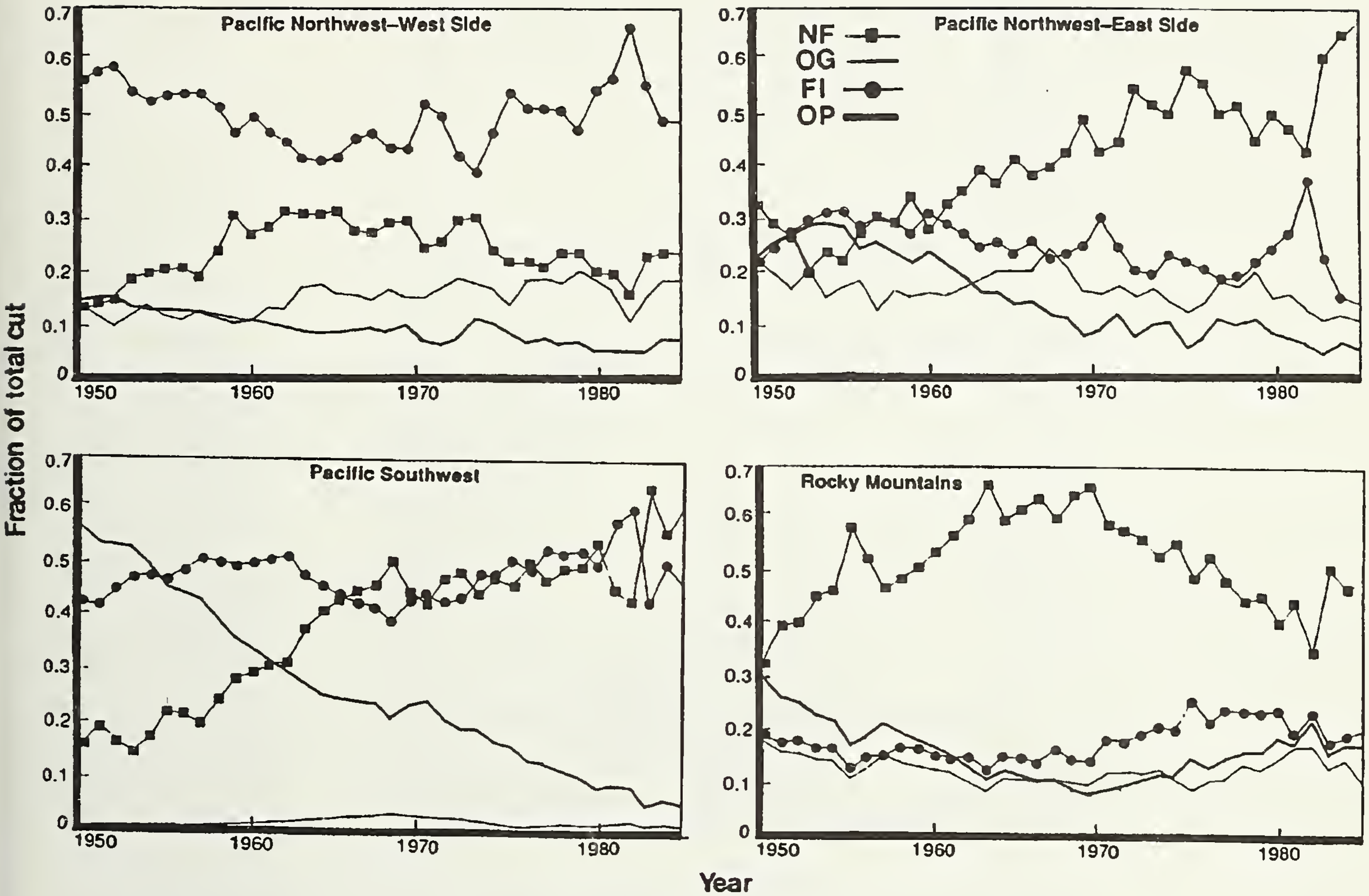

Figure 12—Harvest shares by owner group in the PNWW, PNWE, PSW, and Rocky Mountain regions (FI=forest industry, OP=other private, NF=National Forest, OG=other government).

The final step of the National Forest supply process involves the actual removal of the National Forest harvest volume determined in equation (20) from the uncut volume inventory. As was the case for sold volumes, harvests are distributed around the average cut price in patterns that differ according to market conditions. Figure 13 illustrates harvest distributions by price class from the PNWW for 1977, 1979, and 1983. Figure 14 shows the harvest distribution by termination class for the same region and years. As average cut price rose from 1977 to 1979, the concentration of cut shifts to the right in (fig. 13). The sharp drop in cut price from 1979 to 1983 is accompanied by a similarly dramatic shift to the left in the price distribution. In contrast, the distributions by termination class are extremely stable. Harvest tends to be concentrated in sales nearing termination, with more than 50 percent of the harvest coming from sales terminating within 24 months regardless of the state of the timber market.

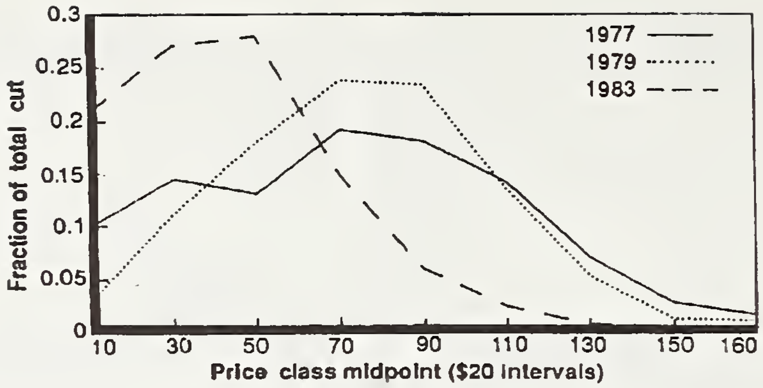

Figure 13—Distribution of timber harvested by real bid price class on National Forests in the PNWW; 1977, 1979, and 1983.

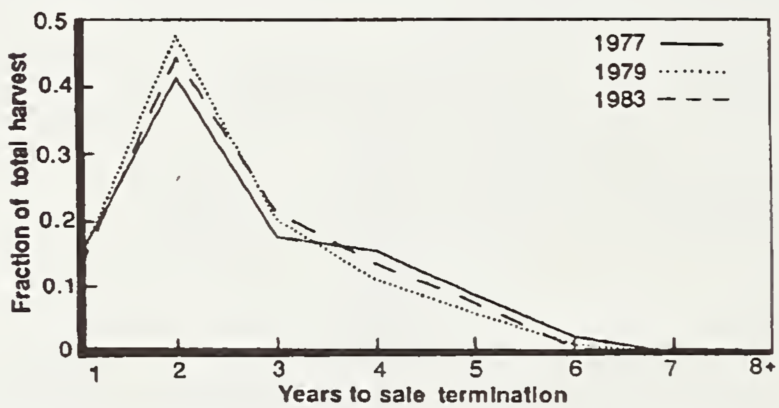

Figure 14—Distribution of timber harvested on National Forests by years to sale termination data in the PNWW; 1977, 1979, and 1983.

The model of harvest distribution by price and termination class follows that described above for bid dispersion. For the PNWW, which serves as our test case, significant simplification was possible in light of the regularities observed in distributional data. Two-parameter Weibull distributions were fit to historical data on the marginal distribution of cut by price class (the distributions in fig. 13). Call this distribution g(b). Both parameters were determined to be linear functions of the average cut price, in the same manner as coefficients of the bid-price Weibull distribution. The marginal distributions by termination class (fig. 14), are stable. Call this marginal distribution g(d). Finally, the actual distributions of cut by price conditioned on termination class, g(b|d), were examined and found to be extremely regular across termination classes within a given year. In effect, the patterns shown in figure 13 (for the marginal distributions) were repeated for each termination class. This result suggested the determination of the joint distribution of cut by price and termination class as the simple product of the marginal price and termination distributions.

In the model, the distribution of harvest determined in this way is removed from the uncut volume inventory. The inventory is then updated by shifting sales to the next smallest termination class (except when this is modified by any contract extensions) and adjusting bid prices by any applicable escalation. Simulation then proceeds to the next annual cycle, beginning with the determination of bid price.

Model Simulations

Implementing the proposed model requires much detailed data on the characteristics of volumes cut and sold and on the uncut volume under contract. Ample information is available on aggregate volumes and prices for most regions, and computerized summaries of sales activities have been maintained by the Forest Service since the late 1960s. Records of the disposition of cut and uncut volumes, however, are available only for the most recent years. As a result, options for testing the model are somewhat limited in both years and regions. From several public and private sources, we assembled a reasonably complete data set for the PNWW region for 1977 through 1985. Though highly restricted, this sample has certain advantages. The PNWW (zone 2 of the Pacific Northwest Region) is the largest single timber-producing region in the National Forest system, accounting for 25-33 percent of all National Forest sales and harvest since the early 1970s. Sales are numerous and diverse, and the market is extremely active. At the same time, the sample years, although few, cover a period of extremely wide variation in price, production, and market conditions.

The model of National Forest supply must be imbedded in a larger model of regional stumpage markets explaining stumpage demand and the supplies of non-National Forest owners. To do this, we used the PNWW regional submodel from the TAMM long-run market model (Adams and Haynes 1980), with the imposition of two significant restrictions. First, attention in the present study focuses on the adequacy of the proposed representation of National Forest supply in explaining stumpage market behavior. Errors in supporting components of the regional submodel will only complicate assessment of the National Forest model. As a consequence, controls were instituted in the TAMM regional submodel to ensure adequate tracking of historical product output and private supply behavior. These controls took the form of a limited number of dummy variables used to estimate the product and stumpage supply relations.

Second, the TAMM regional submodel was removed from the overall spatial structure of TAMM and operated as a stand-alone simulator. Thus prices of lumber and plywood were taken as exogenous and there was no feedback of reactions in other North American producing regions to changes in the PNWW. This approach dramatically simplifies the simulation process by eliminating the need for simultaneous determination of both product and stumpage market equilibria.[11] It also eliminates a further source of external error from overestimation or underestimation of product prices.

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[11] Note that National Forest supply, and hence regional spot stumpage prices, in period t requires information on period t bid price, which in turn depends on period t product prices. In the full spatial structure, product prices are determined in part as functions of period t regional stumpage prices. If the National Forest supply relations were fixed equations, solution of this system would involve only a minor modification of the current TAMM solution procedure. In the proposed model, however, the form of National Forest supply in any given period is determined as a function of period t product prices. One approach to simultaneous solution of this system would involve an iterative process using successive guesses of product prices at the regional level. Iteration would stop when the last product price guess was sufficiently close to the price solution from the current iteration.

Besides the National Forest supply model, the regional stumpage market model includes:

i. Lumber and plywood supply relations, which depend on product prices, nonwood costs, current stumpage price, and production capacity.

ii. Lumber and plywood capacity adjustment relations, which depend on a distributed lag in past profit margin.

iii. Forest industry and other private stumpage supply relations, which depend on spot stumpage price and inventory.

iv. Inventory relations, which update private inventory for harvest and growth.

v. A stumpage supply-demand balance relation (equation 20).

Timber harvest from other Government sources and stumpage demands for miscellaneous products and log exports are taken as exogenous. Product overrun and recovery factors are also set externally.

Equations for behavioral relations i-iii above were derived from the TAMM model. Table 6 gives a summary view of model characteristics in the form of key supply and demand elasticities from both structural and partially reduced form relations. At mean values over the 1977-85 sample period, product supply elasticities from the structural relations range from 0.4 to 0.6, values consistent with findings in most recent econometric studies. This range is reduced somewhat if stumpage price feedback accompanying any product supply shift is recognized. Aggregate stumpage demand is highly inelastic in product price shifts (given the intermediating influence of recovery) and is only modestly sensitive to stumpage price (-0.1). Non-National Forest supply is also inelastic (0.36), industrial supply being its most price-sensitive component.

Table 6—Structural and reduced form elasticities from PNWW regional timber market model computed at 1977-85 sample averages

	For:[a]		
Elasticity of:	Lumber price	Plywood price	Stumpage price
Lumber supply	0.417S/0.374R	–0.030R	–0.135
Plywood supply	–.042R	.556S/.527R	–.132
Industry harvest			.506
Other private harvest			.297
Total stumpage demand	.021	.014	–.101
Non-National Forest timber supply			.359

[a] R refers to reduced-form equations (not including capacity adjustment effects), and S refers to structural equations.

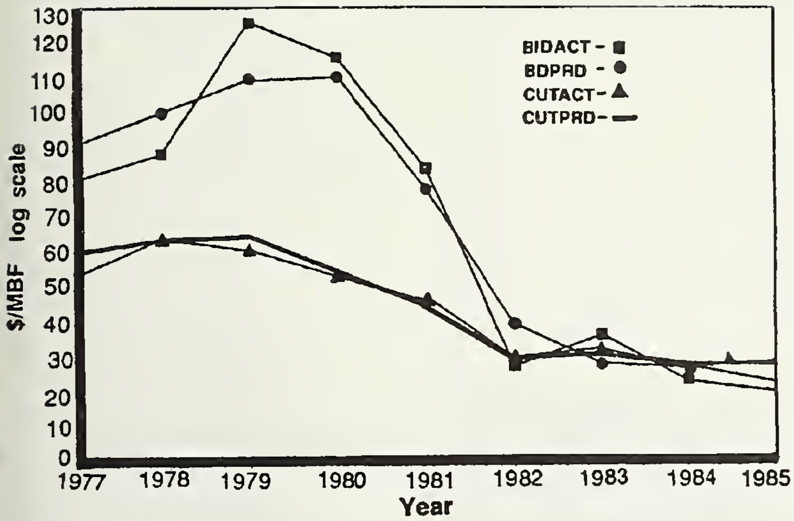

Figure 15—Simulated and actual real National Forest bid and cut prices in the PNWW, 1977-85.

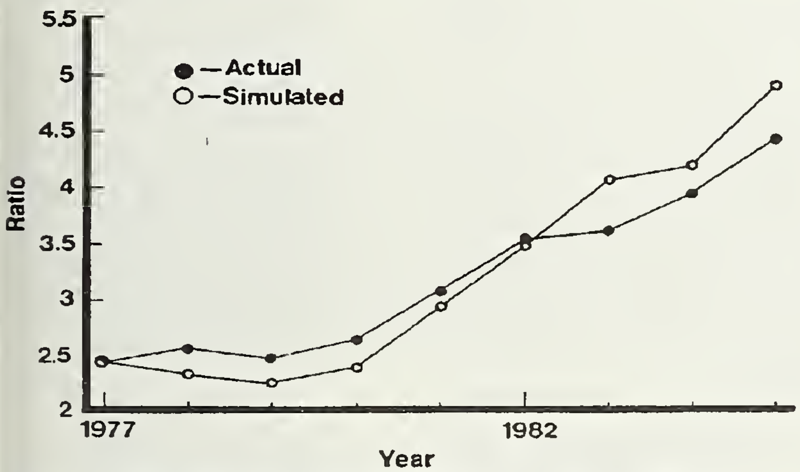

Figure 17—Simulated and actual uncut/sold volume ratio on the National Forests in the PNWW, 1977-85.

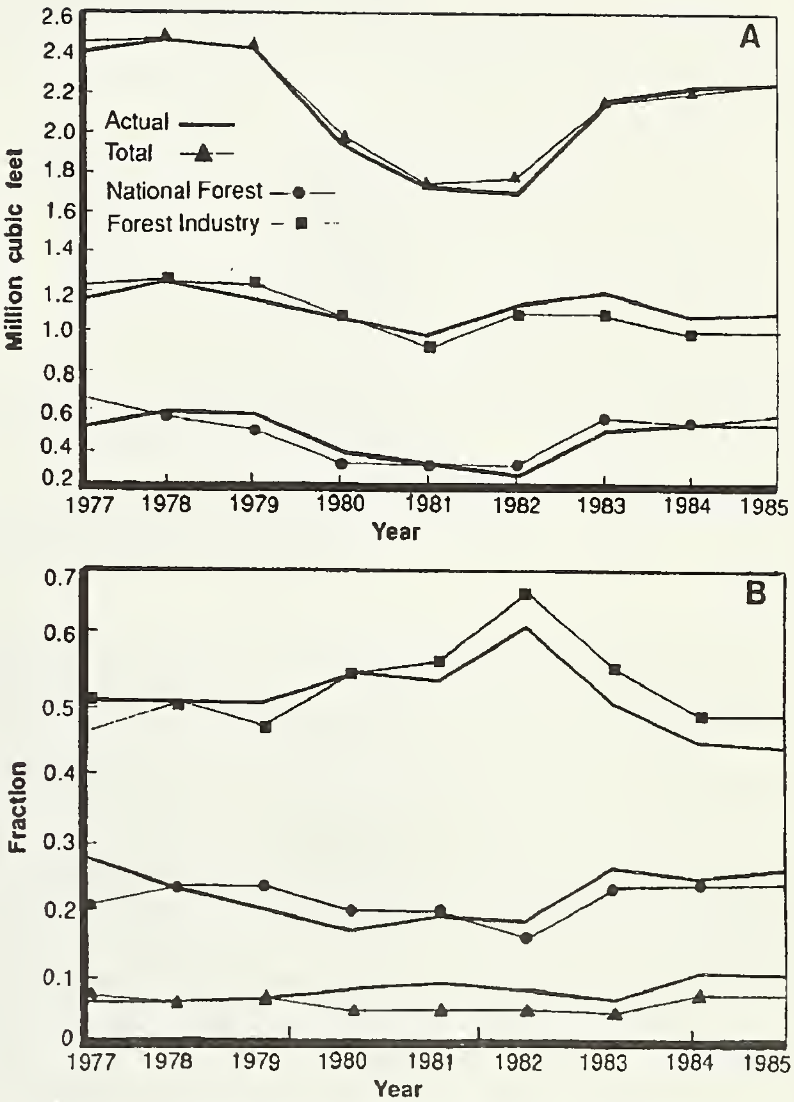

Figure 16—(A) Actual and projected total harvest, National Forest harvest, and forest industry harvest; and (B) share of sawtimber harvest accounted for by each ownership, by owner group in the PNWW, 1977-85.

Historical Simulation: 1977-85

Results of model simulation for key elements of the National Forest supply model are shown in figures 15-17. Error measures are summarized in table 7 for bid and cut prices and National Forest harvest volume. To interpret these results, the reader should recall that bid price is determined by a regression relation with product prices and nonwood costs as regressors. These latter determinants are established exogenously in the simulation, so that bid price should track actual levels fairly well (as suggested by the correlation coefficients in table 2). Cut price and harvest volume, on the other hand, are determined by the mechanisms described in the preceding sections and not by a regression. There is no assurance whatever that simulated values of these variables will track actual levels.

Table 7—Summary of error measures for historical simulation, 1977-85

Variable	AAPE[a]	RMSE[b]	U[c]	r^2[d]	Turning point errors: On U[e]	Turning point errors: On YHAT[f]
Bid price	16.3	0.143	0.447	0.94	0	3
Cut price	4.3	.060	.234	.97	1	1
Cut volume	12.2	.152	.384	.68	0	2

[a] AAPE is average absolute percentage error.
[b] RMSE is the root mean square error as a ratio to the variable mean.
[c] U is Theil's (1971) inequality coefficient computed on the basis of percentage changes in actual and predicted variables.
[d] r^2 is the simple correlation coefficient of actual and predicted values.
[e] Turning points determined from last actual observation.
[f] Turning points determined from last predicted observation.

In the graphic results, simulated bids do not rise to the full extent of the peak in 1979 (fig. 15) and suffer the largest errors in the high-price period of the late 1970s. Cut prices move closely with actuals. National Forest harvest volumes (fig. 16a) show a substantial error in the starting year. Errors in tracking of industrial and other private harvest appear to be compensating (fig. 16b) with the sustained overestimate of industrial cut offsetting the underestimate of other private. Note that simulated harvest shares for National Forest and industrial owners clearly show the traditional opposing cyclical pattern. Finally, the simulated ratio of uncut to sold volume (fig. 17) follows the general pattern of the actual ratio but misses the actual level in most years. This is partially a reflection of errors in the model, and is also a result of adjustments in Forest Service reports of uncut volume due to defaults, cruise-cut errors, and withdrawn sales that cannot be simulated.

These observations are born out in the various error measures in table 7. Cut price has the smallest absolute and relative error, while those for bid price and harvest volume are larger. Note that the inequality coefficient results (U) are based on percentage changes from the actual level in the preceding period (see Theil 1971). Analysis of errors in this form (essentially as one-period forecasts) revealed no consistent tendency of the model to overestimate or underestimate price and volume changes and showed only one turning-point error. Turning-point errors based on the simulated level of the last period are more numerous.

Projection to 2000

As a further test, the model was used to simulate prospective future developments in the PNWW stumpage market up to 2000. Such a test has value for two reasons: First, although nothing is known with certainty about the future level of market prices and volumes, expectations do exist about how the market should behave under certain sets of hypothetical conditions. Because our expectations may be wrong, conformance of model results and expectations is, to be sure, only a weak test. Deviation of model results from expectations, however, requires an investigation of model logic and may suggest modifications in the model, in expectations, or both. Second, as noted, the 1977-85 period was an advantageous historical sample because of wide variations in prices and volumes. It was highly atypical, however, in the accumulation of a large uncut volume at high prices, maintenance of this backlog through a series of across-the-board contract extensions, and eventual elimination of the backlog through policy action. Because the contract extensions and relief legislation are external influences on the model, the historical simulation provided a test of model simulation capabilities over a fairly special set of conditions. A view of model behavior under less extreme conditions is needed.

Our specific scenario of market development from 1987 to 2000 was derived from a variety of independent macroeconomic and forest industry forecasts. Key assumptions are summarized in the top part of table 8. In broad terms, the outlook shows a series of three cyclical upswings peaking in 1989, 1993, and 1997 followed by (monetary) policy-induced recessions. Lumber demand remains at (historically) high levels and follows the cyclical pattern but shows no trend. Declining consumption in residential construction (as a result of declining household formation) is offset by increased use in nonresidential construction, residential maintenance and alteration, and manufacturing. Plywood consumption declines steadily in the face of substitution by OSB-waferboard. Product prices in this scenario are cyclical but show no trend in real terms after the 1989 peak. Log exports from the PNWW decline gradually from recent levels, thereby reflecting expanding self-sufficiency in key offshore markets and increased competition from other log and solid wood products suppliers. Log export prices are also cyclical with no real trend.

As noted earlier, the volume of unsold timber on National Forests in the PNWW has averaged about 3 percent of the volume offered during the late 1970s and early 1980s. In light of this small volume, and to avoid the need to project appraised prices, we have not incorporated the unsold volume relation in the future projection. We assume that volumes of National Forest timber sold will average some 3.0 billion board feet per year, down roughly 10 percent from their 1975-85 average level as a result of revised management plans. Over most of the period from 1950 to 1985, National Forest sold volumes in the PNWW fluctuated from year to year in a fairly regular cycle with a period of about 2 years. The range of variation (ignoring trend) has been about 500 million board feet. A similar cycle was introduced in the forecast, with sold volume ranging between 2.75 and 3.25 billion board feet around the mean of 3.0 billion board feet.

Table 8—Principal input assumptions and projection results for the simulation of PNWW stumpage markets to 2000

		Period average			
Input assumptions	Units[a]	1985	1986-90	1991-95	1996-2000
Real lumber price	1967$/mbf, lt	69	80	77	78
Real plywood price	1967$/msf	54	57	55	56
Real export log price	1967$/mbf, lt	105	107	120	119
Export log volume	mmbf, ls	3004	2961	2860	2760
Nonwood costs: lumber[b]	1967$/mbf, lt	55	55	55	55
Nonwood costs: plywood[b]	1967$/msf	41	42	42	42
Other Government harvest	mmcf, ls	432	385	385	385
National Forest sold[c]	mmbf, ls	2792	3000	3050	2950
Forecast results					
Lumber production	mmbf, lt	8062	8329	7437	6921
Plywood production	mmsf, 3/8 inch	7658	7778	8044	8247
Statistical high bid	1967$/mbf, ls	20	36	40	41
Average cut price	1967$/mbf, ls	28	32	40	43
National Forest harvest[c]	mmcf, ls	649	726	599	582
Uncut volume[d]	mmcf, ls	2865	1512	1176	1145
Industry harvest[c]	mmcf, ls	1159	1089	1032	930
Other private harvest[c]	mmcf, ls	266	268	285	296

[a] lt = lumber talley; ls = log scale.
[b] Net of residue revenue.
[c] Sawtimber plus nonsawtimber volume.
[d] Sawtimber volume only.

In terms of product prices, this scenario is reminiscent of market conditions in the 20 years before 1970. Under less exaggerated cyclical conditions and in the absence of any product price trends, we would expect no trends in either bid or cut prices, except as these might arise from improving recovery or declining nonwood costs. As was the case from 1950 to 1970, we would expect bid and cut prices to cycle around roughly the same average levels (without the wide departures of the 1970s). We would also expect cut and sold volumes to move gradually into line, with no major accumulation or decline in the uncut volume under contract.

Implementation of the Federal Timber Contract Modification Act (U.S. Laws, Statutes 1984) removed only a portion of the high-cost timber from the uncut backlog. Some 2.0 billion board feet remain at prices of $50/mbf and higher. In the simulation, these volumes were not given differential treatment. Further special arrangements may in fact be made for the disposition of this timber; if it was not harvested by its scheduled termination date in the simulation, it was assumed to be defaulted.

Results of the projection to 2000 are shown in figures 18-20 for prices, harvest volumes, and the uncut volume under contract. Additional results are summarized in the lower portion of table 8. Bid and cut prices cycle around roughly the same average level as expected and show little trend after the 1989 peak (see fig. 18). As was often, though not consistently, the case from 1950 to 1970, cyclical peaks and troughs in cut prices tend to lag behind those in bid prices. This partially reflects the movement of the high-cost material sold in the preceding bid-price peak through the uncut volume inventory. In the forecast, the amplitudes of bid- and cut-price cycles are more nearly equal than was the case in the 1950-70 period.

National forest harvest (fig. 19a) declines from the forecast 1987 peak, as cheap timber sold during the period of low bid prices from 1983 to 1986 is gradually removed from the uncut inventory. After this transition and with bid prices increasing, harvest settles into the same cycle as sold volume oscillating around the 0.6-billion-cubic-foot (3.0-billion-board-foot) level. The opposing cycles in industrial and National Forest cut observed in the past persist in the forecast.

After a major drop in 1986 resulting from the Federal Timber Contract Modification Act (U.S. Laws, Statutes 1984), the ratio of uncut to sold volume (fig. 20) continues a gradual decline until the early 1990s. The post-1986 decline reflects continued elimination of high-cost timber from the uncut inventory. Simulation results indicate that about 1 billion board feet of the residual higher cost timber not removed under the Federal Timber Contract Modification Act (U.S. Laws, Statutes 1984) cannot be harvested at prospective future prices. This volume is defaulted in two major blocks in 1988 and 1990. The uncut-to-sold volume ratio subsequently stabilizes, oscillating around the 1.9:1 level. This is somewhat lower than average levels in earlier "normal" periods as a result of the assumed reduction in the volume of National Forest timber sold (to 3.0 billion board feet) and the greater concentration of sales in shorter duration classes beginning in 1981.

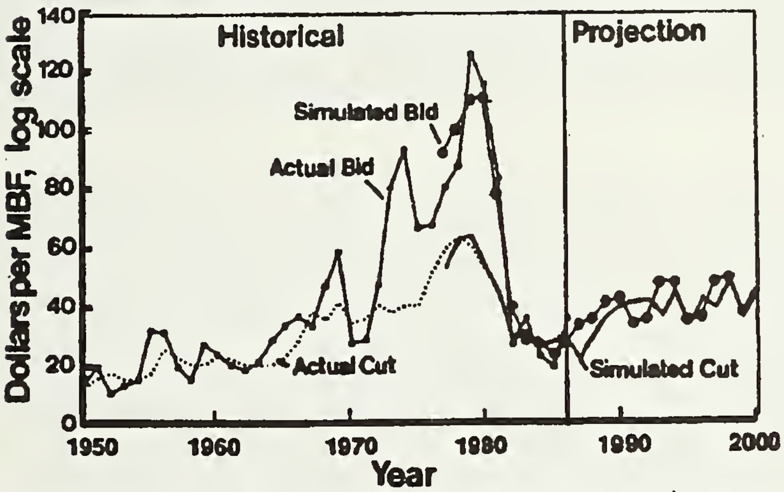

Figure 18—Projected and actual National Forest bid and cut prices in the PNWW region, 1950-2000.

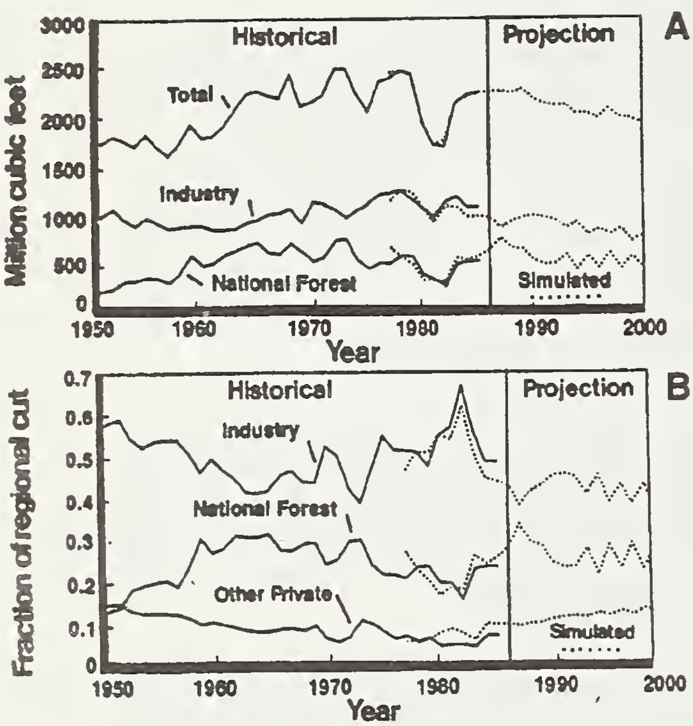

Figure 19—(A) Total harvest ownership, and (B) share of sawtimber harvest accounted for by each ownership, by owner group in the PNWW, 1977-2000.

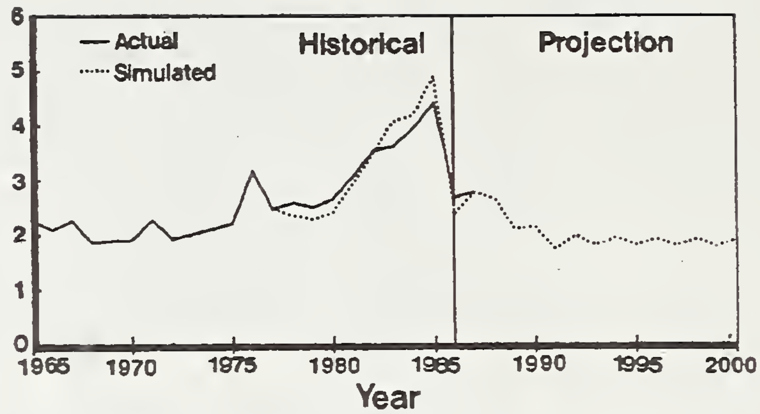

Figure 20—Projected and actual ratio of uncut to sold volume for National Forests in the PNWW, 1977-2000.

Conclusions

This study portrayed the National Forest timber supply process as a series of linked steps or subprocesses ultimately transforming the Agency's planned or allowable cut level into timber volumes harvested. In earlier research, the initial portions of this process—determining the volumes to be offered, establishing the appraised price, and bidding—have generally received the greatest attention. Our analysis makes clear, however, that the uncut volume inventory forms the actual interface between regional stumpage markets and the National Forest supply process. To understand the near-term effects of changes in some aspect of National Forest supply policy on regional timber harvest and prices, one must be able to translate policy shifts into the associated changes in the structure of the uncut volume inventory. The model we developed provides one vehicle for this analysis.

The volume of timber offered for sale in any given period is heavily dependent on the outcome of Congressional budget deliberations. The Agency proposes an offering level based on its policy analysis and decisions under the Renewable Resources Planning Act, but the level of sales authorized depends on available funding for sale preparation and execution (including road construction). Given some volume to be offered for sale, the Agency identifies specific sale parcels and establishes a minimum acceptable price for each sale through an appraisal. The appraisal employs the residual value method.

The sale price for most parcels is established through some form of competitive bidding, either oral or sealed. Preliminary analysis of the time series characteristics of aggregate regional bid prices suggested a market that is relatively efficient in using information relating to timber value and that responds rapidly to changes in this information. Our theoretical model of bid price behavior presumes that the bid is based on buyers' expectations for the future value of the timber being purchased. Expectations were represented by a distributed lag in a constructed timber-value variable. Regression results for the four Western regions indicated that a simple linearly distributed lag with a single lag term was most appropriate. The significance of the once-lagged term, though it has a consistently smaller weight than the unlagged value, suggests some inefficiency in the formation of buyers' expectations. The distribution of sales by bid-price class was approximated by a two-parameter Weibull distribution with parameter values linked to the average regional bid price. Sale distribution by contract duration class derives from Agency policy. Estimates of the joint distribution of sales by both bid and duration class approximated the general structure of observed distributions in the PNWW.

Not all timber offered for sale is actually sold. The geographic pattern of unsold volume appears to parallel variation in competition for sales: regions with low average overbids tend to have the largest fractions of unsold volume. Within a given region, the fraction of uncut volume over time is modeled as a function of the ratio of appraised price to bid price and characteristics of the aggregate of sales offered (sale method, sale size and duration). Tests of this approach in the PNWW and PNWE provide some support for this hypothesis.

The uncut volume under contract is the inventory from which purchasers draw timber for current harvest. In the present study, this inventory is categorized by bid-price class, contract duration, and the year the timber is sold in. The sold volume in any given year is disaggregated by these three categories and added to the residual volumes from sales in earlier years. Our basic hypothesis is that the uncut volume cumulated by bid-price class represents the effective National Forest supply function. Analysis of this relation in the PNWW over the past decade indicates that it has generally had at least unitary elasticity, making it the most price-sensitive component of short-term regional timber supply.

Over time, the cumulative uncut volume shifts in response to harvest and the addition of new volume sold. Because the uncut volume averages two to three times current harvest and sold volumes, however, the impact of changing market conditions on the inventory is buffered by the residual volumes carried over from one period to another. As a consequence, the cumulative uncut-volume function shifts upward in price-quantity space less rapidly in rising markets and downward less rapidly in falling markets. Both the high elasticity and lagged shifts in National Forest supply over time account for the counterpoising changes observed in National Forest and private harvest shares in the Western regions. During rising markets, the share of National Forest harvest tends to rise and the private share tends to fall. Shares change in the reverse direction in falling markets. The traditional assumption of perfectly inelastic National Forest supply is clearly inappropriate, because one would expect to observe precisely the opposite pattern of changes in shares.

Volumes harvested and average harvest price are determined in the proposed model by simple supply-demand equations, where regional supply includes all private and public elements and demand includes the stumpage demands of all sawtimber-consuming industries. This approach assumes that National Forest timber and timber from all other sources are perfect substitutes in the processing industries. As a consequence, average National Forest harvest price is used as the measure of regional price. The results of a comparative analysis of National Forest cut price and estimates of cut price derived from independent reports of log prices provide some support for the assumption of cut-price equality across ownerships. Establishment of the harvest price in the manner proposed here also highlights the marked differences between bid and cut prices. Current-period National Forest bid price is clearly an inappropriate estimate of the average cost of stumpage for current harvest, as often was assumed in earlier studies.

To examine the explanatory ability of the full model, we first simulated historical developments in the stumpage sector of the PNWW region from 1977 through 1985. Both prices and volumes fluctuated widely during this period and induced major shifts in the structure of National Forest uncut volume. This was a fairly stringent test of the model, because errors in either the bidding or harvesting portions of the structure could accumulate in the uncut volume inventory leading to progressive deterioration of predictions over time. Analysis of simulation performance and errors indicated that this was not the case. The model appears to track historical behavior of bid and cut prices, harvest volumes, and the uncut volume under contract reasonably well. We conclude that these results provide some support for the overall theory proposed.

A further test of the model involved a simulation of future stumpage market behavior in the PNWW from 1986 to 2000. It was assumed that product and export log markets would experience modest cyclical swings during this period, but there would be no significant real appreciation in product or export log prices would occur. Even though product output and stumpage demand remain near recent record levels, the general economic environment is similar to that observed during the 1950s and early 1960s. National Forest volumes offered (and sold) were assumed to decline by roughly 10 percent from recent average levels as a result of management policy changes. Under these conditions, we expect that there will be little or no real appreciation in stumpage prices, that bid and cut prices will fluctuate around each other over time with no consistent diverging trend (such as that observed in the 1970s), and that the ratio of uncut volume to sold volume will gradually decline and stabilize at a somewhat lower level than observed during the 1960s and 1970s.

Simulation results conform closely to these expectations. In addition, the model continues to show the counterpoising movements in National Forest and private harvest shares observed in the past and reproduces the 1-year lag between cyclical peaks and troughs in bid and cut prices characteristic of the 1950-68 period. This simulation also suggests that roughly 1 billion feet of high-priced timber sales not excused under the Federal Timber Contract Modification Act (U.S. Laws, Statutes 1984) will be defaulted by 1990.

As a result of our analysis, we believe that the proposed model structure offers considerable promise as tool for analyzing regional stumpage markets and assessing the impacts of changes in National Forest timber supply policy. Though we have not explored these options here, it would be possible to examine changes in methods of appraisal (for example, use of a transactions-evidence approach in which appraised price is a function of past bid prices), shifts in the volume of timber offered, changes in contract duration, alternative forms of price escalation, and changes in policies on sale contract extension. There are also numerous options for extending and further testing our basic results, including:

- Applying the model to other regions in the West, particularly areas of the Rockies or the PNWE characterized by large unsold volumes and low competition for sales.

- Further refinement of the bid- and cut-price dispersion mechanisms by using more observations and alternative distributional assumptions.

- Incorporating the model into a larger market simulator to examine the effects of contemporaneous feedback between bid, cut, and product prices.

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Appendix 1

Development of the Bid-Price Expression

The first element of National Forest timber supply available for future harvest is the volume of timber sold in current sales. Consider the relation between successively higher bid-price levels and the cumulative volume of timber sold at those prices or less as illustrated by curve CS_o in figure 21a. Because sales are sold in discrete quantities, this curve should be a step function with each step corresponding to the volume of sales sold at successively higher bids. Assume for simplicity that the actual volume distribution of bids (of the sort illustrated in fig. 5) can be fully described by a single parameter, the average bid price or BP. The cumulative sold function in figure 21a might then be written as:

$$CS = CS(p, BP, S) , \tag{21}$$

where

CS = the cumulative volume sold at bid price p or less,
BP = the average bid price of all volume sold, and
S = the total volume sold.

Curve CS_o represents a total volume sold of S_o at an average price (and associated distribution) of BP_o.

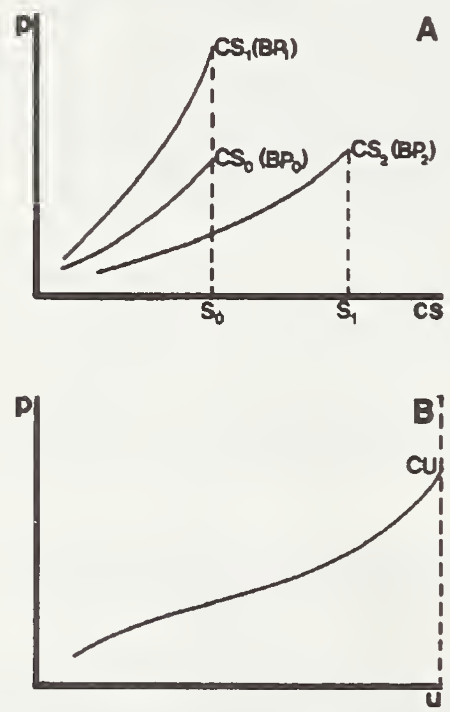

Figure 21—(A) Cumulative sold volume function and shifts with changing average bid (BP_i) and volume sold (s_j).
(B) Persale uncut volume under contract cumulated at successively higher bid prices.

The function CS will be constant or increasing in p. If the volume sold should increase, say from S_o to S_1, but BP remains constant, the CS function might shift as indicated by CS_2. At any given p, more volume has been sold at p or less. For a given p and BP, CS increases as S increases. If S should remain constant but BP rise, as from BP_o to BP_1 in figure 21a, the CS function might shift to CS_1. In this case and at any given p, a smaller fraction of the total S_o has been sold at an average price of BP_1 than was the case at BP_o . For a given S and p, CS declines as BP increases. The above discussion suggests that the partial derivatives of CS (denoted by subscripts) will have the following signs:

$$CS_p > 0 \,, \quad CS_S > 0 \,, \text{ and} \quad CS_{BP} < 0 \,. \tag{22}$$

Obviously, this analysis assumes a great deal of regularity in the behavior of CS, but exceptions can be found. As a first approximation, though, the conditions in (22) seem reasonable and will be used in the subsequent development.

The second element of National Forest supply is the presale uncut volume under contract. Prices and volumes of this timber are known, it being the residual from past sales and harvesting. If the volume in this inventory were cumulated by increasing price (as was done with the CS function), a relation similar to CU in figure 21b might result. Although the actual shape and slope of CU will vary over time, empirical investigation (see detailed discussion below) indicates that its shape is most commonly an inverse sigmoid. If U represents the total presale uncut volume available, CU may be written as:

$$CU = CU(p, U) \,, \text{ and} \tag{23}$$

$$CU_p > 0 \,. \tag{24}$$

Note that U is a parameter in (3) and CU_U may take any sign.

At the conclusion of the bidding process, the total National Forest supply available to buyers for harvest in the forthcoming period is:

$$NFS = CS + CU \,. \tag{25}$$

From (22) and (24) we have that

$$NFS_p > 0 \,, \quad NFS_{BP} < 0 \,, \text{ and} \quad NFS_S > 0 \,. \tag{26}$$

The demand for National Forest timber derives from the production of lumber, plywood, logs, and other products in the region adjusted for supplies from non-National Forest sources. Total derived demand depends, in turn, on prices of products, the nonstumpage costs of manufacture, characteristics of the several production technologies, and the price of stumpage. Non-National Forest supply, from private and other Government ownerships, depends on stumpage price and an array of other shifters (in the case of private owners, these might include growing stock inventory; other Government supply might have a structure similar to that being developed here for the National Forests). For this analysis, we will ignore these latter elements.

Let the function D represent net demand for National Forest timber as described above:

$$D = D(p, X) \, , \qquad (27)$$

where

X = a vector of buyers' expectations for future product prices and costs.

We would anticipate that:

$$D_p < 0 \, . \qquad (28)$$

Within vector X, signs of the partial derivatives of D should be positive for product prices and negative for nonstumpage costs.

Equilibrium in the National Forest stumpage market requires that

$$D = NFS \, , \qquad (29)$$

which asserts that future spot stumpage price is established by the interaction of the net National Forest demand and total uncut volume under contract functions. Equation (29) gives p implicitly as a function of X, S, and the as yet undetermined average bid price, BP.

To complete the system, we restate our initial hypothesis, that bid price is a function of the expected future spot price of stumpage:

$$BP = BP(p) \, , \qquad (30)$$

where theory and empirical results lead us to expect that

$$BP_p > 0 \, . \qquad (31)$$

The basic bid price expression derived from the preceding development is the reduced form equation for BP from equations (29) and (30):

$$BP = BP(X, S) . \qquad (32)$$

Appendix 2

Empirical Evidence

Expectations about the signs for X, S in equation (9) can be derived from empirical evidence. Taking the total differentials of equations (29) and (30) we obtain:

$$D_X \, dX + D_p \, dp = NFS_p \, dp + NFS_{BP} \, dBP + NFS_S \, dS \text{ , and} \qquad (33)$$

$$dBP = BP_p \, dp . \qquad (34)$$

Equations (33) and (34) can be solved by either Cramer's rule or simple substitution to yield:

$$dp = (NFS_S \, dS - D_X \, dX)/(D_p - NFS_p - BP_p \, NFS_{BP}) \text{ , and} \qquad (35)$$

$$dBP = BP_p[(NFS_S \, dS - D_X \, dX)/(D_p - NFS_p - BP_p \, NFS_{BP})] . \qquad (36)$$

Assuming dS/dX and dX/dS are both zero, the signs of dp/dX, dBP/dX, dBP/dS, and dp/dS will depend on the sign of the denominator in expressions (35) and (36), namely $D_p - NFS_p - BP_p \, NFS_{BP}$. After further manipulation, it is seen that the sign of this expression depends on the sign of the elasticity expression:

$$e_{D,p} - e_{NFS,p} - e_{BP,p} \, e_{NFS,BP} \text{ ,} \qquad (37)$$

where

- $e_{D,p}$ = the elasticity of derived demand for National Forest stumpage;
- $e_{NFS,p}$ = the elasticity of total uncut volume under contract (including presale plus current sale components) for stumpage price;
- $e_{BP,p}$ = the elasticity of bid price for expected stumpage price; and
- $e_{NFS,BP}$ = the elasticity of total uncut volume under contract for bid price in the current sale component.

The terms $e_{D,P}$ and $-e_{NFS,P}$ are unambiguously negative, but the third term is positive for our argument that $NFS_{BP} < 0$. Past research and analysis of the characteristics of the uncut volume under contract provide a basis for estimating the relative sizes of the three terms. We use the Douglas-fir region as an example.

Estimates by Adams (1983) suggest that the elasticity of aggregate derived demand for stumpage in subregions of the Douglas-fir region ranges from -0.14 to -0.35, and aggregate private stumpage supply elasticities range from 0.15 to 0.34. Ignoring supplies from non-National Forest Government lands and assuming average regional demand and private supply elasticities of -0.22 and 0.22, respectively, these results suggest an elasticity of demand for National Forest timber alone of $e_{D,p} = -1.54$.[1] Examination of National Forest uncut volume under contract in the Douglas-fir region since the mid-1970s reveals that its average (arc) price elasticity is relatively high. In the neighborhood of actual volumes harvested, a conservative estimate of the elasticity would be $e_{NFS,p} = 1.2$.

The elasticity of National Forest supply for bid price ($e_{NFS,BP}$) is an artificial construct. In the foregoing analysis, it was convenient to assume that bidding on sales occurred only at the beginning of each period and that total uncut volume under contract could be divided into two parts: (i) a presale component with the prices and volumes fixed from past bidding and harvests, and (ii) an increment from current sales with given volumes but with prices determined in the current round of bidding. The sum of these two elements is the total uncut volume available for harvest in the forthcoming period. In fact, of course, sales and harvest proceed continuously and the structure of the uncut volume inventory shifts gradually over time.

It is still possible to make an estimate of $e_{NFS,BP}$ by (i) using the actual historical uncut volume at the start of a given year as the presale uncut volume, and (ii) adding actual sold volumes from the ensuing year at average bid prices differing by fixed percentages from actual average bids. Comparison of actual and simulated uncut volumes by price class provides the basis for estimation of $e_{NFS,BP}$.[2] In conducting these analyses from 1977 through 1985, we found that the impact of a given change in average bid price on the uncut volume varied depending on the level of current bids relative to the average level of bids and cumulative volume in the uncut volume inventory. Values of $e_{NFS,BP}$ ranged from -0.77 in 1978 to -0.42 in 1985. The later years of the sample period were somewhat atypical, because the uncut volume was nearly twice its normal size and contained a large volume of sales at prices much higher than current bids. Values near the high end of the range may reflect "normal" conditions where current and past bids are roughly similar and the uncut volume is roughly two to three times current harvest. We adopt a value of $e_{NFS,BP} = -0.75$ as representative.

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[1] If demand for National Forest timber is the difference between total derived demand for stumpage and private supply, its elasticity can be estimated from the expression $e_D(1/s_{NF}) - e_{PS}(1/s_{PS} - 1)$ where e_D is the elasticity of total derived demand for stumpage, e_{PS} is the elasticity of private supply, and s_{NF} and s_{PS} are the respective shares of National Forest and private suppliers in total stumpage supply. In recent years, National Forests in the Douglas-fir region have supplied roughly 25 percent of total regional harvest. Using the above expression and the average demand and private supply elasticities of -0.22 and 0.22 yields an estimate of the elasticity of demand for National Forest timber of -1.54. This is an underestimate, however, because we ignored any elasticity in the supply of timber from other public ownerships.

[2] The analysis described here was conducted with the simulator developed for the Douglas-fir region market. Because a change in current period average bid also influences the dispersion of bids across bid price classes, this effect is incorporated in the resulting elasticity estimates.

The final element of equation (37) is the elasticity of bid price for expected spot stumpage price. Past theoretical studies of the bidding process provide a limited basis for generating expectations of the magnitude of this elasticity. In the bidding structure developed by Rucker (1984), for example, it is demonstrated that $e_{BP,p} > 1$, depending on the specific form of the increase in p and on the unknown probability distribution of expected future stumpage price growth. A similar result comes from Alden's (1984) model, because expected price at time of sale must be at least as large as bid price if there is a positive risk premium. Of the many empirical studies in the forestry literature, only the work by Berck and Bible (1985) provides readily interpretable results. In our study, expected future price was calculated as the appraised price (taken as the current spot stumpage price) adjusted for price growth as estimated from lumber and plywood future contract prices. Berck and Bible found values of BP_p on the order of +2.2 for sales in the Siuslaw National Forest during the 1972-82 period from which we compute an elasticity ($e_{BP,p}$) slightly greater than unity.

Combining the results of the above discussion in expression (37)

we obtain:

$$e_{D,p} - e_{NFS,p} - e_{BP,p}\, e_{NFS,BP} = -1.54 - 1.2 + -0.75 e_{BP,p} \,. \qquad (38)$$

This expression will be negative for values of $e_{BP,p}$ greater than -3.6 in algebraic terms. Available empirical and theoretical results suggest that this elasticity may be only modestly less than -1.0. As a consequence, we conclude that the denominator of expressions (35) and (36) is negative in practical cases of interest for the PNWW region and hence that:

$$\frac{dp}{dX} > 0, \frac{dp}{dS} < 0, \frac{dBP}{dX} > 0, \text{ and } \frac{dBP}{dS} < 0 \,. \qquad (39)$$

Expected future spot and current bid prices will rise as expected future market conditions improve (X increases) and fall as the volume sold (S) increases.

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Adams, Darius M.; Haynes, Richard W. 1991. National Forest timber supply and stumpage markets in the Western United States. Res. Pap. PNW-RP-435. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 55 p.

This paper presents an aggregate regional model of the National Forest timber supply process and the interaction of National Forest and non-National Forest supply in determining regional stumpage prices and harvest volumes. Model simulations track actual behavior in the Douglas-fir regional stumpage market with reasonable accuracy; projections for the next two decades suggest that little real appreciation in stumpage prices will occur, that cut and bid prices will fluctuate around each other, and that the ratio of uncut volume to sold volume will gradually decline and stabilize at somewhat lower levels than were observed during the 1960s and 1970s.

Keywords: Market model, timber supply, National Forest timber sales, bidding, forecasting, econometrics.

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