Marginal effective tax rates for capital in the Canadian mining industry

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Abstract. We model a firm that explores, develops, and extracts a depletable asset, taking into account various features of Canadian corporate and Ontario and Quebec mining tax law. We derive the user cost of capital and effective tax rate for investments undertaken by a mining firm. Calculations based on 1985 tax law show that there is considerable dispersion in effective tax rates, most being negative, especially for processing assets. We conclude that these taxes have been very poor collectors of mining rents compared with a neutral cash flow tax.

A propos des taux marginaux effectifs d'imposition du capital dans l'industrie minière canadienne. Les auteurs construisent un modèle de firme qui est engagée dans le processus d'exploration, de développement et d'extraction d'un actif épuisable, compte tenu des lois canadiennes sur l'imposition des sociétés ainsi que des lois ontariennes et québécoises d'imposition qui ont un impact sur le secteur minier. Ils développent des mesures du coût d'utilisation du capital et du taux effectif d'imposition pour les investissements de cette firme minière. Les calculs construits à partir de la législation en existence en 1985 montrent qu'il y a des variations considérables dans les taux effectifs d'imposition – la plupart s'avérant négatifs, particulièrement pour ce qui est des actifs dans le secteur de la transformation. Les auteurs concluent que ces impôts ont été de bien pauvres percepteurs de rentes minières si on les compare à un impôt neutre sur le cash-flow.

INTRODUCTION

A considerable literature has developed in recent years with the aim of calculating effective tax rates on marginal investment projects. (See the summary in Auerbach, 1983.) Much of this literature has pertained to manufacturing and service industries and is only of limited applicability

We thank the Department of Energy, Mines and Resources, which helped provide financing for the first part of this project. We also wish to thank members of the Tax Policy Branch, Department of Finance, who provided useful comments during various discussions.

Canadian Journal of Economics Revue canadienne d'Economique, xx, No. 1
February février 1987. Printed in Canada Imprimé au Canada

0008–4085 / 87 / 1–16 $1.50

to resource industries. The purpose of this paper is to derive an expression for the marginal effective tax rates facing a firm extracting a depletable asset and to provide some sample calculations for mining corporations in Ontario and Quebec.

The earlier work on effective tax rates proceeded by simply dividing total taxes paid by some measure of industry profits (e.g., Feldstein, Poterba, and Dicks-Mireaux, 1982 (U.S.); Jenkins, 1985 (Canada)). The result was an average effective tax rate applicable on all investments taken in total. As pointed out in the literature on effective tax rates, there is a significant difference between the average and the marginal tax rate. The marginal tax rate involves measuring the before-tax required rate of return on investment and subtracting from it the after-tax rate of return on savings. One would expect the marginal tax rate to be lower than the average tax rate to the extent that there exist economic profits or rents in the industry, since an average tax rate includes the taxes generated on inframarginal capital investment. This point is particularly important in resource industries where rents are relatively large.

A corporate tax on pure profits or rents provides a good example of how average and marginal tax rates can diverge. A tax on rents is neutral, since the value of economic costs of production are deducted from the tax base. In this case the tax on the marginal investment is zero, but the average tax rate is positive.

To date, effective tax calculations for mining firms have tended to be average rates rather than marginal.[1] While these calculations show large positive average tax rates, such rates could be misleading as indicators of the effect of the tax system on the incentive to invest. It is quite possible, for example, to have positive average tax rates accompanied by negative marginal ones. One of the objectives of this paper is to see whether marginal tax rates faced by mining firms in Canada are indeed negative, suggesting that the tax system is an inefficient collector of rents.

Resource firms tend to differ significantly from manufacturing firms. First, resource firms are involved in holding and exploiting depletable assets, which distinguishes them from manufacturing firms, whose assets are all reproducible. Second, the tax laws facing the resource firm differ considerably from those faced by manufacturing firms. For example, at the federal level, some provisions of the corporate income tax are specific to the resource industries, such as the earned depletion allowance and the resource allowance. In addition, the costs of exploration and development are subject to a rapid write-off. Provincial corporate income taxes, while generally similar to the federal one, can vary in certain respects, such as Ontario's treatment of depletion. Provinces also have additional taxes on mining firms. In most cases, these are special mining profit taxes, but there can be a variety of other devices used, such as royalties and other capital taxes. Special incentives for processing also exist in

1 See the recent discussion paper of the Department of Energy, Mines and Resources entitled *Mineral Policy*.

provincial tax systems. As provincial mining taxes vary considerably in definition, we have limited the scope of this paper to a study of the tax rules applicable in the Ontario and Quebec mining industries, which account for a substantial portion of metal and mineral production.[2]

DERIVATION OF THE MARGINAL EFFECTIVE TAX RATE IN MINING

The methodology for deriving marginal effective tax rates is well established for manufacturing corporations[5] and we follow that here, essentially extending it to allow for the existence of depletable assets and for the special tax treatment of mining. The basic idea is to derive an expression for the gross-of-tax marginal product of capital for the various types of capital used by the firm. Using the dynamic neoclassical theory of the firm, the gross-of-tax marginal product of capital equals the user cost of capital – that is, the marginal investment project must yield a return just sufficient to cover the user cost. By measuring the user cost, we are effectively measuring the gross marginal product for the marginal investment project. This gross marginal product less the depreciation rate is the rate of return on the marginal project. Subtracting the after-tax return on saving from the rate of return on the marginal project gives the marginal tax. Dividing this tax by the gross-of-tax marginal return to capital provides the marginal effective tax rate.

We have constructed the simplest model of the firm we could imagine that would capture the main components of the problem. Consider a firm producing a mineral output Y using a three-stage production process. At the first stage a depletable asset is acquired by the use of intangible exploration and development inputs L according to the function $S(L)$. At the second stage the firm applies tangible depreciable capital K to the depletable asset and develops a deposit ready for extraction according to the production function $X(F, K)$, where F is the flow of depletable asset used in this production process. At the third stage the firm extracts the depletable asset according to the nominal cost function $C(Y)$.

There are other more complicated production processes that could be analysed as well. Depreciable capital could also be used for the first or third stages of production. Current inputs could be used in the second stage of production as well as in the first and the third stages. As we shall discuss later, the derivation of user cost of capital in our model is not sensitive to the stage of production in which the asset is used. The formula remains the same so long as the tax treatment of assets does not vary with the stage of production. Only in certain circumstances will the tax treatment of assets differ according to the stage of production. For example, investments in mine shafts are treated as a special CCA class after extraction has begun, while they are treated as an exploration expense incurred at the preproduction stage. When mine shafts are treated as exploration expense, they qualify for earned depletion and are not

2 A further discussion of these tax rules may be found in Boadway and Mintz (1985).

deducted from the resource allowance base. These details of tax law are more easily handled after we present the simplest form of the model.

The nominal price of output is P, of exploration and development is W, and of capital goods is Q. (We delete time subscripts except where necessary for exposition, though most variables are time dependent). The stock of debt of the firm outstanding is B and the nominal interest rate is i. The nominal stream of dividends of the firm may be written:

$$D = PY - C(Y) - WL - Q(\dot{K} + \delta K) + \dot{B} - iB - T_f - T_p - T_m, \qquad (1)$$

where δ is the depreciation rate on capital, T_f is federal corporate tax liabilities, T_p is provincial corporate tax liabilities, and T_m is provincial mining tax liabilities. We are assuming that there are no new equity issues, though they could be added with no great difficulty.

Federal tax liabilities can be expressed as:

$$T_f = u_f(PY - C(Y) - WL - \alpha\hat{K} - \text{RA} - \text{DA} - iB) - \phi Q(\dot{K} + \delta K), \qquad (2)$$

where u_f is the federal tax rate, α is the capital cost allowance (CCA), $\hat{K}$ is the value of the CCA base for tax purposes, ϕ is the investment tax credit, RA is the resource allowance, and DA is the earned depletion allowance. The latter two are given by

$$\text{RA} = \sigma(PY - C(Y) - \alpha\hat{K}) \qquad (3)$$

$$\text{DA} = dWL, \qquad (4)$$

where σ is the resource allowance rate and d the earned depletion rate. In fact, the earned depletion allowance is defined as a proportion of exploration and development expenditures, but the amount claimed in a year may be limited by a proportion of net taxable income, with the excess carried forward indefinitely. We assume that the firm is able to use immediately all deductions, so that the effective constraint on earned depletion is a proportion of exploration and development expenditures.[3]

Provincial corporate taxes in Ontario are given by

$$T_p = u_p(PY - C(Y) - WL - \alpha\hat{K} - \text{DA}_p - iB), \qquad (5)$$

where, for provincial tax purposes in Ontario, the depletion allowance is given by

$$\text{DA}_p = \gamma(PY - C(Y) - WL - \alpha\hat{K} - iB). \qquad (6)$$

3 The profit constraint affects the present value of exploration and development expenses written off over time. The incorporation of this constraint is thus similar to the problem that arises when deductions cannot be fully used, resulting from imperfect loss offsetting under the corporate tax system. We shall not deal with refundability of tax losses and unused deductions. See Mintz (1985) for a discussion of these issues.

That is, Ontario depletion allowances are automatic rather than having to be earned through quality investment expenditures. The Ontario provincial mining tax liability is given by

$$T_m = \tau(PY - C(Y) - WL - \alpha_m \hat{K}_m), \tag{7}$$

where α_m is the CCA rate under the mining tax, which differs from α, and $\hat{K}_m$ is undepreciated capital cost base for provincial mining tax purposes.

The book value of the capital stock for corporate tax purposes is the undepreciated sum of past investments net of the investment tax credit. It is given by

$$\hat{K}_t = \hat{K}_0 e^{-\alpha t} + \int_0^t (1 - \phi)(\dot{K}_s + \delta K_s) Q_s e^{-\alpha(t-s)} ds. \tag{8}$$

Equivalently, taking the derivative of (8) with respect to t, we obtain a flow relationship between K and $\hat{K}$:

$$\dot{\hat{K}} + \alpha \hat{K} = (1 - \phi) Q(\dot{K} + \delta K). \tag{9}$$

An analogous expression holds for $\hat{K}_m$. A similar analysis could be done for Quebec but is omitted here.

Substituting (2), (5), and (7) into (1), collecting terms and multiplying by $e^{-\Pi t}$ (where Π is the inflation rate), we obtain an expression for real dividends:

$$\begin{aligned} \text{Div} = {} & (pY - c(Y))(1 - u_f(1 - \sigma) - u_p(1 - \gamma) - \tau) + \dot{B} \\ & - i(1 - u_f - u_p(1 - \gamma))Be^{-\Pi t} - wL(1 - u_f(1 + d) \\ & - u_p(1 - \gamma) - \tau) - (\dot{K} + \delta K) q(1 - \phi) + \alpha \hat{K}(u_f(1 - \sigma) \\ & + u_p(1 - \gamma)e^{-\Pi t}) + \tau \alpha_m \hat{K}_m e^{-\Pi t}, \end{aligned} \tag{10}$$

where p, c, and q are the real equivalents of P, C, and Q.

The problem of the firm is to maximize the present value of the stream of future real dividends discounted at the shareholders' real after-tax discount rate $(\rho - \Pi)$:

$$V = \int_0^\infty e^{-(\rho - \Pi)t} \text{ Div } dt.$$

Suppose we take the debt-equity ratio (B/V) to be exogenously given as b, so $b = B/V$. It can be shown[4] that maximizing the present value of cash flows associated with real transactions discounted by the after-tax real cost of capital $(R - \Pi)$ is equivalent to maximizing the present value of dividends. Since this

4 This can be shown as follows. The value of the equity in a firm is defined by $V_t = \int_t^\infty e^{-(\rho - \Pi)(s-t)}$ Div ds. Differentiating with respect to t yields $\dot{V}_t = (\rho - \Pi)V_t -$ Div. Using the expression for dividends, given by (10), defining $W = B + V$, and $b = B/V$, this differential equation can be reduced to $\dot{W} = (R - \Pi)W -$ CF, where CF is cash flow, defined as Div $- \dot{B} + i(1 - u_f - u_p(1 - \gamma))Be^{-\Pi t}$. Integrating this expression gives wealth as the present value of real cash flow discounted at $(R - \Pi)$. Since $W = (1 + b)V$, maximizing W is equivalent to maximizing V.

is a simpler problem for expositional purposes, that is what we use here. The full problem facing the mining firm is

$$\max_{Y,\, \dot{K},\, \hat{K},\, \hat{K}_m,\, L,\, F} \int_0^\infty e^{-(R-\Pi)t}[(pY - c(Y))(1 - \tilde{u}) + \alpha\hat{K}\hat{u}e^{-\Pi t} - wL(1 - u_f(1 + d) - u_p(1 - \gamma) - \tau) - (1 - \phi)q(\dot{K} + \delta K) + \alpha_m\hat{K}_m\tau e^{-\Pi t}]dt \tag{11}$$

subject to

$$\dot{\hat{K}} = -\alpha\hat{K} + (1 - \phi)(\dot{K} + \delta K)qe^{\Pi t}$$

$$\dot{\hat{K}}_m = -\alpha_m\hat{K}_m + (\dot{K} + \delta K)qe^{\Pi t}$$

$$\int_0^\infty [Y - X(F, K)]dt = 0$$

$$\int_0^\infty [F - S(L)]dt = 0,$$

where the cost of finance is a weighted average of the net-of-corporate tax costs of debt and equity to the firm:

$$R = \frac{bi[1 - u_f - u_p(1 - \gamma)] + \rho}{1 + b}$$

and $\tilde{u} = u_f(1 - \sigma) + u_p(1 - \gamma) + \tau$, and $\hat{u} = u_f(1 - \sigma) + u_p(1 - \gamma)$. The last integral constraint ensures that the total amount of resources eventually developed does not exceed the amount acquired via exploration. The second-last constraint states that the amount of resource extracted over all time periods equals the amount developed. Equivalent constraints must be satisfied at each point of time: that is, the amount of resource developed cannot exceed the amount that has been found by then and the amount extracted cannot exceed the amount that has been developed. For simplicity of exposition, we assume that these constraints are not binding.

The first-order conditions reduce, after some simplification, to the constraints plus the following three equations:

$$\frac{\dot{p} - \dot{c}'}{p - c'} = R - \Pi \tag{12}$$

$$(p - c')\frac{\partial X}{\partial F}\frac{\partial S}{\partial L} = w\frac{[1 - u_f(1 + d) - u_p(1 - \gamma) - \tau]}{1 - \tilde{u}} \tag{13}$$

$$\frac{(p - c')}{q}\frac{\partial X}{\partial K} = (R - \Pi + \delta)\frac{(1 - \phi)}{(1 - \tilde{u})}\left[1 - \frac{\alpha\hat{u}}{R + \alpha} - \frac{\tau\alpha_m}{(1 - \phi)(\alpha_m + R)}\right] \tag{14}$$

These three equations represent the marginal conditions on the three sorts of real decisions in the three consecutive stages taken by the firm – exploration (13), depreciable capital investment (14), and extraction (12). The condition for extraction is the familiar Hotelling Rule for depletable assets: that is, that the rate of change of the net-of-cost price of the resource (the return from holding the resource in the ground) equals the real cost of finance facing the firm (the opportunity cost of holding the resource). Taxes influence the rate of return to the extent that they affect $R - \Pi$.

The equation for exploration and development states that the net value of the marginal product of exploration and development, valued at the price of the resource after extraction costs, equals the cost of the current exploration and development inputs adjusted for taxes.

The equation on depreciable capital is basically the same as that derived for the non-resource industries.[5] The left-hand side is the value of the marginal product of capital evaluated at the resource price net of extraction costs. The right-hand side is the user cost of capital incorporating the various taxes and credits. The only difference with the manufacturing industries is the incorporation of the resource allowance and the mining tax τ into the formula.

Equation (14) represents the most general condition for depletable assets. There are some variants in the tax treatment of depreciable capital at different stages of production which will affect the formula presented in equation (14). In the case of new mine assets (Class 28), structures and machinery qualify for earned depletion and can be written off as fast as the new mine earns profits (or at a minimum rate of 30 per cent). The investment tax credit reduces both the earned depletion and the capital cost allowance base. Assuming the average exponential CCA rate remains constant, then the user cost for Class 28 can be derived on the same basis as before. Its marginal condition becomes

$$\frac{\text{VMP}}{q} = (R - \Pi + \delta)\frac{(1 - \phi)}{(1 - \tilde{u})}\left[1 - \frac{\alpha\hat{u}}{R + \alpha} - u_f d - \frac{\tau\alpha_m}{(1 - \phi)(\alpha_m + R)}\right]. \tag{15}$$

VMP is the value of marginal product.

Another special case are expenditures on certain types of depreciable capital after production has begun. We can reformulate the problem to include capital in the cost function: $C(Y, K)$ where $C_K \leqq 0$. For example, mine shafts are expensed (Class 12) while other depreciable capital is treated on the same basis as before. For mine shafts in Class 12 the marginal condition becomes:

5 See Boadway, Bruce, and Mintz (1984a). The expression here differs from Gaudet and Lassere (1984), who treat depreciable capital as an input that increases extraction and fix the amount of reserves available for extraction. In contrast, depreciable capital augments extractable reserves in our model. Our model could be amended to make depreciable capital important in the extraction phase, as shown in equation (16).

$$\frac{-C_K}{q} = (R - \Pi + \delta)\frac{(1-\phi)}{1-\tilde{u}}\left[1 - \hat{u} - \frac{\tau\alpha_m}{(1-\phi)(\alpha_m + R)}\right]. \tag{16}$$

For other assets used in the extraction stage, the user cost remains the same as the right hand side of equation (14). Expressions for the user costs of other assets in equations (12) and (13), are unaffected, except that their decision will depend on the amount of depreciable capital used in extraction, since c' and $\dot{c}'$ both depend on K as well as output, Y.

Mining firms may also invest in assets used for processing, in which case they are allowed a processing allowance under the provincial mining tax. The processing allowance is a write-off at a rate defined as a percentage of the asset value before it is scrapped but subject to a profit limitation. The rate varies according to whether the investment is for concentrating, smelting or refining, and in Ontario it varies across regions. Processing assets also qualify for earned depletion under the corporate tax. Viewing processing investment as improvements in quality (hence price) of the ore, we can derive a user cost of capital by extending the model to include processing. The marginal condition for processing becomes

$$\frac{\text{VMP}}{q} = \frac{(R - \Pi + \delta)}{1-\tilde{u}}\left[(1-\phi)\left(1 - \frac{\hat{u}\alpha}{\alpha + R} - u_f d\right) - \frac{\tau\alpha_m}{R + \alpha_m} - \frac{\phi_p \tau}{R + \delta}\right], \tag{17}$$

where VMP denotes the value of the value of marginal product of processing investment and ϕ_p is the processing allowance.

The marginal effective tax rate applicable to an investment decision is defined to be the difference between the before-tax rate of return on investment (r_g) and the real cost of funds available on the market (r) as a proportion of r_g. This gives the marginal distortion due to corporate and mining taxation alone. As discussed in Boadway, Bruce, and Mintz (1984a), there will be an additional distortion on capital markets, owing to personal taxes. The size of that distortion will be the same for the mining industry as it is for others, so we omit its calculation here. The real cost of funds on capital markets is

$$r = bi/(1 + b) + \rho/(1 + b) - \Pi. \tag{18}$$

In the case of depreciable investment, the before-tax rate of return is simply the right-hand side of (14), (15), (16), or (17), less the true depreciation rate δ. The rate of return from holding depletable assets is $R - \Pi$ given by (12).

Since we treat exploration and development expenses as current in nature, the effective tax rate is simply defined to be the difference between the value of the marginal product before tax, given by the right-hand side of (13), and the opportunity cost of the inputs, w.

The following sections describe the data used in calculating these effective tax rates and presents some results.

EMPIRICAL CALCULATION OF CORPORATE AND MINING MARGINAL TAX RATES

Careful measurement of marginal tax rates on mining industries in Canada requires modelling of each of the provincial mining taxes and, in the case of Ontario, Quebec, and Alberta, the provincial corporate income tax as well. To limit the scope of empirical work we concentrate on effective tax rates for only Ontario and Quebec, which are major producing provinces of metals and non-metallic minerals.[6]

In this section we describe the 1985 features of federal and provincial corporate income taxes and Ontario and Quebec mining taxes that are relevant to our calculations. We then discuss the methodology used to calculate marginal tax rates and conclude with a presentation of the results.

Corporate, provincial, and mining taxes

The federal corporate income tax is similar to that applicable to other industries except for a few important aspects. The federal tax rate is taken to be 36 per cent, since few mining companies qualify for the small business deduction. For federal tax purposes, earned depletion, a resource allowance, property right costs, exploration and development expenses, interest, and the CCA are deductible as capital costs from corporate taxable income. Earned depletion is equal to one-third of intangible exploration and development expenses, new mine and processing asset expenditures. The resource allowance is equal to 25 per cent of net revenues less CCAs. Only exploration and development expenditures that are intangible are expensed, but the cost of acquiring property is written off at a 30 per cent rate on a declining balance basis. The most important CCA classes for mining are Class 10 (structure and machinery written off at a 30 per cent rate on a declining balance basis); Class 12 (post-production mine shafts written off at a 100 per cent rate); and Class 28 (new mine assets written off at a minimum of 30 per cent, or as fast as the new mine earns profits). An investment tax credit reduces taxes payable and the bases for earned depletion and the CCA. The investment tax credit in 1985 was equal to 7 per cent normally, and 10 per cent for northern Ontario and Quebec.

Ontario and Quebec (along with Alberta) collect their own corporate taxes outside the Tax Collection Agreements. The Quebec corporate income tax is similar to the federal tax, except that the tax rate is 5.5 per cent and the cost of acquiring mining property is written off at a rate of 100 per cent rather than 30 per cent. The Ontario corporate income tax is similar to the federal tax as well. The exceptions are that the rate of tax is 14.5 per cent and that 'automatic'

6 Current work is being conducted on other provinces, although results are not yet available. None the less, the main conclusions arising from our empirical work in this section of the paper have equal applicability to the other provinces, as suggested by the preliminary work that is not reported here.

rather than earned depletion is deducted, the allowance being equal to one-third of taxable income. Also, the cost of acquiring mining property is written off at a 100 per cent rate.

Both Quebec and Ontario levy mining taxes on mining operating income with no deduction allowed for interest and corporate income taxes. The main features of the mining taxes are the following:

1. The mining tax rate structure in Ontario is 20 per cent levied on income over \$500,000. We use 20 per cent as the effective statutory tax rate. Quebec now has a flat tax rate of 18 per cent on income that is incorporated in the calculations.
2. Production assets are written off at a rate of 15 per cent on a straightline basis. Processing assets are written off at a 15 per cent straightline rate in Ontario and a 30 per cent straightline rate in Quebec.
3. Exploration and development expenditures are written off at a 100 per cent rate.
4. A processing allowance equal to a percentage of the original cost of the depreciable asset is deducted from taxable mining profits. In Quebec this rate varies from 8 per cent for concentrating assets to 15 per cent on all processing assets for operations engaged in smelting, refining, and concentrating. In Ontario the rate is 8 per cent for concentrating assets only, 12 per cent for smelting and concentrating assets, and 16 per cent for refining, smelting and concentrating assets (20 per cent for processing in northern Ontario). The processing allowance in both Quebec and Ontario is subject to a minimum of 35 per cent and a maximum of 65 per cent of mining income in Quebec and 50 per cent in Ontario.
5. Interest, royalties, and depletion costs are not deductible. In Quebec an earned depletion allowance is deducted equal to one-third of exploration and development expenses and expenditures on new mine and processing assets.

In our calculations we use the values described above for estimating marginal effective tax rates. We also assume that all corporations are tax paying and ignore complications arising from the use of taxable losses as an unused deduction. For similar reasons we assume that the profit limit on earned depletion is not binding. The processing allowance granted for mining purposes, however, is so generous that we also provide an estimate of the effective tax rate assuming that the allowance is no more than 65 per cent (Quebec) or 50 per cent (Ontario) of mining profits.

Methodology

The methodology used to measure marginal tax rates closely follows Boadway, Bruce, and Mintz (1984a). Numerical values for parameters appearing in equations (12)–(18) and in footnote 7, below, were estimated from various sources reflecting the current economic and tax situations faced by mining corporations in Canada. Effective tax rates are calculated for

1. depletable assets
2. machinery (all CCA classes and of Class 28 (new mine assets))
3. buildings (including Class 28, mine shafts)
4. land
5. exploration and development (only intangible expenses qualify)
6. processing assets
7. inventories.

The estimates of effective tax rates on depreciable assets take into account the half-year convention[7] which allows a corporation to claim only one-half of its CCA in the first year (exceptions are for Classes 7 and 12). The formula for the cost of holding inventories was derived by extending the work developed in Boadway, Bruce, and Mintz (1982).[8]

The estimates of various parameters are listed in a data appendix. The most up-to-date information was used for tax parameters. Current values are taken for expected values. Other statistics, such as the portion of investment financed by debt and the risk premium on equity, are averages of past values as a proxy for long-run expected values. The cost of debt and equity is calculated from current market statistics, and the expected rate of inflation is a long-term forecast of the expected inflation rate expressed in annual terms.

Presentation of marginal tax rates

Marginal tax rates are calculated for Ontario and Quebec mining corporations for two cases, depending on whether the processing allowance is binding or not. In table 1 effective federal and provincial corporate income taxes and mining tax rates are presented, assuming that no constraint is binding in claiming the processing allowance. These tax rates demonstrate the extent to which the corporate and mining tax rates can influence the incentive to various types of investment undertaken by these companies. The most important effects are discussed below.

It is clear from table 1 that the current tax system encourages investment in exploration and development and in processing activities. The effective tax rates for these expenditures are negative, reflecting the fact that the present value of deductions is worth more than the economic cost of acquiring the asset. The negative effective tax (or subsidy) rate for exploration and development arises from the provision for earned depletion as well as the non-deductibility of exploration and development expenses from the resource

7 The formula used for capital cost allowances is derived as follows. In the first year, the firm claims $\alpha/2$ on each dollar of new investment, where α is the CCA rate. In the next year the CCA base is equal to $(1 - \alpha/2)$, which is written off at the rate α. Using R as the firm's nominal discount rate, the per cent value of CCA is equal to

$$\frac{\alpha}{2} + \left[1 - \frac{\alpha}{2}\right] \sum_{t=1}^{\infty} \frac{(1-\alpha)^{t-1}}{(1+R)^t} = \frac{\alpha}{2} + \left(1 - \frac{\alpha}{2}\right)\frac{\alpha}{(\alpha + R)(1+R)}.$$

8 The formula used for the calculation of the cost of holding inventories is equal to $[R - \Pi + u(\Pi - v)]/(1 - u)$, with the holding period of inventories being less than one year.

TABLE 1

1985 effective tax rates for Ontario and Quebec mining (processing allowance profit constraint not binding)[a]

		Federal corporate income tax		Provincial corporate income tax		Total corporate income tax		Provincial mining tax		Total tax	
		Ont	Que	Ont	Que	Ont	Que	Ont	Que	Ont	Que
Depletable asset	$-t$:	−1.9	−1.9	−0.5	−0.3	−2.4	−2.2	0.	0.	−2.4	−2.2
	$-t_r$:	−19.4	−19.4	−4.6	−2.5	−25.9	−23.0	0.	0.	−25.9	−23.0
Buildings	$-t$:	−0.1	−0.6	1.3	1.1	0.3	−0.6	1.9	1.9	2.3	0.6
	$-t_r$:	−1.0	−5.6	9.9	8.4	2.7	−5.2	14.4	13.8	16.4	4.6
Equipment	$-t$:	−1.7	−2.4	0.3	−0.1	−1.1	−2.3	0.7	0.6	0.8	−1.4
	$-t_r$:	−16.7	−25.8	1.4	−1.1	−10.3	−24.7	5.9	5.1	6.4	−13.1
Exploration and development[b]	$-t$:	−28.8	−28.8	0.	−3.4	−33.2	−35.1	0.	−7.3	−48.5	−59.4
	$-t_r$:	−28.8	−28.8	0.	−3.4	−33.2	−35.1	0.	−7.3	−48.5	−59.4
Inventories	$-t$:	2.6	2.6	1.0	0.3	4.4	3.2	3.5	3.1	13.0	9.4
	$-t_r$:	18.3	18.3	7.5	2.5	27.3	−21.5	23.1	20.9	52.5	44.4
Processing assets[c]: smelting	$-t$:	−4.1	−4.7	0.3	−0.4	−3.8	−5.2	−0.8	−3.1	−6.6	−11.2
	$-t_r$:	−53.3	−67.5	2.9	−3.1	−46.9	−78.0	−7.2	−35.3	−125.8	−1947.5
Concentrating and smelting	$-t$:	−4.1	−4.7	0.3	−0.4	−3.8	−5.2	−.1	−5.0	−8.9	−14.4
	$-t_r$:	−53.3	−67.5	2.9	−3.1	−46.9	−78.0	−21.1	−74.6	−317.0	NA
Refining, concentrating and smelting	$-t$:	−4.1	−4.7	0.3	−0.4	−3.8	−5.2	−5.0	−5.6	−14.0	−15.0
	$-t_r$:	−53.3	−67.5	2.9	−3.1	−46.9	−78.0	−39.4	−74.6	−2616.3	NA

[a] The *marginal tax is* $t = r_g - r_n$, where r_g is gross of tax return to capital, and r_n is the net of tax return to capital.
The *marginal tax rate is* $t_r = (r_g - r_n)/r_g$.
[b] For exploration and development the *marginal tax rate* is $t_r = (r_g - w)/w$, where w is normalized to unity.
[c] In some cases the processing allowance is so generous that r_g is negative. Hence NA is reported.

allowance base. The latter allows the firm to deduct exploration and development expenses at a higher tax rate than the tax rate applied to income generated by these activities. The Ontario corporate income and mining taxes do not in themselves affect the exploration and development decision since intangible costs are expensed.[9] The highly negative tax rate on processing assets results largely from the availability of earned depletion and the processing

9 In this model exploration and development is treated as a point input-point output process. Intangible exploration and development expenditures have no lasting value to the firm, so that expensing of intangible expenditures is neutral in this sense. If the process were point input / flow output, the effective tax rate would be lower in value. This can be seen as follows. Suppose exploration and development inputs, L, create a stock of capital that has lasting value, although it depreciates over time. If F is the stock of capital, then $\dot{F} = S(L) - SF$, where S is the rate of depreciation. If reserves made available for extraction depend on the stock of capital created by exploration development ($X(K, F)$), then the cost of exploration and development capital would be as follows:

allowance. It especially favours smelting and refining, which are activities that can be especially sensitive to the cost of capital.

The depletion or extraction decision is also directly affected by the corporate income tax. The deductibility of the interest cost on borrowed money reduces the cost of funds or the firm's discount rate R. This encourages the postponement of extraction as the opportunity cost of leaving the resource in the ground is lowered. The 'automatic' depletion allowance in Ontario also affects the extraction decision. With the deductibility of borrowed financing costs from the depletion allowance, the firm's discount rate is increased, thus encouraging depletion. On the other hand, the earned depletion allowance, which depends on exploration and development of new mine and processing expenditures, has no direct effect on the firm's discount rate and hence the extraction decision.

Other assets are more highly taxed. Building and machinery assets are taxed at higher rates, although new mine assets that are included in buildings and machinery assets and claim earned depletion are subsidized (figures not shown). Inventories are the most highly taxed form of investment.

Mining taxes in Ontario and Quebec favour exploration, development, and processing. The treatment of processing under the mining tax is so generous that marginal return to capital is close to zero, thereby encouraging unproductive marginal processing projects to be undertaken in the economy.

The generosity of the processing allowance arises from the use of the undepreciated cost base of the processing assets to calculate the allowance until the assets are scrapped. It is likely that the profit constraint in claiming the processing allowance is binding, although we have no evidence on the matter. In table 2, we provide estimates of the effective tax rates on mining assuming the processing allowance to be constrained by a percentage of net mining income. This limit reduces substantially the range in marginal rates since the effective statutory mining tax rate is reduced from 25 per cent to 8.75 per cent in Quebec and 12.5 per cent in Ontario. Thus the marginal tax rate falls for buildings, equipment, and inventories, and the tax rate increases for exploration, development, and processing.

The federal and provincial corporate income and mining taxes not only distort decision-making but also do a relatively poor job of collecting rents on behalf of the governments. Excluding exploration and development, the overall effective tax rate of table 1 is -16.6 per cent in Ontario and -55.6 per cent in Quebec when the processing constraint is binding. This is much lower than that found for other industries (see Boadway, Bruce, and Mintz, 1984a). If a tax

$$(P - c')\frac{\partial X}{\partial F}\frac{\partial S}{\partial L} = (r + \delta)\left[\frac{1 - u_f(1 + d) - u_p(1 - \gamma) - \tau}{(1 - \tilde{u})}\right]w.$$

This was procedure used in the Department of Finance's discussion paper, *The Corporate Income Tax: A Direction for Change*, May 1985.

TABLE 2

1985 marginal effective tax rates for Ontario and Quebec mining with the processing allowance profit constraint binding[a]

		Federal corporate income tax		Provincial corporate income tax		Total corporate income tax		Provincial mining tax		Total tax	
		Ont	Que	Ont	Que	Ont	Que	Ont	Que	Ont	Que
Depletable assets	$-t$:	−1.9	−1.9	−0.5	−0.3	−2.4	−2.2	0.	0.	−2.4	−2.2
	$-t_r$:	−19.4	−19.4	−4.6	−2.5	−25.9	−23.0	0.	0.	−25.9	−23.0
Buildings	$-t$:	−0.2	−0.6	1.3	1.1	0.3	−0.6	1.5	1.4	1.1	−0.3
	$-t_r$:	−1.1	−5.6	9.9	8.4	2.7	−5.2	11.4	10.4	8.8	−2.2
Equipment	$-t$:	−1.7	−2.4	0.2	−0.1	−1.1	−2.3	0.3	0.1	−0.4	−2.1
	$-t_r$:	−16.7	−25.8	1.4	−1.1	−10.3	−24.7	2.2	1.0	−2.9	−21.2
Exploration and development[b]	$-t$:	−28.8	−28.8	0.	−3.4	−33.2	−35.1	0.	−2.2	−39.4	−42.0
	$-t_r$:	−28.8	−28.8	0.	−3.4	−33.2	−35.1	0.	−2.2	−39.4	−42.0
Inventories	$-t$:	2.6	2.6	1.0	0.3	4.4	3.2	1.6	1.0	7.9	5.0
	$-t_r$:	18.3	18.3	7.5	2.5	27.3	21.5	11.8	7.5	40.2	29.8
Processing assets[c]:	$-t$:	−4.1	−4.7	0.3	−0.4	−3.8	−5.2	0.8	−0.3	−3.0	−5.8
	$-t_r$:	−53.3	−67.5	2.9	−3.1	−46.9	−78.0	6.2	−2.2	−33.5	−98.3

[a] The *marginal tax* is $t = r_g - r_n$, where r_g is gross of tax return to capital, and r_n is the net of tax return to capital.
The *marginal tax rate is* $t_r = (r_g - r_n)/r_g$.

[b] For exploration and development the *marginal tax rate is* $t_r = (r_g - w)/w$, where w is normalized to unity.

[c] With a binding profit constraint, all concentrating smelting and refining assets will be treated the same under the tax law.

were imposed on pure profits or rents, the marginal tax rate would be zero rather than negative. The federal corporate income tax generally subsidizes marginal investment in the sense that companies can write off generous deductions against other sources of income such as inframarginal profits. The size of the subsidy, however, depends on the manner in which taxable losses can be used.

CONCLUSIONS

The corporate and mining taxes imposed on Ontario and Quebec mining corporations tend to distort the production structure of these businesses significantly. The taxes encourage exploration and development and processing while discouraging extraction and other investment. The substantial range in marginal effective tax rates on mining suggests that tax policy could aim at reducing some of the distortionary effects of the current system. One goal may be to move to a *cash flow tax* which would allow for the expensing of investments and non-deductibility of interest costs (or some equivalent tax in present value terms, as argued by Boadway, Bruce, and Mintz, 1984b). Such a tax would be to remove the impact of taxes on the structure of production and timing of extraction and tax economic rents only.

The theory and empirical work as presented here can be further developed in two ways. First, an alternative characterization of the exploration and development process would lead to a different measure of the cost of capital and the effective tax rate. One possibility is to view exploration and development as a flow of expenditures made in creating a knowledge of exploitable resources in a particular area. This would require modelling the process of exploration and development as a flow input / point (or flow) output problem rather than the point input / point output process used here. A second extension is to take into account the inability of mining companies fully to use all taxable losses and deductions. The impact of imperfect loss offsetting is to make generous deductions available for exploration and development less valuable to the firm. However more highly taxed assets help use up losses on other assets, so their effective tax rates are lower. To the extent that firms are unable to use all tax deductions, the effective tax rates calculated in this paper would be underestimates when the tax rate is negative and overestimates when the tax rate is positive.

DATA APPENDIX

1. Physical depreciation δ	Taken as $2/T$, where T is the service life reported in Statistics Canada, *Fixed Capital, Flows and Stocks* (12–211)
2. Interest rate on debt i	Weighted average of corporate bond yields of more than five-year term for mining corporations (source: *Northern Miner*) and equal to 13.3 per cent.
3. Cost of equity ρ	Based on capital asset pricing model estimates of risk premium taken from Parker (1983) and Calvet and Lefoll (1984). The estimate of risk premium is for mining stocks traded on the Toronto Stock Exchange. The risk premium of 9.3 per cent was added to a weighted average of three-month Treasury Bill rates.
4. Debt/asset $b/(1 + b)$	Debt is taken as in a ten-year average of increases in short- and long-term liabilities excluding deferred tax liabilities and minority interest. Equity in the increase in shareholder's equity. Debt asset ratio was taken as 40 per cent.
5. Expected inflation rate Π	Average forecast of various agencies' three-year inflation rate expressed in annual terms

6. Investment tax credit ϕ	Amount of investment tax credit earned divided by additions to CCA class base
7. Inventory allowance σ	Amount of inventory allowance earned divided by open-year balance of inventory allowance.
8. Cost of buildings and machinery capital q	Required return to capital calculated for each CCA class and aggregated according to the distribution of additions to the CCA class. New mine assets were apportioned into buildings and machinery using sources of data on structure and machinery investments made by mining firms.

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