Optimizing the public gains from the exploitation of mineral resources

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SYNOPSIS

Every nation must decide how it should exploit its mineral resources so as to contribute most to its national objectives. It is argued that the present value of the future corporate income tax flow derived from mineral exploitation may serve as a useful indicator in moving toward a taxation policy that would contribute optimally toward the greatest public benefit.

The future stream of corporate income taxes depends largely on the mineral endowment, consisting of deposits now being mined, known unmined deposits, and unknown deposits.

Unknown deposits may be estimated by geological inference. Both known and unknown deposits can be categorized according to grade and size, and divided into economic and uneconomic deposits on the basis of certain prices, costs, rate of return and taxation levels.

Computer simulations can be run of discounted cash flow models at various taxation levels to show the impact of taxation changes on future tax revenues.

SINOPSIS

Iedere nasie moet besluit hoe om haar minerale bronne te ontgin om sodoende die beste bydrae tot haar nasionale objektiewe te lewer. Dit kan geredeneer word dat die huidige waarde van die toekomstige geïnkorporeerde inkomste-belasting vloei afkomstig van minerale bewerking as 'n waardevolle rigsnoer mag dien om in die rigting van 'n belastings beleid te beweeg wat bes moontlik mag bydra tot die grootste voordeel vir die publiek.

Die toekomstige stroom van geïnkorporeerde inkomstebelastings is grootendeels afhanklik van die minerale rykdom bestaande uit afsettings wat nou gemyn word, bekende afsettings wat nog nie gemyn is nie en onbekende afsettings.

Onbekende afsettings mag geskat word deur middel van geologiese gevolgtrekkings. Beide bekende en onbekende afsettings kan gekategoriseer word volgens graad en grootte en kan verdeel word in ekonomiese en onekonomiese afsettings op die basis van sekere pryse, kostes, inkomste koers en belasting vlakke.

Komper nabootsing kan op gediskonteerde kontant vloei modelle op verskeie belastings vlakke bereken word om die invloed van belastings veranderinge te bewys op toekomstige belastinginkomste.

INTRODUCTION

It is beyond dispute that exploitation of mineral resources may contribute substantially to the economic development of a country. Minerals provide raw material for secondary and manufacturing industries. If exported, they bring in foreign exchange. The tapping of mineral resources generates direct income and employment. Through the multiplier effect, significant additional income and employment may result.

It is also a fact that a government has various means at its disposal to either stimulate or hinder the extent and rapidity of mineral development within its jurisdiction. For instance, it can grant tax allowances to industry that will enhance the profitability of developing certain mineral deposits.

It follows that any nation possessing mineral resources is faced with a range of options. Every such nation must decide how it should exploit its mineral resources so as to contribute most to its overall national objectives, whatever these may be. Stated differently, the question is how to obtain the greatest public benefit from these resources.

We cannot state categorically what this means, as it depends on various economic as well as non-economic objectives. The definition of 'greatest public benefit' rests on value judgements that are made ultimately in the political arena, either explicitly or implicitly. These include consideration of who ends up with the 'spoils', the importance given to domestic employment opportunities or to adverse environmental effects, questions of national security and sovereignty, effects on the balance of payments, and perhaps concern about depriving future generations of essential minerals. Certainly, there is ample scope to differ on the relative emphasis that should be given to these various considerations, for any particular set of conditions. Where these conditions show wide disparities, as they typically do among nations, differences in emphasis are indeed called for.

Since mineral resources are both exhaustible and non-renewable, errors in mineral policies may have expecially grave consequences. After careless exploitation or over-exploitation of minerals, nature gives us no second chance. On the other hand, it may be equally wasteful to leave minerals in the ground, where they benefit no one, if they could be developed economically

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This paper will be included in the Proceedings of the Tenth International Symposium on the Application of Computer Methods in the Mineral Industry, which will be published in due course.

now. In the future, certain minerals may decrease in value if technology passes them by. Others will rise in value, but if living standards in general continue to rise, perhaps our grandchildren will be less in need of a trust fund than we are, and we should count on their ingenuity to find solutions to whatever scarcity problems future technologies will pose. But we do not intend to become embroiled here in such fundamental questions, as they need not be solved in any particular way in the context of this paper. Suffice it to note that they lurk in the background.

A CRITERION FOR EVALUATING PUBLIC GAINS

Our aim is to develop a criterion that can serve as a useful guidepost for evaluating the effectiveness of governmental actions in striving for the 'greatest public benefit' from the available mineral resource base. The social value of a mineral resource is the sum of its private and public value; it is the public value which is con sidered here.

As background for the choice of our criterion, let us first of all consider some basic concepts about equity on which substantial agreement is likely to exist. In Canada, as no doubt in most other countries, it is felt that the nation's mineral wealth is a national heritage and that all Canadians are entitled to a share of it. This 'wealth', however, is not ready-made but requires several steps for its creation. It takes imagination, work, capital, and some gambling blood to find and develop mineral deposits, to dig minerals from the ground, convert them to a marketable form and deliver them where they are needed. Only then do minerals have value, and only then may there be any monetary benefits to be divided, namely, the profits realized. In the name of all citizens, the Government takes part of these profits in the form of corporate income taxes. Thus, part of the wealth inherent in the country's mineral heritage ends up with all citizens (providing the government spends it wisely).

Now, in general terms, the question is: how high should these taxes be so that they are not so high that entrepreneurs will be discouraged from investing in mineral resources (so that a decline in future corporate income tax receipts would result), and yet not so low that tax receipts will be lower than they could be? To be more specific, at what level of taxation will the present value of the future income stream of corporation taxes be maximized?

We do not claim that this level of taxation corresponds necessarily to achieving the greatest public gains. For one thing, other forms of revenues (and subsidies) exist such as royalty payments for the use of public lands, export duties on mineral products, and import duties on mining equipment, but these are not so significant in Canada. More fundamentally, even if a particular taxation level will result in a substantially smaller total revenue from corporate income taxes than the maximum possible, such a level may be closer to an overall optimum if certain favourable aspects, such as additional employment opportunities, overshadow the loss of tax revenues.

As far as receipts from personal income taxes are concerned, we need not consider these in the case of a full-employment economy. Under such conditions, the assumption is that if people do not work in the mineral industry, they will work elsewhere. However, the generation of personal income taxes by a certain level of mineral resource development *should* be considered a net benefit to the government if an equivalent number of people would otherwise be *un*employed. But in that case, the net benefit would also include the provision of jobs, which itself would likely be a much greater benefit socially; moreover, it would save the costs of unemployment benefits. In this overall context, it is of considerable interest to a government to know the *cost* of providing jobs specifically in the mineral industry through certain tax incentives. After all, there might be cheaper ways of generating jobs. This cost can be expressed in terms of corporation taxes foregone, perhaps qualified by some considerations that are harder to quantify (such as environmental effects and regional balance).

Thus we wish to define the relationship between taxation policies and the present value of future tax revenue streams. The maximum revenue, we suggest, can serve as a guidepost for an optimal taxation policy. At the point of maximum revenue, an assessment is in order of the levels of employment opportunities, environmental effects, foreign exchange receipts, and any other considerations deemed pertinent. If any of these call urgently for a lower or higher level of activity in mineral exploitation, a simulation at any different level will yield the corresponding tax income. Thus, the cost of a change, in terms of revenue foregone, can be calculated and evaluated. (Of course, this 'cost' is in effect a transfer of profits from the public to a small group of entrepreneurs.) Being able to measure the relationships between mineral policy, various mineral deposit characteristics, and government revenue is a prerequisite for a rational approach toward an optimal mineral policy.

A MEASURING PROCEDURE

Having provided an objective, we may now describe how one may calculate the required relationships. For the sake of simplicity, we will not include in this model the additional corporate income tax generated through multiplier effects. Moreover, we will limit ourselves here to base metal resources.

The amount of corporate income tax paid annually to the federal government by a company operating in Canada depends upon the size of its taxable income and on the tax rate. The taxable income is determined by gross revenue minus costs and minus special tax allowances. We may break these components down further to see at what points government policies control the development of a mineral deposit.

The total gross revenue from a deposit is mostly a function of size of deposit, grade of ore, mineral prices, and rate of production.

Tax-deductible costs include exploration costs, capital costs, development costs, operating costs of mining, ore treatment costs, and transportation costs.

Deductions for income tax purposes in Canada consist essentially of:

(i) write-offs of exploration and development expenses,
(ii) depreciation allowances,
(iii) percentage depletion allowances, and
(iv) tax-exempt periods.

Obviously, government control lies chiefly in the category of tax regulations. The task is to show quantitatively how sensitive mineral development and corporate income tax revenues are to shifts in taxation levels.

In a fundamental way, future corporate income taxes will depend on the mineral endowment on which mineral resource developers can draw. This endowment may be divided into three categories, namely,

(i) the remainder of deposits presently in the process of being mined,
(ii) known deposits not yet being mined, and
(iii) unknown deposits.

Let us start with the last two categories of deposits, that is, those which are not yet being exploited. We might ask, firstly, how many deposits exist that might potentially be developed profitably under various price/cost/taxation relationships, and, secondly, how large and how rich are they? We wish to consider only those deposits likely to be mined during the period for which income tax provisions are normally stable—say a period of 20 years.

To find approximate answers for unknown deposits, the assumption is made that all base metal deposits follow a size and grade distribution pattern, related to geology, that can be inferred by extrapolation from the observation of known deposits, whether or not these are mined out at present. Thus, we can estimate the distribution, within a given region, of total untapped resources in terms of numbers of deposits of certain sizes and grades, irrespective of their immediate economic merits. This can be done by soliciting judgements of the physical endowment from selected geologists in the best position to make such judgements.

Next, we can make certain assumptions about future prices and production costs. Then, on the basis of a particular set of tax laws and a rate of return typical for the industry (which the industry may also use as a discount rate to evaluate properties), we may estimate which deposits would be economically viable. This can be done for both known and unknown deposits.

Let us visualize the tonnages and grades of potentially mineable Canadian base metal deposits as a joint distribution $D(t,g)$, where t represents the tonnage of each deposit and g is the grade, expressed in dollars per ton and evaluated in a consistent way, such as by the value of concentrates at the mine mouth. The conversion of grade to dollars per ton is a device allowing us to aggregate the metal content, per ton of ore, of several different metals.

Fig. 1 illustrates the principle. All economically viable base metal deposits that we know or postulate to exist may be plotted on this diagram. They will all lie to the right of line AB, the 'break-even' line. This line corresponds to deposits that would yield only a minimum acceptable return. The line would shift toward A^1B^1 if costs were higher, prices lower, taxation levels higher, or if a higher minimum rate of return were used. At A, the line approaches a cut-off grade for large deposits; at B, it reaches a cut-off tonnage, that is, the minimum size of deposit that could be exploited economically even at the highest expected grade.

This illustration contains two simplifications. For one thing, the break-even 'line' is in reality a *zone*, because of differences in mining depth, ease of mining, metallurgical complications, and any other factors affecting costs. The second simplification is that location relative to markets is not specified; this is justified only if the locational effects on costs (that is, on market value of concentrates at mine sites) do not diverge too much from an average. If they do, areal subdivision is required.

It is obvious that the distribution density of mineral deposits in Fig. 1 diminishes as one moves away from the origin, for large and rich deposits are less common than small and lean ones. Hence, the mineral potential is made up very largely of deposits that are close to the break-even line. A small shift of this line is likely to have a substantial effect on the number of economically viable deposits available in nature.

If, for example, the tax rate is increased moving the break-even line from AB to A^1B^1, this removes from the usable mineral endowment all deposits that lie between AB and A^1B^1. Furthermore, it also diminishes the profitability of all deposits above A^1B^1,. Therefore, changing the taxation level has a double-barrelled effect on the level of mineral activity.

Now, if we assume costs and prices constant, and postulate a particular minimum rate of return that can be used as a discount rate, we can attempt to measure the effects of changes in the taxation level. We can do this by simulating what would happen at various levels of taxation, using the concept of the discounted cash flow model, which can be set up in computerized form.

For operating mines, the corporate income tax for

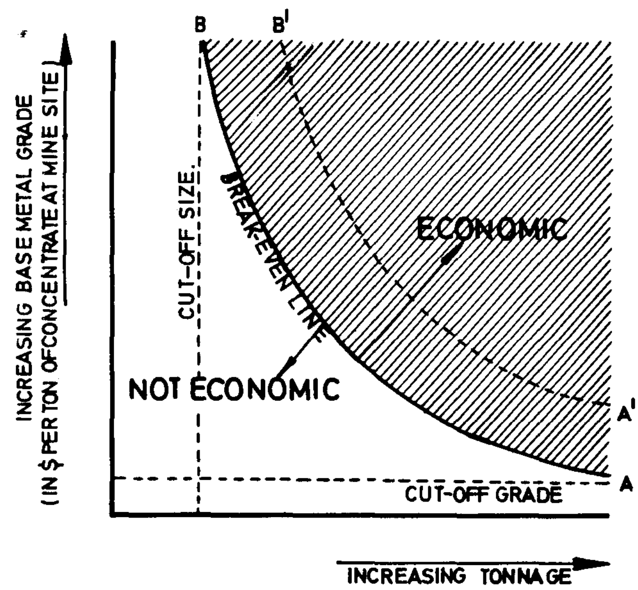

Fig. 1—Base metal deposits divided into economic and non-economic by size and base metal content, under certain assumptions of costs, prices, taxation levels, and rate of return.

each remaining year of life may be discounted to present value and added up. This can be done for various simulated taxation levels, to show the effect of tax changes on tax revenues. It should be borne in mind, of course, that increasing the tax has a chilling impact on entrepreneurs who have made investments on the assumption that the rules of the game were set. In a realistic simulation, therefore, one may make some provision for a transition period for operating mines if taxes were to be increased. Mining men are much less prone to worry about fairness when taxes are cut and profits are increased unexpectedly.

As for known but undeveloped deposits, these also may be run through a cash flow model at various taxation levels to gauge the effect on the present value of future corporate income taxes. Such simulations will at the same time indicate which deposits will become uneconomic at what taxation level. This question is not likely to be important for existing mining operations, as many of the costs have already been incurred.

For known deposits, a forecast can usually be made of starting date and duration of the exploitation process. For unknown deposits, the time factor is much more elusive. Even assuming that a number of deposits of certain sizes and grades exist, *when* will they be found and during what period will they be exploited and yield a stream of corporate income taxes? We may approach this problem as follows.

The life of a mine is a function of the size (tonnage) of the deposit and the rate of mining. Generally speaking, deposits of certain sizes allow corresponding economies of scale that lead to corresponding rates of exploitation, so that there is a fairly consistent relationship between the size of a deposit and the duration of its exploitation.

It is therefore useful to develop a function linking capital and development costs, operating costs, the rate of production, and the life of the mine with the tonnage of the deposit. Also, base metal deposits smaller than a certain tonnage (say, 10 million tons) may be assumed to be mined underground, and larger ones by open pit.

As a simpler alternative, one may divide the size/grade diagram of Fig. 1 into vertical zones representing tonnage *ranges* t_i where i indicates each zone. For each t_i, a set of cost input data could be used in the cash flow model that would be typical for that size range. The potential gross revenue inherent in a deposit of size t_i, arrived at by multiplying t_i by the grade, must be spaced out over a number of years typically representing the life of a mining operation in size range t_i. And again, simulation can show us the break-even line in each zone t_i for various taxation levels.

In Table I, by way of illustrating the principle, the results of a few simple, simulated taxation changes are shown. The simulation was done for two typical Canadian mineral deposits. One is a relatively high-grade deposit (I), the other is a large, low-grade deposit (II). Tonnage, grade, and other operating data of these two deposits are shown in Table II.

Four cases were considered. For each, a particular Federal taxation feature was varied; changes were applied to the duration of the tax-exempt period, to the rate of Federal corporation income tax, and to the rates of depreciation and depletion allowances. To asses the effects of these changes on the total income tax receipts (both Federal and Provincial), the present values of a hypothetical company's cash flows and governmental tax revenues were calculated by computer. These are shown in Table I.

TABLE I

EFFECTS OF SOME SIMULATED CHANGES IN TAXATION ON THE PRESENT VALUE OF TAX RECEIPTS

					Deposit I		Deposit II	
	Tax holiday (years)	Federal Corporate income tax rate[1] (%)	Depreciation rate (multiple of existing rate)[2]	Depletion rate (%)	Net present value of cash flows discounted @ 15% (in million $)	Present value of tax revenue discounted @ 7% (in million $)[3]	Net present value of cash flows discounted @ 15% (in million $)	Present value of tax revenue discounted @7% (in million $)[3]
Case A:	5	50	1,00	33,3	109,17	145,22	7,26	55,90
	3	50	1,00	33,3	101,11	161,53	5,13	60,83
	0	50	1,00	33,3	83,85	190,58	0,48	69,69
Case: B	3	40	1,00	33,3	107,25	142,72	6,77	54,16
	3	50	1,00	33,3	101,11	161,53	5,13	60,83
	3	60	1,00	33,3	90,24	180,34	−1,25	(67,50)
Case: C	3	50	1,50	33,3	107,68	148,33	13,36	27,43
	3	50	1,00	33,3	101,11	161,53	5,13	60,83
	3	50	0,50	33,3	94,91	164,49	−2,60	(67,36)
Case D:	3	50	1,00	33,3	101,11	161,53	5,13	60,83
	3	50	1,00	25,0	97,29	173,25	4,10	65,00
	3	50	1,00	15,0	92,68	187,37	2,87	70,01

NOTE: (1) The changes in tax rate apply only to the taxable income in excess of $35 000.
(2) The changes in depreciation allowances were introduced through multiplication by certain factors of the original allowance which was calculated based upon the existing legislation.
(3) The tax revenues include the revenues received by both Federal and Provincial Governments.

A rate of 15 per cent was assumed as the minimum acceptable rate of return for a private company; this rate was used to discount the cash flows of the company in the present value computation. This computation serves especially to find the tax rate at which the present value of the cash flow becomes negative, which means that the deposit would not be developed, so that the tax revenue in parenthesis in Table I is *not* received.

To calculate the present value of tax receipts, these receipts were discounted at seven per cent (as a characteristic public interest rate) to the beginning of exploration expenditures. The difference in discount rates makes the present value of the tax receipts appear large relative to that of the cash flows, and these two columns cannot be compared properly.

TABLE II

SPECIFICATIONS OF SIMULATED DEPOSITS OF TABLE I

	Deposit I	Deposit II
Ore reserves (million tons)	63	300
Ore Grade: % of copper (or equivalent $/ton	2,94 29,40	0,615 6,15
Deposit's gross place value (million $)	1 864	1 845
Exploration expenditures (million $)	4,74	4,74
Mining method	Open pit	Open Pit
Production rate (million tons/year)	2,8	7,5
Mining life (years)	23,0	40,0
Overall recovery factor (%)	90	90
Costs: Capital and development (million $)	27,1	64,0
Replacement costs (million $)	1,35	3,20
Operating and processing ($/ton of ore)	3,266	2,000
Transportation + other costs ($/ton of ore)	2,646	0,554

This still leaves us with the questions of when unknown deposits above the break-even line are likely to be discovered, and when their exploitation might start. Here we have only past experiences on which to rely, so that estimates have to be made on that basis. We have remarked earlier that the profitability of all deposits is increased by a tax cut. This is a stimulus to exploration and may speed up the rate of discovery. So, as we simulate cash flows at various tax rates, we should make some allowance for corresponsing changes in the timing of these cash flows. Persons who have had considerable experience in the field of exploration are likely to be the best source for usable estimates in this regard.

Simulations such as this must be conducted for *all* significant deposits contained in the mineral endowment, to find out what the aggregate response to tax changes would be, or at least what the *direction* of such a response would ultimately be in reaction to a particular change. Such information is crucial in the process of optimizing the public gains from the exploitation of a nation's mineral resources.

CONCLUSIONS

What we have discussed here is an outline of a procedural framework for a quantitative assessment of public gains from mineral exploitation. Clearly, one could not begin to try to calculate simulations on such a broad problem without the help of the computer.

It is our hope that we have succeeded in demonstrating that, to make headway in solving such a complex problem, it is necessary to make some drastic simplifying assumptions. We have left ample room for refinements. For instance, the incorporation of price and cost trends would improve greatly the realism of the study.

Yet, we would always have to stop very far short of perfection to avoid staggering complexities. Welfare-economic subjects are intrinsically difficult to tackle piecemeal, as a proper study of them must of necessity be in a systems context. But, as long as we resist being mesmerized by the sheer power of computers to manipulate numbers and as long as we are careful to keep track of all the assumptions that limit the significance of these manipulations, computers may undoubtedly help us in deriving larger public gains from our minerals.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the contribution of Mr C. G. Delbridge to the initial stages of this paper.