Inflation and the rule-of-thumb method of adjusting the discount rate for income taxes

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Abstract: The rule-of-thumb method of adjusting discount rates for income taxes is (after-tax rate) = (before-tax rate) × (1 – tax rate). Previous researchers have concluded that the rule-of-thumb adjustment for income taxes is accurate only when the investment alternative used to define the opportunity cost of capital has certain characteristics: if other investments are limited to land rental, taxable bonds, and bank certificates of deposit, for example. In the present article we demonstrate that inflation is also an important factor in the rule-of-thumb's accuracy in accounting for income taxes. If the unmodified rule-of-thumb adjustment for income taxes is applied to a discount rate specified in uninflated terms, the estimated discount rate may be significantly higher or lower than the actual rate. If applied to real interest rates and not corrected for the effect of inflation, the rule-of-thumb will overestimate the after-tax discount rate that is equivalent to a specific before-tax rate; it will underestimate the before-tax rate equivalent to an after-tax rate specified in real terms. Discount rates estimated by the unmodified rule-of-thumb applied in real terms can be six percentage points or more too high or too low, depending on the rate of inflation, the income tax rate, and whether a before-tax or an after-tax discount rate is being estimated. We present modified rule-of-thumb formulas to adjust real discount rates for income taxes. They include a correction factor to account for the impact of inflation. We summarize these and other formulas used to adjust discount rates for inflation and income taxes in discounted cash flow analysis.

Résumé : La méthode de la règle du pouce qui sert à l'ajustement des taux d'escompte pour les taxes sur le revenu s'établit ainsi : (taux après taxe) = (taux avant taxe) × (1 – taux de taxation). Des chercheurs précédents ont conclu que la règle du pouce utilisée pour ajuster les taxes sur le revenu est précise uniquement quand l'investissement alternatif utilisé pour définir le coût d'opportunité du capital possède certaines caractéristiques : ces investissements sont limités à la location foncière, aux obligations taxables et aux certificats de dépôts bancaires, par exemple. Dans le présent article on démontre que l'inflation est aussi un facteur important dans la précision de la règle du pouce pour comptabiliser les taxes sur le revenu. Si l'ajustement des taxes sur le revenu obtenu par la règle du pouce non modifiée est appliqué à un taux d'escompte sans tenir compte de l'inflation, le taux d'escompte estimé peut être significativement plus ou moins élevé que le taux réel. Si la règle du pouce est appliquée à des taux d'intérêt réels et non corrigée pour tenir compte de l'effet de l'inflation, elle surestime le taux d'escompte après taxe, ce qui est équivalent à un taux spécifique avant taxe ; elle sous-estime le taux avant taxe équivalent à un taux après taxe spécifié en termes réels. Les taux d'escompte estimés par la règle du pouce non modifiée et appliquée en termes réels peuvent être six points de pourcentage ou plus trop haut ou trop bas, selon le taux d'inflation ou le taux de taxation du revenu et selon qu'on estime un taux d'escompte avec un taux avant taxe ou un taux après taxe. On présente des formules modifiées de la règle du pouce afin d'ajuster les taux d'escompte réels pour les taxes sur le revenu. Elles incluent un facteur de correction pour tenir compte de l'impact de l'inflation. Les auteurs présentent un bilan sommaire de ces formules et d'autres qui sont utilisées en vue d'ajuster les taux d'escompte pour l'inflation et les taxes sur le revenu dans l'analyse du flux monétaire escompté.

[Traduit par la Rédaction]

Introduction

Discounted cash flow (DCF) methods are often used to estimate financial returns for forestry investments. For accurate results in DCF analysis, it is very important to be consistent in accounting for income taxes and inflation. To be consistent, all costs and revenues in a DCF analysis should either include or exclude inflation, and all variables should either be before taxes or after taxes (Gregersen 1975; Klemperer 1979).

In the present article, we consider another important aspect of accounting for inflation and income taxes in forestry investment analysis. We demonstrate that, unless a specific correction factor is applied, the "rule-of-thumb" method of adjusting a discount rate for income taxes can seriously overstate or understate the correct after-tax rate in real terms. The discount rate is an extremely important variable in DCF analysis of forestry investments. An incorrect rate can result in significant error in net present value and other financial criteria, which can lead to faulty decisions for valuable land and timber assets.

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Fig. 1. Four alternatives for DCF analysis.

	Before Taxes	After Taxes
Nominal Terms (With Inflation)	**I. Nominal, Before-tax** Discount Rate	**II. Nominal, After-tax** Discount Rate
Real Terms (Without Inflation)	**III. Real, Before-tax** Discount Rate	**IV. Real, After-tax** Discount Rate

The rule-of-thumb method of adjusting the discount rate from a before-tax basis to an after-tax basis is

$$[1] \qquad i_{at} = i_{bt}(1 - t)$$

where i_{at} is the after-tax discount rate, i_{bt} is the before-tax discount rate, and t is the marginal income tax rate. The simple adjustment shown in eq. 1 was termed the "rule-of-thumb" method of estimating the after-tax rate of return for forestry investments by Campbell and Colletti (1990). These authors cited Gunter and Haney (1984), Levy (1968), Levy and Sarnat (1986), and Watts and Helmers (1979) as references for the income tax adjustment. Campbell and Colletti investigated the accuracy of the rule-of-thumb discount rate adjustment for taxes and concluded that the estimate was "generally satisfactory" for forest landowners whose other investment opportunities are limited to land rental, taxable bonds, bank certificates of deposit, or other alternatives involving non-depreciating assets that return equal annual payments.

In the present article, we assume that the rule-of-thumb is being applied to adjust the discount rate for income taxes in a DCF analysis where the investment meets the conditions for accuracy specified by Campbell and Colletti (1990). We demonstrate, however, that even with these conditions met, inflation can have a significant impact on the rule-of-thumb adjustment's accuracy. The impact of inflation on the rule-of-thumb adjustment has been discussed in the finance literature (e.g., see Robison and Barry 1996), but the effect is poorly understood and often ignored by many foresters and forestry analysts. Campbell and Colletti (1990), for example, applied the rule-of-thumb in real terms, but they did not mention the impact of inflation in their investigation of the rule-of-thumb's accuracy. Basic forestry references such as Gunter and Haney (1984) and Bullard and Straka (1998) also do not mention the effect of inflation on the rule-of-thumb discount rate adjustment for income taxes. In continuing education short courses, we have seen many professional foresters and landowners routinely apply the rule-of-thumb adjustment for income taxes to real interest rates. This can be a serious mistake in forest valuation and investment analysis, where the long-term nature of many investments makes the discount rate extremely important. As stated previously, an incorrect discount rate can result in significant error in net present value and other financial criteria, which can lead to faulty decisions for valuable land and timber assets.

Unless a specific correction factor is applied, the rule-of-thumb method of adjusting a discount rate for income taxes can seriously overstate or understate the correct after-tax rate in real terms. The results apply to discount rates in general. However, the rule-of-thumb adjustment should not be applied to the specific rate identified as an investment's rate of return.[2] We present a summary of income tax and inflation adjustments to discount rates in DCF analysis, including a rule-of-thumb correction factor based on the rate of inflation and the investor's marginal tax rate. We summarize discount rate adjustments in a figure that can be used as a basic reference in forest valuation and investment analysis.

Inflation and the rule-of-thumb adjustment for income taxes

Considering income taxes and inflation, there are four alternatives for the discount rate and other values in a specific DCF analysis (Fig. 1). In the following discussion, the quadrants in Fig. 1 are referred to as QI through QIV.

The rule-of-thumb method of converting a nominal, before-tax discount rate (QI) to a nominal after-tax rate (QII) is shown in eq. 1. For example, assume an investor expects a 13% before-tax rate of return (QI), and the investor's marginal income tax rate is 30%. Applying eq. 1, this investor's after-tax guiding rate of return in nominal terms (QII) is i_{at} = 0.13(1 – 0.30) = 0.91 = 9.1%.

Is 9.1% an accurate estimate of the after-tax rate of return? Consider a US$100 investment that produces a profit of US$13 before taxes after 1 year; the investment has a 13% rate of return before taxes. If this investor pays 30% of the US$13 profit in income taxes, the after-tax profit is US$13.00 – US$13.00(0.30) = US$9.10. The after-tax rate of return on the US$100 investment is therefore 9.1%. For this investor, a 13% guiding rate of interest before taxes is equivalent to 9.1% after taxes. Note that our example fits the conditions specified by Campbell and Colletti (1990) for accuracy of the rule-of-thumb method, and eq. 1 correctly estimates the after-tax discount rate. Also note, however that the example was in nominal terms; the equation was applied to discount rates that included inflation.

In the above example, what is the real discount rate equivalent to the 13% return before taxes and the real rate equivalent to the 9.1% return after taxes? A simple formula can be used to adjust a nominal discount rate for inflation (see Bullard and Straka 1998; Klemperer 1996):

$$[2] \qquad r = \frac{1+i}{1+f} - 1$$

where r *is* the discount rate in real terms (before or after taxes), i is the discount rate in nominal terms (before or after taxes), and f is the annual rate of inflation. Assuming 4% inflation, for example, the 13% nominal, before-tax rate of

[2] The "rate of return" is an investment's average rate of capital appreciation. Also known as the "return on investment" and "internal rate of return," it is the specific discount rate at which an investment's present value of revenues and present value of costs are equal (Gunter and Haney 1984; Bullard and Straka 1998). The methods, formulas, and conclusions presented in this article apply to discount rates in general, but the rule-of-thumb is not applicable to the specific discount rate that is the rate of return for a particular investment.

return above (QI) is approximately equal to 8.65% before taxes in real terms (QIII):

$$r_{bt} = \frac{1+i_{bt}}{1+f} - 1 = \frac{1.13}{1.04} - 1 = 0.086\,538\,6 \approx 8.65\%$$

The 8.65% result can be confirmed by applying the rate of inflation and the estimated real rate of return to the example US$100 investment with a US$13 before-tax profit after 1 year. Applying these interest rates, the correct (US$113) total investment value is obtained after 1 year: US$100.00(1.086 538 5)(1.04) = US$113.00 before taxes.

With 4% inflation, using eq. 2 the 9.1% nominal, after-tax rate of return (QII) in the above example is approximately equal to 4.9% in real terms (QIV):

$$r_{at} = \frac{1+i_{at}}{1+f} - 1 = \frac{1.091}{1.04} - 1 = 0.049\,038\,5 \approx 4.9\%$$

We have now calculated three rates of return that are approximately equal to 13% before taxes, considering specific values for income taxes and inflation. These rates are shown in Fig. 2, with arrows indicating the direction of the three example calculations.

Note in Fig. 2 that a bold line separates QIII from QIV. The unmodified rule-of-thumb formula (eq. 1) should not be used to adjust discount rates for income taxes if the rates are specified in real terms. In the following discussion, we demonstrate that: the rule-of-thumb method will overstate the discount rate if the adjustment is from a before-tax rate to an after-tax rate in real terms (QIII to QIV); the rule-of-thumb will understate the discount rate if the adjustment is from an after-tax rate to a before-tax rate in real terms (QIV to QIII); in both cases the degree of error can be significant; and the absolute value of the error is positively related to the rate of inflation and the marginal tax rate.

Rule-of-thumb error and correction, QIII to QIV

If the unmodified rule-of-thumb is used to adjust a real before-tax discount rate (QIII) to a real after-tax rate (QIV), the adjusted rate will be overstated if inflation and the tax rate are positive. The error can be predicted by examining the difference between the correct calculation of the after-tax rate in QIV with the incorrect rate calculated by the unmodified rule-of-thumb. The correct calculation of the after-tax rate in QIV is

$$[3] \qquad r_{at} = \frac{1+[i_{bt}(1-t)]}{1+f} - 1$$

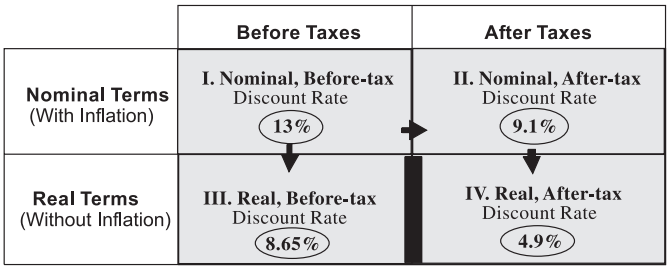
Equation 3 is a combination of eqs. 1 and 2. The term in brackets in eq. 3 is eq. 1, the rule-of-thumb adjustment of the before-tax nominal rate to an after-tax nominal rate. This term is placed in eq. 2 as the interest rate variable. Equation 3 therefore applies eq. 1 to proceed from QI to QII and eq. 2 to proceed from QII to QIV.

If, however, the unmodified rule-of-thumb is used to calculate the after-tax rate in QIV from the real, before-tax rate in QIII, eq. 1 is used with r_{bt} as the interest rate:

$$[4] \qquad r_{at} = r_{bt}(1-t)$$

or, using eq. 2 to represent r_{bt}, the rule-of-thumb calculation of the rate in QIV from the before-tax rate in QIII is

Fig. 2. An example of equivalent discount rates assuming 4% inflation and a 30% marginal tax rate.



$$[5] \qquad r_{at} = \left(\frac{1+i_{bt}}{1+f} - 1\right)(1-t)$$

The rule-of-thumb error is the difference between these calculated rates (eq. 5 minus eq. 3):

$$[6] \qquad E_{III\to IV} = \left(\frac{1+i_{bt}}{1+f} - 1\right)(1-t) - \left(\frac{1+[i_{bt}(1-t)]}{1+f} - 1\right)$$

where $E_{III\to IV}$ is the error in the discount rate calculated if the rule-of-thumb is used to convert a real before-tax discount rate (QIII) to a real, after-tax rate (QIV); all other variables are as previously defined. Equation 6 can be algebraically simplified to

$$[7] \qquad E_{III\to IV} = -t\left(\frac{1}{1+f} - 1\right)$$

Note that if the tax rate is positive and inflation is positive, the error is positive. That is, if the rule-of-thumb is used to obtain an after-tax discount rate from a before-tax rate in real terms, the discount rate calculated will be overstated. As illustrated in Fig. 3, the degree of error can be significant. The error is positively related to the tax rate and the rate of inflation (Fig. 3).

An accurate calculation of the real, after-tax discount rate can be obtained by subtracting the error predicted by eq. 7 from the after-tax rate obtained using the rule-of-thumb:

$$[8] \qquad r_{at} = r_{bt}(1-t) - \left[-t\left(\frac{1}{1+f} - 1\right)\right]$$

or, simplifying terms:

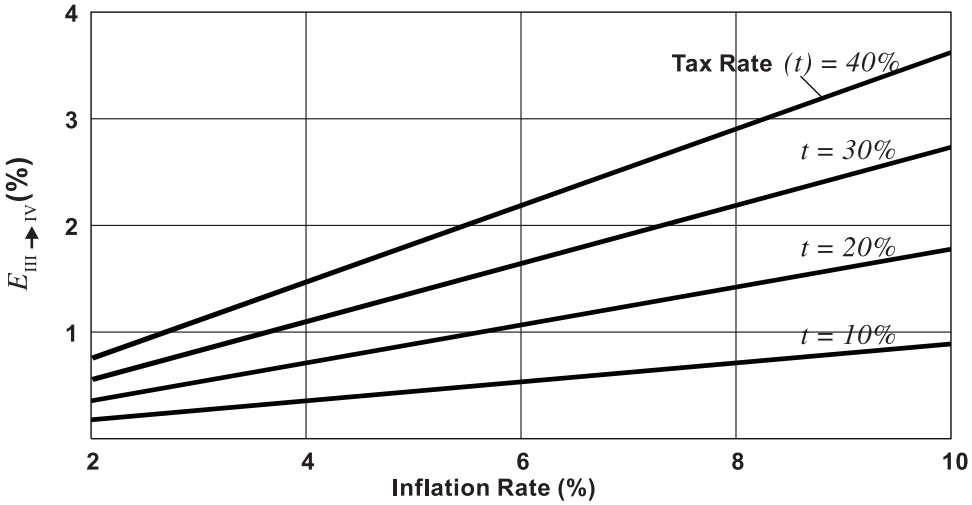
$$[9] \qquad r_{at} = r_{bt}(1-t) + t\left(\frac{1}{1+f} - 1\right)$$

Equation 9 includes the correction factor to account for the effect of inflation. It can be used to calculate the after-tax guiding rate of interest from the before-tax rate in real terms (QIII to QIV). For the specific values in Fig. 2, for example, applying the rule-of-thumb to the 8.65% discount rate in QIII results in a rate that is over one percentage point higher than the 4.9% shown in QIV:

Rule-of-thumb estimate of the QIV discount rate = 0.086 538 5 (1 – 0.3) = 0.060 577 = 6.057 7%

The error 0.060 577 – 0.049 038 5 = 0.011 538 5 = 1.153 85%, as predicted by eq. 7:

Fig. 3. Degree of overstatement if the rule-of-thumb is used to convert a before-tax discount rate to an after-tax rate in real terms (eq. 7).



$$E_{\text{III}\rightarrow\text{IV}} = -t\left(\frac{1}{1+f}-1\right) = 0.3\left(\frac{1}{1.04}-1\right) = 0.011\,538\,5$$

The correct after-tax rate (4.9%) is accurately predicted by the rule-of-thumb with the correction factor applied (eq. 9):

$$r_{\text{at}} = 0.086\,538\,5\,(1-0.3) + 0.3\left(\frac{1}{1.04}-1\right)$$

$$= 0.049\,038\,5 \approx 4.9\%$$

Rule-of-thumb error and correction, QIV to QIII

If a guiding rate of interest is specified in real terms on an after-tax basis (QIV), the equivalent rate on a before-tax basis (QIII) can also be calculated using the rule-of-thumb with a correction factor. Uncorrected, the rule-of-thumb calculation is the inverse operation to eq. 4:

$$[10] \qquad r_{\text{bt}} = \frac{r_{\text{at}}}{(1-t)}$$

The correct calculation of the before-tax rate in real terms, however, involves three steps. First the after-tax rate in real terms should be converted to an after-tax rate in nominal terms (QIV to QII). The nominal after-tax rate should then be converted to a nominal before-tax rate (QII to QI). Finally, the nominal before-tax rate should be converted to a real after-tax rate (QI to QIII). Algebraically these steps are the reverse of those presented in the previous section. It can be shown that the result of these steps, i.e., the correct calculation of a real before-tax discount rate from a real after-tax rate (QIV to QIII), is

$$[11] \qquad r_{\text{bt}} = \frac{1+\left[\dfrac{r_{\text{at}} + f + r_{\text{at}}(f)}{1-t}\right]}{1+f} - 1$$

The difference between eqs. 10 and 11 therefore represents the error from using the rule-of-thumb to convert an after-tax discount rate to a before-tax rate in real terms. After combining terms and simplifying, eq. 10 minus eq. 11 is

$$[12] \qquad E_{\text{IV}\rightarrow\text{III}} = \frac{-t}{1-t}\left(1-\frac{1}{1+f}\right)$$

If the tax rate and inflation rate are positive, the error predicted by eq. 12 is negative. The rule-of-thumb adjustment in eq. 10 understates the before-tax discount rate in real terms. As shown in Fig. 4, the error can be significant. The absolute value of the error is positively related to the tax rate and the rate of inflation (Fig. 4).

An accurate calculation of the before-tax discount rate in real terms can be obtained by subtracting the error predicted by eq. 12 from the before-tax rate obtained using the rule-of-thumb (eq. 10):

$$[13] \qquad r_{\text{bt}} = \frac{r_{\text{at}}}{(1-t)} - \left[\frac{-t}{1-t}\left(1-\frac{1}{1+f}\right)\right]$$

or, simplifying terms:

$$[14] \qquad r_{\text{bt}} = \frac{r_{\text{at}}}{(1-t)} + \frac{t}{1-t}\left(1-\frac{1}{1+f}\right)$$

Using the tax rate and inflation rate in the earlier example (t = 30%, f = 4%), applying the rule-of-thumb to the QIV rate in Fig. 2 yields a QIII estimate of approximately 7%:

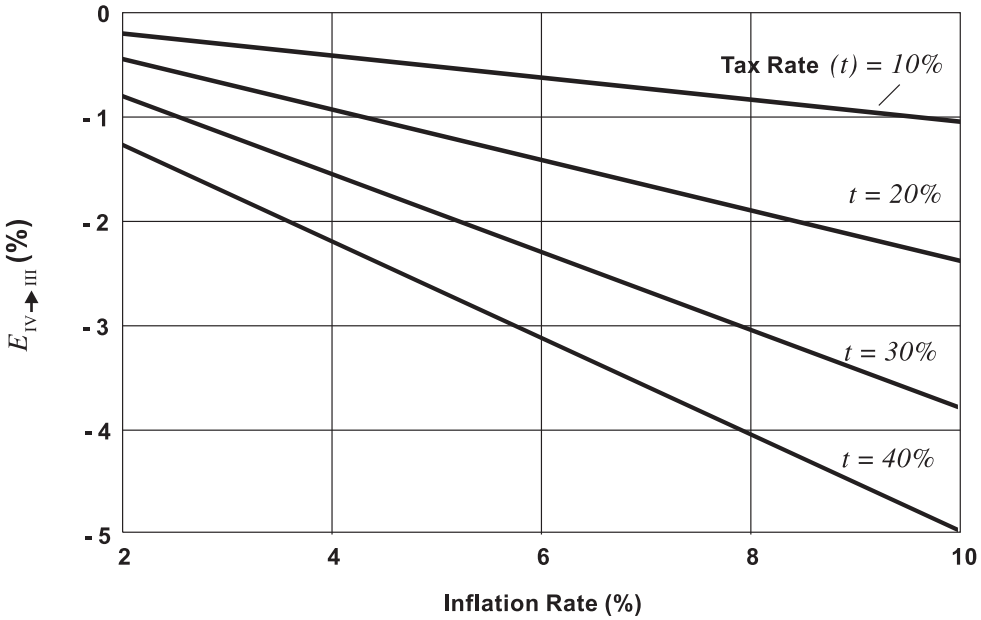
Rule-of-thumb estimate,

$$\text{QIV to QIII} = \frac{0.049\,038\,5}{(1-0.3)} = 0.070\,055 = 7.005\,5\%$$

The correct rate calculated for QIII, however, was 0.086 538 6, or approximately 8.65%. The rule-of-thumb error in this example is 0.070 055 – 0.086 538 6 = –0.016 483 6, or approximately –1.65%. This error is correctly predicted by eq. 12:

$$E_{\text{IV}\rightarrow\text{III}} = \frac{-0.3}{1-0.3}\left(1-\frac{1}{1.04}\right) = -0.016\,483\,6$$

Fig. 4. Rule-of-thumb error when used to convert a before-tax discount rate to an after-tax rate in real terms (eq. 12).



The correct before-tax discount rate in real terms is obtained using eq. 14:

$$r_{bt} = \frac{0.049\,038\,5}{(1-0.3)} + \frac{0.3}{(1-0.3)}\left(1 - \frac{1}{1.04}\right) = 0.086\,538\,6$$

Conclusions

DCF analysis of forestry investments must be consistent in accounting for income taxes and inflation. In a specific analysis these factors should either be included or excluded in the discount rate and in all costs and revenues. In many cases, net present value, rate of return, and other financial criteria estimated with DCF analysis are most accurate when they are estimated in nominal terms on an after-tax basis.

When a guiding rate of return is specified in before-tax terms, the rule-of-thumb method is often used to adjust the discount rate to an after-tax basis: (after-tax rate) = (before-tax rate) × (1 – tax rate). The inverse operation can be used to estimate a before-tax interest rate from an after-tax rate. Previous researchers have concluded that the rule-of-thumb adjustment for income taxes is accurate only when the investment alternative used to determine the opportunity cost of capital involves a non-depreciating asset returning equal annual payments, whose salvage value is exactly 100% of first cost, or when the alternative investment's life is 1 year. The rule-of-thumb has been found to be an appropriate discount rate adjustment for forest landowners whose other investments are limited to land rental, taxable bonds, and bank certificates of deposit, for example.

Inflation is also an important factor in the rule-of-thumb's accuracy in accounting for income taxes. If the unmodified rule-of-thumb adjustment for income taxes is applied to a discount rate specified in uninflated terms, the estimated discount rate may be significantly higher or lower than the true equivalent rate. If applied to real interest rates and not corrected for the effect of inflation, the rule-of-thumb will overestimate the after-tax discount rate that is equivalent to a specific before-tax rate. The rule-of-thumb will underestimate the before-tax rate equivalent to an after-tax rate specified in real terms if inflation is not considered.

When the rule-of-thumb is applied to discount rates specified in real terms, the error can be predicted as a function of the tax rate and the rate of inflation. A correction factor can therefore be applied to obtain accurate discount rate estimates, assuming the investment alternatives have the characteristics necessary for accuracy of the income tax adjustment. Figure 5 summarizes rule-of-thumb discount rate adjustments for taxes, as well as discount rate adjustments for inflation. Formulas 1 and 2 in Fig. 5 are the rule-of-thumb equations to adjust for income taxes when the discount rate is specified in nominal terms. Formulas 7 and 8 are the rule-of-thumb equations to adjust for income taxes when the discount rate is specified in real terms. Note that formulas 7 and 8 in Fig. 5 are similar to formulas 1 and 2, but each has a correction factor to account for the impact of inflation when the analysis is in real terms.

If uncorrected for the effects of inflation, discount rates estimated by the rule-of-thumb applied in real terms can be up to six percentage points too high or too low, depending on the rate of inflation, the income tax rate, and whether a before-tax or an after-tax discount rate is being estimated. With 2% inflation, for example, applying the unmodified rule-of-thumb to real discount rates generally results in an error of one percentage point or less. If inflation is 4%, however, the error can be over two percentage points, depending on the tax rate and whether a before-tax or an after-tax rate is estimated. Note that a discount rate error of one to two percentage points can be extremely important in DCF analysis of forestry investments. Because of the relatively long time periods involved in many forestry investments, an incorrect discount rate can result in significant error in net present value and other financial criteria, which can lead to faulty decisions for valuable land and timber assets.

Fig. 5. Formulas for discount rate adjustments for inflation, and rule-of-thumb discount rate adjustments for income taxes.

Quadrants in the diagram below represent income tax–inflation combinations corresponding to the eight formulas for adjusting discount rates.

	Before Taxes	After Taxes
Nominal	QI. Nominal Rate, Before Taxes i_{bt}	QII. Nominal Rate, After Taxes i_{at}
Real	QIII. Real Rate, Before Taxes r_{bt}	QIV. Real Rate, After Taxes r_{at}

	Quadrants	Type of Discount Rate Adjustment	
(1)	I → II	Nominal rates, before taxes to after taxes	$i_{at} = i_{bt}\ (1-t)$
(2)	II → I	Nominal rates, after taxes to before taxes	$i_{bt} = \dfrac{i_{at}}{(1-t)}$
(3)	I → III	Before-tax rates, nominal to real	$r_{bt} = \dfrac{1+i_{bt}}{1+f} - 1$
(4)	III → I	Before-tax rates, real to nominal	$i_{bt} = r_{bt} + f + r_{bt}(f)$
(5)	II → IV	After-tax rates, nominal to real	$r_{at} = \dfrac{1+i_{at}}{1+f} - 1$
(6)	IV → II	After-tax rates, real to nominal	$i_{at} = r_{at} + f + r_{at}(f)$

The six formulas above are interest rate adjustments for income taxes and inflation that are well-documented in the literature. The two formulas below are the corrected rule-of-thumb adjustments for income taxes where the discount rates are specified in real terms.

(7)	III → IV	Real rates, before-taxes to after-taxes	$r_{at} = r_{bt}\ (1-t) + t\left(\dfrac{1}{1+f} - 1\right)$
(8)	IV → III	Real rates, after-taxes to before-taxes	$r_{bt} = \dfrac{r_{at}}{(1-t)} + \dfrac{t}{1-t}\left(1 - \dfrac{1}{1+f}\right)$

Notation:

i	nominal (inflated) discount rate;	In all of the formulas,	
r	real (uninflated) discount rate;	bt	before-tax discount rate;
f	annual rate of inflation; and	at	after-tax discount rate; and
t	marginal income tax rate.		all rates are expressed in decimal percent.

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