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ABSTRACT: *Income taxes and inflation must be correctly accounted for in forest valuation and investment analysis. In a specific analysis, the discount rate and all costs and revenues should be either before or after taxes, and they should include or exclude inflation consistently. We summarize eight formulas for adjusting discount rates for income taxes and inflation in a simple three-step process. A one-page figure is presented that can be used as a stand-alone tool for correctly adjusting discount rates. South. J. Appl. For. 24(4):193–195.*

The discount rate is extremely important in evaluating the financial attractiveness of forestry investments. In this article, we define the "discount rate" as the minimum rate of compound interest an investor considers acceptable for a specific project. This rate of interest is sometimes called the guiding rate, the hurdle rate, the alternative rate of return, or the cost of capital.

Discount rates are sometimes adjusted—increased or decreased—to account for investment characteristics such as risk, liquidity, and duration. Here we emphasize discount rate adjustments for inflation and income taxes. Our purpose is to promote consistency in accounting for these factors in forestry investment analysis. In a given analysis, foresters should ensure that the discount rate and all costs and revenues are either before or after taxes, and that inflation is either included or excluded consistently. Relatively common inconsistencies in forestry investment analysis include:

- Applying a before-tax discount rate to after-tax costs and revenues; and
- Comparing the rate of return estimated for a forestry investment using today's timber prices (an uninflated rate) to interest rates that can be earned on corporate bonds or bank certificates of deposit (inflated rates).

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In this article we present a one-page summary of eight formulas that can be used to adjust discount rates for income taxes and inflation. The formulas are very useful in ensuring consistency in forestry investment analysis. An important caution is needed, however. The eight formulas we summarize should not be used to adjust the "return on investment" or "internal rate of return" for a specific investment project. The relationship between the before- and after-tax internal rate of return for a project is affected by many factors, including tax credits, deductions, cash-flow timing, and other factors specific to the project.

Our experience in undergraduate education and in continuing education of professional foresters indicates that this one-page summary of eight formulas is a very useful tool for applied forestry investment analysis. Readers interested in derivations of the formulas summarized here may consult Gregersen (1975), Gunter and Haney (1984), Bullard and Straka (1998), Bullard et al. (2000), Campbell and Colletti (1990), Harou (1983), and Klemperer (1979).

Adjusting Discount Rates

Depending on the specific project, investments may be evaluated with or without inflation, and before or after taxes—so there are four potential choices for the discount rate. These choices are represented in the shaded diagram quadrants in the upper part of Figure 1. For consistency, the discount rate and all of the costs and revenues associated with a specific investment must be in the same quadrant of this diagram. That is, the discount rate and all costs and revenues must either be on a before-tax or an after-tax basis, and they must either be in nominal (inflated) or real terms.

Step 1.

In the shaded diagram at right, find the quadrant that represents the current discount rate.

Step 2.

Find the quadrant that represents the equivalent rate you would like to calculate.

	Before Taxes	After Taxes
Nominal (Inflated)	Q I — $i_{b.t.}$ Nominal Rate, Before Taxes	Q II — $i_{a.t.}$ Nominal Rate, After Taxes
Real	Q III — $r_{b.t.}$ Real Rate, Before Taxes	Q IV — $r_{a.t.}$ Real Rate, After Taxes

Step 3.

Using a specific tax rate and/or inflation rate, apply the appropriate formula below.

	Quadrants	Type of Discount Rate Adjustment	
1.	I ⇨ II	**Nominal rates, before taxes to after taxes ...**	$i_{a.t.} = i_{b.t.}(1-t)$
2.	II ⇨ I	**Nominal rates, after taxes to before taxes ...**	$i_{b.t.} = \dfrac{i_{a.t.}}{(1-t)}$
3.	I ⇨ III	**Before-tax rates, nominal to real ...**	$r_{b.t.} = \dfrac{1+i_{b.t.}}{1+f} - 1$
4.	III ⇨ I	**Before-tax rates, real to nominal ...**	$i_{b.t.} = r_{b.t.} + f + r_{b.t.}(f)$
5.	II ⇨ IV	**After-tax rates, nominal to real ...**	$r_{a.t.} = \dfrac{1+i_{a.t.}}{1+f} - 1$
6.	IV ⇨ II	**After-tax rates, real to nominal ...**	$i_{a.t.} = r_{a.t.} + f + r_{a.t.}(f)$
7.	III ⇨ IV	**Real rates, before-taxes to after-taxes ...**	$r_{a.t.} = r_{b.t.}(1-t) - \left[\dfrac{tf}{1+f}\right]$
8.	IV ⇨ III	**Real rates, after-taxes to before-taxes ...**	$r_{b.t.} = \dfrac{r_{a.t.}}{(1-t)} + \dfrac{t}{1-t}\left[\dfrac{f}{1+f}\right]$

Notation:

i = the nominal (inflated) discount rate;

r = the real (uninflated) discount rate;

f = the annual rate of inflation; and

t = the marginal income tax rate.

In all of the formulas,

b.t. indicates a before-tax discount rate;

a.t. indicates an after-tax discount rate; and

all rates are expressed in decimal percent.

Figure 1. A three-step process for adjusting discount rates for income taxes and inflation.

A discount rate in one quadrant of the shaded diagram can be converted to an equivalent rate in any other quadrant using the eight formulas summarized in Figure 1. To correctly adjust discount rates for income taxes and inflation, follow the three steps shown in Figure 1, as demonstrated by the following example:

Example: Adjusting a Real Discount Rate From a Before-Tax Basis to an After-Tax Basis.

Your analysis indicates that a **real rate** of return of 8.2% can be earned on a forestry investment on an *after-tax* basis. Is this investment attractive if your alternative rate of return is a *real* rate of 10% *before taxes*? Assume a tax rate of 28% and an inflation rate of 3%.

Step 1

The 10% alternative rate of return is a real rate, before taxes—represented by QIII in the diagram in Figure 1.

Step 2

The alternative rate of return is not comparable to the 8.2%, however, because it is specified on a before-tax basis—after-tax real rates are represented by QIV in the diagram.

Step 3

We therefore apply formula 7 in Figure 1 to adjust a real rate, before taxes to a real rate, after taxes:

$$r_{a.t.} = 0.10(1-0.28) - \left[\frac{0.28(0.03)}{1+0.03}\right] = 0.06384 \approx 6.4\%$$

The alternative rate of return on a real, after-tax basis is 6.4% compared to the 8.2% that can be earned on the forestry investment.

Note that since a nominal, before-tax discount rate ($i_{b.t.}$) can be converted to a nominal, after-tax rate ($i_{a.t.}$) by multiplying the former by one minus the marginal income tax rate ($1-t$) [i.e., as shown in formula 1 ... $i_{a.t} = i_{b.t.}(1-t)$], it seems logical that a *real*, before-tax rate could be converted to a real, after-tax rate by the same process [i.e., $r_{a.t} = r_{b.t.}\ (1-t)$]. However, due to the interaction of inflation and taxes, such a computation is incorrect and results in overestimates. In the previous example:

Incorrect:

$$r_{a.t} = r_{b.t.}\ (1-t) \qquad \text{(formula 1)}$$

$$r_{a.t} = 0.10\ (1-0.28) = 0.072 = 7.2\%$$

Correct:

$$r_{a.t.} = r_{b.t.}(1-t) - \left[\frac{tf}{1+f}\right] \qquad \text{(formula 7)}$$

$$r_{a,t,} = 0.10(1-0.28) - \left[\frac{0.28(0.03)}{1+0.03}\right] = 0.06384 \approx 6.4\%$$

Note that formula 7 is different than formula 1—an additional term is applied in formula 7 to correctly account for the interaction of inflation and taxes. See Bullard et al. (1999) for additional explanation of formulas 7 and 8.

The three-step process summarized in Figure 1 can be applied in a similar manner to other types of discount rate adjustments. If necessary, the process summarized in Figure 1 can also be applied in combination. For example, if the current discount rate is expressed in nominal terms on an after-tax basis (QII in Figure 1) and you would like to convert the rate to an equivalent rate in real terms on a before-tax basis (QIII in Figure 1), the adjustment can be made by first adjusting for taxes (QII to QI), then by adjusting for inflation (QI to QIII).

Discussion

In most cases, forestry investments are most accurately evaluated when the analysis is done in nominal terms on an after-tax basis. This type of analysis accounts for the impact of income taxes on costs and revenues, and since inflation is included, it accounts for "equity erosion" that occurs when costs are capitalized during inflationary periods. Since many forestry investments should be evaluated after taxes, an important question is "How accurate are the discount rate adjustments for taxes that are listed in Figure 1?" This question was investigated by Campbell and Colletti (1990), who concluded that the adjustments are accurate if the alternative investment involves nondepreciating assets returning equal annual payments, or where the alternative investment's life is 1 yr. They concluded that the income tax adjustments are "*generally satisfactory*" for "*the private forest landowner, whose investment alternatives (other than the forestry practice under evaluation) are limited to opportunities such as land rental, taxable bonds, or bank certificates of deposit.*"

Finally, our purpose in this article is to present an easy-to-use process for discount rate adjustments for income taxes and inflation. We have found Figure 1 to be very useful in undergraduate education and in continuing education of professional foresters. We encourage readers to photocopy Figure 1 and use it as a "ready reference" for discount rate adjustments.

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