DISCUSSION PAPER

August 2015 ■ RFF DP 15-37

The Effects of a Federal Tax Reform on the US Timber Sector

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Abstract

Under discussion in the US Congress is the desirability of reforming much of the US federal tax code. Recent proposals include lowering rates and broadening the tax base by, among other things, eliminating tax expenditure write-offs, preferences, and incentives. This study focuses on tax changes that might apply to the timber sector. The study looks at the effects of ending the capital gains treatment of timber, eliminating the timberland ownership form known as a real estate investment trust (REIT), restricting the deductibility of current management costs, and repealing the deductability of reforestation costs. Additionally, because our study focuses exclusively on the timber sector, it treats the rest of the federal tax system as unchanged except in one scenario, where we introduce lower corporate and individual income tax rates. We examine these changes using the Timber Supply Model, which projects their effects on timber sector investment, growing stock, harvests, prices, and international trade (net imports).

The effects of a proposed tax change on the timber sector include the following:

- a reduction in investments in timber production, with both timber regeneration and management levels declining substantially;
- the revaluation of timber assets downward even though the physical forest is initially unchanged;
- a reduction in the physical timber stocks over time, reflecting the decrease in investment compared with what would have occurred if taxes were not changed;
- a decline in US comparative advantage in timber production as foreign production replaces US production causing a increased trade deficit of by up to $3.6 billion per year;
- a reduction in the area of US timberlands, which would be up to 15 million acres less than it would have been in the absence of the tax change; and
- dominance of the negative effects of the tax increases over the positive effects of a corporate tax decrease of 10 percent, as examined in the study.

Finally, note that the declines in the timber sector take place in the context of pretax long-term declines projected in the default or base case of the model.

Key Words: timber, forests, tax reform, investment, harvest, timberlands, forestlands

JEL Classification Numbers: Q23, Q24, C51, H25

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Introduction

Reforming the federal tax code in the United States is almost always up for debate among lawmakers. During the last Congress, Representative David Camp (R-MI), then chairman of the House Ways and Means Committee, introduced a proposal to fundamentally reform the tax code by lowering rates and broadening the tax base. Certain tax expenditure write-offs, preferences, and incentives would be eliminated. This study uses that proposal as a frame of reference to model tax changes that might apply to the timber sector while treating the rest of the tax system as unchanged, except in one scenario. We estimate the effects of the proposed changes on the US timber industry. In addition to the specific "timber tax" provisions, we examine the effects of repealing the treatment of timberland as real property for purposes of the real estate investment trust (REIT), a change that would eliminate the REIT as a timberland ownership form. The study also looks at the effects of ending the capital gains treatment of timber, restricting the deductibility of current management costs, and repealing the deductibility of reforestation costs. Since our study focuses exclusively on the timber sector, it treats the rest of the federal tax system as unchanged except in one scenario, where we introduce lower corporate and individual income tax rates.

The purpose of this study is not to argue for or against any of the tax proposals, but rather to examine in an objective manner the likely effects of specific changes in timber taxation on the industrial timber resources of the United States. Although timber and forests generate environmental as well as economic effects, only economic effects are analyzed here. Ultimately it is for policymakers to determine whether tax changes with the anticipated implications are desirable in the broad policy context.

Early analysis by Quantria Strategies suggests substantial consequences for the forest sector:

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- a major reduction in timber harvesting, resulting in a loss in sales and jobs in the forest industry;
- a substantial reduction in active forest management; and
- a reduction in investments in US forestland, which will result in a restructuring of forest ownership, investment outflows to foreign sites, a decrease in domestic forest products production, increased US imports of forest products, and the conversion of forests to other uses.

Although using a different approach, the current study confirms those general effects on the forest industry. Our findings are that the effects of a proposed tax change on the timber sector include the following:

- a reduction in investments in timber production, with both timber regeneration and management levels declining substantially;
- the revaluation of timber assets downward even though the physical forest is initially unchanged;
- a reduction in the physical timber stocks over time, reflecting the decrease in investment compared with what would have occurred if taxes were not changed;
- a decline in US comparative advantage in timber production as foreign production replaces US production causing a increased trade deficit of by up to $3.6 billion/yr.;
- a reduction in the area of US timberlands, which would be 11–15 million acres less than it would have been in the absence of the tax change; and
- a dominance of the negative effects of the various industry-specific tax increases over the positive effects of a corporate tax decrease of 10 percent, as examined in the study.

Additionally, it should be noted that these declines occur in a timber sector that is already experiencing declines in its base conditions.

Our basic tool is the Timber Supply Model (Sedjo and Lyon 1990), sometimes called the Global Timber Trade Model, which has been updated, modified, and expanded (e.g., Sohngen et al. 1999). The model used in this exercise is a modified update of the version used by Daigneault et al. (2012). The model can project aspects of the timber sector, including both industrial wood production and forest carbon potentials, through time. It incorporates all US forestland, public and private, but looks at tax changes only on the 342 million acres of private timberland, since public harvests are assumed to be unaffected. The supply side of the basic model consists of

forestland with various biological yield rates that can be modified by changes in investment and management levels, as well as land use changes. Superimposed on this system is a demand side that anticipates increasing demand levels though time based on past experience. The economically driven supply side uses an optimal control type approach, which essentially generates a long-run supply function, to respond in an economically optimum manner to demand and demand changes, which grow modestly through time. In our study, the model makes projections through 2055. The base case or default projection is a business-as-usual situation that implicitly embodies the current tax code and anticipates an increasing demand though time Since the supply side responds to increasing demand, the base case will see harvest and timber price changes through time, even in the absence of any tax changes. In the four scenarios, we introduce tax changes explicitly and compare their results against the base case. Thus the effect of the change in taxes is the difference between the projections under the base case and the projections after the tax changes of each scenario are introduced in 2015 and maintained into the indefinite future.

The Timber Supply Model examines timber from inception, from either a natural stand or the establishment of a planted forest. The value of the timber is that determined on the stump ("stumpage"). Thus harvesting costs and transport are not explicitly considered in the model but are important to the extent that they affect stumpage prices.

General Approach

We assess the effects on the US timber industry—specifically, the forest stock, timber prices, harvest and investment levels, and timber imports—of proposed tax reforms as applied to the various types of private forest ownerships. The approach involves two phases. First, we identify the tax changes and business types to which the changes apply, and estimate the tax impacts on the costs and net returns of the various business forms. Second, we apply subsets of the cost estimates cumulatively to the Timber Supply Model under four alternative scenarios to estimate their respective and aggregate effects on timber production and investment levels through time.

More specifically, Phase 1 examines the several current private forest ownership forms to determine the anticipated effect of the proposed tax changes on their respective costs of growing timber. These business forms are C corporations; public and private REITs, including partnerships, S corporations, LLC, and others; and both large and small proprietorships. An estimate is made of the effect on the costs of each type of tax change for a representative business ownership for each type of business form.

Phase 2 incorporates these business forms and associated tax changes into an adapted version of the Timber Supply Model on an area weight-adjusted basis. The focus is on the timber resource—the timber stock, harvest, investments, and changes in the stock over time. The estimates of cost changes associated with each type of tax change are integrated into the appropriate business form in the underlying model to project the effects on the business forms' costs, investments, and production. The model then captures the effects of timber cost changes associated with the tax revisions for a typical or representative firm of each type.

The model provides projections though time of timberland based on economic conditions and forest biology. It is an optimal control model and thus captures these changes during the transition as the sector adapts to the new tax conditions. These results are compared with the levels prior to the introduction of the tax reform, with the difference being an estimate of the effects of the tax changes.

US Timberland Ownership

Most commercial timber comes from timberland, defined by the US Forest Service as that subset of forestland that has the biological potential to produce timber on a sustainable commercial basis. Although somewhat arbitrary, the Forest Service gives a figure of 22 cubic feet/acre/year. By this measure, the total area of forest with this potential is estimated at 474 million acres. However, this study defines timberlands as any land managed for commercial timber. In most cases the definitions coincide.

Table 1 classifies the land area by ownership type. We examine four basic private ownership types: corporations, public REITS, private REITs and similar ownerships, and proprietorships (large and small).

Table 1. US Timberland Ownership, 2014

	Acres of timberland (million)
Public REITS	20
TIMOs, private REITs	22
Proprietorships: Large owners[a]	100
Other (over $10 million revenues)	100
Other Under $10 millionrevenues	100
Total private	342
Public timberland	132
Total US timberlands	474

Sources: AF&PA (2010); Butler (2008); Tracy Evans, personal communication; Evans and Myers (2014); Forisk (2013, 2014); Mitchell (2006); US Forest Service (2012).
Notes: REIT = real estate investment trust; TIMO = timberland investment management organization
[a] 286 larger owners average 348,000 acres.

Proposed Tax Changes: More Specifics

We use the changes included in Representative Camp's tax reform proposal (as mentioned above) as a first approximation because the suggested changes appear representative, although that proposal is just one among several. The changes examined in this study all affect the costs of growing and maintaining a stock of timber, or stumpage, through harvesting. Issues such as transport and mill activities are not examined.

The major proposed tax and related changes are as follows:

- Ending the capital gains treatment for timber revenue. Since 1944, the Internal Revenue Code has treated proceeds from timber harvests and the sale of standing trees as capital gains (IRC Sections 1231(b)(2) and 631(a)&(b)). The proposal takes the position that timber is not a capital asset and therefore would tax timber income as ordinary income.
- Elimination of REIT status for timberland ownership (IRC Sections 856 through 859). REITs, an ownership form chosen by many current forest owners and investors, allow so-called pass-through entities (e.g., Kleinbard 2015). The repeal of capital gains treatment would effectively exclude timberland from REIT status.
- Restricting the deductability of current timber management and operating costs to taxpayers with less than $10 million in annual gross receipts. Current law allows most forest landowners to deduct management and operating costs in the year they are incurred, rather than capitalizing these costs (IRC Sections 162 and 263A(c)(5)). The new

provision would require that tax deductability be taken in the year of timber sale for larger firms.

- Repeal of the deduction for reforestation costs. The current code allows most forest owners to deduct up to $10,000 of reforestation costs annually on qualified timberland per stand as these costs are incurred and to amortize the remaining costs over 84 months (IRC Section 194). The proposal would require that these costs be capitalized and not claimed until the timber is harvested or sold.

In addition, recent proposals have suggested the following tax related changes that this study does not address:

- Elimination of timber revenue as qualifying income for publicly traded master limited partnerships.
- Repeal of the provision excepting payment of interest on deferred payments for installment sales of timberland.
- Repeal of the like-kind exchange provision allowing an adjustment of basis rather than immediate payment of tax ("Starker exchanges," IRC Section 1031). This provision was intended to maintain the economic viability of 450 million acres of private forests (not all of timberland quality) owned and managed by more than 22 million forest owners, including individuals, families, institutional investors, and businesses.

Anticipated Effects of Proposed Tax Changes on the Various Timber Business Types

This section estimates the anticipated effects of the major elements of proposed tax reforms (outlined above) on the timber sector. It demonstrates how the specific estimates of the net effect of the tax changes on the timber revenue stream are calculated in this study. The numerical estimates are found in Tables 2 and 3. The approach is to compare the net effect of the impacts of the tax changes on the firm's revenue stream. For example, if a 20 percent capital gains tax were raised to 39.6 percent as a corporate tax were replaced by an individual personal income tax, the increased draw on the net revenue would be 19.6 percent (39.6 – 20.0). Thus a 19.6 percent reduction in net price to the firm would be built into the model to estimate the changes in the behavior of the forest sector after the new tax rate is introduced.

1. Repeal of Capital Gains Treatment for Timber Revenue and Elimination of the Timber REIT

The effects of the capital gains provision vary by business type and become particularly complicated when applied to REITs and their elimination. The tax proposal takes the position that timber is not a capital asset and thus timber income should be taxed as ordinary income. Under this proposed change, our analysis treats timber income as no longer qualifying for capital gains status and to be taxed at the ordinary income rates. The direct manifestation of the capital gains change is found largely in proprietorships that would have to pay ordinary income tax rates on timber revenues, rather than lower capital gains rates (see below).

Corporations

The loss of capital gains treatment in itself would have little direct effect on C corps. Their capital gains are already taxed at the ordinary income rate—currently at the maximum corporate tax rate of around 35 percent, plus an average of about 4 percent state income tax. In addition, corporate shareholders pay individual income taxes on corporate dividends, reflecting the well-known double taxation of corporations. However, there are few timber corporations, as most already have converted to REITs.

Public REITS

Under current law, for an organization to qualify as a REIT, a number of conditions apply, including the requirement that the organization be otherwise taxable as a domestic corporation. In this case, elimination of REIT status causes former REITs to be taxed as corporations.

The ability of timberland ownerships to be classified as REITs, either public or private, has substantial tax implications. This classification enables the firms to bypass both federal and state corporate taxes and pass the tax liabilities to the individual investors, where the income is taxed as the shareholder's ordinary income, usually at lower rates. Today most former timber corporations have modified their organizations so that they qualify and are taxed as public REITS, which trade on financial exchanges. These companies continue to manage their timberlands directly and, as REITs, taxes are collected as dividends or capital gains to the shareholders..

The proposed new tax legislation would specifically exclude timberland ownership from REIT status, thereby eliminating the timber REIT tax advantages. As noted, since a firm must be a corporation to qualify as a REIT, the loss of REIT status implies the firm will now be treated as

a corporation for tax purposes. In our analysis, we treat the loss of public REIT status as instituting a corporate income tax. Under the proposed tax, timber's tax liability would rise from about a 20 percent capital gains rate to a 35 percent corporate rate plus the appropriate state corporate tax, which averages about 4 percent nationwide. Additionally, a tax applies on the investor's dividend at ordinary rates, currently topping at 39.6 percent. This is an increase of 19 percent, plus the tax rate on the investor dividend. If the corporate tax rate were reduced to, say, 25 percent, as in our Scenario P4, the total tax would be increased by 9 percent plus the tax on the investor dividend. For weighting purposes in the model, we estimate timberland area in public REITS to be about 20 million acres.

Private REITs

Private REITS, which are managed by timberland investment management organizations (TIMOs), also pass income to owners who pay taxes at their individual ordinary rates. TIMOS are organizations that are not timberland owners but are forestland managers. The TIMOs manage holdings for various ownerships that are structured in one of several ways:

- Private REITs that do not pay taxes directly. Rather, the timber income is passed through to shareholders. As the majority of private REIT owners are tax-exempt institutions, such as pension funds or universities, they pay no taxes. For taxpaying private REIT shareholders, income would generally be taxed as dividends or capital gains.
- Master limited partnership (MLPs), which have many of the same type of tax advantages as a REIT but without the requirement to distribute all of their income.
- Limited liability companies (LLCs) and limited partnerships (LPs), which are private investment vehicles for high net-worth individuals and institutional investors. Many TIMOs have private investments in these forms. Many LLCs have tax advantages similar to those of a REIT but, for example, may not have to pay out income every year.

In many cases, the private REIT investor is a nontaxable organization, such as a pension fund or university, and the proceeds are not normally taxed. For a private investor, capital gains treatment has been of some benefit if the individual investor's ordinary tax is higher than the individual capital gains rate (20 percent). But this advantage would be lost with the demise of the timber REIT status when ordinary corporate taxes are imposed. To avoid this situation would probably require the REIT structure to be unwound and the individual invested in timber to find an alternative structure. The experts we conferred with differed in regard to the implications of eliminating the private timberland REIT. Some believe that it would be relatively costless to shift

to another low-tax form. However, most experts we met with believed that in treating timber as inventory, the proposed reforms may intend to tax otherwise tax-exempt organizations within TIMOs on their timber income by treating it as unrelated business taxable income (UBTI), and avoiding these taxes will be difficult and costly. We accept the view that such changes would be costly, and in most cases, the individual tax rates would probably rise from the current dividend rate of 20 percent to the ordinary income rate of about 39.6 percent for wealthier investors. This is the situation examined in our scenarios.

Finally, the private timber REIT also has a special provision for foreign investors that exempts them from a tax associated with the sending of proceeds offshore. This has made REITs attractive to foreigners. Discontinuation of their tax-exempt status could have a major effect. The Foreign Investment in Real Property Tax Act (26 USC Section 1445) requires that a buyer withhold 35 percent of the amount realized by the foreign seller in the sale of an interest in US real property. If the seller is a foreign person and the buyer fails to withhold, the buyer may be held liable for the tax. However, if a foreign investor invests as a minority interest in a domestically controlled private timber REIT, then the sale of the REIT shares does not trigger this tax withholding, since the REIT provides indirect ownership of the real property. The loss of the REIT vehicle for foreign investors might trigger tax consequences. We treat the 15 percent of private REITs that are foreign holdings as other private REITs

Proprietorships

The loss of capital gains treatment for timber would probably have the greatest effect on individual proprietorships, which in many cases would need to pay the higher individual income tax rate rather than the lower capital gains rate on their stumpage sales. We estimate that the removal of capital gains treatment would affect roughly 300 million acres of private timberlands: 100 million acres of large ownerships and 200 million acres of other family ownerships, typically smaller and on sites with lower productivity. The tax rate would generally be higher for large timberland holders and lower for smaller holders. For example, suppose the tax on timber rose from the current 20 percent capital gains rate to an ordinary income tax level of 39.6 percent for 200 million acres of large holdings and to an ordinary income tax level of perhaps 25 percent rate for 100 million acres of smaller holdings. The large holdings of 200 million acres would experience a 19.6 percent increase in tax, and the smaller holdings would experience only a 10 percent increase. This is, in effect, a reduction of 19.6 percent in net price received by the large timber producers and 10 percent in net price received by smaller producers.

2. Restriction of the Deductability of Current Management Costs

The tax code allows most timberland owners to deduct current management costs related to timber held as an investment or a business against income from any source (US Forest Service 2013). The proposed tax reform would limit these deductions for timber management costs only to taxpayers with less than $10 million in annual gross receipts.

We estimate that most timberland owners with 10,000 acres or less (accounting for about 100 million acres) would be under the $10 million threshold. Restricting the deduction of management costs would not affect these small private timberland holdings, but it would substantially reduce the value of management cost deductions for an estimated 300 million private timberland acres in all ownership types.

The costs are likely to be large for the firms affected and will depend on the length of the harvest rotation and the discount rate. For example, if we assume a 20-year rotation and a 3.5 percent discount rate, the effective value of the capitalized costs for tax deduction purposes would fall by 50 percent of the costs, had they occurred in the first year, thereby substantially reducing the deduction and increasing the effective tax rate. Since most management costs for a site are incurred within the first two years and rotations are commonly longer than 20 years (e.g., Sedjo 1983), the simplified assumption is that the value of management costs when used as a deduction will be reduced by at least 50 percent. This assumes a very conservative 3.5 percent discount rate. Finally, we would expect that a doubling of costs would create incentives to shorten the rotation substantially.

We estimate that the threshold for this restriction—annual gross receipts of less than $10 million—would apply to taxpayers with 10,000 acres or less, which we estimate at about 86 million acres. These taxpayers would experience no change, but the provision would substantially reduce the value of cost deductions for an estimated 264 million private timberland acres in all ownership types.

The costs are likely to be large for the affected firms and will depend on the length of the harvest rotation and the discount rate. For example, if we assume a 20-year rotation and a 3.5 percent discount rate, the effective value of the capitalized costs for tax deduction purposes would be decreased by 50 percent, had the costs occurred in the first year. This tax change substantially reduces the deduction and increases the effective tax. Since most management costs for a site are incurred within the first two years, although the harvest rotations are commonly over 20 years (e.g., Sedjo 1983), the simplifying assumption that the undiscounted value of the management costs falls by 50 percent appears reasonable.

So for the large private owners and the 88 million acres of large family ownerships, accounting for about 270 million acres, the change reduces the value of the management cost deduction by 50 percent. If we suppose that management costs are 40 percent of long-term variable costs (as above), then the absence of immediate tax write-offs of management costs will directly increase the timber cost (supply) function by 20 percent. All but the smallest ownerships (86 million acres) would be affected by a 20 percent upward shift of the cost function.

3. Ending the Deduction for Reforestation Costs

Currently, qualified reforestation expenditures (or afforestation, in the case of planting or seeding nonforested land) paid or incurred in a tax year, up to a maximum of $10,000 per qualified timber property, can be immediately deducted (except by trusts) as they are incurred, and any additional costs can be amortized over 84 months.

The repeal of this provision would substantially reduce the value of the deductions and increase taxable revenues. Under the reform, these costs would be capitalized and could be claimed only when the timber was harvested or sold. This provision would apply to all private timber ownership forms and would reduce the incentive for planting and productivity-enhancing innovations.

Provisions (3) and (4) above are likely to affect most private landholdings, including REITs. They would substantially increase the effective costs of both management and reforestation. We would expect the loss of the $10,000 reforestation write-off to be a disincentive to planting.

According to the Joint Committee on Taxation (2012), the total amount associated with these cost write-offs is in the neighborhood of $100 million/year for corporations and proprietorships. Given our estimated land areas, this amounts to about $2/acre/year for proprietorships and $15/acre/year for corporations. Supporting data is found in OMB 2012.

However, over a 20-year rotation, this amounts to about $40/acre for proprietorships and $300/acre for corporations in cost reductions per acre harvested in year 20. If the tax benefit were delayed for a 20-year rotation, the present value of the deductions at harvest would be decreased by about 50 percent.

4. A New CorporateTax Level

In addition to eliminating some tax deductions and preferential treatments, as discussed above, most tax reform proposals would lower the overall corporate tax rate from 35 percent to,

for example, 25 percent. When the timber REIT is eliminated and such entities are taxed as C corps, a new 25 percent rate would give the producer an effective net price increase of 10 percent. However, the individual shareholder would still be liable for a 20 percent tax on the dividend, which would increase by 10 percent. So the tax advantage to the corporation entity, including shareholders, under the reduced corporate tax is a net reduction in taxes of 8 percent (–10 + 2). Thus with this arrangement, the net price facing the corporation owners under the reduced corporate rate after losing the deduction is an increase in after-tax earnings of 8 percentage points.

The result is that the corporate business structure, while still facing double taxation, receives a net benefit of about an 8 percent tax reduction, assuming no changes in the other elements of the existing tax system. The effect of this tax change on the timber sector is examined in Table 3 and Scenario P4.

Calculated Cost Changes Associated with Tax Proposals

Based on the discussion above, Table 2 summarizes the effects of the various changes, with the right-hand column indicating the percentage effect of the changes on the new tax level. The changes posited here are to the existing system, where the corporate tax rate is held at 35 percent.

Table 2. Timberland Ownership and Cost Increased by Business Type, C-Corps Tax at 35% + State Corporate Tax at 4%, Individual Tax Max 39.6%, Elimination of the Timber REIT

Business type change	Timber acres	Old tax	New tax	Percent change
Public REIT (eliminated) and conversion to C corps taxation.	20 million	Capital gains (0%) + dividend (20%)	Capital gains (35%) + state corps (4%) + individual change (12%)	+31%
		Accelerated management cost deductions	Ordinary deduction	+20 %
		Reforestation deduction	Ordinary deduction	+$45/acre
TIMO (private) REIT (eliminated)				

to corps				
- Nontaxed, treated as UBTI	18 million	Corp (0)	Corp (35%) + state corp (4%)	+39
- Taxed	4 million	Individual (20%)	Corp 35% + state (4%) + individual 12%	+31%
		Accelerated management cost deductions	Ordinary deduction	+20%
		Repeal of reforestation deduction	Ordinary deduction	+$45/acre
Proprietorships				
- Large owners	100 million	Capital gains (20%)	Ordinary income (39.6%)	+19.6%
		Accelerated management cost deductions	Ordinary deduction	+20%
		Repeal of reforestation deduction	Ordinary deduction	+$15/acre
- Other family Over $10 M revenue	100 million	Capital gains (20%)	Ordinary income (39.6%)	+19.6%
		Accelerated management cost deductions	Ordinary deduction	+20%
		Repeal of reforestation deduction	Ordinary deduction	+$15
- Family Under $10 M revenue	100 million	Capital gains (15%)	Ordinary income (25%)	+10%
		Accelerated management cost deductions	Ordinary deduction	Zero
		Repeal of reforestation deduction	Ordinary deduction	+$15/acre
Total private	**342 million**			

Results: Intuition

The Timber Supply Model examines the commercial timber sector both at a point in time and through time. As a global market model, it recognizes the global interactions among the various supply sources. For example, the US timber market is influenced by foreign supply sources—most importantly, Canada. The various domestic US supply sources are developed in substantial detail, and these are the only suppliers directly affected by the changes associated with the tax reform. The technical model is presented in Appendix A. The discussion in this section is designed to give the reader a nontechnical intuition of the nature of the model and an expectation of the likely results.

The model is a dynamic supply-and-demand model that uses an optimal control approach to trace changes in basic outputs through time. The bulk of the model detail is on the supply side. The basic model incorporates information on the area of timber, level of timber stocks at a point in time, and site-specific yield functions, which describe biological growth over time. The model is calibrated and parameterized to represent the current period based on current conditions and past performance. Although the existing tax structure is not explicitly imposed in the model, it is implicitly captured in current and future projections using these parameters. In contrast with the detail of the supply side, the demand function is superimposed on this system at a level consistent with current conditions and is expanded through time at a rate consistent with recent historical experience. The basic projected outputs include timber harvests, prices, investments levels, and timber land areas, which are typically reported.

Our approach addresses the question of how the timber industry reacts when it makes a transition from one tax environment to another. This situation is fundamentally different from that of many other industries, including agriculture. Agricultural commodities are typically produced within one season. In essence, each year begins anew with a zero stock and produces the harvested stock within a season. By contrast, timber requires many seasons to become a useful commodity: 20 years is among the shortest harvest rotations in the United States. At any point in time, a typical forest owner has available for harvest only a small portion of the stock. Thus timber stocks can increase and decrease over decades but not over seasons. One implication is that the transition of the physical forest from one tax regime to a different regime will take a considerable amount of time.

This study compares the levels of the critical variables in the base case (i.e., no tax changes) with the level of these variables in the higher tax cases, as represented by four scenarios. We look at the effects of tax increases on changes in timber stocks, timberland area,

and investment levels in timber. Most of the tax changes considered will mean that the supplying agent receives a lower net price. A decrease in net price would be expected to reduce supply, especially in the longer term. The analysis explicitly looks at the timber market through time. The focus is not on short-term prices and harvest volumes but, more importantly, on the longer-term effect of investments on timber stocks and related harvests though time. Our projections do not attempt to anticipate short-term perturbations or business cycle fluctuations.

The level of investment in timber production considered in the model is a function of current and future economic returns to timber, as captured in the net price of timber. An expectation of growing future demand, other things equal, suggests increasing investments and therefore higher timber stocks in anticipation of improved market conditions. Similarly, anticipation of declining future returns due to higher taxes implies lower investment levels and an associated decline in timber stocks.

An immediate response of US managers to higher taxes and lower expected future returns would be to reduce investment levels both currently and into the future. In addition, lower future returns suggest that the current stock of forest is too large, and this would result in uncompetitive returns, since the stock and investment levels were originally developed to their current levels in expectation of higher returns. Thus timberland owners would try to liquidate some of the existing surplus and redirect capital to find higher returns outside the timber industry. However, the timber owner inherits a physical stock—a physical asset—which does not change immediately with a change in taxes and net returns. The asset can be sold but only at a discounted price, since the market revalues the asset, reflecting financial changes. The physical stock will change over time only as the forest is harvested and investments in regeneration and management decline. Furthermore, there is no financial incentive to accelerate the harvest, since the future market price path is only minimally affected by the US tax increases in which future market prices are expected to be higher than current market prices. Domestic timberland owners respond by decreasing investments in timber production and redirecting capital to alternative, higher-return investments. This redirection also includes reducing the land area devoted to timber production and perhaps converting it to development or agriculture. Simultaneously, foreign suppliers anticipate the future US timber production declines and move in to take advantage of the higher market prices (since they do not pay the higher tax) and fill the gap.

In summary, we would expect the model to project a relative decline in timber investments, which continue to fall over time compared with levels that would be expected to occur in the absence of tax changes. As domestic harvest declines over time, we would expect a contraction of timberland area, again compared with the base case, reflecting the comparative

decline of investment levels sufficient to maintain the forest stocks at levels consistent with the earlier tax regime.

Scenarios

Each of our four scenarios is run against the business-as-usual base case, which captures the existing tax structure and current timberlands performance. The first three scenarios are run assuming the corporate tax is 35 percent. Scenario P1 provides an estimate of the effects of eliminating REIT status for timberland for both public and private REITs, which then become C corps. Scenario P2 adds the effect of restricting the rapid write-off of management and operation expenses only to forest landowners with less than $10 million in annual receipts. The firms must now capitalize these costs. Scenario P3 adds the repeal of the provision allowing most forest owners to deduct up to $10,000 of reforestation costs annually. Thus Scenario P3 provides the cumulation of all the tax increases. Finally, Scenario P4 assumes that all the changes of the first three scenarios are in place but introduces the tax reform that also reduces the corporate tax from 35 to 25 percent and reduces the top individual income tax rate from 39.6 to 35 percent. Table 3 presents the percentage effect on revenues of these tax changes by business type.

Table 3. Timberland Ownership and Cost Changes Associated with Tax Changes, by Business Type, Including C Corps Tax Reduction to 25% and Reduction of Top Individual Tax Rate to 35% + State Corporate Tax at 4%, Elimination of the Timber REIT

Business type change	Timber acres	Old tax	New tax	Percent change
Public REIT (eliminated) to corps	20 million	Capital gains (0%) + dividend (20%)	Capital gains (25%) + state corps (4%) + individual change (15%)	+24%
		Accelerated management cost deductions	Ordinary deduction	+20 %
		Reforestation deduction	Ordinary deduction	+$45/acre
TIMO (private) REIT (eliminated) to corps				
- Nontaxed,	18 million	Corp (0)	Corp (25%) + state	+29

treated as UBTI			corp (4%)	
- Taxed	4 million	Individual (20%)	C corps 25% + state (4%) + individual 12%	+23%
		Accelerated management cost deductions	Ordinary deduction	+20%
		Repeal of reforestation deduction	Ordinary deduction	+$45/acre
Proprietorships				
- Large owners	100 million	Capital gains (20%)	Ordinary income (35%)	+15%
		Accelerated management cost deductions	Ordinary deduction	+20%
		Repeal of reforestation deduction	Ordinary deduction	+$15/acre
- Other family Over $10 M revenue	100 million	Capital gains (20%)	Ordinary income (35%)	+15%
		Accelerated management cost deductions	Ordinary deduction	+20%
		Repeal of reforestation deduction	Ordinary deduction	+$15
- Family Under $10 M revenue	100 million	Capital gains (15%)	Ordinary income (25%)	+10%
		Accelerated management cost deductions	Ordinary deduction	Zero
		Repeal of reforestation deduction	Ordinary deduction	+$15/acre
Total private	**342 million**			

The Base Case and the Four Scenarios

This section compares projections of harvests, net prices, and investments in the US forest sector under the current tax system with that of the forest sector under proposed tax changes, where the effects of the broader tax base and the various individual tax changes on the sector are systematically considered.

The Base Case

Although the model does not try to pick up short term fluctuations it does try to capture long-term trends. The US share of global industrial roundwood production peaked in 1999, at 28 percent, but declined thereafter being 17 percent in 2013. This decline has been attributed to a combination of cyclical factors and long-run trends (Prestemon et al. 2015). Thus, over the last decade or so US timber harvests have declined vis a vis the global timber system even in the absence of any tax changes. This weakness is reflected in the base case projections of the model which anticipate US harvests to experience decreases of nearly 10 percent in the long-term trend between 2015 and 2045 even without adverse tax changes. The base case anticipates lower planting levels to persist and projects future harvest declines even without tax changes, thereby reflecting the substantial reductions in tree planting that have already occurred in the US after 2000. Additionally, these results use an updated version of the basic model that is more responsive to market changes in the initial periods with yield functions that are more non-linear providing more choice over rotation age. The tax changes that are subsequently introduced in the scenarios are projected to precipitate additional harvest declines above those already occurring in the base case. It is these additional tax generated declines from the base case that are the principle focus of this study.

Scenario P1

This section summarizes the results of Scenario P1, which repeals favorable capital gains treatment and eliminates the REIT as a legal business form for timberland ownership, thereby resulting in taxing former timber REITs as C corps. As a result, the individual forest ownership groups in the model experience the percentage changes in the level of taxes on revenues as presented in Table 2. As shown on the graphs, the changes in the variables are relative to what they would have been with the current tax system—that is, the base case without any tax reform. Thus, although we are focusing on the effects of the tax changes, the total change is generally larger, being the sum of the change in the base case plus that precipitated by the tax changes.

This scenario consists of the following changes:

- Public REITs: Eliminated and taxed as C corps; taxes on harvests increase by 20 percent.
- TIMO private REITs: Eliminated and taxed as C corps; taxes on harvests increase by 35 percent for nontaxed ownerships and 28 percent for taxed ownerships.
- Large proprietorships: Taxes on harvests increase by 15 percent.
- Large family owners: Taxes on harvests increase by 15 percent.
- Small family owners: Taxes on harvests increase by 5 percent.

Total US harvests initially stay roughly the same as without the tax changes but gradually decrease over time, to a 3.2 percent reduction by 2035 and a 6.3 percent reduction by 2055, relative to the base case. Global timber prices, which are essentially the same as US prices adjusted for transport and variable taxes, rise significantly in absolute terms. However, they remain roughly the same as in the base case after the tax change, rising by less than 0.1 percent by 2055, compared with the base case, as foreign timber production makes up most of the decline in the United States. Although not shown in these data, US net imports of wood and wood products would increase to essentially completely fill the gap caused by the tax-driven US harvest declines.

In this model, harvests fall in the US and only increase sometime after 2055.

Scenario P1:

Figure 1. US Timber Harvests, Scenario P1

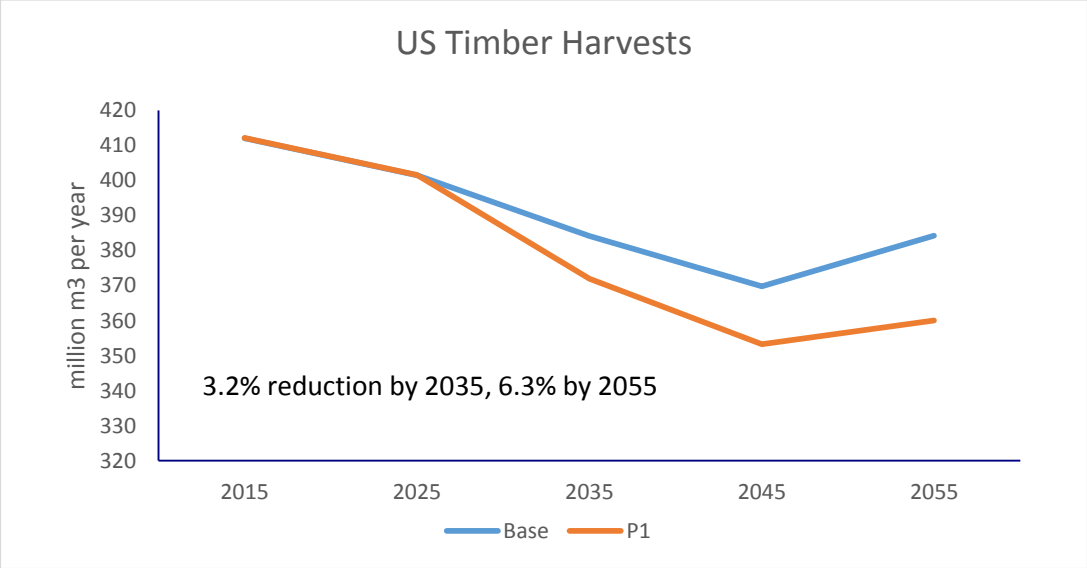

Figure 2. Global Timber Prices, Scenario P1

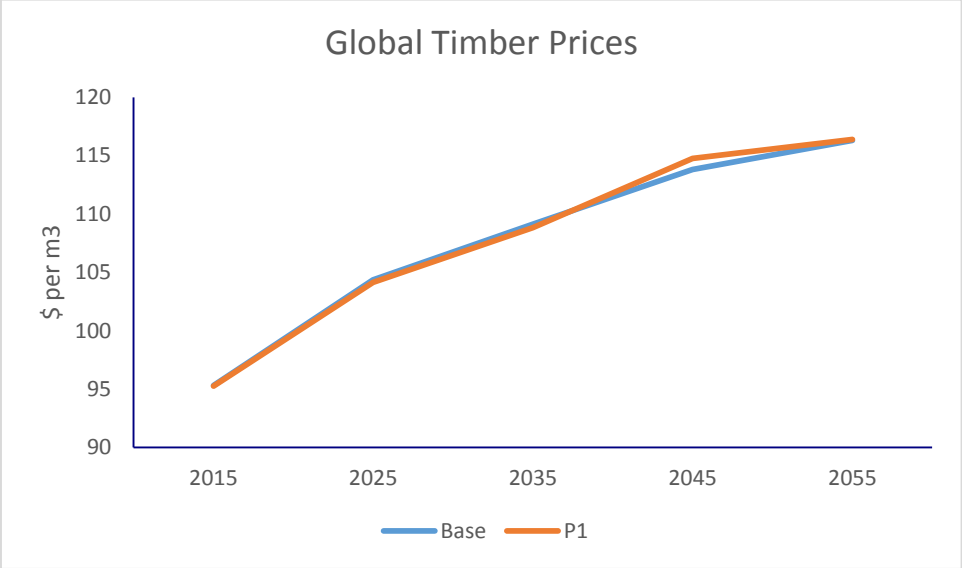

Table 4. Regeneration and Management Expenditures, Scenario P1

	% change in reforestation expenditure	% change in total timber management cost
2015	-22.8%	-20.8%
2025	-21.2%	-20.3%
2035	-18.7%	-20.3%
2045	-11.1%	-27.5%
2055	-9.2%	-22.1%

Table 5. Revenue and Expenditure Changes, Scenario P1

Gross revenues in timber harvesting change on average by	-$541	million per year
Total Expenditures in Timberland Mgmt change by	-$3,760	million per year
Net returns to timberland change by	$3,219	million per year

Table 6. Timberland Area (million ha) in Base Case and Scenario P1

	Base	P1	Difference	
2015	248.37	248.37	0	0.0%
2025	253.79	251.29	-2.5	-1.0%
2035	255.81	252.88	-2.93	-1.1%
2045	259.38	255.77	-3.61	-1.4%
2055	261.71	257.56	-4.15	-1.6%

The comparative stability in timber harvests in the short term is due to the recognition by producers that although net prices to US producers have declined, the timber stock available for harvest is already largely in place and thus these existing stocks continue to be harvested. However, over time the stock declines with reduced investment and management, and this is reflected in the relative reduction in future US harvests.

Global timber prices continue to rise gradually over time but are essentially unaffected by the US tax changes because the US portion of the global timber supply is relatively small, roughly 20 percent and declining as foreign producers fill in for US harvest declines. The overall trend has been a declining share of global production originating in the United States, and this trend accelerates as production shifts abroad. This implies an increase in net US imports of wood and wood products.

As a result of these changes, particularly the lower net price to the producer, US landowners invest less in their forests. There is an immediate 22.8 percent reduction in reforestation expenditure and an overall reduction in timber production expenses of 20.8 percent. Over the long run, forests are less intensively managed, with management costs declining by 9 to 11 percent. Timberland area contracts by about 10 million acres in 2055, compared with the base case acreage.

Scenario P2

Scenario P2 restricts the rapid write-off of management and operation expenses only to forest landowners with less than $10 million in annual receipts.

Figure 3. US Timber Harvests, Scenario P2

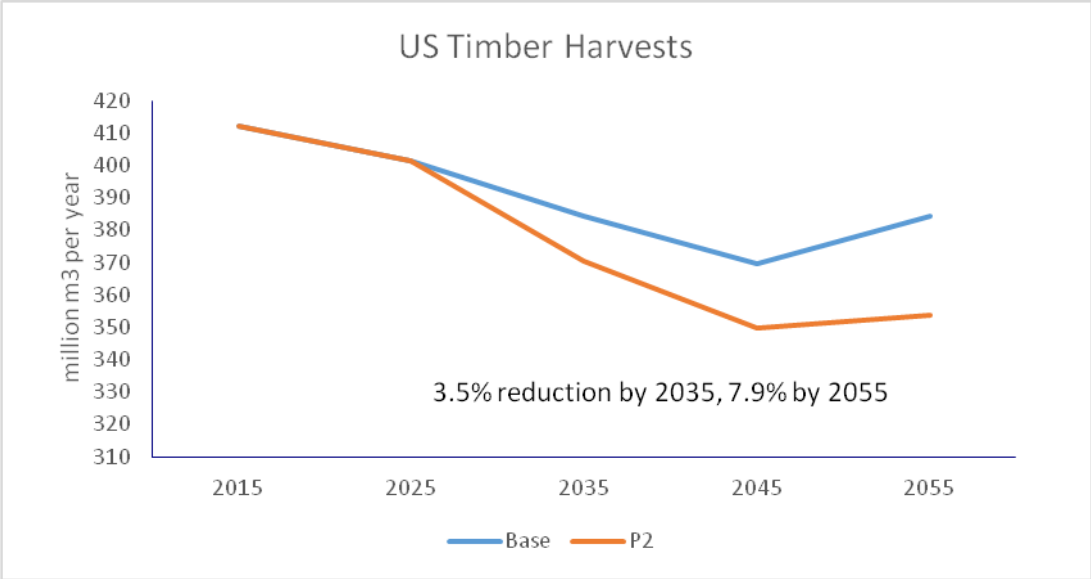

Figure 4. Global Timber Prices, Scenario P2

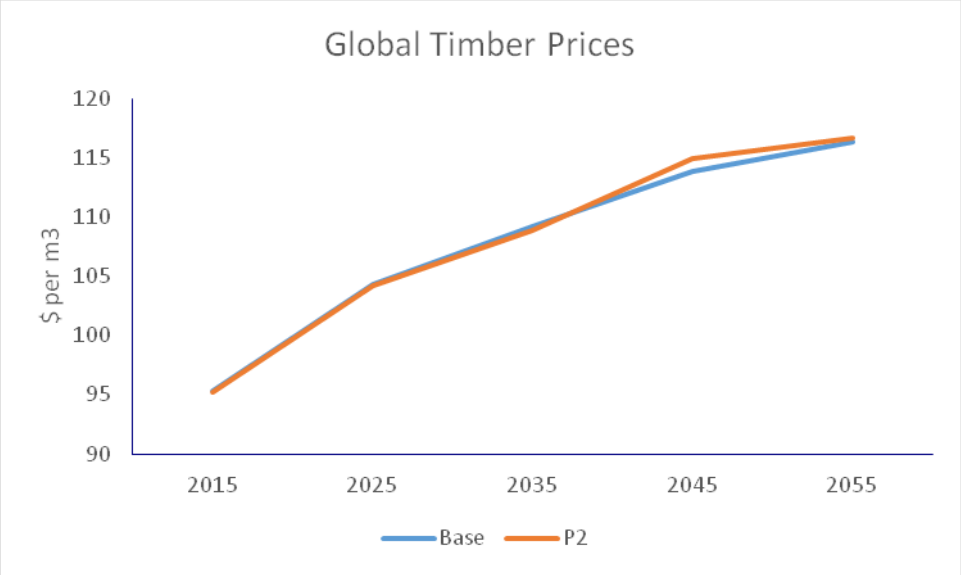

Table 7. Reforestation and Management Changes, Scenario P2

	% change in reforestation expenditure	% change in total timber management cost
2015	–29.9%	–20.4%
2025	–33.4%	–20.3%
2035	–30.6%	–19.6%
2045	–17.4%	–28.9%
2055	–14.2%	–25.4%

Table 8. Revenue and Expenditure Changes, Scenario P2

Gross revenues in timber harvesting change on average by	–$636 million per year
Total expenditures in timberland mgmt change by	–$3,879 million per year
Net returns to timberland change by	$3,243 million per year

Table 9. Timberland Area (million ha) in Base Case and Scenario P2

	Base	P2	Difference	
2015	248.37	248.37	0	0.0%
2025	253.79	251.17	–2.62	–1.0%
2035	255.81	252.98	–2.83	–1.1%
2045	259.38	255.28	–4.1	–1.6%
2055	261.71	257.18	–4.53	–1.7%

Scenario P3

Scenario P3 shows the cumulative effects of all the tax increases experienced by the timber sector.

Figure 5. US Timber Harvests, Scenario P3

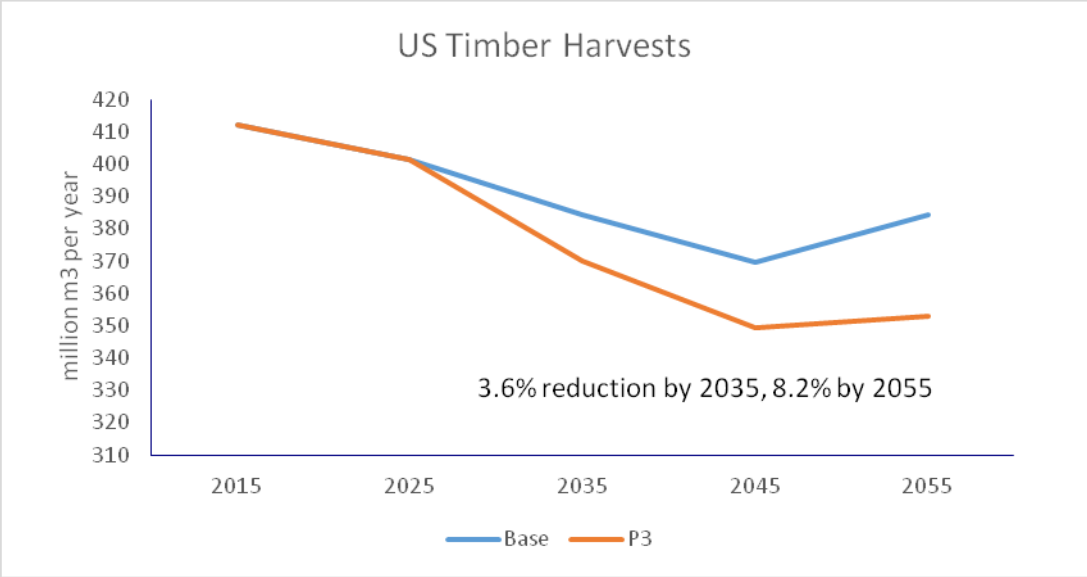

Figure 6. Global Timber Prices, Scenario P3

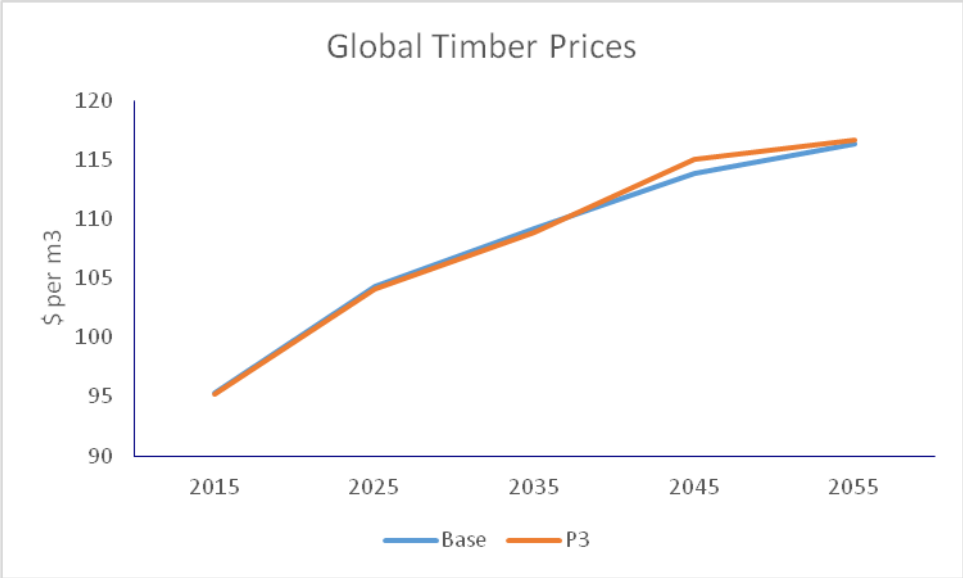

Table 10. Reforestation and Management Changes, Scenario P3

	% change in reforestation expenditure	% change in total timber management cost
2015	–29.4%	–21.1%
2025	–32.7%	–20.8%
2035	–31.4%	–21.2%
2045	–17.8%	–29.6%
2055	–14.0%	–24.3%

Table 11. Revenue and Expenditure Changes, Scenario P3

Gross revenues in timber harvesting change on average by	–$654 million per year
Total expenditures in timberland mgmt change by	–$3,889 million per year
Net returns to timberland change by	$3,235 million per year

Table 12. Timberland Area (million ha) in Base Sase and Scenario P3

	Base	P3	Difference	
2015	248.37	248.37	0	0.0%
2025	253.79	250.2	–3.59	–1.4%
2035	255.81	251.68	–4.13	–1.6%
2045	259.38	254.39	–4.99	–1.9%
2055	261.71	255.7	–6.01	–2.3%

Scenario P4

The first three scenarios, P1–P3, assume an ordinary C corps tax rate of 35 percent. Since any comprehensive tax reform would likely include a major reduction in the US corporate rate, Scenario P4 modifies Scenario P3 by using a federal corporate rate of 25 percent.

Figure 7. US Timber Harvests, Scenario P4

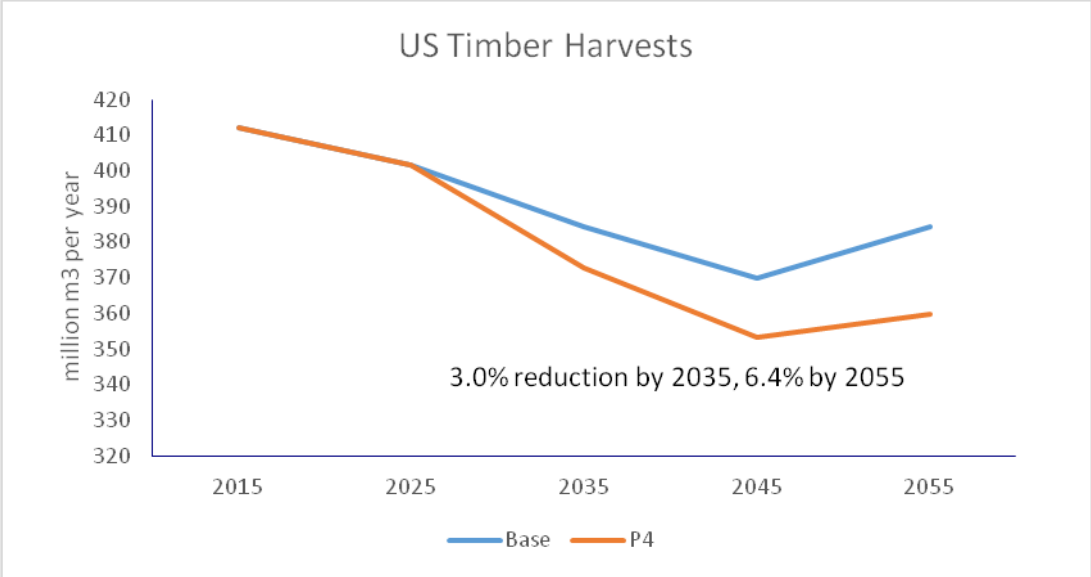

Figure 8. Global Timber Prices, Scenario P4

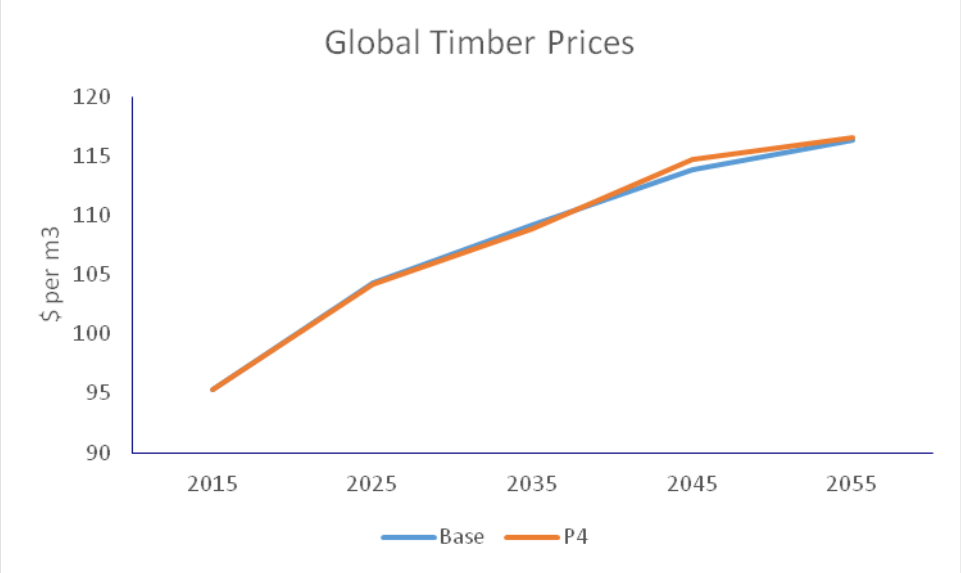

Table 13. Reforestation and Management Changes, Scenario P4

	% change in reforestation expenditure	% change in total timber management cost
2015	–28.0%	–16.5%
2025	–26.3%	–16.2%
2035	–22.7%	–16.4%
2045	–12.8%	–23.3%
2055	–9.7%	–18.9%

Table 14. Revenue and Expenditure Changes, Scenario P4

Gross revenues in timber harvesting change on average by	–$532 million per year
Total expenditures in timberland mgmt change by	–$3,037 million per year
Net returns to timberland change by	$2,504 million per year

Table 15. Timberland Area (million ha), in Base Case and Scenario P4

	Base	P4	Difference	
2015	248.37	248.37	0	0.0%
2025	253.79	250.87	–2.92	–1.2%
2035	255.81	252.36	–3.45	–1.3%
2045	259.38	255.11	–4.27	–1.6%
2055	261.71	256.99	–4.72	–1.8%

Discussion

Overall Results: The first three scenarios involved systematically adding more taxes to the timber sector by reducing various tax avoiding features of the current system. Not surprisingly, these changes have generally negative effects on the industry reducing harvests, investments, revenues, managed forest area, etc., while increasing wood imports compared to what would be expected in the absence of the changes.

One rationale for tax changes is that the advantages of a lower corporate rate would largely compensate for the loss of the various tax advantages in the existing system. Although this result could be the outcome for some sectors of the economy, this is not the case for the timber industry. This situation involving reduced corporate taxes levels, etc., is examined for the timber industry in scenario P4. Indeed, offsetting positive results do occur. However, the set of tax changes of the type examined in this study has an overall largely negative effect on the timber industry, despite the positive effect of the lower corporate and individual rates. Specifically, in the US timber industry, the elimination of the timber REIT and certain tax preferences would overwhelm the positive effects of a 10 percent reduction in the corporate tax and a reduction of the top individual tax from 39.6 to 35 percent. If the timber tax measures were implemented without the reductions in federal tax rates, the total area of timberland is projected to contract by an additional 15 million acres (45 million hectares) over that of the trend between 2015 and 2055. Even if federal corporate and individual tax rates are also reduced as posited, the projected area of timberland would still contract by an additional 11 million acres (26 million hectares) more than in the base case. This decline in timberland area would be accompanied by declines in gross revenues in forestry averaging more than $500 million/year to 2055. Finally, even with the decline in corporate tax rates (Scenario P4), US net imports of wood and wood products would increase by about 28 million cubic meters though the period, and the wood trade deficit would increase by about $3.6 billion per year by 2055.

An interesting outcome is the relative absence of a significant effect on timber prices associated with any of the tax changes posited. Earlier examinations (Sedjo et al. 1986; Sedjo and Lyon 1990) of the effects of higher taxes showed a price increase over the base case as the reduced investments led to a reduction in the future timber stock and an associated reduction in effective supply. Why is this effect absent in this study's results? In the 1980s, some 60 percent of the world's timber supply was viewed as autonomous and not responsive to market forces, and of the market-responding countries, the United States accounted for almost 50 percent of the responsive supply. Thus the United States was largely a price maker in world markets: its production changes could affect world timber prices. Today, however, essentially the entire world is market responsive, and the United States now produces only about 22 percent of the total responsive supply. Additionally, the effect of the long-term trend and tax increases on US producers is to substantially reduce the U.S share further. As a relatively much smaller producer, the United States is now largely a price taker in world markets. Thus tax increases cause a decline in investment and future harvests rather than an immediate decline in harvests. Over time, the US role as a timber producer declines, and the gap is filled by foreign producers.

International Trade Implications: As we have seen in the above scenarios, the tax reform reduces domestic timber production modestly in the short term but increasingly through time as the timber stock contracts after the repeal of financial incentives. Although a separate analysis of trade could be modeled (e.g., Sedjo and Sohngen 2013), that exercise is not necessary here; the level of world demand gradually increases but is largely invariant to the US tax regime. Also, harvest price changes are negligible, since foreign timber almost perfectly substitutes for domestic. Thus in this analysis, US consumer prices are estimated to be the same regardless of the tax regime. What is different is the mix of domestic and international timber as domestic harvests decline, leaving a gap that imported timber fills. The analysis suggests that compared with the base case, for each unit of reduction in domestic timber there will be a roughly equal increase in foreign timber imports (or foreign wood embodied in products). Thus, for example, in Scenario P4, domestic production will be 3 percent lower by 2035 and 6.4 percent lower in 2055 than in the base case. At harvest levels of about 375 million cubic meters, this amounts to approximately 14 million cubic meters in additional timber imports in 2035 and 30 million additional cubic meters in 2055. At the prices posited, this amounts to roughly a $1.54 billion increase in net imports per year by 2035 and $3.6 billion by 2055.

Timberland Area: The future direction of US forest area has been subject to alternative expectations. Although the US Forest Service (2012) assessment anticipates that forest stocks could be lower by 2060, other studies suggest that the land area in forest is likely to increase (Nepal et al. 2014; Smith et al. 2014). This study projects the timberland area to expand modestly in the base case, but the effects of the tax increase would mitigate about one-half of that anticipated expansion, although allowing for a very modest timberland expansion. The decline in harvests over the slightly larger land base reflects decreased production per land unit manifesting the long-term lower investment levels. .

The projected decrease in timberland area in Scenario P4 is about 11.5 million acres (–.26 million hectares) below the base case level. For context, in 2012, US forestland was estimated at 751 million acres, with timberland accounting for 521 million. Data published by the US Forest Service (2014) indicate that US timberland expanded by more than 35 million acres between 1987 and 2012, from 486 million in 1987 to 521 million acres in 2012.

In general, the longer-term data show relative stability of total area of forest but with much shifting among forestland, agricultural, and development land uses (Smith et al. 2003; US Forest Service 2012). As development occurs, it displaces forest and agriculture. While some of the agricultural land goes to development, forests also move to abandoned agricultural land. This transition has commonly occurred in the latter part of the 20th century through tree planting.

Thus new managed forests were created even as total forestland has remained reasonably stable over time. Much of the more than 50 million acres planted between 1960 and 2000 occurred in the South on land previously in crops such as cotton and tobacco; this trend undoubtedly contributed to the overall expansion in timberlands in the latter part of the 20th century.

The Timber Supply Model captures both timberland and forestland, but not all lands are managed or harvested in our model. For many forestlands, the timber price is not sufficient to draw owners into managed production. However, as prices increase in the model, more lands are drawn into management and the market solution. Thus the expansion in timberland comes to some extent from forestlands drawn into management, but probably more from former agricultural lands that are converted, planted to trees, and managed. Note that since timberland is defined as managed forest, timberland expansion can occur even if the net change in total forestland is zero.

Summary and Conclusions

This study uses a well-recognized forest sector model to examine the effects of a comprehensive tax reform similar to that suggested by Representative Camp. The model incorporates the business forms common in timber production, adjusting for the amount of timberland ownership by business type. The basic approach is to compare the future timber resource and industry under baseline conditions with scenarios that include, after 2015, changes in the tax regime. In Scenario P1, capital gains tax treatment for timber and the timber REIT business form are eliminated. Scenario P2 adds elimination of the accelerated tax depreciation for management and operational costs. Scenario P3 adds elimination of the deduction for reforestation for firms. These scenarios have increasingly negative effects on the timber industry. Finally, Scenario P4 adds a reduction in the corporate tax from 35 to 25 percent and a reduction of the individual income tax rate from 39.6 to 35 percent. Although the lower corporate and personal tax rate has a positive effect on the timber industry, the effect is modest and nowhere near enough to offset the combined negative tax changes indicated by Scenario P3.

In all scenarios, US timber harvests decline compared with the base case. The largest relative harvest decline is in Scenario P3, which includes all of the negative tax consequences, at 9.1 percent, roughly 36 million cubic meters annually less in 2055. During the 40-year period, investment expenditure in timber production falls substantially, along with investment in regeneration and management. Timberland area also declines throughout the period compared to what it would have been with out the tax change, being about 15 million acres (6 million hectares) less in 2055 in Scenario P3 than in the base, . The lower corporate tax examined in

Scenario P4 mitigates that effect slightly, but harvests and managed forestlands both still decline substantially: the harvest falls by 7.2 percent and managed timberlands contract by more than 12 million acres by 2055.

An interesting finding is that timber prices are unlikely to change significantly in any of the scenarios because of the global influences. With current timber harvests at about 1.9 billion cubic meters, the United States accounts for only slightly more than 20 percent of timber harvests worldwide. A 32 million cubic meter decrease in US production would be small, well under 1.5 percent of world production by 2055. Such a small decrease in global production will have little overall effect on world wood production. Any temporary price increase will be quickly swept away by increased production elsewhere.

In summary, overall the proposed tax changes discussed here would substantially reduce future harvests and financial returns to the timber industry. Over time, the reduced investments would have an increasingly negative effect on the area of timberland and future harvests. The US share of global timber harvests would continue to decline and foreign supply would increasingly replace US timber in the markets as imports from foreign suppliers would increase the US trade deficit would occur for some sectors or in an aggregate economy-wide sense,

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Acknowledgments

The authors would like to thank several people and organizations for their help in undertaking this study. These include Bill Siegel, Sam Radcliffe, Tracey Evans, and Michael Kelly. Furthermore, we especially wish to thank Clark Binkley and Alberto Goetzl for their useful specific comments on an earlier draft of the paper. Also, a number of individuals with tax backgrounds assisted in estimating the size of the tax changes. However, the authors take full responsibility for this study and for any errors that might remain in the tax representations and interpretations or in the implications of the economic analysis.

We are also grateful to the US Forest Service, especially Jimmy Reaves, Deputy Chief for Research & Development, for providing a significant portion of the funding for this study. Additionally, we thank those organizations that have supported the work of the Forest Economics and Policy Program (FEPP) currently and through the years. Furthermore, we wish to express our gratitude to Resources for the Future, especially President Philip Sharp and Vice President for Research Molly Macaulay, for their long-term continuing support of the FEPP, its research activities, and particularly this study. Also, we want to thank Adrienne Young of RFF for her assistance and patience in preparing the various draft versions of this paper. Again, the authors take full responsibility for the study and are responsible for any errors that might remain.

Appendix: Modified Timber Supply Model

This analysis uses a variant of a well-known dynamic optimization forest management model (Daigneault et al. 2012; Sohngen et al. 1999; Sedjo and Sohngen 2013; Sedjo and Lyon 1990) to examine the effect of a tax reform, which changes the levels of various existing taxes on timber. The model involves the incorporation of a forward-looking forest management projections approach—used increasingly in forestry (e.g., Sohngen et al. 1999; Adams et al. 1996). The model, which uses a discrete time nonlinear optimization approach, is presented below. The model maximizes the net present value of net surplus in timber markets. Net surplus is defined as the area between the timber demand curve and the land rent cost.

This paper modifies the model in Daigneault et al. (2012) by associating specific ownership types with particular forest areas. Additionally, the model has been adjusted to recognize that after 2000 tree planting in the US declined largely to selected replacement. This change has been incorporated into the projections thereby reducing base case levels of future forest stocks. The social planner's problem is to maximize the net present value of consumer's plus producer's surplus for timber harvesting as follows:

For the purposes of describing the model, each of the timber types in the model is allocated into one of three general types of forest stocks. Stocks in type "i" are moderately valued forests, managed in optimal rotations, and located primarily in temperate regions. Stocks "j" are high value timber plantations that are managed intensively. Subtropical plantations are grown in the southern United States (loblolly pine plantations), South America, southern Africa, the Iberian Peninsula, Indonesia, and Oceania (Australia and New Zealand). Stocks in "k" are relatively low valued forests, managed lightly if at all, and located primarily in inaccessible regions of the boreal and tropical forests. The inaccessible forests are harvested only when timber prices exceed marginal access costs. In this study, forests in inaccessible regions are harvested when marginal access costs are less than the value of the standing stock plus the present value of maintaining and managing that land as an accessible forest in the future.

The forestry model maximizes the present value of net welfare in the forestry sector. Formally, this is:

$$Max \sum_{0}^{\infty} \rho^{t} \left\{ \begin{array}{l} \int_{0}^{Q^*(t)} \left\{ D(Q_t, Y_t) - C_{H^i}(\cdot) - C_{H^j}(\cdot) - C_{H^k}(\cdot) \right\} dQ(t) - \\ \sum_{i,k} C_G^{i,k}(G_t^{i,k}, m_t^{i,k}) - \sum_{j} C_N^{j}(N_t^{j}, m_t^{j}) - \sum_{i,j,k} R^{i,j,k}\left(\sum_{a} X_{a,t}^{i,j,k}\right) + CC(t) \end{array} \right\} \quad (1)$$

where $Q_t = \sum_{i,j,k} \left(\sum_{a} H_{a,t}^{i,j,k} V_{a,t}^{i,j,k}(Z_{a,t}^{i,j}) \right)$

In equation (1), $D(Q_t,Y_t)$ is a global demand function for industrial wood products given the quantity of wood, Q_t, and income, Y_t. The quantity of wood depends upon $H^{i,j,k}$, the area of land harvested in the timber types in i, j, or k, and $V_{a,t}^{i,j,k}(Z_{a,t}^{i,j})$, the yield function of each plot. The yield per hectare depends upon the species, the age of the tree (a), and the management intensity at the time of planting. As shown below, $m_t^{i,j,k}$ is chosen at the time stands are established and this management intensity sticks with the stand throughout its life in the variable Z. $C_H(\blacksquare)$ is the cost function for harvesting and transporting logs to mills from each of timber type. Marginal harvest costs for temperate and subtropical plantation forests (i and j) are constant, while marginal harvest costs for inaccessible forests rise as additional land is accessed. $C^{i,k}_G(\blacksquare)$ is the cost function for planting land in temperate and previously inaccessible forests, and $C^{j}_N(\blacksquare)$ is the cost function for planting forests in subtropical plantation regions. $G^{i,k}_t$ is the area of land planted in types i and k, and N^{j}_t is the area of land planted in plantation forests. The planting cost functions are given as:

$$\begin{aligned} C_G^{i,k}(\cdot) &= p_m^{i,k} m_t^{i,k} G_t^{i,k} \\ C_N^{j}(\cdot) &= p_m^{j} m_t^{j} N_t^{j} + f(N_t^{j}, \sum_{a} X_{a,t}^{j}) \end{aligned} \quad (2)$$

where $m^{i,j,k}_t$ is the management intensity of those plantings purchased at price p^{i}_m, p^{j}_m, or p^{k}_m. $f(N_t^{j}, \sum_a X_{a,t}^{j})$ is a function representing establishment costs for new plantations. The cost function for establishing new plantations rises as the total area of plantations expands.

The yield function has the following properties typical of ecological species: Va>0 and Vaa<0. We assume that management intensity is determined at planting. The following two conditions hold for trees planted at time t_0 and harvested "a" years later $(a+t_0) = t_{ai}$:

$$\frac{dV^i(Z^i_{a,t})}{dZ^i_{a,t}} \geq 0 \quad \text{and} \quad \frac{d^2V^i(Z^i_{a,t})}{dZ^{i\ 2}_{a,t}} \leq 0 \tag{3}$$

The total area of land in each forest type is given as $X^{i,j,k}_t$. $R^{i,j,k}(\blacksquare)$ is a rental function for the opportunity costs of maintaining lands in forests. The rental function is given as:

$$R\left(\sum_a X^{i,j}_{a,t}\right) = \propto \left(\sum_a X^{i,j}_{a,t}\right)^4 \tag{4}$$

The parameters of the rental function are chosen so that the elasticity of land supply is 0.25 initially, the reported relationship between forests and agriculture in the US (Hardie and Parks, 1997; Plantinga et al., 1999). This elasticity implies that the area of forests could increase by 0.25% if forests can pay an additional 1% rental payment per year. The same elasticity estimate is applied globally.

The stock of land in each forest type adjusts over time according to:

$$X^i_{a,t} = X^i_{a-1,t-1} - H^i_{a-1,t-1} + G^i_{a=0,t-1} \qquad \text{i = 1 - I}$$

$$X^j_{a,t} = X^j_{a-1,t-1} - H^j_{a-1,t-1} + N^j_{a=0,t-1} \qquad \text{j = 1 - J}$$

$$X^k_{a,t} = X^k_{a-1,t-1} - H^k_{a-1,t-1} + G^k_{a=0,t-1} \qquad \text{k = 1 – K} \tag{5}$$

Stocks of inaccessible forests in (k) are treated differently depending on whether they are in tropical or temperate/boreal regions. All inaccessible forests are assumed to regenerate naturally unless they are converted to agriculture. In tropical regions, forests often are converted to agriculture when harvested, so that $G^k_{a=0}$ is often 0 for tropical forests in initial periods when the opportunity costs of holding land in forests are high. As land is converted to agriculture in tropical regions, rental values for remaining forestland declines, and land eventually begins regenerating in forests in those regions. This regeneration is dependent on comparing the value of land in forests versus the rental value of holding those forests. In this study, we do not track the type of agriculture to which forests are converted, i.e. crops or grazing. Inaccessible forests

in temperate/boreal regions that are harvested are converted to accessible timber types so that $G^{k}_{a=0}$ is set to 0. The stock of inaccessible forests is therefore declining over time if these stocks are being harvested. Each inaccessible boreal timber type has a corresponding accessible timber type in "I", and forests that are harvested in inaccessible forested areas in temperate/boreal regions are converted to these accessible types. Thus, for the corresponding timber type, we set $G^{i}_{a=0} \geq H^{k}_{a-1}$. Note that the area regenerated, $G^{i}_{a=0}$, can be greater than the area of the inaccessible timber type harvested because over time, harvests and regeneration occurs in forests of the accessible type.

Stocks of forest management are maintained as follows:

$$Z^{i}_{a,t} = Z^{i}_{a-1,t-1} + m^{i}_{a=0,t-1} \qquad \text{i= 1-I}$$

$$Z^{j}_{a,t} = Z^{j}_{a-1,t-1} + m^{j}_{a=0,t-1} \qquad \text{j=1-J}$$

The model is programmed into GAMS and solved in 10 year time increments. Terminal conditions are imposed on the system after 150 years. These conditions were imposed far enough into the future not to affect the study results over the period of interest. For the baseline case, tax policies are assumed to be consistent with current taxes. For the scenarios, taxes are assumed to differ.