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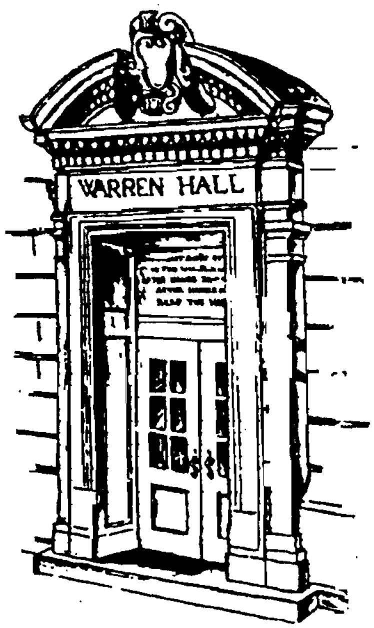

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Old-Growth Forest and Jobs

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ABSTRACT

An optimal control model is constructed where the cutting of old-growth forest generates jobs and adds to the stock of land devoted to "new-growth," rotational forestry. Welfare is determined by the number of jobs in the forest economy and the stock of old-growth forest, which provides "nontimber" benefits. Starting from a large inventory, the economy needs to determine when it is optimal to stop cutting old-growth forest and preserve what's left. When the economy stops cutting old growth it reaches a steady state where the number of jobs is based on the harvest of timber from new-growth forest. An inventory rule is derived for a general model. For plausable functional forms this rule implies and explicit solution for the optimal inventory of old-growth forest. The specific model is estimated for the Douglas fir region of western Washington and Oregon, where perhaps 17.5 percent of the pre-logging stock of old-growth remains. Estimates of the marginal social value for the remaining stock of old growth range from $2,089 to $7,173 per hectare, depending on the rate of discount. These values should be interpreted as "hurdle values." If a direct valuation method, such as contingent valuation, reveals that the "true" marginal social value is likely to exceed these values, then all remaining old-growth outside the National Parks should be preserved.

Old-Growth Forest and Jobs

I. Introduction and Overview

> *A vast acreage of primeval forest thus remains, embracing many large tracts of splendid old-growth timber, with trees 5 feet and larger in diameter and cruising over 100,000 board feet per acre. ... In this region an immense logging and lumbering industry has come into being within the past few decades. Washington now ranks first among the States in volume of lumber production and Oregon has second place. Each year approximately 75,000 acres in western Oregon and 145,000 in western Washington are logged over. The 579 sawmills and 144 shingle mills in the western part of these two States in 1927 cut 9,881,414,000 board feet of lumber and of this 80 per cent was Douglas fir. Inasmuch as the stand of virgin timber is by no means unlimited, the permanence of this lumber industry, which now contributes 65 per cent of the entire industrial pay roll of Oregon and Washington, hinges to a considerable degree upon the continued production of forest crops from lands chiefly suitable for this purpose. ... As the supply of mature timber becomes less, the forests which today are immature and the lands which are yet to be reforested will furnish an increasing large part of the timber supply. Ultimately the lumber production of the entire region must come from such young or second-growth stands.*
>
> Richard McArdle (1930)

What if we could travel by timeship back to the Pacific Northwest of 1927. Depending on one's definition, we might find an inventory of more than six million hectares (14.826 million acres) of old-growth forest, dominated by Douglas fir, but also containing Western hemlock, Cedar, and Sitka spruce. Suppose you were appointed to a position akin to Samuelson's

(1976) forest planner. How much of that inventory of old-growth would you choose to preserve? More specifically, when would you halt the cutting of old-growth and establish a forest economy based on rotational forestry?

This paper presents a model designed to answer the last question. It presumes that as forest planner you are interested in the number of jobs in the forest economy, but also in the remaining stock of old-growth forest because of the multitude of nonmarket benefit flows which such forests provide. In the next section a model is constructed which permits the derivation of an optimality condition that in turn implies an inventory or stopping rule. Some plausible functional forms are suggested, and the optimality condition in this case yields an explicit solution for the optimal inventory of old-growth forest.

In Section III the parameters of the model are estimated with the exception of one critical parameter, the weight assigned to the old-growth benefit function. As an "end-run," the optimal inventory rule is then used to obtain an estimate of this parameter, under the assumption that the 1986 stock of old-growth forest (estimated to be 17.5 percent of the pre-logging, old-growth inventory) is optimal. In other words, what would the weighting parameter have to be for 0.175 to be the optimal inventory to preserve from a pre-logging, old-growth inventory of one (1.000). With this estimate of the weighting parameter, it is possible to estimate the marginal social value of the remaining (1986) old-growth inventory. That estimate, for the base-case parameters, is $4,591 per hectare. This estimate has the following policy implication: If one can independently estimate the marginal social value of old-growth in the Douglas fir region (say by a contingent valuation survey), and if that estimate exceeds $4,591 per hectare, then all remaining old-growth forest should be preserved and the forest economy should be based strictly on harvests from "new-growth" forest. Conclusions and caveats are offered in Section IV.

II. The Model

The optimal old-growth, inventory model will be based on the following notation. Let

J = the number of jobs in the forest sector at instant t,
Q = the number of hectares of old-growth cut at instant t,
q = the number of hectares of new-growth cut at instant t,
S = the stock of old-growth forested land at instant t,
P = the stock of new-growth forested land at instant t,
$W = \Phi(S,J)$ = welfare at instant t, it depends positively on S and J,
$J = J(Q,q)$ = the number of jobs depends positively on Q and q,
$q = F(P)$ = the number of hectares of new growth cut at t depends on P
$W = \Phi(S,J(Q,F(P))) = W(S,P,Q)$ = welfare as a function of S, P, and Q
$\dot{S} = -Q$ = the change in the stock of old-growth forest,
$\dot{P} = Q$ = the change in the stock of new-growth forest, and
δ = the social rate of discount.

Several comments are in order. First, old-growth forest is viewed as a nonrenewable resource. The inventory of old growth can be reduced, but it cannot be replenished, even by very old second growth. If this were not the case, if, after a suitable period of time (say 200 years), second growth could achieve old-growth status, then the current model would not be appropriate, and it would have to be modified to an age-structured model.

Second, the model assumes that after a hectare of old-growth is cut it will be replanted, and that the land will subsequently remain in rotational forestry *forever*. There is no "leakage" of forest land to other uses. Old growth may be irreversibly converted to new growth, but the total amount of land in forestry is fixed.

Third, there are no random forest fires which might "naturally" destroy old growth. In reality, forest fires created an age-structured forest inventory prior to the arrival of white settlers and the commencement of commercial logging. In this model an old-growth forest reaches some sort of climactic equilibrium, and when a tree topples and dies its biomass is instantaneously replaced by growth in the remaining trees.

Fourth, the number of new-growth hectares cut at instant t depends only on the cumulative stock of new-growth land, P. In reality, the number of "financially mature" new-growth hectares will depend on the age-structure of the new-growth forest and economic parameters like the discount rate, δ. In steady state, when the optimal old-growth and new-growth inventories have been established, the new-growth forest might be "synchronized" by a Faustmann rotation. In steady state the number of hectares cut at a particular instant would be $q = F(P) = (1/\tau) P$, where τ is the Faustmann rotation.

While it would be possible to relax these assumptions it would lead to an age-structured and/or stochastic model which would make the derivation of an optimal inventory rule much more difficult, and in all likelihood preclude estimation and numerical analysis. The present model will provide such a rule, along with an estimate of the marginal social value of the remaining old-growth inventory.

Determining when to stop the cutting of old-growth forest might be formally stated as a dynamic optimization problem which seeks to

$$\text{Maximize} \quad \int_0^{\infty} W(S,P,Q)\, e^{-\delta t}\, dt$$

$$\text{Subject to} \quad \dot{S} = -Q,\ \dot{P} = Q,\ S_0 \text{ and } P_0 \text{ given.}$$

where the control variable is Q, the rate at which old-growth land is cut and placed in the new-growth inventory. The current-value Hamiltonian for this problem may be written as

$$\tilde{H} = W(S,P,Q) - (\lambda - \mu)Q \tag{1}$$

where $\lambda > 0$ is the current-value shadow price on old-growth forest and $\mu > 0$ is the current-value shadow price on new-growth forest. The first-order necessary conditions require

$$\partial\tilde{H}(\bullet)/\partial Q = W_Q - (\lambda - \mu) = 0 \tag{2}$$

$$\dot{\lambda} - \delta\lambda = -\,\partial\tilde{H}(\bullet)/\partial S = -\,W_S \tag{3}$$

$$\dot{\mu} - \delta\mu = -\,\partial\tilde{H}(\bullet)/\partial P = -\,W_P \tag{4}$$

$$\dot{S} = \partial\tilde{H}(\bullet)/\partial\lambda = -\,Q \tag{5}$$

$$\dot{P} = \partial\tilde{H}(\bullet)/\partial\mu = Q \tag{6}$$

It is easiest to identify the steady-state optimum and then, depending on the separability and concavity of $W(\bullet)$, discuss uniqueness and approach dynamics. In steady state $\dot{S} = \dot{P} = \dot{\lambda} = \dot{\mu} = Q = 0$. The first-order necessary conditions imply that $W_Q = \lambda - \mu$, where $\lambda = W_S/\delta$, $\mu = W_P/\delta$, and thus

$$\delta W_Q + W_P = W_S \tag{7}$$

This last expression has a straight-forward, capital-theoretic interpretation. It says that you stop cutting old-growth forest when the interest payment on the marginal welfare obtained from cutting one more hectare (δW_Q) plus the value of having one more hectare of land devoted to new-growth forest (W_P) equals the marginal value of an additional hectare of old-growth forest (W_S). The left-hand-side (LHS) of this equation can be interpreted as the value of cutting the marginal hectare of old-growth and devoting it to new-growth forestry. The right-hand-side (RHS) is the marginal value of preserving that hectare of old-growth.

To illustrate, consider the case when $\Phi(\bullet)$ is strictly concave in S and concave in J. Specifically, let $\Phi(\bullet) = \alpha \ln(S) + \omega J$, where α and ω are positive constants and $\ln(\bullet)$ is the natural log operator. Suppose, as suggested earlier, that $q = (1/\tau)P$, where $\tau > 0$ is the Faustmann rotation for new-growth forest. The rotation length adopted by new-growth foresters will depend on the rate of discount, the price for timber and the cost of cutting and replanting. Let the number of jobs be given by $J = \kappa Q + \nu q = \kappa Q + (\nu/\tau)P$, where κ and ν are positive job coefficients. These functional forms imply

$$W(S,P,Q) = \alpha \ln S + \omega[(\nu/\tau)P + \kappa Q] \tag{8}$$

The steady-state optimality condition $\delta W_Q + W_P = W_S$ implies

$$S^* = \frac{\alpha\tau}{\omega[\delta\kappa\tau + \nu]} \tag{9}$$

and, assuming $S_0 > S^*$, the steady-state number of hectares of new-growth forest will be $P^* = P_0 + (S_0 - S^*)$. In this case the current-value Hamiltonian is linear in Q and the optimal approach path is "most rapid." Suppose there is an upper bound on the rate at which old-growth can be cut given by Q_{MAX}. Then $Q^* = Q_{MAX}$ from $t = 0$ to $T^* = (S_0 - S^*)/Q_{MAX}$.. In steady state the number of hectares of new-growth cut each year from the synchronized forest under rotation τ will be $q^* = (1/\tau)(P_0 + S_0 - S^*)$ and the number of jobs in the forest sector will be $J(0,q^*) = J^* = \nu q^* = (\nu/\tau)(P_0 + S_0 - S^*)$. The complete solution for this case is shown in Figure 1.

III. Estimation and Calibration

Unfortunately, there is no timeship and no possibility of changing the historical evolution of old growth. By 1986 Booth (1991) estimates that approximately 82.5 percent of the old-growth in Washington and Oregon had been cut, burned or lost in the eruption of Mt. St. Helens. This estimate might be put to interesting use. Suppose we can estimate or assign values to all the parameters in equation (9) with the exception of α, the parameter weighting the old-growth benefit function, ln(S). Suppose, tentatively, that the remaining stock of old-growth in 1986 was optimal; that is $S^* = 0.175$, where the initial stock of old growth has been normalized, $S_0 = 1$. Then, one can solve (9) for $\alpha = S^*\omega[\delta\kappa\tau + \nu]/\tau$. With an estimate for α one can calculate the marginal value of old-growth as $d[\alpha \ln(S^*)]/dS = \alpha/S^*$. Finally, if an independent estimate of the marginal value of old-growth could be obtained (say by a contingent valuation survey) and if that estimate exceeds α/S^*, then all remaining old-growth should be preserved. The remainder of this section will present estimates for κ, ν, ω, δ and τ and the resulting marginal social value for old growth.

We begin with estimates of κ and ν, the job coefficients per hectare of harvested old-growth and new-growth, respectively. Table 1 contains pooled cross-section (Washington and Oregon) time-series (1983-1993) data on jobs (in thousands) in the lumber and wood products sector. Table 1 also contains the volume of timber harvested from private and public lands in millions of board feet, Scribner scale. Public land includes State and National Forest, Bureau of Land Management, Bureau of Indian Affairs and other public lands. The odd-numbered observations are for the State of Washington and the even-numbered observations are for Oregon. These data come from Warren (1995, Tables 16 and 21).

Jobs were regressed on the volume of timber cut from private and public land using OLS while suppressing the constant. The coefficients, with t-statistics in parentheses, are given below.

$$\text{Jobs} = \underset{(5.7450954)}{0.0060110}\ \text{Private} + \underset{(7.9913085)}{0.0094389}\ \text{Public} \qquad F = 27.42595 \qquad (10)$$

With jobs measured in thousands, these coefficients imply that approximately 6.0 jobs per year are generated per million board feet harvested from private land and that 9.4 jobs per year are generated per million board feet cut from public land. If public land contains older (larger diameter) trees that require more custom work at the mill, then the larger coefficient per million board feet from public land makes sense. Greber (1994, Table 2) reports on a U.S. Forest Service study which estimated that a million board feet would generate a total of 7.8 direct jobs in logging, sawmills, veneer/plywood, millwork and other forest sector activities. The job coefficients for new growth (ν = 6.0) and old growth (κ = 9.4) estimated from the data in Table 1 bracket that estimate in a plausible way.

The coefficients κ and ν, however need to measure the jobs generated per hectare of old-growth and new-growth. The coefficients on private and public land need to be associated with one or the other forest type and adjusted for the average volume per hectare of new-growth and old-growth. Table 2 is a yield table (part of Table 4) from McArdle (1930). It contains the yield per acre in board feet, Scribner scale, for 10 year intervals across 14 site quality classifications. The site quality index ranges from 80 to 210, with 80 being the lowest quality site and 210 being the highest quality site.

We will discuss, momentarily, the estimation of a yield function for an acre of site class 140 land. The Faustmann rotation (τ) when $\delta = 0.05$ is 62 years. If this rotation were used to manage private lands, the yield function would predict the volume at harvest to be 17,674 board feet per acre. A hectare is 2.471 acres, so the jobs generated per hectare of harvested (private) new-growth could be calculated as

$$\nu = (6.0)(17{,}674)(2.471)/1{,}000{,}000 = 0.26 \text{ jobs per year.}$$

For old-growth forest, recall in the opening quote that McArdle refers to stands which might "cruise" at 100,000 board feet per acre. Instead of taking this, perhaps overly optimistic, estimate of the volume on an acre of old growth, we averaged the yield for 160 year-old trees across the 14 site classification obtaining an average of 95,171 board feet per acre. The number of jobs generated by cutting a hectare of (public) old-growth would be calculated as

$$\kappa = (9.4)(95,171)(2.471)/1,000,000 = 2.21 \text{ jobs per year.}$$

The data in Table 2 can be used to estimate yield functions for each site class. A functional form frequently used in fitting timber volume, V, to age, t, is the exponential $V(t) = e^{a - b/t}$. For Site Class 140 the natural log of volume was regressed on 1/t with the following results (t-statistics in parentheses)

$$\ln V = \underset{(71.51)}{12.96} - \underset{(-16.72)}{196.11}\,(1/t) \qquad \text{Adjusted } R^2 = 0.95 \tag{11}$$

With the yield function it is possible to determine the Faustmann rotation as the value, τ, which maximizes $\pi = \pi(\tau) = (pV(\tau) - c)/(e^{\delta\tau} - 1)$, the present value of all future rotations. π is also referred to as "land expectation value," or the value of bare land devoted to new-growth forestry under rotation, τ, where p is the net (stumpage) price per board foot for Douglas fir, c is the cost of replanting an acre of land, and δ is the discount rate. With given values for p, c and δ, it is possible to solve for τ, π, and $V(\tau)$. A net stumpage price of p = \$0.65 per board foot was selected. This was the average price in 1994. A replanting cost of c = \$182 per acre was adopted based on an estimate of \$150 per acre (circa 1980) used by Gamponia and Mendelsohn (1987). This replanting cost was adjusted upward by the producer price index. The discount rate was varied from $\delta = 0.02$ to $\delta = 0.08$. The values for τ, $V(\tau)$ and π are reported in the first three rows of Table 3.

Recall that the job coefficient, ν, depended on the volume at harvest, $V(\tau)$, according to $\nu = 6*V(\tau)*2.471/1.0E6$. These values are calculated in the fourth row of Table 3. The weight assigned to a job in the forest sector (ω) was set at \$40,000 per year; reflecting an estimated average salary of \$32,000 and benefits of \$8,000 per year.

With $\kappa = 2.21$, $\omega = \$40,000$, and τ, and ν depending on δ, it is possible to calculate the old-growth weighting parameter, α, and the marginal social value of remaining old growth, α/S^*, *assuming* $S^* = 0.175$. These values are calculated in the fifth and sixth row of Table 3.

The first thing to note is the significant effect which the discount rate has on the Faustmann rotation, volume at harvest and land expectation value. As the discount rate increases from 0.02 to 0.08, the rotation length drops from 91 to 50 years, volume at harvest goes from 49,130 board feet per acre to 8,347 board feet per acre, and land expectation value drops from $6,156 per acre to $99 per acre.

The job coefficient also declines with an increase in the discount rate, since v directly depends on the volume at harvest. The weighting parameter on the old-growth benefit function was calculated as $\alpha = S^{*}\omega[\delta\kappa\tau + v]/\tau$. Assuming $S^{*} = 0.175$, this coefficient increases as δ increases and the rotation shortens. This implies that the marginal social value of remaining old-growth, α/S^{*}, must increases as δ increases. This value might be regarded as a "hurdle value;" that is, a value which must be exceeded by a direct estimate of marginal old-growth values. At low discount rates, and longer rotations, the volume of timber coming off new-growth lands is considerably higher than the volume at high discount rates. The opportunity cost of the old-growth inventory is lower according to our general inventory rule, $\delta W_Q + W_P = W_S$. This implies that the marginal value of preserved old growth need not be as high as when the discount rate is higher and the rotation length, volume at harvest and jobs per hectare are smaller. With a higher discount rate the marginal social value of old-growth forest must be higher to justify preservation of the remaining stock.

This preservation rule might be contrasted to the rule suggested by Conrad and Ludwig (1994) based on a model where no explicit value was placed on jobs in the forest sector. In that model, the optimal inventory of old growth was determined by equating marginal social value to the interest earned on the sum of old-growth stumpage plus land expectation value. If B(X) denotes the nontimber benefit flow from the old-growth inventory, and if N is the net (stumpage) value of a hectare of old-growth timber, then the inventory rule was to preserve X^* where $B'(X^*) = \delta[N + \pi]$. If a hectare of old-growth Douglas fir yields 235,168 board feet at a stumpage value of $0.65 per board foot, the net value would be N = $152,859. If we add land expectation value from Table 3 and multiply by the corresponding rate of discount, we would obtain opportunity cost values of $3,180, $7,670, and $12,237 for discount rates of δ = 0.02, 0.05, 0.08, respectively. The corresponding opportunity costs in the present paper are $2,089, $4,591 and $7,173 (see Table 3). Thus, based on either the opportunity cost of jobs, or the opportunity cost of old-growth plus new-growth timber, we obtain reasonably similar estimates of the marginal nontimber values needed to justify preservation of the remaining old-growth stock.

Finally, Table 4 provides estimates of the number of jobs in the steady-state forest economy if all remaining old growth is preserved. Haynes

(1986) estimated that 1,378,390 hectares of old-growth forest remain in western Washington and Oregon. Of this amount, 267,098 hectares were located in National Parks, and thus protected from logging. Booth (1991) estimates that the stock of old-growth forest (trees 200 years or older), prior to settlement by whites, was 7,878,106 hectares. Thus the remaining stock of old growth, outside the national parks, had been reduced to about 14% of its pre-settlement level.

In 1987 the total amount of forested land (old-growth and new-growth) outside the National Parks was estimated by Powell *et al.* (1994) to be 15,756,373 hectares. Subtracting the estimate of old growth leaves 14,645,081 hectares of new-growth forest. If we consider discount rates of $\delta = 0.02$, 0.05, and 0.08, with rotations of 91, 62, and 50 years, the corresponding job coefficients (v) will imply a steady-state workforce with 117,225, 61,887, and 36,232 jobs in the lumber and wood products sector.

Warren (1995) estimated that there were 89,400 jobs in the lumber and wood products sector in 1993. There were an additional 25,800 jobs in paper and allied products for a total of 115,200 jobs. The job figures in Table 4 assume that there is no loss of land from new-growth forestry to other uses. As in Table 3, the discount rate and rotation length have a significant effect on the steady-state level of employment. Berck (1979) found evidence that forest companies were discounting at a real rate of five percent. Prevailing rotation lengths on private industrial land are about 50 years, perhaps implying a discount rate closer to eight percent. Thus, the discount rate adopted on public and privately controlled forest land, can have a significant effect on the steady-state work force in the lumber and wood products sector. The U.S. Forest Service has been criticized for maintaining stocks of overmature timber, at a considerable present-value cost to society. In the model of this paper, longer rotations and higher harvest volumes per hectare will lead to more steady-state jobs in the forest economy. This might be regarded as another rationale for maintaining older stands of timber in the public, new-growth inventory.

IV. Conclusions and Caveats

This paper has attempted to examine the trade-off between jobs and the preservation of old-growth forest in the Douglas fir region of western Washington and Oregon. An optimal control model was constructed which gave rise to an optimal inventory rule which in turn determined when to stop the cutting of old growth. This inventory rule equated the interest payment on the value of cutting one more hectare of old growth, plus the value of one more hectare of new growth, to the marginal social value of preservation ($\delta W_Q + W_P = W_S$). For plausible functional forms, this inventory rule defined an explicit expression for the optimal old-growth inventory,

$S^* = \alpha\tau/[\omega(\delta\kappa\tau + \nu)]$. With the exception of α, the weighting parameter on the old-growth benefit function, all parameters could be estimated or assigned plausible values. If one were willing to assume that the remaining stock of old growth (including old growth in National Parks) was optimal, then $S^* = 0.175$, where $S_0 = 1$, prior to the commencement of commercial logging. In this model the discount rate (δ) determined the optimal rotation (τ), volume at harvest [$V(\tau)$], and thus the new-growth job coefficient (ν). The old-growth job coefficient (κ) and the value of a job in the forest sector (ω) did not depend on the discount rate and were estimated based on the average volume of timber coming off 160 year-old, even-aged stands of Douglas fir, and on the average salary and benefits in the lumber and wood products sector, respectively. It was possible to use the optimal inventory rule to calculate values of α for alternative discount rates and then use α to estimate the marginal social value of remaining old growth (α/S^*). These values might be thought of as hurdle values. If a direct evaluation of the public marginal value of old-growth, say by a contingent valuation (CV) survey, exceeded α/S^*, then all remaining old growth, including the 1,111,292 hectares outside the National Parks, should be preserved. For the model in this paper the CV estimates would need to exceed $2,089 per hectare at $\delta = 0.02$ or $7,173 per hectare at $\delta = 0.08$.

In steady state, where jobs in the forest economy are based entirely on the flow of timber from new-growth forest, employment was highly sensitive to the discount rate and the volume at harvest from a new-growth hectare. At $\delta = 0.02$, $\tau = 91$ years and $V(\tau) = 49{,}130$ board feet per acre. If the inventory of new-growth forest under public and private ownership were unchanging at 14,645,081 hectares, this would translate into 117,225 jobs in the lumber and wood products sector. If the discount rate were $\delta = 0.08$, $\tau = 50$ years and $V(\tau) = 8{,}347$ board feet per acre. With the same new-growth inventory the number of jobs falls to 36,232. Approximately 53 percent of the new-growth inventory is publicly held with many tracts regarded as financially overmature (ie, excessively old) when evaluated at a rate of discount of $\delta = 0.05$ (Berck, 1979). Thus, current federal policy, while resulting in a loss of present value to U.S. taxpayers, may help soften the reduction in forest sector jobs as the Douglas fir region inevitably moves toward a steady-state forest economy.

The model in this paper was a highly stylized depiction of a forest-based economy trying to determine how much of an old-growth inventory to cut before preserving the remainder. In steady state the volume of timber and forest sector jobs would be based on rotational harvests from new-growth forest. A steady state would exist under the assumption that no new-growth forest land would be converted to other land uses. This latter assumption is not realistic for a region that has witnessed significant growth in population and industry. According to Powell *et al.* (1994), between 1952 and 1992 the total forest inventory (public and private) had declined from 18,161,068 hectares to 15,318,089 hectares (a 15.6 percent reduction).

The Faustmann model, which was used to determine rotation length and volume at harvest, presumes a stationary growth function and a constant price-cost ratio. In reality stumpage prices for Douglas fir are highly volatile and the harvest and inventory decisions by large forest products firms reflect a system optimization in the face of considerable price uncertainty.

Some observers have maintained that the Pacific Northwest may be at a competitive disadvantage in rotational forestry relative to the southeastern United States where fast growing pines might be harvested on a 30 year rotation. It has been argued that the industry in the Pacific Northwest was based on the large old-growth inventory and, when that played out, the southeastern U.S. was a better place to grow trees. Dynamic, interregional forest competition was not incorporated in the present model.

Finally, the actual forest policy adopted by the Clinton Administration has been one of compromise. A decision to preserve all remaining old-growth was viewed as too harsh an approach to the steady-state forest economy. During the debate over how to provide adequate habitat for the northern spotted owl, the Forest Ecosystem Management Assessment Team (FEMAT) laid out a series of options that were expected to reduce timber harvest (from all owners) by between 0.8 to 2.1 billion board feet, or about a 7 to 17 percent reduction from the 1990-1992 average (Greber 1994). Thus, even if a well done CV study revealed a higher marginal social value to preservation, it is unlikely that all remaining old-growth in the federal inventory would be preserved.

Perhaps the question becomes "If not now, when?" At the other extreme from preserving all remaining old growth today, is a decision to continue cutting until all remaining old growth resides in the National Parks. Economic models, such as the one presented here, will not capture all the important aspects of old-growth forest policy, but they can focus on important trade-offs and cause us to consciously think about the inventory of natural environments we wish to preserve for the future.

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Figure 1. The MRAP Approach and the Steady-State Forest Economy

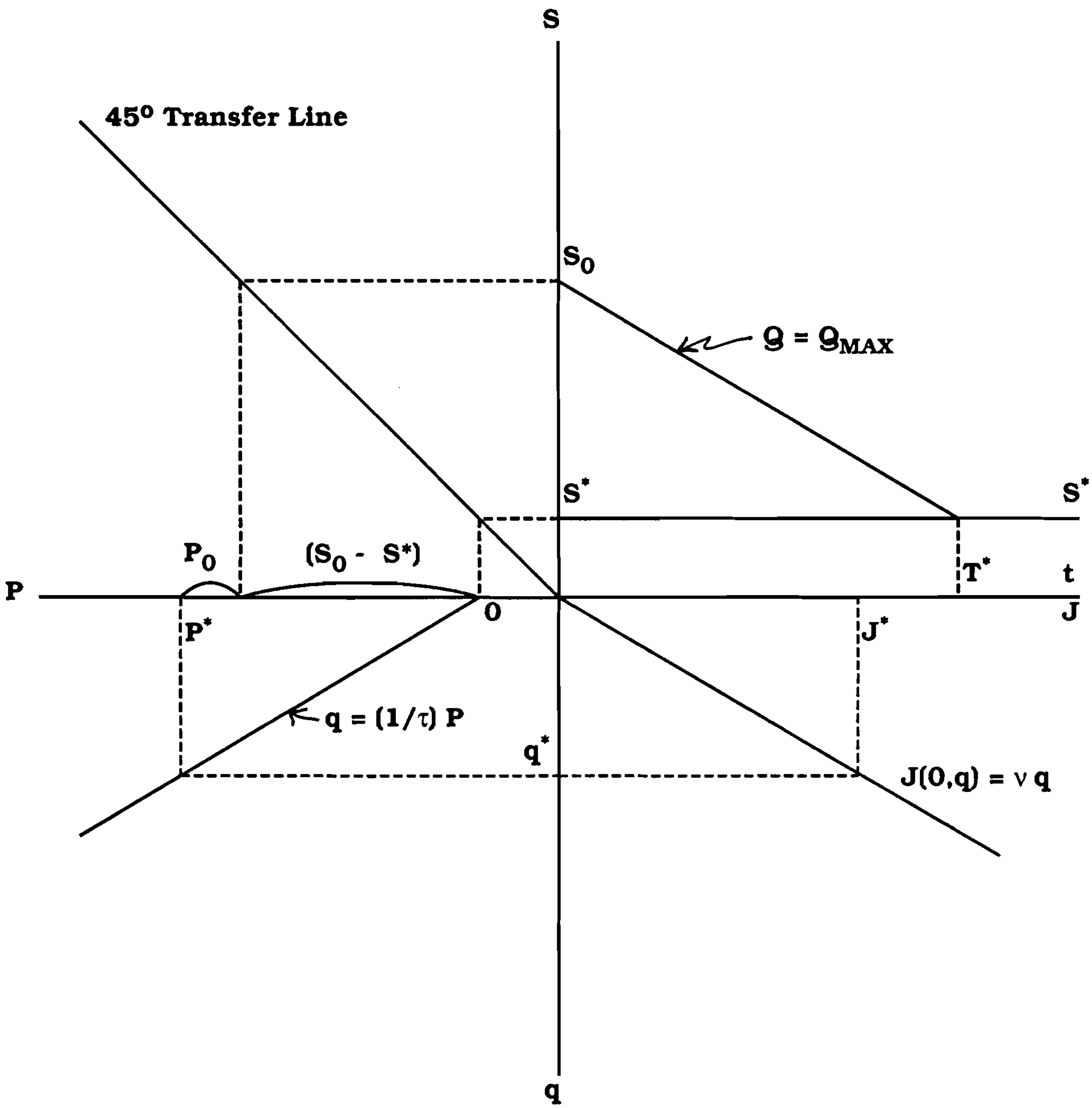

Table 1. Jobs and the Volume of Timber Harvested from Private and Public Lands

Observation Number	Jobs	Private	Public
1	41.1	4,025	2,063
2	62.6	3,374	4,090
3	41.0	3,545	2,257
4	66.7	3,078	4,472
5	37.3	3,561	2,402
6	63.6	3,332	4,795
7	36.7	3,989	2,567
8	63.9	3,494	5,249
9	39.2	4,367	2,670
10	66.5	3,281	4,934
11	41.7	4,406	2,639
12	67.9	3,259	5,356
13	41.1	4,520	2,268
14	67.0	3,721	4,699
15	39.9	4,147	1,702
16	63.7	3,229	2,990
17	36.4	3,650	1,454
18	57.1	3,312	2,768
19	36.5	3,844	1,174
20	54.3	3,581	2,161
21	36.1	3,321	986
22	53.4	3,608	1,686

Notes:

1. Source: Warren (1995, Tables 16 and 21).
2. Jobs are in thousands of jobs in the lumber and wood products sector.
3. Private is the volume of timber harvested from private lands in million of board feet, Scribner scale.
4. Public is the volume of timber harvested from State, National Forest, Bureau of Land Management, Bureau of Indian Affairs and other public lands, also in million of board feet, Scribner scale.
5. Odd numbered observations correspond to Wahington State, even numbered observations to Oregon State, for the period 1983 to 1993, inclusive.

Table 2. Yield in Board Feet, Scribner Scale, for Douglas fir on a Fully Stocked Acre, by Age and Site Class.

	Site Class Index													
Age	80	90	100	110	120	130	140	150	160	170	180	190	200	210
30	0	0	0	0	0	0	300	900	1,500	2,600	4,000	6,000	8,000	10,500
40	0	0	0	200	1,200	2,600	4,500	6,500	9,000	11,900	15,500	19,600	24,400	29,400
50	30	200	1,600	3,300	5,500	8,400	12,400	17,000	22,200	27,400	32,700	38,400	44,100	50,000
60	1,100	2,600	4,800	8,100	12,500	18,000	23,800	29,600	36,200	42,800	49,300	55,900	62,000	68,300
70	2,400	5,300	9,000	14,000	20,600	27,900	35,200	42,500	50,000	57,200	64,600	71,500	78,200	85,000
80	4,400	8,600	13,900	20,100	28,600	37,000	45,700	54,300	62,100	70,000	78,000	85,400	92,500	99,800
90	6,900	12,000	18,600	26,000	35,700	45,200	55,000	64,000	72,900	81,000	89,200	97,200	104,800	112,300
100	9,600	15,400	22,800	31,400	42,000	52,400	62,800	72,400	81,800	90,400	98,900	107,100	115,100	122,900
110	12,200	18,900	26,700	36,300	47,500	58,500	69,400	79,400	89,200	98,300	107,000	115,200	123,700	131,200
120	14,700	21,800	30,400	40,700	52,400	63,900	75,000	85,500	95,500	105,100	114,100	122,500	131,100	139,000
130	17,000	24,600	33,800	44,700	56,700	68,700	80,000	91,000	101,100	111,000	120,000	128,900	137,700	146,100
140	19,200	27,200	36,800	48,300	60,600	72,900	84,500	95,900	106,200	116,300	125,500	134,500	143,500	152,000
150	21,300	29,600	39,700	51,600	64,000	76,600	88,600	100,300	111,000	121,200	130,700	139,500	148,700	157,200
160	23,300	31,900	42,200	54,600	67,100	80,100	92,400	104,400	115,400	125,700	135,400	144,400	153,500	162,000

Source: McArdle (1930, Table 4)

Table 3. Faustmann Rotation (τ), Volume at Harvest for New-Growth [$V(\tau)$], Land Expectation Value (π), New-Growth Job Coefficient (v), Old-Growth Weighting Parameter (α), and the Marginal Social Value of Remaining Old-Growth (α/S^*).

	$\delta = 0.02$	$\delta = 0.03$	$\delta = 0.04$	$\delta = 0.05$	$\delta = 0.06$	$\delta = 0.07$	$\delta = 0.08$
τ	91	77	68	62	57	53	50
$V(\tau)$	49,130	33,367	23,850	17,674	13,407	10,499	8,347
π	6,156	2,365	1,077	543	293	167	99
v	0.7284	0.4947	0.3536	0.2620	0.1997	0.1557	0.1237
α	365	509	655	803	953	1,104	1,255
α/S^*	2,089	2,909	3,745	4,591	5,446	6,307	7,173

Notes:

1. τ in years, $V(\tau) = e^{a - b/\tau}$, in board feet (Site Class 140), π in dollars per acre, v in jobs/year/hectare of cut new-growth, α in dollars, α/S^* in dollars per hectare.
2. $a = 12.96$, $b = 196.11$, $c = \$182$/acre, $p = \$0.65$/bd. ft., $\kappa = 2.21$, $\omega = \$40,000$/year, $S^* = 0.175$

Table 4. Jobs in the Lumber and Wood Products Sector if Remaining Old-Growth is Preserved.

	$\delta = 0.02$	$\delta = 0.05$	$\delta = 0.08$
τ	91	62	50
v	0.7284	0.2620	0.1237
P	14,645,081	14,645,081	14,645,081
Jobs = $(v/\tau)P$	117,225	61,887	36,232

Notes:

1. The total amount of forest land, outside the National Parks, in 1987 was estimated at 15,756,373 hectares (Powell *et al.*, 1994 Table 7, p. 42).
2. The amount of old-growth forest outside the National Parks was estimated by Haynes (1986) to be 1,111,292 hectares. This amounts to seven percent of total forested land outside the National Parks.
3. If all remaining old-growth forest outside the National Parks were also preserved and if the remaining forest land (private and public) were devoted to new-growth, rotational forestry, then P = 14,645,081 hectares.

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