Costs and regional impacts of restoration thinning programs on the national forests in eastern Oregon

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Abstract: An intertemporal spatial equilibrium model of the eastern Oregon softwood log market was employed to estimate the market and economic welfare impacts of restoration thinning programs established on national forests in the region. Programs treated only lands with sawtimber thinning volume and varied by the extent of public subsidies for costs, the types of costs that could be subsidized, and the form of the subsidy payment. Impacts on private harvest timing, numbers of mills, and postprogram log prices in the region were found to vary markedly with the form of the program. Log consumers (lumber mills) consistently realized relatively large surplus gains, while private log producers' surplus showed smaller but consistent losses. For a comparable subsidy budget, programs that subsidized only hazard removal costs, on sites where net unsubsidized sawtimber returns promised to be less that these costs, led to a larger area treated than did programs with more flexible subsidy conditions. Across all programs, net agency receipts from sawtimber sales were estimated to be insufficient to cover the costs of all areas in need of thinning treatment (lands with and without sawtimber thinning volume).

Résumé : Les auteurs considèrent le marché des billes résineuses de l'est de l'Oregon, défini à l'aide d'un modèle d'équilibre spatial inter-temporel, pour estimer l'impact des programmes d'éclaircie de restauration mis en œuvre dans les forêts nationales de la région sur le bien-être économique et sur le marché comme tel. Ces programmes visent seulement les zones présentant des volumes d'éclaircie de qualité sciage. Ils varient selon l'envergure des subventions qui couvrent les coûts de réalisation des travaux d'éclaircie, le type de coûts pouvant faire l'objet de subventions et la forme sous laquelle les subventions sont versées. Les impacts sur la programmation des coupes, le nombre d'usines et le prix des billes en région après la fin des programmes varient sensiblement selon la forme des programmes. Les consommateurs de billes (usines de sciage) ont constamment réalisé des gains excédentaires relativement importants tandis que les producteurs privés de billes ont subi des pertes plus faibles quoique constantes. Avec des budgets similaires, les programmes qui subventionnaient seulement le coût d'enlèvement des tiges dites « dangereuses », sur les sites où les revenus nets escomptés d'une intervention non subventionnée auraient été inférieurs, ont permis de traiter de plus grandes superficies que les programmes de subvention dont les conditions sont plus flexibles. Considérant l'ensemble des programmes, les revenus nets tirés des ventes de billes de sciage par l'agence s'avèrent insuffisants pour couvrir le coût du traitement de toutes les superficies nécessitant une éclaircie (zones avec et sans volume d'éclaircie de qualité sciage).

[Traduit par la Rédaction]

Introduction

Millions of acres (1 acre = 0.4047 ha) of the national forests in eastern Oregon are at increased risk of damage from fire because of dense stocking and abnormal accumulations of fuel. Stemming, in part, from a long history of indiscriminate fire suppression and from cutting practices that focused on ponderosa pine, the "forest health" issue has become prominent in recent years as a result of several seasons of large wildfires and increased attention from the media and high-level policy-makers. Thinning these stands to lower mortality in the residual stems and to reduce fuel hazards has been proposed as one approach to restoration.[2] Though many considerations come into play, the feasibility and desirability of thinning programs will depend, in part, on the costs of thinning, the quality of the material to be removed, and the impacts of potentially large volumes of thinned material on regional markets and market participants. The type and conditions of any cost subsidies associated with a thinning program will also influence the area of forest that can be treated. Of particular concern are (*i*) the fraction of the costs of removing merchantable logs and nonmerchantable hazard material that is to be subsidized, and (*ii*) any site or financial conditions that must be met to be eligible for subsidy payments.

This paper employs a dynamic, spatial equilibrium model of the eastern Oregon forest sector and timber resource to

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[2]The Healthy Forests Restoration Act of 2003 was enacted to address these issues, but its provisions have yet to be elaborated or made operational (see http://www.healthyforests.gov/initiative/legislation.html and associated links, accessed 15 September 2004).

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examine the market and welfare impacts of a set of hypothetical restoration thinning programs on national forests. The analysis provides estimates of the areas that might be treated under various types of thinning programs and associated levels of subsidy expenditure as well as the program-induced impacts on log consumers' and producers' surpluses in the eastern Oregon sawtimber sector. We also describe the potential effects of thinning programs on aggregate regional log production and prices and on more detailed aspects of sector behavior such as the number of mills and processing capacity. In the following sections we review past work on the economics of restoration thinning programs, outline the models developed to describe the regional market and timber resource, discuss the thinning programs to be examined, and present projection results. A final section offers some observations on the implications of our simulation experiments for the future development of restoration thinning programs in eastern Oregon and similar areas.

Studies of restoration thinning

Widespread interest in restoration thinning programs is of relatively recent origin. Most studies, including those that deal with economic issues, have focused at the "project level" and have looked at specific cases and site conditions and (or) treatment methods that influence costs and revenues. Fiedler et al. (1999), for example, considered a range of treatment methods and site conditions in the northern Rockies to develop broad guidelines for designing projects that might produce revenues in excess of treatment costs. They conclude that to be useful in restoring ecosystem function, thinnings should reduce stand density enough to allow reproduction and increase the vigor and the growth of residual stems. Thinning across diameter classes, rather than exclusively from below, consistently led to projects with positive net revenues in their analysis. McIver and Matzka (2002) describe an ongoing national study designed to refine project-level cost and revenue estimation techniques across a range of treatment types, equipment, and regions. Their preliminary results suggest that while controlled burning may be the least costly method of density reduction, there are so many circumstances in which it cannot be applied that mechanical thinning remains an essential tool in any broad-scale thinning program. Barbour et al. (2001) and Fiedler et al. (2001) assemble and discuss data from a range of sources on thinning and fuel treatment costs by site characteristics and treatment technique in New Mexico and Montana. These data were subsequently incorporated into thinning and treatment cost models that can be applied to a broad range of stand and site conditions (Fight et al. 2003; Barbour et al. 2004).

Some studies have also looked at the impacts of fuel reduction and restoration thinning activities at what might be called the "program level", i.e., treatments applied to many stands over a broad geographic region to meet forest health restoration goals, as envisioned, for example, in the Healthy Forests Restoration Act.[2] The Blue Mountains Task Force (BMTF) (2002) examined the costs and returns of restoration thinning using a stand density index (SDI) reduction approach on national forests in the Blue Mountains region of northeastern Oregon. It concluded that even if only the costs of removing merchantable timber were considered, little area could be thinned with revenues in excess of cost. This finding was due, in part, to the exclusion of any area set aside under present internal Forest Service administrative guidelines and to thinning guidelines that called for the removal of relatively limited volumes of merchantable material.

Prestemon et al. (2002) outline an ongoing national study to examine the effects of thinning programs on prices and economic welfare through the development of market models linked to regional assessments of treatment needs. Details of the approach were not available at the time of the original report, but the authors make a clear case for the need to consider price and output impacts in existing product markets resulting from increases in public harvest associated with restoration thinning programs. Rummer et al. (2003) extend this discussion of market impacts, noting that the extent of the price impacts from a timber supply expansion would vary with any response in mill establishment and (or) capacity expansion. Using regional inventory data and a thinning paradigm based on reduction in SDI to 30% of the forest type maximum, Rummer et al. (2003) conclude that regional-scale thinning programs on public and private lands in the western United States could generate volumes of sawtimber-size material far larger than the volume that could be processed with existing lumber and plywood production capacity.

The FIA BioSum (Forest Inventory and Analysis Biomass Summarization System) project in the US Forest Service[3] (Fried et al. 2003) also looks at program-level impacts through a georeferenced model of regional forest inventory linked to cost and revenue models. BioSum provides estimates of the volumes of both sawlog and biomass materials that could be removed to maximize net revenue under user-specified treatment prescriptions and the costs and revenues associated with a program given hypothetical locations of biomass-consuming power-generation facilities. BioSum uses fixed prices to estimate product revenues. It does not model market behavior, and it does not attempt to model changes over time in thinning removals, prices and costs, or private harvest response.

In this binary taxonomy of work to date, our study is a "program-level" analysis. We develop a spatial inventory model of national forest timberlands in eastern Oregon from which we can estimate the volumes of sawtimber and non-sawtimber that would be removed from these lands under hypothetical restoration thinning programs, together with the associated costs of treatment and transportation. This resource model is linked to a spatial model of the region's private forests and the sawtimber market, from which we estimate the impacts of the additional thinned sawtimber volume on prices, private harvest, mill log consumption, numbers of mills, and milling capacity. We vary the budgets that can be expended by public agencies to subsidize thinning costs, the types of costs that can be subsidized, and the conditions under which treatable areas qualify for a subsidy, to examine the budget costs of achieving various levels of treated area.

[3] USDA Forest Service, Pacific Northwest Research Station, Forest Inventory and Analysis Unit, BioSum. Available from http://www.fs.fed.us/pnw/fia/ear/jfried/projects/fia_biosum/ [accessed 22 April 2004].

A model of the eastern Oregon forest sector

Projections of market price, private harvest volumes, and the area of public land treated under a given thinning program are derived from a model of the eastern Oregon forest sector. An earlier version of this model is described in Latta and Adams (2005), together with details of the estimation of key demand and capacity parameters. In its general structure the model is a dynamic, spatial-equilibrium market model of the broad type described in Adams et al. (1998). It focuses on the market for softwood sawlogs, since there are only minor volumes of pulpwood produced in the region. Sawlog demand derives from lumber and plywood producers; sawlog supply, from both private and public timberlands. The model finds the market clearing sawlog quantities and prices over the projection period (100 years in 5-year intervals) by maximizing the discounted sum of producers' and consumers' surpluses (we used a real rate of 6%) subject to an array of constraints describing the dynamics of the timber resource, capacity in lumber and plywood mills, and log flows from producers to consuming mills. The present model departs from earlier dynamic forest sector models (e.g., Sohngen and Mendelsohn 1998; Adams et al. 1996) in its detailed spatial treatment of the timber resource and the use of individual mills as demand centers with endogenous capacity decisions.

A mathematical outline of the model is given in the Appendix. Notation relating to time, mill, landownership, and condition class has been omitted, with the exception of the initial time summation in the objective function (Appendix eq. A1) to suggest the intertemporal nature of the problem. Decision variables include management regime (three even- and three uneven-aged schemes) and harvest timings for all existing and regenerated stands (E and R) over time, the levels of mill capacity over time by mill location (K), and the area to be treated under a thinning program on national forest lands (A). Appendix constraints A2 and A3 require that all existing (initial) areas be allocated to some management regime and that the area of even-aged regeneration in a given period be no larger than the area clear-cut from existing or previously regenerated even-aged stands. The price of an additional unit of harvest delivered to a mill is the shadow price of the harvest equation (eq. A4). The capacity adjustment mechanism is defined in constraints A5–A8. Mills drop out of the sector if they wish to operate below the minimum operating rate ($(H/K)_{\min}$ in eq. A8). Thinning programs that involve limits on subsidies are controlled by eq. A9, which varies with the form of the program. Sawtimber harvest volumes forthcoming from thinnings are related to the area of thinning treatment through the process of eq. A10.

Sawlog demand (the function P_D in Appendix eq. A1) was estimated at the regional level using a normalized, restricted quadratic profit function then disaggregated to individual mills. The industries were assumed to have one output (lumber or plywood), with residues treated as by-products. Inputs include logs, labor, and other variable inputs. Capital stock (measured here as the maximum physical log-processing capacity) is treated as quasi-fixed in the short term (1–5 years), and technology is represented by a time trend. The price of logs was treated as endogenous; prices of output, labor, and other variable inputs, as exogenous. The estimation model for each industry consisted of the log-demand equation together with the output supply, labor demand, and profit function equations. Since virtually all of the data series exhibited some evidence of nonstationarity, coefficients were estimated with data in first-difference form using iterative nonlinear three-stage least squares.

As there are no time-series data on mill-level inputs, outputs, and costs, we approximated log demand at the mills by scaling the regional-demand equation to the mill level using estimated mill outputs in 1998. This assumes that log demand at each mill has the same elasticities for log price and other demand variables as does the regional equation. Similar assumptions have been used in other studies to derive demand elasticities at finer geographic scales (see, e.g., Kutcher 1983; Adams and Haynes 1996), but it is recognized that this is a relatively restricted approach.

A key addition to the model was a set of relations that allow mill-level capacity to change in the long term (across 5-year periods), shifting both the log-demand equation and the capacity bounds on log use. A mill's physical production capacity is reflected in an upper bound on log demand (Appendix eq. A6). Capacity over time follows the usual inventory identity (eq. A5) including losses to depreciation. The costs associated with capacity follow a three-tier system. Basic maintenance is required on all capacity, and a low level of cost is charged for this maintenance so long as output is positive. Basic maintenance does not alter capacity or offset depreciation. A second tier involves repair and replacement of depreciated equipment. These costs do not expand capacity but simply maintain the current maximum output level. Investment in new capacity to expand output beyond current levels represents a third step. This is the most costly action and reflects the addition of new production lines or the costs of returning capacity to operational levels some time after a mill has closed (to meet minimum capacity requirements).

Unlike other dynamic forest sector models that have included log processing capacity constraints (e.g., Adams et al. 1996), mills in the eastern Oregon model are constrained to operate at or above a minimum operating rate (defined as output/capacity), and their absolute capacity cannot fall below a specific minimum level (eqs. A7 and A8). The minimum operating rate is meant to mimic the point of minimum average variable cost on the output marginal cost curve in traditional cost-curve analysis. The firm's optimal strategy is to shut down rather than lose more than its fixed costs, and log demand would drop to zero. We approximate this shut down – start up point with a minimum operating rate. Historical industry behavior in the region suggested that operating rates below 80% have seldom been observed for periods longer than 1 year. We set the minimum operating rate for all mills at this level.

The minimum capacity constraint assumes that there is a minimum mill size below which it is not economic to operate. To be profitable and competitive, a mill must have at least some minimum processing capacity. This threshold requires maintenance expenditures of some minimum level to offset depreciation. It also establishes a barrier to entry, or reentry, into the regional industry. If a mill drops out of production and its capacity is allowed to depreciate, it must invest in new capacity to bring it at least to the minimum threshold before restarting production. Levels for this minimum plant size varied by firm and were based on analysis of the types of products produced and the number and type of primary log breakdown facilities (derived from Random Lengths Publications[4]).

The private timber inventory is modeled using a combination of Johnson and Scheurman's "model I" and "model II" approaches (Johnson and Scheurman 1977). This can be seen in the treatment of the E (existing stands) and R (regenerated stands) variables in Appendix eqs. A2 and A3. Private inventory data for this study derive from the Forest Service's 1999 remeasurement of permanent plots on private forestland in eastern Oregon (Azuma et al. 2002). Plots were divided into "condition classes", i.e., portions of the plot comprising uniform vegetation type, stand size, stocking, and previous harvest treatment. We treat the condition class as the basic resource unit with separate yield projections for each class.

Management practices on private lands were divided into reserve (no harvest), even-aged, and uneven-aged classes with three regimes in each nonreserve class representing increasing levels of intensity. These regimes were adapted from work by Bare et al. (1995) in an analysis of harvest potential in roughly comparable forest types in eastern Washington. The initial and all subsequent allocations of areas to these regimes are endogenous. Projections of current and future inventory volumes and stand characteristics (on an individual-tree basis) for all condition classes and management regimes were derived from the Forest Service's Forest Vegetation Simulator stand projection system.[5] Results reported here assume a constant land base.

The small volumes of log flows from public ownerships allowed under current policies (not related to any restoration thinning program) are considered to be exogenous. Their geographic location is explicit and subject to appropriate harvest and transport costs. But, consistent with agency practices, the volumes assumed to be made available do not vary with price or other endogenous elements of the model.

Analysis of restoration thinning programs

Restoration thinning programs on the national forests could assume a wide range of forms and intensities, varying with the types of material to be removed (live and (or) dead), objectives for influencing the vigor of the post-thinning stand (remove hazard material only and (or) reduce live basal area to increase growth), size concentration of removals (between smallest and largest diameters), and impacts on potential fire behavior and intensity in the residual stand. They might also differ in the extent of any subsidies provided by the national forests to ensure treatment of high-cost areas or expand the area thinned and any conditions that must be met to qualify for a subsidy.

In the present study we assess the impacts of a set of thinning programs by running the eastern Oregon forest sector model described above with and without the programs and by examining differences in measures of sector behavior, including the areas and volumes of thinning treatments undertaken. In the "base" simulation (without a thinning program), public harvests are not sensitive to market conditions, and they appear in Appendix constraints A4 as exogenous additions to harvest (g). The restoration thinning programs are simulated by augmenting the set of private inventory condition classes with plots for the eastern Oregon national forests taken from the most recent Current Vegetation Survey of these lands.[6] Each public plot (expanded to represent its total area) has associated volumes for thinnings of merchantable (sawtimber) and nonmerchantable or hazard material. The model is then rerun and allowed to pick the portions of plots and volume to be treated over time subject to varied conditions on the financial aspects of the program and the extent of agency subsidies for costs. In the present study we are interested only in approaches that would generate some volume of sawtimber material usable by existing mills with current technologies. We also assume that any thinning program must be completed by the year 2020.

Data for the thinning analysis came from an unpublished study by Wilson et al.[7] who developed a proposal for thinning to accelerate residual growth. In this study, national forest Current Vegetation Survey plots were examined to determine which were "densely stocked" — defined as SDIs in excess of 75% of the maximum SDI for their respective forest types. Tree removals were then computed for these stands to reduce SDI to 50% of the maximum, by cutting from below (smallest first).[8] We employ the board foot volumes, measured for trees at least 9 inches (1 inch = 2.54 cm) in DBH, as the merchantable volume, and consider only the plots with nonzero board foot thinning volumes. From these same plots we also measure the volumes and numbers of standing live trees less than 9 inches and dead trees of all sizes that would be removed to reduce fuel hazard. We term this the "smallwood" component of the treatment. Plots with no merchantable volume could be candidates for treatment based entirely on subsidies, but we do not consider these options in this analysis, since the market model has nothing to say about the impacts of these choices.

Smallwood material is assumed to be removed to the landing and burned, with appropriate costs included in the agency program budget. While there are many potential options for disposition of this material, such as chipping for reconstituted panels or pulpwood or burning in biomass energy generators, eastern Oregon at present either has no facilities of

[4] Random Lengths Publications. Various editions. Random Lengths Buyers' & Sellers' Guide, Eugene, Oregon.

[5] USDA Forest Service, Forest Management Service Center. Documentation of the Forest Vegetation Simulator forest growth and yield model. Available from http://www.fs.fed.us/fmsc/fvs [accessed 21 January 2004].

[6] The USDA Forest Service, Pacific Northwest Region describes the Current Vegetation Survey and its link to inventories on private lands. Available from http://www.fs.fed.us/r6/survey [accessed 23 August 2004].

[7] D.S. Wilson, D.A. Maguire, and R.J. Barbour. 2002. Assessment of the small-diameter timber resource from restoration treatments in densely-stocked stands on national forests in eastern Oregon. Unpublished report on file at the College of Forestry, Forest Research Laboratory, Oregon State University, Corvallis, Oregon.

[8] Rummer et al. (2003) consider a similar approach for the entire western United States but reduce residual stand density to 30% of maximum SDI, generating larger volumes of merchantable material.

this type (biomass energy) or has a capacity far too small to absorb the volumes that would be generated. As a result, we assume the material is simply burned with costs born by the agency and not the contractor. This treatment will raise problems of timing and, in some locations, concerns for air quality.

Given the details of the thinning and plot characteristics, harvest costs (to the landing) were computed for the merchantable sawlogs using the cost model of Fight et al. (1999).[9] Hauling costs depend on distance and equipment assumptions, as in the approach used for private harvest. Costs of treating the smallwood were derived from Barbour et al. (2001) and vary by size of stem, number of stems per acre, and slope in the stand. Burning costs were based on estimates from R. Fight.[10] Wilson et al.[7] identify some 2.4 million acres of densely stocked stands on public lands in eastern Oregon with 6.4 billion board feet of potentially merchantable thinning volume. Wilderness areas were excluded from the analysis. We also exclude (*i*) 0.4 million acres (with 2.0 billion board feet of merchantable material) that lie within the boundaries of other formally protected areas, and (*ii*) 0.4 million acres in stands that are not protected but have no sawtimber thinning volume.[11] All remaining areas, including those presently classified as administratively reserved, are included on the argument that a restoration thinning program would have to treat a fairly large, contiguous region to reduce the severity of fire damage and mimic the results of presettlement, natural wildfire regimes.

Thinning program options

Many past studies of restoration thinning have provided information on the subsidies that would be required, or the net revenues that would be generated, in treating a given area under a specific thinning prescription (e.g., Blue Mountains Task Force 2002; Rummer et al. 2003). In some cases multiple thinning prescription options have been considered (Fried et al. 2005). Most conclude that sizable subsidies would be required to treat most of the area in need of thinning, though estimated subsidies vary markedly with the type of thinning regime and assumptions about product markets and prices. In the present study, we employ a single thinning prescription and focus on the conditions for receipt of subsidies and the extent of subsidy payments by public owners. In all cases we assume that the national forests pay to burn the smallwood material at the landing (either directly or as a further payment to contractors).

It is not clear at this point how operators would be chosen to process the thinning units (harvest the timber and remove smallwood). The agency might use some form of competitive bidding, appraise and offer thinning units at fixed prices, or some combination of these approaches, depending on unit characteristics. In this study we assume that the agency establishes a fixed minimum price per thousand board feet (MBF) for sawtimber stumpage rather than using a bidding process. The unit-specific log and haul and smallwood removal costs then determine whether the unit will yield positive or negative returns as

$$[1] \qquad P_{\mathrm{D}}V_i - \mathrm{L\&H}_iV_i - \mathrm{SW}_i - \mathrm{ST}V_i \gtreqless 0$$

where P_{D} is delivered log price (\$/MBF) determined endogenously in the market projection, V_i is merchantable timber volume per acre on unit *i* (MBF), $\mathrm{L\&H}_i$ is log and haul cost for sawlogs from thinning unit *i* (\$/MBF), SW_i is the smallwood removal cost for unit *i* (\$/acre), and ST is the minimum stumpage price per MBF.

Based on an analysis of delivered log prices in the base case and of costs for smallwood and log and haul across thinning units, we employ a fixed minimum timber price (ST_i) of US\$276 per MBF.[12]

We allowed the total amount of the subsidy, the types of costs that could be subsidized, and the form of the subsidy payment to vary among subsidy programs. In all programs, the simulation model picks those thinning opportunities that yield the greatest increase in the objective function, given costs, subsidies, and payment conditions. There are no restrictions on the spatial or temporal distributions of the treatments and no requirements that some minimum area must be treated. Five hypothetical "programs" were considered:

(1) No subsidies. This is a single case in which thinning contractors (log buyers) pay all smallwood removal costs and the fixed price per MBF for the sawtimber stumpage.

(2) Screened subsidy. This program allows smallwood subsidies only for those areas where the estimated net returns from sawlog sales cannot cover the smallwood removal costs. That is, to qualify for a subsidy, estimated returns in eq. 1 must be negative. In effect, a positive subsidy term is added to eq. 1, the net impact of which could also be viewed as a reduction in the sawtimber stumpage payment. We allowed total subsidies to range from US\$69 million to US\$276 million for the program through 2020.

(3) Unscreened or open subsidy. In this program subsidies are paid only up to the amount of the smallwood costs, but no net sawtimber return screen is applied to candidate areas. Any thinning unit can receive a subsidy regardless of the returns from harvest of merchantable thinning material, so eq. 1 can have any sign. With no restrictions on access to the subsidy, operators could use some portion of the subsidy to enhance returns from already profitable units rather than expand the area treated to units with eq. 1 negative. Again we examine a range from US\$69 million to US\$276 million.

(4) Fixed-per-acre subsidy. In the previous cases, subsidies were limited to the amount of the smallwood costs. In

[9] Harvesting costs in the Fight et al. (1999) model vary with a wide range of logging technology and site conditions. We use their default assumptions for all inputs except stem diameter, volume per acre to be removed, trees per acre to be removed, move-in distance, slope, and whether the harvest is a thin or not (all are thinnings in our case).

[10] Roger Fight, USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon, personal communication, August 2004.

[11] These areas, as mapped by the USDA Forest Service, include National Recreation Areas, National Volcanic Monuments, and National Wild and Scenic Rivers as well as inventoried roadless areas where road construction and reconstruction are prohibited.

[12] All prices and costs in this study are in 2003 US dollars unless otherwise noted.

this simulation operators are given a fixed subsidy for each acre treated regardless of estimated levels of smallwood cost or returns from merchantable thinning (no screen on net returns in eq. 1). There are many areas that would have negative returns even if smallwood costs were zero because of high log and haul costs. Under this program, the subsidy can be used to offset both smallwood costs and costs of logging merchantable material. As in the case of the open subsidy, with no screen on net returns augmentation of already positive returns is possible. We look at a range of cases from US$138 to US$414 per acre.

(5) Full subsidy. This is a single case in which all smallwood treatment costs are subsidized and the contractor pays nothing for the sawtimber. Operators continue to pay the costs of sawtimber harvest and removal, so some areas would still have negative returns in eq. 1. The total subsidy from the agency perspective includes both the smallwood removals costs and foregone sawtimber payments. Areas untreated under this approach would require further subsidization of sawtimber log and haul costs to produce positive returns.

Simulation results

Market impacts

The eastern Oregon forest industry is a sector in decline. Since the late 1980s, more than 25 sawmills have closed as timber harvest has fallen in the wake of revised management directions on public lands. In the base case, total eastern Oregon harvest continues to fall after the 2003 period (2001–2005) then rises modestly after 2028 (Fig. 1). The decline after 2003 results from a large downward shift in forest industry harvest. Over the past 30 years, forest industry inventory has declined in the region. Gross growth has fallen, while harvest has remained stable and mortality has increased in the face of widespread insect and disease outbreaks. In the model projections, current harvest levels cannot be maintained past the first period. As indicated in Fig. 2 the number of active sawmills declines as well, reaching a minimum of nine by 2028. Between 2003 and 2023 the number of mills (and log demand) does not decline fast enough to offset the reduction in log supply, so that delivered log prices (Fig. 3) rise. After 2023, declining capacity (backward shift in demand) and a resurgent private harvest combine to reduce prices through the remainder of the projection.

A restoration thinning program would come at an opportune time for the eastern Oregon forest sector, augmenting regional harvest during the period of most rapid projected decline in private cut. As illustrated for selected programs in Fig. 1, however, thinning would postpone but not eliminate the projected harvest reduction. We make comparisons among the $276 million screened, $276 million open, and $414 per acre fixed programs because they involve approximately the same level of subsidy payments to operators and roughly similar total budget costs to the national forests (including burning costs). Each program raises regional harvest during the program period and entails harvests higher than the base case in some portion of the postprogram period as well. Part of the higher postprogram harvest comes from "savings" of private inventory through substitution of public cut during

Fig. 1. Total eastern Oregon softwood timber harvest under the base case and alternative thinning program scenarios (see text for program definitions).

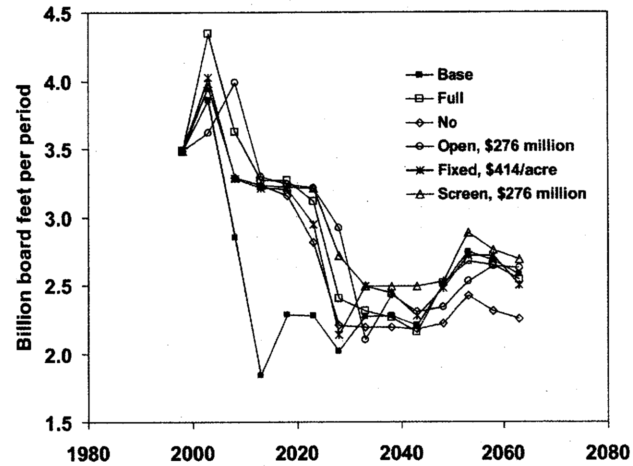
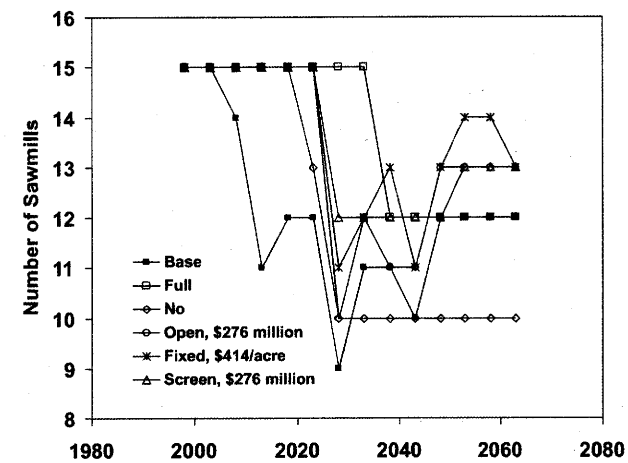


Fig. 2. Number of sawmills in eastern Oregon under the base case and alternative thinning program scenarios (see text for definitions of programs).

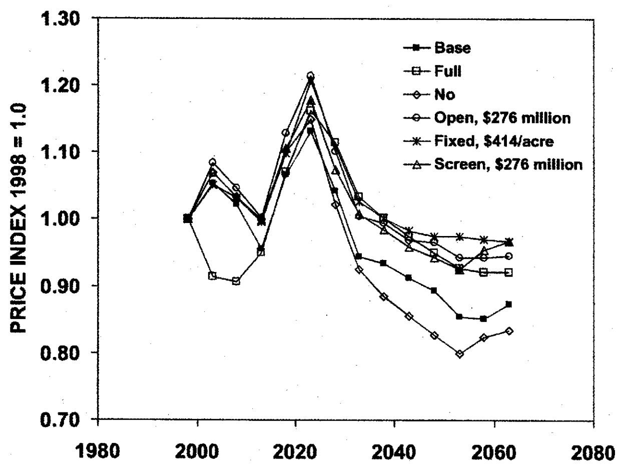


the program period. As illustrated in Table 1 these shifts are substantial in some instances but the time pattern varies markedly among the cases.

Higher postprogram harvests for some programs also reflect larger numbers of mills remaining in operation (Fig. 2) with higher demand for delivered logs. All of the thinning programs would allow the initial 15 mills to remain open through the program period. In subsequent years the number of mills falls to varying degrees depending on the program. The full subsidy program provides the largest volume increment and keeps the 15 original mills operating for the longest period. The no-subsidy program generates the least additional volume. The number of mills and their capacity drop below the base case after 2030, and private harvest falls below the base case as well (Table 1) because of lower mill demand.

With the exception of the no-subsidy case, more mills stay open in the postprogram period as a result of the thinning programs, but aggregate regional lumber processing capacity

Fig. 3. Delivered softwood sawlog price in eastern Oregon under the base case and alternative thinning program scenarios (see text for program definitions).



does not rise relative to the current (2003) level. Thinning programs simply slow the rate of capacity contraction. As with total regional harvest, capacity decline is postponed but not eliminated (Fig. 4), and average mill size (capacity per mill) falls in all cases through the program period.

While the overall results of the program simulations appear as might be expected for scenarios of timber supply augmentation, prices are not particularly sensitive to the changes. Only the large harvest increase under the full-subsidy program has much impact on regional delivered sawlog prices during the program period (Fig. 3) with prices in the 2003 and 2008 periods 12%–14% below base case levels. In the postprogram period prices move apart, reflecting differing levels of capacity and harvest in the five program cases. This insensitivity of prices reflects the "lumpiness" of processing capacity (mills), the start up – shut down barriers of minimum operating rate and capacity, and the impact of capacity on the log-demand functions. With thinning, mills remain open, keeping capacity and demand higher than they are in the base case, thus reducing the price impacts associated with the supply increments.

Costs of alternative programs

The immediate objectives of a restoration thinning program, at least as they appear to be foreseen in the 2003 Healthy Forests Restoration Act, would be to reduce hazardous fuels and lower mortality on relatively large areas of the national forests containing overstocked stands. In establishing such a program, the managing agency (the US Forest Service) would be concerned with its costs and the efficient use of budgets to treat stands. To explore some of the possibilities, we examined a limited array of alternative thinning program structures with varying budgets. The example programs are "efficient" in the sense that areas are selected for treatment by potential thinning operators (from a large set of possible thinning activities) to maximize the change in net regional market surpluses for a given budget and set of subsidy conditions. They do not necessarily maximize the area treated for a given subsidy. Indeed, other subsidy arrangements might be found that would give larger areas treated for a given budget.

From the US Forest Service's perspective, all programs will require knowledge of the sawtimber volumes to be removed by the thinning and the desired characteristics of the post-thinning stand. The US Forest Service will have to monitor treated areas to insure that desired post-thinning conditions are obtained and smallwood removal is completed. Costs of these oversight activities are not included in the present analysis. Apart from the no-subsidy and full-subsidy cases, the hypothetical programs differ in terms of the complexity of the subsidy-granting process and the amount of information required by program administrators. The fixed-per-acre approach is the simplest, and administrators need not estimate the costs of removing the smallwood volume or net revenues from sawtimber harvests. The screened program, in contrast, would require closer accounting of the smallwood costs and estimates of the net returns from sawtimber sales, both to prioritize areas for subsidy eligibility prior to treatment and to reimburse operators.

Relationships between subsidy level and area treated and sawtimber volume thinned for the example programs are shown in Fig. 5. Even with no subsidy (and a fixed sawtimber stumpage payment), nearly 500 000 acres would be treated. This result stands in contrast to the conclusions of the BMTF for the northern part of eastern Oregon where less than 50 000 acres were found to produce positive net revenue with no stumpage payment. This difference reflects, in part, our inclusion for treatment of a large area of administratively set-aside land not considered in the BMTF study. At the opposite extreme, the full-subsidy case would treat about 975 000 acres, roughly 5% higher than the largest (US$276 million) screened case but at a budget nearly two-thirds larger.[13]

There is a clear pattern among the programs in the area treated at various levels of subsidy budget. In the open cases, the smallwood subsidy can be obtained (and consumer surplus expanded) even on sites where net sawtimber revenue exceeds smallwood costs. There is no incentive or requirement to treat more costly areas. As a result the open cases treat the smallest area for a given budget. The budget increment from roughly US$69 million to US$207 million produces no additional area treated (Fig. 5) and even includes a reduction in the volume of sawtimber removed at the US$138 million level. While the total objective function for the open cases rises consistently over this budget interval, there is no net volume gain to the thinning program because the mix of selected treatment opportunities is simply being rearranged to maximize the gains in market surplus from the subsidy.

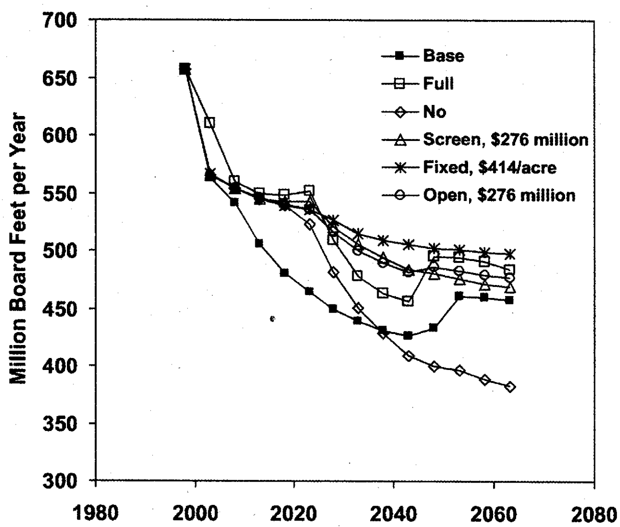
The fixed-per-acre subsidy produces more area treated at all budget levels than the open cases. Unlike the open (and screened) programs the fixed subsidy can be used to offset smallwood and (or) sawtimber harvesting costs and is not restricted to the actual amount of either of these costs (being a fixed grant per unit area). This gives operators considerably more flexibility in choosing areas to treat, including those with low smallwood costs but higher sawtimber thinning costs. At the same time, some portion of the subsidy can still be used to enhance the returns from otherwise attractive

[13]The full-subsidy budget shown in Fig. 5 does not include an additional US$793 million in foregone sawtimber payments.

Table 1. Total eastern Oregon harvest (in millions of board feet) and changes in private harvest (in millions of board feet) during the thinning program (2003–2018), immediate post thinning (2023–2028), and long-term post thinning (2033–2063).

		Program					
Harvest	Period	Base	No subsidy	\$276 million screened	\$276 million open	\$414/acre fixed	Full subsidy
Total eastern Oregon	2003–2018	10 802.4	13 501.0	13 607.9	13 656.0	13 692.1	14 527.3
Change in private cut from base	2003–2018	—	−123.5	−959.7	−462.6	−485.3	−245.3
Total eastern Oregon	2023–2028	4 304.7	5 114.2	5 796.9	5 143.9	5 083.3	5 498.7
Change in private cut from base	2023–2028	—	809.5	1 492.2	839.2	778.5	1 194.0
Total eastern Oregon	2033–2063	17 261.1	16 280.3	18 265.6	17 285.1	17 667.5	17 096.1
Change in private cut from base	2033–2063	—	−980.8	1 004.5	24.0	406.4	−165.1

Fig. 4. Capacity in eastern Oregon sawmills under the base case and alternative thinning program scenarios (see text for program definitions).



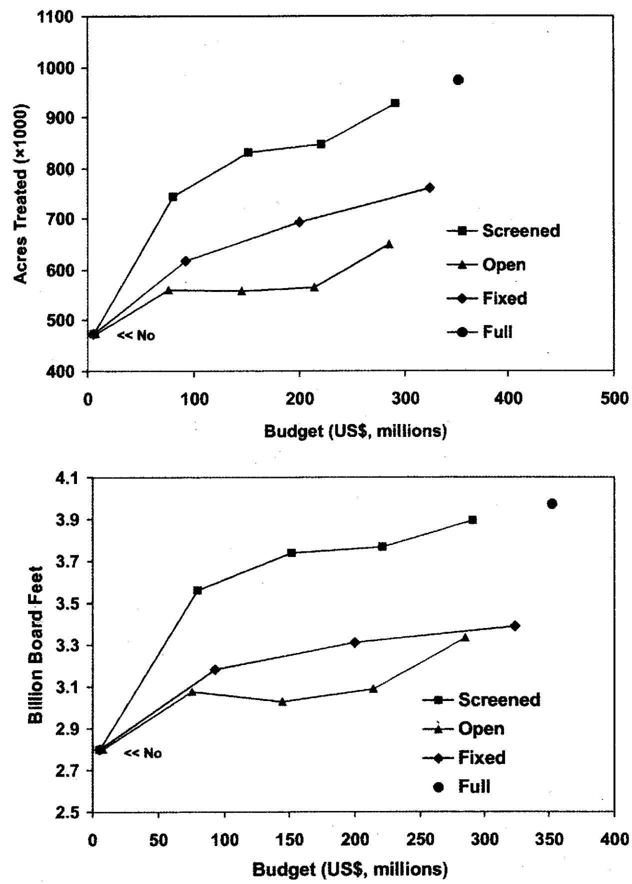
treatment options (sawtimber returns exceed smallwood costs), as in the open case.

In eliminating this latter option, the screened cases produce the largest area treated for any budget level (but have lower market surplus gains as noted below). Under this program, treatment options with sawtimber returns in excess of smallwood costs are not eligible for subsidy but would still be selected if they contributed anything to the overall objective function. In large part these areas do continue to be treated in the screened case together with additional (higher cost) areas made attractive by the subsidy.

The lower portion of Fig. 5 shows that sawtimber thinning volumes follow patterns relative to budget levels that are very similar to the patterns of the areas treated. While it is true that the average sawtimber thinning volume per acre declines as budgets rise (it is highest for the no-subsidy case and lowest for the full-subsidy case), the range of variation is not great (4100–5900 board feet per acre). Thus treating more area generally yields more sawtimber, though at a decreasing rate as treated area expands.

One of the important policy questions in considering adoption of a restoration thinning program is the distribution of the economic costs and benefits of the program across groups.

Fig. 5. Area treated and sawtimber volume harvested by budget level for thinning programs (cost of full-subsidy program does not include sawtimber revenues foregone; no-subsidy program includes only smallwood burning cost).



Apart from the budget and administrative costs born by the government, who gains and loses from the program? Table 2 shows percent changes in consumers' and producers' surpluses in the eastern Oregon sawtimber market relative to the base case for the various thinning programs and budgets. With the exception of the full-subsidy case, the largest percentage gains in total market surplus occur in the more flexible open and fixed programs with smaller gains in the screened cases. For comparable subsidy levels the open pro-

Table 2. Program budgets, stumpage receipts, consumers' and producers' surpluses from the base case, and percent change from the base case for restoration thinning programs (constant 2003 dollars).

						Percent change from the base		
Program	Payment to operators (US$)	Budget (US$, millions)[a]	Stumpage receipts (US$, millions)[b]	Stumpage receipts less budget (US$, millions)	Cost to treat remaining areas (US$, millions)[c]	Consumers' surplus	Producers' surplus	Total market surplus
Base surplus level ($US, millions)						2194	3283	5477
No subsidy	0	6	773	768	1123	19.3	−4.4	5.1
Screened budget	69 million	80	983	902	970	21.6	−4.9	5.7
	138 million	151	1032	881	921	23.1	−6.1	5.6
	207 million	221	1039	819	911	23.5	−5.9	5.9
	276 million	292	1075	783	856	22.9	−5.3	6.0
Open budget	69 million	76	849	773	1082	22.1	−2.5	7.4
	138 million	145	835	691	1090	22.8	−2.6	7.6
	207 million	214	852	638	1080	24.1	−2.4	8.2
	276 million	285	920	635	1020	25.0	−3.2	8.1
Fixed per acre	138/acre	93	878	785	1061	20.6	−1.5	7.4
	276/acre	200	913	713	1032	20.9	−0.6	8.0
	414/acre	324	936	612	1008	21.9	−0.4	8.5
Full subsidy		1551[d]	0	−1551	826	46.8	−1.5	17.8

[a]Payment to operators plus smallwood burning costs.
[b]From merchantable timber sales at assumed $276 per thousand board feet.
[c]Remaining areas include both those with no merchantable thinning and those with thinning volume but not treated under the program.
[d]Treatment costs plus foregone stumpage revenue.

gram, where the subsidy could be used to augment already positive returns, has higher net gains than the screened program.

Across all programs, private producers (forestland owners that sell sawtimber) consistently lose in this accounting. As noted in the discussion of market impacts, the price effects of most cases are small but the timing of private harvest is changed, shifting volumes to later years in the projection with revenues subject to heavier discounts. These shifts are most pronounced in the screened program, because it produces more sawtimber volume from the thinnings and thus has larger negative private producer impacts. Consumers (lumber and plywood mills) consistently gain from the programs, with surplus increments that are larger than producer losses in both absolute and percentage terms. Since the programs augment regional timber supply, consumer gains vary directly with the volume of sawtimber harvested. The large consumer gain in the full-subsidy case results from the elimination of the sawtimber stumpage payment as well as the subsidization of all smallwood costs.

Summary and discussion

For comparable levels of subsidy payments, the national forest thinning programs examined here clearly vary in their impacts on the eastern Oregon timber market. For example, comparison of the fixed, open, and screened approaches at a direct subsidy in the neighborhood of US$276 million shows quite different patterns of intertemporal harvest substitution between public and private owners, number of mills, and postprogram log prices and processing capacity. While the price and harvest shifts are reflected in the aggregate surplus analysis, varying patterns of mill numbers indicate differential impacts of policies on specific communities within the eastern Oregon region (the communities in which the mills are located). Some types of policies will impact mill operation (and associated employment and income) in some locations more or less than in other locations. We do not explore these intraregional variations here, but they will require consideration and explicit trade-offs by policy-makers in determining both the form and extent of any thinning program.

The alternate program simulations suggest that the form of the program may have a sizable impact on the area of forestland that can be treated for a given subsidy budget. At a subsidy payment of about US$276 million, the screened program would treat nearly 43% more area than the open program and 22% more than the fixed-per-acre payments. To the extent that the scale of treatment is a concern in undertaking restoration thinning, these differences must be weighed against the varying costs and effort required to administer each program type.

Our analysis finds that private forestland owners would be consistent losers under restoration thinning programs of the type examined here, while sawlog consumers (mills) would realize consistent increments in surplus. These changes conform in qualitative terms to expectations for the impacts of a policy of exogenous market supply augmentation. But while the producers' surplus losses are small relative to consumer gains, this accounting only recognizes welfare changes on variable inputs. Shifting private harvest timing and timber prices would also influence the value of forestland assets and the form and intensity of management of private lands. Land values in our model are the shadow prices of constraints A2 in the Appendix: the present value of the net increment in market surplus from an additional acre of some condition class. Relative to the base case, we find that land prices decline by 5%–30% depending on the program, with the biggest reductions on sites with stands that are presently at or near financial maturity (Adams and Latta 2004).

There are also modest shifts in the form of management (silviculture) applied to private lands. In the base case roughly 90% of private lands are treated using uneven-aged (partial cutting) systems with the remainder in even-aged (clearcut) systems. The US$276 million open program reduces the uneven-aged portion slightly to 89%, while the comparable screened program employs uneven-aged systems on 84% of the land base. These changes may impact to some degree the size and species diversity of the region's private forests and the quality of associated wildlife habitat.

As scientists work to develop new methods for treating large areas of smallwood, there is considerable uncertainty in the estimation of smallwood costs. We employed estimates of these costs that were roughly five years old at this writing (Barbour et al. 2001). To examine the sensitivity of our results to the smallwood cost assumptions, we repeated the screened US$69 million simulation with smallwood costs reduced by 10%. In response, area treated rose by 13% and sawtimber harvest volume rose by 5%.

One of the persistent concerns in discussions of restoration thinning on public lands is whether receipts from sawtimber charges would cover the costs of smallwood treatment. We address this question in two stages in Table 2 for the programs considered in this study. In all but the full-subsidy case, stumpage receipts exceeded the sum of budgeted subsidy payment plus smallwood burning costs. This is not surprising given that we focused only on lands with sawtimber thinning volumes. But even in the full-subsidy case, some 564 000 acres of land remain unthinned out of a total treatable base of 1.535 million acres having sawtimber thinnings. There is also an additional 430 000 acres in need of treatment that has no sawtimber volume. Table 2 shows the estimated cost of treating these remaining areas (both with and without sawtimber). In all cases, net returns from the timber-related program are smaller than the anticipated costs.

Our model is silent about potential impacts of thinning programs on the supplies of nonsawtimber goods and services for both residents of eastern Oregon and residents of broader regions. Restoration thinning has been the subject of intense controversy, in part, because of the potential harvest of larger sawtimber trees and the general site disturbance that would accompany smallwood removal. Some groups oppose these actions because of possible effects on wildlife habitat, aesthetics, nontraditional forest products, and other noncommodity services. Other groups argue that thinning may have detrimental short-term impacts on these services but long-term positive effects. Clearly these additional gains and losses must also be assessed in the policy decision.

The model and analysis presented in this study allow several useful extensions. We believe our basic findings regarding the sensitivity of market impacts to the form and extent of the thinning program can be extended in broad terms to other regions in the western United States that face similar future trends of declining private harvest and contracting milling capacity, including the northern Rockies and interior California. The model framework could also be readily adapted to other regions where georeferenced plot-level data on private and public inventories are available. Within the existing modeling framework, it would be useful to expand the inventory modeling process to allow projection of the future conditions of thinned and unthinned national forest plots. At present we only consider the current stand conditions, sawtimber volumes, and smallwood removals. Projection of national forest plots over time would allow examination of thinning programs with multiple entries, as will surely be required if there is no reintroduction of some regular fire regime. Finally, it would be useful to allow endogenous determination of the thinning regime for each national forest plot within the market model. In the current model we employ only a single regime structure based on the SDI reduction approach of Wilson et al.[7] We assume that these treatments meet the silvicultural objectives for ecological restoration on all plots (in line with the arguments of Fiedler et al. (1999) to restore stand vigor) and that this in turn meets fire management objectives as well (see Graham et al. (2004) for a broad discussion of options). The latter may not be true, or managers may have quite different fire management concerns, e.g., reducing fuel ladders or the intensity of ground fires. In these cases, endogenous selection of the thinning regime to meet a specific target, as in the static BioSum model (Fried et al. 2003), would allow analysis of treatments and programs with a broader array of objectives.

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Appendix A

Simplified representation of the eastern Oregon market and resource model including thinning programs with time, owner, conditions class, and mill notation suppressed to reduce complexity.

[A1] $$\max_{(E,R,K,A)} \sum_{t=1}^{T}\left[\int_0^H P_D(q)\,\mathrm{d}q - M(E,R) - C(\Delta K, K_{-1}) - \mathrm{TH}(V,A) - \mathrm{SW}(A)\right](1+i)^{-t} + \mathrm{TC}_T(E_T, R_T)$$

subject to

[A2] $$\sum E = I$$

for all condition classes.

[A3] $$\sum R_{(e)} = \sum E_{t(e)} + \sum R_{t(e)}$$

for even-aged regimes only.

[A4] $$H = h(E,R) + V + g - N$$

[A5] $$K = k(K_{-1}, \Delta K)$$

[A6] $$H \le K$$

[A7] $$K \ge K_{\mathrm{MIN}}$$

[A8] $\frac{H}{K} \geq \left(\frac{H}{K}\right)_{\mathrm{MIN}}$ or $\frac{H}{K} = 0$

[A9] $\sum \mathrm{SW}(A) \leq B_P$ or $F(A) \leq B_P$

the specific form varies with the thinning program.

[A10] $V = v(A)$

where

A is the area treated in a thinning program

B_P is the budget available to subsidize various costs for a particular thinning program P

$C(\Delta K, K_{-1})$ is the cost of capacity addition ΔK given start of period capacity K_{-1}

E and R are the areas of existing and regenerated stands allocated to any management regime, respectively

$E_{t(e)}$ and $R_{t(e)}$ are areas of existing and regenerated stands allocated to even-aged (e) regimes that are clear-cut, respectively, in period t

$F(A)$ and $\mathrm{SW}(A)$ are the fixed-per-acre subsidy and the costs of treating the smallwood or hazard material, respectively, on thinning area A

g is the volume of public cut not associated with a thinning program

H is the harvest in eastern Oregon used by regional mills

$h(E, R)$ is the private harvest, which is a function of the areas allocated to existing (E) and regenerated (R) stands

i is the discount rate

I is the total area in a condition class

K and K_{-1} are the current and previous, respectively, end of period log consumption capacities

$k(\Delta K, K_{-1})$ is the capacity adjustment process, combining depreciation, depreciation offsets, and expansion

K_{MIN}, and $(H/K)_{\mathrm{MIN}}$ are the minimum capacity level and the minimum operating rate, respectively

$M(E, R)$ are the silvicultural management costs associated with allocation of areas E and R to existing and regenerated stands on private lands plus the costs of logging and hauling the associated sawtimber harvest volumes to mills

N is net log trade (imports less exports) from eastern Oregon

$P_D(q)$ is the derived demand for logs at mills in price dependent form

$\mathrm{TC}_T(E_T, R_T)$ are the terminal conditions for private inventory, defined here as the net market surplus derived from the perpetual harvest that could be obtained from the terminal inventory if managed on an even-flow basis

$\mathrm{TH}(V, A)$ is the cost of harvesting and transporting volumes V from a thinning program of area A

V, $v(A)$ is the sawtimber thinning volume associated with a particular thinning program of area A

$\Delta K = K - K_{-1}$ is the net change in capacity

The problem was formulated and solved in GAMS using the CPLEX solver in mixed integer format (Brooke et al. 2004). Additional details from an earlier model version are given in Latta and Adams (2005)

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