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Issues in Evaluating Tax and Payment Arrangements for Publicly Owned Minerals

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No single revenue instrument can be assumed to be superior for mineral-dependent developing countries. And more than one instrument may be needed to meet a government's multiple objectives.

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This paper — a product of the Public Economics Division, Country Economics Department — is part of a larger effort in PRE to identify mineral payment/tax systems in developing countries that are simple, fair, and efficient. Copies are available free from the World Bank, 1818 H Street NW, Washington DC 20433. Please contact Ann Bhalla, room N10-059, extension 37699 (50 pages with figures and tables, plus 19 pages of appendices).

Many developing countries depend heavily on mineral extraction to generate fiscal revenue and earn foreign exchange. Are these countries collecting enough in return for depleting their reserves? Are they carrying too much of the risk? Conrad, Shalizi, and Syme describe work in progress to develop a practical framework for analyzing these questions.

In the first part of the paper they review the central issues that must be addressed in designing mineral tax and payment schemes. They note the need to determine both the opportunity cost of mineral extraction (including externalities vis-a-vis other sectors of the economy) and the costs borne by the country through risk-sharing arrangements.

Observing that at present there is no practical analytical framework to analyze tradeoffs or determine the rate structure for different revenue generating instruments, they introduce a simple cash-flow model in the second part of the paper. With this model they illustrate how different instruments affect risk-sharing between the government and the producer. Applying criteria for ranking revenue instruments to three typical instruments — royalties, income taxes, and resource rent taxes — they conclude that although profit- and rent-based taxes are gaining in popularity over production-based taxes, no single instrument can be presumed to be superior for mineral-dependent developing countries. Each country has different endowments and faces different risks. These factors must be taken into account when selecting instruments and determining rates. In some cases production-based payments, such as royalties, may be justified and should not be systematically deemphasized as they are now.

Using simple models of the type described in the paper will enable governments to engage in reasonably sophisticated risk analysis at a relatively low cost when designing tax and payment arrangements. Further work is required to develop a practical framework which models additional tradeoffs.

Issues in Evaluating Tax and Payment Arrangements for Publicly Owned Minerals

by
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Summary

Many developing countries are still heavily dependent on mineral extraction to generate fiscal revenue and to earn foreign exchange. When minerals form a significant proportion of the country's asset base it is particularly important to have a framework to evaluate the adequacy of compensation schemes. Are these countries collecting enough in return for depleting their reserves? Are these countries carrying too much of the risk? This paper describes work in progress in developing such a framework.

In many mineral dependent countries, the government holds the mineral rights and enters into compensation agreements with public or private firms that will extract the resources. In practice, the distinction between factor payments and taxes is increasingly confused, in part because governments have a dual role as both mineral owner and tax collector. This distinction is more than a semantic one since factor payment policies are judged according to a different set of economic criteria than are tax policies. From this perspective, the current emphasis on modifying mineral tax/payment arrangements to maximize rent-capture, without adequate evaluation of the opportunity costs associated with the arrangements, may be misplaced.

Given the high degree of risk and uncertainty associated with mineral development, determining tax/payment arrangements is further complicated by the need to develop risk-sharing schemes between the government (as owner) and the resource extractors, and the need to identify externalities affecting other sectors in the economy that might justify additional modification of the tax/payment arrangements. The first part of

the paper reviews these issues briefly and concludes that when objectives are not perfectly correlated it is preferable to use multiple instruments and to match each instrument to an objective.

Despite substantial advances in the theoretical literature, there is at present no practical analytical framework with which to analyze tradeoffs or to determine the rate structure for the different instruments. The second part of the paper reports on preliminary results from a simple cash-flow model designed to illustrate one aspect of the mineral contract: how different revenue generating instruments affect risk-sharing between two parties--the resource owner and the resource extractor. In models of developed economies if the government is owner of the mineral resource it is assumed to be risk neutral since it is better able than a resource extracting firm to diversify its portfolio and hedge against risks associated with resource extraction. However, mineral dependent developing countries with limited access to international capital markets, may not be able to hedge adequately against financial risks arising from variations in commodity prices, exchange rates, interest rates, etc. Even if financial risks can be accommodated, there are non-financial risks associated with mineral development, such as reserve or operating risks, which can expose the public revenue structure of developing countries to shocks that necessitate difficult adjustments. Stabilization funds can buffer some unevenness in revenue flows but are not intended to address risks arising from project failure.

The purpose of the initial simulations is twofold. First, to demonstrate that even with a very simple model it is possible to illustrate how different instruments affect risk-sharing between the producer and the government; and second, to develop a practical evaluation tool that can be used in developing countries with limited data. All computations are feasible on a personal computer using a spreadsheet with a risk simulator. Government analysts applying this type of model to their country's unique circumstances will be able to understand better the nature of revenue variability under different contract regimes.

Three typical instruments found in mineral contracts are used in the initial analysis: the ad valorem royalty; an income tax of the "free equity" type; and a resource rent tax (RRT). The ad valorem royalty is a charge per unit of output measured as a percentage of the nominal price. The type of income tax used in the analysis is one in which there is less than perfect accrual accounting. It is similar in effect to a production-sharing arrangement with allowance for depreciation. That is, the mineral owner receives a fixed proportion of current book profits for each period in which profits less accumulated losses carried forward are positive. The owner receives zero if losses exceed profits. Losses are carried forward without interest. The RRT scheme carries losses forward with interest when the net assessable receipts are negative. The RRT scheme provides the resource owner with positive revenues only in periods where the accumulated net assessable receipts are positive.

The instruments are analyzed one at a time to illustrate their effect on the risks incurred by the contracting parties. A highly stylized mining project cash flow is generated by the model using stochastic prices and costs with covariance between the two. The model then calculates the expected value and variance for each instrument's flows to the government and producer using a risk simulator. To simplify the initial analysis, it is assumed that the geological composition of the deposit and investment costs are known with certainty, and that the extraction profile is determined exogenously (these restrictions will be relaxed in future research).

When one party to a contract is risk-averse and the other risk neutral pareto efficiency requires that the risk be borne by the risk neutral party. The applied literature has focussed on the ranking of instruments from the perspective of a risk-averse firm and a risk neutral government. The simple model used in this paper is able to simulate these results well. The model can therefore be applied with some confidence to the ranking of instruments from the perspective of a risk averse resource owning government. The results show that the ranking of the instruments by government can be opposite that of the firm's. This is an important issue which has not been widely addressed in the literature. For example, in selecting an instrument to address risk and uncertainty it is not sufficient to look only at the overall variability in a project's cash flow. It is also important to determine the probability that the net present value (NPV) of the cash flow is positive. For instance, under a RRT, the government receives revenues only in cases where the NPV of the project is positive. Thus, if the probability is 60 percent that the NPV of the project will be positive, the government stands a 40 percent chance of never receiving any revenue. The Government will be forced then to incur adjustment costs even though it depletes the mineral asset. By contrast, both the royalty and the income tax will lower the risk to the government (the former more than the latter) since they generate a positive NPV (revenue flow) to the government in every period that extraction is positive, whether or not the NPV of the project is positive. This benefit to the government accrues at a cost to the firm as it lowers the probability that the NPV of the producer's after-tax cash flow will be positive. To correctly evaluate the risk element associated with each instrument, however, it is necessary to compare instruments holding the mean NPV shares of the contracting parties constant. This requirement provides a convenient and practical benchmark for determining rates for the different instruments. That is, if the government negotiates a 40 percent share of a project's expected NPV, then, given the parameters of the model, it must set the royalty rate at 1 percent or the RRT rate at 13 percent when there is an approximately 40 percent chance that the project will fail, and at 3 percent or 32 percent respectively if the probability of failure is much less at approximately 25 percent. The lower the probability of failure, the higher the mean NPV and the higher the rate required to capture 40 percent of it.

When the probability of a positive NPV for the project is less than 100 percent, the probability distributions are also no longer symmetric about the mean. As a result the variance is not an adequate measure of risk. In such situations, particularly if the parties are risk-averse and the various instruments treat positive and negative project outcomes differently, it is better to use second-order stochastic dominance as a general measure to rank risk-sharing features of revenue instruments in lieu of mean-variance analysis.

Applying these techniques to the simple model enables one to demonstrate numerically a familiar result from the risk-sharing literature; namely, if both parties are risk averse, they will not necessarily have the same ranking of schemes, holding the mean returns constant. Therefore, in general, it will be necessary for contracting parties to trade mean expected values for risk. This implies that no single instrument (or set of contract terms) can be, *a priori*, advocated as superior for mineral dependent developing countries. Each country has different endowments (portfolio of initial assets) and faces different risks. These factors must be taken into account when selecting instruments and determining rates. In some cases royalties may be justified and should not be systematically deemphasized as they are now. The current tendency to focus on mean values in mineral project evaluation could also be misleading since the probability is zero that the mean value will occur.

The advantage of the practical framework being developed is that it will eventually enable governments to engage in this type of risk analysis at a relatively low cost when designing tax/payment arrangements. The results reported in this paper are illustrative and preliminary, but they point in the direction where future work is necessary such as developing additional tradeoffs, empirically estimating parameters, and testing the simple framework in applied situations.

INTRODUCTION

1. Many developing countries are still heavily dependent on mineral extraction to generate fiscal revenue and to earn foreign exchange. In over thirty developing countries, mineral exports account for 25 to 75 percent of total exports. Unlike other export oriented sectors, however, mineral sectors tend to be enclaves with few inter-industry linkages. Therefore, for mineral wealth to become a major endowment for financing development (in other words, to facilitate growth and diversification of a country's asset base), it is necessary not only to extract it[1] but also to ensure a positive net fiscal impact over and above that required to replace the asset.

2. An important feature of mineral sectors is the presence of "rent", in fact a variety of rents -- natural resource rents, Ricardian rents, monopoly rents, windfall rents, and so on.[2] This opens up options for tax/payment arrangements not often available to non-mining economies. It is not surprising, therefore, that, on average, mining economies have public revenue[3] to GDP ratios approximately twenty five percent higher than non-mining economies.[4] On the other hand, there are also constraints on

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1/ Mineral wealth, unlike many other types of economic assets, can generate income (liquidity) only if extracted. Since extraction is irreversible (depletion), it is equivalent to selling the asset.

2/ Definitions of these terms and a selected set of others used in the paper are provided in Appendix 4.

3/ Public revenue consists of tax revenue and non-tax revenue (such as fees, royalties and other payments).

4/ A considerable number of these mineral exporting countries collect a third to two thirds of their revenue from the mineral sector.

how much revenue they can extract from the mining sector. If a country's mining taxes are too high relative to competing countries, investment may choose to shift to the relatively lower tax countries. In practice there is a substantial variation in the ratio of mineral revenue to mineral value added between countries (for example, 75 percent in Botswana versus 25 percent in Papua New Guinea). These differences are significant. They might be explained by differences in the composition of the mineral base,[5] by phases in the life cycle of mineral extraction,[6] or by risk sharing arrangements, among other possibilities. However, no framework based on practical criteria has yet been developed that can determine whether the revenue instruments are collecting too much or too little from the mineral sector or whether the revenue instruments in use generate signals that are consistent with the overall development of the sector, as well as, the rest of the economy.

3. When minerals form a significant proportion of a developing country's asset base, it is particularly important to have a framework to evaluate the adequacy of compensation schemes. Are these countries collecting enough in return for the depletion of their reserves? Are these countries carrying too much of the risk? This paper describes the work in progress in developing such a framework.

4. The first part of the paper briefly reviews the issues that need to be included in an analytical framework before it can be used to evaluate different tax/payment instruments. The second part of the paper reports on

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5/ Some minerals have a higher rent content than others (for example, diamond vs copper).

6/ At earlier phases of development, net revenue is often low as the initial outlay in capital intensive investments is recouped through "expensing" or accelerated depreciation.

the development of a module to examine the risk sharing features of selected revenue instruments.[7] The paper concludes with a summary and a set of appendices.

PART I

EVALUATING TAX/PAYMENT INSTRUMENTS IN THE MINERAL SECTOR: SELECTED ISSUES [8]

5. The literature on mineral economics is vast and a number of approaches have been developed to address different problems. Each problem is defined narrowly in order to make it tractable. However, tax/payment instruments are ranked differently depending on the problem addressed. For example, cash flow taxes emerge as eminently suitable for collecting economic rent and for sharing risk when the contracting parties are risk neutral but not if they are risk averse. Production or profit sharing contracts are good for generating revenue but not for economizing on costs. Each result depends on assuming away some of the other issues which, however, cannot be ignored in practice.

6. In many mineral dependent countries, the government holds the mineral rights and enters into compensation agreements with public or private firms that will extract the resources. As a result, in practice, the distinction between factor payments and taxes is increasingly confused, in part because a government has a dual role as both the seller of

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7/ This does not imply that risk sharing can necessarily be separated from the other elements of a contract. Often, all contract terms are not strongly separable. For instance, the level of risk borne by all parties might be a function of the total quantity extracted and the time period in which the particular quantities are extracted. However, an examination of risk sharing in isolation enables a comparison of particular contract terms relative to an exogenous distribution of risks and returns.

8/ This section is based on Part II of a research proposal to develop a framework to evaluate mineral payments/taxation schemes (Shalizi and Conrad, 1989).

resources and the collector of taxes. This distinction is more than a semantic one as factor payment policies are judged according to a different set of economic criteria than are tax policies. From this perspective, the current emphasis on modifying mineral tax/payment arrangements to maximize rent capture, without adequate evaluation of the opportunity costs associated with the arrangements, may be misplaced. Given the high degree of risk and uncertainty associated with mineral development, determining tax/payment arrangements is further complicated by the need to develop risk sharing schemes between the government (as owner) and the resource extractors, and the need to identify externalities affecting other sectors in the economy that might justify additional modification of the tax/payment arrangements.

7. As mineral stocks represent part of an economy's capital endowment at any point in time, it is important that the government compute the public sector selling price of its reserves and evaluate the variability of its returns through time. This price will be based on the opportunity cost of extraction and can include up to three interrelated elements (Conrad 1989): (i) the scarcity value of the <u>finite</u> reserves; (ii) pure risk sharing; and (iii) the general equilibrium opportunity cost of extraction. The government, acting as tax collector, can then assess taxes.

8. Thus, of the many issues addressed in the literature, four have been identified as being particularly important in designing a practical framework to evaluate tax/payment instruments: (1) how to design natural resource rent collection schemes; (2) how to design risk sharing arrangements; (3) how to incorporate general equilibrium effects/adjustment costs of the transition to and from mineral dependency; and (4) how to design tax policy in the mineral sector. These issues are distinct, and

lack of attention to the distinctions can lead to inappropriate policies in developing economies, such as overstating the supposed inefficiency of extraction-related payments. We now discuss each issue and place them in a broader framework.

A. What is Natural Resource Rent?

9. A central feature of the literature on mineral economics has been the development of methods for the determination of an efficient intertemporal extraction profile. The time path of extraction is treated as an endogenous variable.[9] The general result of this literature is that extraction should proceed in each time period until the discounted opportunity cost of extraction is equal between any two time periods. This result defines an allocative supply price based on the rent accruing to a finite, depleting stock. In Hotelling's (1931) original formulation, this implied that the time path of the supply price of the resource (opportunity cost of extracting the resource) should rise at the rate of interest.

10. Hotelling's model presumed physical exhaustion of the resource (a rare occurrence in reality as increasing marginal costs of extraction usually preclude physical exhaustion) and constant returns to scale (zero extraction costs are a special case of constant returns to scale). With the subsequent incorporation of stock effects[10] and increasing marginal costs of extraction, physical resource exhaustion is no longer required to generate positive natural resource rents in theoretical models. Economic

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9/ This differs from some practical approaches where, in order to facilitate and simplify determination of user costs/prices for natural resources, it is assumed that the extraction profile is exogenous (see Schramm 1986).

10/ Such as changes in the cumulative stock of resources due to exploration efforts or depreciation.

depletion thus preempts physical depletion. As a result, the Hotelling rule has evolved into a more general rule that states that the resource payment (in other words, user cost or natural resource rent) should equal the opportunity cost of capital. While the shadow price of the resource (the "royalty" as defined by Hotelling) is constant in real terms, there is no longer a requirement that its time path should rise at the rate of interest.[11]

11. "Natural resource rent" (or the price of the unprocessed mineral below ground) is the difference between the market price of the unprocessed mineral above ground and the marginal cost of extracting it. However, the more general formulation that the opportunity cost of mineral resources is the same as the opportunity cost of capital has led some authors in the 1970s to equate "natural resource rent" with "pure economic rent". Such treatment de facto implies that "natural resource rent" serves no allocative function (as it did in the Hotelling formulation). As a result, this rent can be captured by charges that are not related to extraction with no efficiency cost. This interpretation has led to proposals to maximize rent collection, favoring income related charges over royalties, culminating in instruments such as the Garnaut and Clunies-Ross Resource Rent Tax (RRT).[12]

12. It is inappropriate to equate "natural resource rent" with pure economic rent. Natural resource rent is a price and serves as an important

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11/ See Fisher (1979).

12/ An RRT is essentially a cash flow tax except that, in the case of losses, an RRT does not result in a rebate to the firm, as would happen in a cash flow tax, but allows losses to be carried forward at the rate of interest. As noted in Lund (1985), the RRT was originally proposed as a complete mineral payment/tax system. In practice, it has also been used in conjunction with other instruments.

market signal to owner/producers indicating how to allocate the resource intertemporally so that they can be indifferent about whether to extract now or later. As a first approximation, the price represents the "scarcity rent" arising from supply restrictions on a finite resource of uniform quality and has nothing to do with Ricardian differential rents[13] or other forms of economic rent based on monopoly, windfalls or other factors. As a price of an input, it is an element of the cost of production and not an intramarginal rent. Without knowing the shadow price of extraction, no party, owner or producer can determine an efficient extraction profile. It might be possible to reduce this stream of payments to a lump-sum contemporaneous payment, like the valuation of corporate stock. However, it must be emphasized that the source of this equality stems from the computation of the shadow price of reserves on a per unit basis. That is, only after determining the natural resource rent or price can one determine the present value of any deposit.

13. A related strand of this literature has focused on auctions as the best means for the owner of the resource to capture the present value of the resource due to him as the holder of the property rights. This approach is applicable in principle both to private and public owners of the resource. (It is used, for example, by the U.S. in leasing offshore tracts). Note that in practice, however, if there is inadequate competition in the auction bidding process, the government has to determine a reservation price for the resource.[14] This can be done using a portfolio

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13/ Op cit.

14/ Recently bonus bids or auctions have also been contested on theoretical grounds when sovereign risk and moral hazard problems are incorporated into the analysis (Nellor and Robinson, 1984)--problems more prevalent in developing countries. If subsequent governments are not bound by auction results, then a stream of payments (in the form of royalties) may be superior to collecting the net present value at one time in an auction.

or factor of production approach to analyze the efficient use of the natural resource.

14. In a portfolio approach, natural resources are one component of an economy's capital stock. Without a competitive return, no party, including the government, would be willing to own and husband this stock. Thus, in a portfolio type model, "natural resource rent" serves as the return from investing in ownership of stocks in the ground relative to the return from investing in other types of capital. In effect, this is what is implied by the original Hotelling Rule. Minerals in the ground must be extracted to generate cash through time. This time path of cash withdrawals is calibrated so that the owner of the stock captures a return just sufficient to hold reserves for future use. Again, "natural resource rent" serves an important allocative function. This allocative function is implicit in the demonstration by Feldstein (1977) in which he changed the allocation of capital within and among sectors to prove that attempts to "tax" this rent can be inefficient.

15. In a factor of production approach, "natural resource rent" is the return to the owner from a factor of production and thus constitutes an efficiency based payment (Conrad 1989). That is, the owner of mineral rights is the owner of a productive input, not output. To produce mineral outputs, labor, capital and mineral inputs are required. The cost of reproducible capital and labor are included in the expenses that are incurred in the production of mineral outputs. The cost of mineral inputs should also be included. This point has been a source of some confusion as many theoretical models used in the economic analysis of mineral development do not make a distinction between the resource owner and the producer. This distinction is conceptually important because "natural

resource rent" is the payment made by the producer to the owner for the purchase of the resource input (even if they are legally the same entity in practice). Furthermore, this efficiency payment is defined on a per unit basis, just like the wage rate for labor or the rental value of capital. Thus, like the supplier of any factor, the resource owner must determine how to sell his inventory intertemporally and what opportunity costs exist to establish the relevant reservation wage for this factor of production.

16. In summary, what these different approaches to shadow pricing the resource have in common is that in all cases the extraction related payments serve an important allocative function both for the resource owner and the economy as a whole. Such payments (suitably calibrated) are efficient and do not distort extraction decisions. The payment for the sale of a ton of minerals in the ground should not be conceptually any different from the payment for the sale of any other input.

17. Because of this, recent attempts to equate natural resource rent with pure economic rent have been problematic, leading to poor policy analysis. In particular, the current emphasis on income related charges has concentrated the debate on the maximum amount a country can receive for its minerals, with little regard to intertemporal and intersectoral opportunity costs or to the risks to the country associated with mineral extraction. A return to a more appropriate factor payment policy might force decisionmakers to examine the costs as well as the benefits of mineral developments. More importantly, regardless of the ultimate method employed by a government to collect the value of its mineral wealth, renewed emphasis on the supply price of the resource will serve as a benchmark for evaluating alternative policies.

B. Risk Sharing

18. Given the inherent uncertainty regarding the size of mineral stocks before exploration and of the revenue and cost streams associated with mineral development after exploration, risk sharing arrangements are important in the rational development of mineral tax payments/schemes. This is particularly important where markets for contingent claims across different states of nature are neither complete nor perfect. One of the major innovations in recent mineral contracts, in the petroleum sector in particular, is the development of risk sharing contracts or contracts with significant risk sharing aspects. In general, these innovations require the mineral producing firm to surrender part of the "net profits" from the positive cash flows that are generated after exploration and development costs are recouped. Theoretical support for such schemes was first established in an important paper by Leland (1978). Leland demonstrated that an extraction related charge (for example, a royalty) is an inefficient method for risk sharing.

19. Subsequent analysis of risk sharing between two risk neutral parties has shown that in the case of mean preserving spreads (in other words, for equal expected levies), profit sharing is a more effective method for spreading risk, followed by royalties and then fixed fees (such as bonus bids). However, in the case of a small, risk averse firm and a large, risk neutral (diversified) government (such as the U.S. or Canada), royalties could be superior to profit sharing when there is positive covariance between uncertain revenues and costs (Sebenius and Stan 1982). In the case of developing countries, the issues are slightly different as the contract is likely to be between a large multinational firm and a small, poorly diversified developing country (Garnaut and Clunies Ross

1975). The ranking of instruments, however, is likely to depend again on the covariance between uncertain revenues and costs.

20. Mineral reserves have uncertain present values, as does labor in a dynamic labor market. This implies that the Hotelling formulation, while instructive, may not be appropriate in all situations where physical capital, labor and reserves are owned by different parties and where there are risks that must be borne by some (or all) parties. In such cases, two prices might be computed, one for the real wage for minerals and one for the price of risk bearing. Mineral owners and contractors, have developed numerous methods whereby both risk and return can be combined into a single payment, again as in contracts between employers and employees.

21. The fixed wage rate is itself one type of risk sharing device with the particular property that the firm will continue to employ that factor as long as it is profitable to do so. Thus, the input seller bears the risk that his fixed price is too high relative to the value of his marginal product as dictated by either current (or future) market conditions. In minerals, such unemployment of factors is sometimes called "high grading". However, the use of a fixed wage rate is not irrational for the mineral owner as long as the opportunity cost of selling additional inputs is not zero. Rationality in this context includes weighing the potential gains against the risk of unemployment and will depend on the risk preferences of the input seller.

22. In general, not only must risk sharing be evaluated in the proper context, but specific instruments might have to be used to accommodate risk relative to other costs associated with mineral ownership and development. That is, it may not always be efficient to design a single payment structure (for example, a profit sharing contract or a resource rent tax

[RRT]) both to capture the natural resource rent and to provide for risk sharing.[15] The ability of a particular economy to bear the significant risks associated with such schemes as profit sharing or the RRT will depend on the particular attributes of the economy, for example, the degree of existing diversification, the relative size of the mineral sector and the overall level of wealth. It is necessary, therefore, to price the risk. To our knowledge, there is no theoretical demonstration that in general it is efficient for small, poorly diversified developing economies to bear a disproportionate amount of risk relative to large diversified multinational firms.

23. Thus, the high amount of risk bearing currently undertaken by some countries (for example, Gambia and Nigeria) may be the inadvertent consequence of failing to differentiate between risk bearing and the collection of natural resource rent, both at the margin and in total. Willingness to bear risk is a form of insurance provided by the country to the firm, while natural resource rent is the factor payment to which the country is entitled by right of property ownership. The payments are conceptually different, and practical policy advice should be directed towards clearly distinguishing these concepts and to developing alternative instruments where necessary. These differences are important as a country that adopts an RRT, profit sharing or income related scheme exclusively could have all its natural resource endowment extracted, incur significant

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15/ For instance, the RRT proposed by Garnaut and Clunies-Ross (1983) is designed to capture rent (regardless of the nature of these rents). It handles risk to the firm by excluding from the tax base a high rate of return on investment (no distinctions are made between discount rates before and after exploration or between returns on total investment versus equity investments). However, neither the RRT nor other means of capturing supposed natural resource rent directly address the issue of risk bearing by the country or the price of this risk.

transition costs and never collect a positive payment for its ownership of the resource endowment.

C. Economy Wide Effects

24. Much of the development literature has emphasized the enclave nature of mineral developments and that the primary linkage between natural resource production and the remainder of the economy is fiscal (Nankani 1979). This is true to a certain extent, but as another strand of the literature has noted, important indirect production linkages can arise through factor markets and through changes in key macro prices such as exchange rates, interest rates and wage rates (Corden 1984). This occurs most noticeably when significant mineral deposits are discovered[16] that increase an economy's capital stock in a sector specific way. In this case, there will be a change in the economy's comparative advantage even if there are no other direct linkages with the rest of the economy. For instance, signi icant mineral discoveries can change the nature of comparative advantage from traditional exports (such as agriculture) to mineral exports. If the country is a price taker, one can expect that, as mineral development proceeds, mineral exports will rise and traditional exports will fall (holding world prices constant). This process also operates in reverse. That is, as minerals are depleted and production costs rise, the economy's comparative advantage might return to traditional exports (or to output from other sectors into which the economy has

16/ The significant scale of the discovery relative to the size of the economy is important in determining whether or not to incorporate general equilibrium effects. For genuinely marginal finds, partial equilibrium analysis is sufficient to determine the endogenous extraction profile.

diversified). Such incremental changes in comparative advantage due to mineral developments are one component of "Dutch Disease". This substitution effect is generally complemented by an income effect since a mineral discovery increases the economy's wealth. It is even possible for changes in the nature of demand (for example, a rise in demand for non-tradables) to occur when there is no change in the economy's production possibilities.

25. To the extent that such changes in comparative advantage result from well functioning markets, "Dutch Disease" is not a disease; that is, it is not an inefficient outcome. However, markets do contain friction and adjustment costs from one type of comparative advantage to another as capital and labor previously employed in one export sector (say, from traditional exports initially to mineral exports subsequently) flows to another sector. This can become a problem for the economy if the period of mineral dependency is relatively short. It must, therefore, be incorporated in any framework determining the rate of extraction and compensation arrangements. In such cases, governments must be concerned about developing mineral extraction profiles consistent with the more general benefits of joint outputs (minerals plus other outputs) rather than simply maximizing mineral values. As mineral exhaustion causes a continuous change in the nature of comparative advantage (in other words, in the marginal rate of transformation) through time, the optimal extraction profile for the resource owner will be affected.

26. It is thus misleading to think of mineral development as truly enclave in nature. Even in cases where the major source of project finance and skilled labor is external, mineral developments may generate significant costs to the economy at the margin. This should not be a

surprise. Rather, it is simply a restatement of the fact "that there is no free lunch". An economy must adjust to changes in its comparative advantage in minerals. This implies that from a general equilibrium perspective, the government must compute the cost of increased current mineral output as the value of output foregone in other sectors. Thus, a supply curve for resource sales (a scarcity value) can be generated even in cases where the mineral is not physically exhausted. That is, the value added of increased sales from mineral inventories should be equal to the marginal value of output foregone in other sectors before the country decides to increase extraction. Thus, the supply curve of resource sales is not perfectly inelastic either within or between time periods.

27. In the presence of significant adjustment costs in the transitions to and from mineral dependence, countries with major mineral endowments might need to attribute the proceeds from sales between two categories of compensation--one for the finite nature of the mineral and the other for the cost of foregone output in other sectors. Proper attribution of these costs at the margin is important so that the country is compensated for them and so that the asset sales profile is adjusted until exogenous marginal gains equal endogenous marginal costs. If such costs are not recovered, then the benefits from mineral ownership and development may be lost.

D. Tax Policy

28. One means of capturing rents of any form is to use national taxation. However, in an economy where mineral rights are held by the state, "taxing the natural resource rents" will merely amount to the government taxing itself if the natural resource pricing policy is properly

designed. In reality, government must wear two hats--tax collector and natural resource owner. Thus, there must be a clear delineation of the role of taxes and efficiency prices to ensure consistent policy.

29. The large literature on natural resource taxation (Dasgupta, Heal, Stiglitz 1980; Conrad and Hool 1981; Slade 1982; Nellor 1984; Heaps and Helliwell 1985) has demonstrated that output related charges (such as royalties and export taxes) employed as taxes may generate significant efficiency costs. Such instruments can result in "high grading" or in the premature closure of marginal mines. However, as already noted, a charge by the owner for the sale of minerals is no more a tax than the wage charged by a worker for his labor. The allocative incentives created by different types of payments must be evaluated relative to the intention of the policy. There is no necessity to apply the "neutrality" norm of tax analysis to those extraction related charges designed to compensate government for its ownership of mineral rights.[17]

30. Many developing country governments have begun to rely more heavily on income related charges in the mineral sector. As a result, general income tax rules are superseded and modified for the mineral sector. This creates difficulties in comparing effective rates of taxation (both average and marginal) across sectors. For instance, it is difficult to measure the marginal effective tax rate unless the resource is correctly costed and deducted from the corporate tax base with adjustments for risk sharing provisions. If the opportunity costs of mineral sales are understated (through, for example, inadequate deductions for the legitimate

17/ The use of terms such as the Resource Rent Tax further confuses the issue. A scheme to capture 100 percent of the "natural resource rent" for the owner is not a tax at all as established by Hotelling. It is important for governments to set a price for mineral extraction before different taxes or other instruments are employed.

cost of mineral inputs), the true burden of taxes will be overstated. On the other hand, if provisions in the tax code to compensate for risk are treated as deductions, the tax burden will be understated. Some recent studies of developed economies (Kemp 1987; Boadway, Bruce, McKenzie, Mintz 1987) have found that current tax/payment schemes are not even efficient at collecting rent as the mineral sector is subsidized at the margin (negative marginal effective tax rates). These findings are disturbing as they suggest that, despite the high rents in the sector, the incentives in the fiscal system are biased in favor of heavier investment in minerals relative to other sectors. Little empirical work has yet been done for developing economies along these lines.

31. Mineral tax policy should definitely be separated conceptually, and possibly in practice, from natural resource pricing policy (user costs) and risk sharing arrangements. To increase intersectoral neutrality, mineral developments should be taxed in a manner similar to other sectors. Sector specific mineral features should be addressed through other instruments. Thus, general taxation instruments that cut across sectors should not be modified to become a means of collecting payment for the resource as a factor input, of sharing risks or of compensating for general equilibrium effects, thus having to do double duty. Therefore, when objectives are not perfectly correlated, it may be preferable to use multiple instruments and to match each instrument to an objective.

PART II

AN ILLUSTRATION OF RISK SHARING THROUGH DIFFERENT INSTRUMENTS

32. The second part of this paper describes preliminary results from a simple cash flow module[18] designed to illustrate one aspect of the mineral contract: how different revenue generating instruments affect risk-sharing between two parties--the resource owner and the resource extractor. One purpose of these simulations is to demonstrate the utility of simple models as practical evaluation tools. All computations are feasible on a personal computer using a spreadsheet with a risk simulator. The presentation of this part is in three sections: in Section A the instruments selected for simulation are described; in Section B, the ranking criteria and methodology; and in Section C, the results.

A. Selected Mineral Tax/Payment Arrangements

33. Three typical instruments found in mineral contracts are used in the initial analysis--the ad valorem royalty, an income tax of the "free equity" type and a resource rent tax (RRT).

18/ Despite substantial advances in the theoretical literature, there is at present no practical analytical framework with which to analyze tradeoffs or to determine the rate structure for the different instruments used to collect public revenue from the mineral sector. Work is in progress to develop such a framework. The framework will consist of a number of modules. The first module will be used to compute a price for the resource that is unadjusted for risk. This will generate an endogenous extraction profile for the resource. In the next module, the risk sharing features of the revenue instruments will be evaluated, taking the extraction profile as exogenously determined. The preliminary form of this module is described in the section above. Other modules will address general equilibrium effects and intersectoral taxation, for example. To be practical, it should be possible to operate the modules separately. To be useful, however, they will have to be mutually consistent.

(a) **Ad Valorem Royalties**

34. An ad valorem royalty is a charge per unit of output measured as a percentage of price. Unlike a per unit or "specific" rate charge, the resource owner now participates in price risk.[19] The extensive (and exclusive) use of royalties to capture the return from mineral extraction and to share risk has declined during the past 20 years in developing countries.[20] Economists have contributed to this decline by showing separately that, as a tax, ad valorem royalties can distort production decisions to result in inefficient resource use (Conrad and Hool 1981) and that fixed rate royalties may not be optimal as a first best method of risk sharing (Leland 1978). First best risk sharing is essentially the provision of optimal (mutual) insurance. The fact that a fixed percentage royalty is not optimal results from the simple fact that the insurance agent (the government in this case) does not compensate the insured in bad states of the world (negative present values).[21] Both criticisms are justified subject to a couple of caveats. First, if royalties are designed to collect the value of the resource they can function as a user cost rather than as a tax. As a reflection of the opportunity cost of mineral extraction from the resource owner's point of view, the royalty would be a charge leading to the efficient allocation of resources rather than a tax leading to the inefficient allocation of resources. Second, given monitoring costs (on both sides of the contract), administrative costs,

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19/ The value of this payment to the resource owner varies both with the volume and the price of the output. This variation is perfect in the case of a fixed percentage royalty but not in the case of a progressive rate royalty.

20/ It is still extensively used by private mineral owners in the United States.

21/ This is equivalent to purchasing fire insurance where the insured pays a nonnegative premium for fire insurance but receives no payment even when the house burns down.

asymmetric information and other market friction, it is possible that a royalty used as a factor payment is still in contention as a second best policy for risk sharing.[22]

(b) An Income Tax of the "Free Equity" Type

35. A second type of compensation scheme for mineral owners has been labeled "free equity." In this scheme, the owner receives a proportion of the stock issued from formulating the project. In other words, the mineral owner receives a fixed proportion of current book profits for each period in which profits less accumulated losses exceed profits. Exploration and development costs are immediately expensed (written off) and losses are carried forward without interest.

36. Free equity is actually a misnomer. Mineral production requires two types of capital--non-renewable minerals in the ground and reproducible physical capital. The asset base is, therefore, the summation of the value of minerals in the ground plus the value of the other types of capital. A free equity share of, say, 40 percent is thus effectively a statement about the proportion of the value of mineral assets to total capital (minerals plus physical capital). From this perspective, free equity is no more "free" than an entrepreneur with an idea for a new product who forms a corporation with owners of physical capital and receives in return a proportion of the common stock.[23]

22/ Unlike windfall profits, a royalty is paid for each and every ton of ore extracted. Thus, there is a tangible relationship between extraction and payment. A resource firm might prefer such a payment system to a windfall profit scheme, for example, if the likelihood increases with the latter scheme that the resource owner might stop selling the resource, nationalize production or seek new contract terms because the resource owner observes extraction for several years with no compensation and with only a promise of future compensation.

23/ The value of the reserves in the ground (as well as the value of the idea) may not be known with certainty. However, this does not preclude the contracting parties from agreeing on an initial ex-ante division of the total returns to capital.

37. In such an agreement, both parties expect to receive the risk adjusted return to their capital bases. If perfect income accounting were possible, one method to do this would be to repay invested capital via depreciation and depletion deductions, and to charge the respective capital balances the appropriate interest charge. In actual situations, the return to equity (both minerals and physical capital) is based on cash flow after book depreciation (and perhaps book depletion) and the opportunity cost of funds is not a charge against income. Thus, in practice, the 40 percent ownership interest in the present value does not necessarily correspond to 40 percent of the cash flow due to timing and other book accounting differences. Like the purchaser of any common stock, the mineral owner has limited downside risk with free equity. If the present value of the project is negative, the resource owner's liability is limited to the initial invested capital. This can affect the risk-sharing structure relative to contracts where equity's liability is not limited as in a general partnership.[24]

38. Common production sharing agreements are akin to free equity in terms of their risk sharing properties. Production sharing agreements generally allow an investor to recover the capital investment (in undiscounted terms) using immediate expensing, and allow losses to be carried forward without limit before the resource owner receives any share

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24/ It is well known that pure unlimited liability shares are efficient risk sharing devices. However, whether such an arrangement is optimal in a particular situation depends on the distribution of possible outcomes and the preferences of the partners. Few arrangements in pure form are found in practice and with good reason. Part of the contract structure must include the opportunity cost of the resource owner and some positive payment may also be required to compensate the resource owner for risk.

of the gross (or net) proceeds. Once the capital is recovered, the resource owner gets a specific share of the net cash flow (either in cash or in kind).

(c) **Resource Rent Tax or Excess Profit Charges**

39. Some countries have contract terms that specify that the return to mineral ownership should be an increasing function of some measure of ex-post profitability. The most famous type of charge is the Resource Rent Tax (RRT) advocated by Garnaut and Clunies-Ross (1975; 1979; 1983).[25] This charge is zero if the net present value of the project is less than or equal to zero, and is positive (at proportional or progressive rates) if the net present value is positive.[26] To a developing country that is relatively poor but rich in resources and that anticipates using mineral resources to finance development and diversification, this charge can have significant risk as it is possible for the mineral asset base to be exhausted without ever generating a single payment to the resource owner.

40. A larger array of contract arrangements are described in Appendix 1 with their risk sharing properties and structure. The use of any particular instrument (or combination of instruments) will depend upon the nature of the mineral deposit, the general structure of risk in the project and the extent of risk aversion of the parties.[27] To make better decisions, it is important for decisionmakers to be aware of the risk

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25/ Windfall charges and excess profit charges are used in Indonesia, Papua New Guinea, and some provinces in Canada.

26/ The discount rate used for the purpose of computing the present value is generally a contract term.

27/ If both parties are risk neutral, then the issue of risk sharing would be irrelevant as all decisions would be based on the expected values with no regard for the expected variation.

sharing properties of each instrument and how the instruments rank relative to some criterion of risk bearing. The next section describes a metholology that can facilitate such an analysis. It illustrates how rankings can be developed for each party.

B. **Ranking Criteria and Methodology**

41. **Ranking Criteria:** If both parties to a contract were risk neutral or if markets for contingent claims were complete and perfect, there would be no need to examine and rank the risk sharing properties of instruments. Because markets for such claims do not always exist and one or both parties to a contract may be risk-averse, it is necessary to evaluate the risk sharing properties of tax/payment instruments.

42. When one party to a contract is risk neutral and the other risk-averse, pareto efficiency requires that the risk be borne by the risk neutral party (that is, the one who is better able to carry the risk). In the analytic literature used to rank pure forms of tax and contract instruments that spread risk (Sebenius and Stan, 1982) it is assumed that the agent--the resource extracting firm--is risk-averse and the principal--the government--is risk neutral. This assumption is generally borne out in analysis of developed economies as the government is better able than a resource extracting firm to diversify its portfolio and hedge against the risks associated with resource extraction. In such cases, it is sufficient for the government to rank projects based on their expected value, that is the mean net present value. (This is relatively straightforward and is common practice in project analysis).[28] The results of the

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28/ Note that the most likely value (the mode) will be the same as the expected value (the mean) when the probability of different outcomes is normally distributed. However, when the two measures of central tendency deviate, it is the mean that is the more appropriate statistic for risk analysis.

analytic literature show charges on income (such as an income tax) to be superior to charges on output (such as a royalty) which are in turn superior to fixed charges (bonus bids). A sufficient condition to obtain these risk sharing rankings is to have statistical independence between prices and costs as noted by Thon and Thorlund-Petersen (1987). If prices and costs are statistically dependent, however, the ranking may or may not hold. Thus when there is covariance between prices and costs, simulation techniques are necessary to rank instruments.

43. When there is uncertainty and returns are normally distributed, a conventional way of describing the risk associated with an investment is to specify the variance of the distribution of returns in addition to specifying the mean. Using this mean variance analysis, instruments can be ranked by a pair of values--mean and variance. The instrument with the highest mean and lowest variance is to be preferred. When an instrument does not dominate both statistics, it is still possible to rank those with one statistic in common. That is, for a given risk (holding the variance constant) one can select the instrument with the highest return (highest mean value), or for a given return (holding the mean value constant) one can select the instrument with the lowest risk (lowest variance). The ranking can be made independent of the unit of measurement by using a standardized measure of the project's variability known as the coefficient of variation (standard deviation divided by the mean). Ranking by a pair of values (mean and variance) becomes problematic when one instrument has both a higher mean (desirable) and a higher variance (undesirable) than another instrument. In such cases, the criterion of first order stochastic dominance can be used to rank instruments.[29] With this criterion, an instrument X is ranked superior to an instrument Y if X's cumulative

29/ Actually it is not the instrument itself but the value of the asset associated with the use of the instrument that is ranked.

probability distribution always lies to the right of Y's. This is equivalent to saying that for any arbitarily chosen threshold w*, there is a greater probability that the return W_i is smaller than w* for instrument Y than for instrument X.

44. These criteria cannot be used, however, if the contracting parties are risk averse or the probability distribution of their returns is not normal. Mineral dependent developing countries, with limited access to international capital markets, may not be able to hedge adequately against financial risks arising from variations in such factors as commodity prices, exchange rates and interest rates. Even if financial risks can be accommodated, there are non-financial risks associated with mineral development, such as reserve or operating risks, that can expose the public revenue structure of developing countries to shocks that necessitate difficult adjustments. Stabilization funds can buffer some unevenness in revenue flows but are not intended to address risks arising from project failure. It is, therefore, more appropriate to treat mineral dependent developing countries as risk averse. This can have a bearing on the choice of instrument and the setting of rates.

45. It is important to note that in evaluating the risk sharing characteristics of an instrument, it is not sufficient to look only at the overall variability in a project's cash flow. It is also necessary to determine the probability that the net present value (NPV) of the cash flow is positive. For instance, under an RRT, the government receives revenues only in cases where the NPV of the project is positive. Thus, if the probability is 60 percent that the NPV of the project will be positive, the government stands a 40 percent chance of never receiving any revenue. The government will then be forced to incur adjustment costs even though it depletes the mineral asset. By contrast, both the royalty and the income

tax will lower the risk to the government (the former more than the latter) because they generate a positive NPV (revenue flow) to the government in every period in which extraction is positive, whether or not the NPV of the project is positive. This benefit to the government accrues at a cost to the firm as it lowers the probability that the NPV of the producer's after tax cash flow will be positive. When the probability of a positive NPV for the project is less than 100 percent and prices and costs are not normally distributed, the probability distributions are no longer symmetric about the mean. As a result, the variance is not an adequate measure of risk. Thus, mean variance analysis does not correctly rank risk sharing instruments when the agents have concave utility functions (in other words, are risk averse) or when the frequency distribution of outcomes for each party is not symmetric (or both).

46. Therefore, to evaluate the risk element associated with each instrument correctly, it is necessary to compare instruments holding the mean NPV shares of the contracting parties constant (mean preserving spread). This implies that the risk sharing issue becomes one in which the parties select among alternative distributions of outcomes with a constant mean return. Thus, in situations where the contracting parties are risk averse and the various instruments treat positive and negative project outcomes differently, it is better to use second order stochastic dominance as a more general measure[30] to rank risk sharing features of revenue instruments.

47. One distribution, f(x), of uncertain outcomes is said to dominate another distribution, g(y), if:

30/ In which it is not necessary to specify the utility function of the agents.

$$(1) \qquad \int_{-\infty}^{Wi} [G_y (W) - F_x (W)] \, dW \geq 0 \text{ for all } W$$

and

$$G_y (W_i) \neq F_x (W_i) \text{ for some } W_i$$

where: G_y = cumulative density for Y

F_x = cumulative density for X

W_i = wealth in state i.

Equation (1) says that, in order for instrument X to be preferable to instrument Y, the accumulated area under the cumulative probability distribution of Y must be greater than the accumulated area for X, below any given level of wealth (w_i). In other words, instrument X has a lower variability than instrument Y if the cumulative difference between G_y and F_x is non-negative for any level of wealth w_i.[31]

48. The importance of second order stochastic dominance is that all risk-averse investors[32] would consistently prefer one distribution of outcomes over another if the criteria in equation (1) are satisfied. It should be noted that <u>this criterion is not an efficiency rule but a ranking rule</u> for alternative distributions of uncertain outcomes. It is not the purpose of this paper to explore optimality issues at this stage. Rather, the intention is to illustrate that governments (and firms) must evaluate the entire distribution of outcomes and not simply the mean.

49. **Methodology:** Even though rankings have been determined analytically in the literature in an expected utility or mean variance

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31/ See Copeland and Weston (1980) for a non-technical introduction of this concept.

32/ Investors with concave utility functions in wealth.

framework as noted earlier, they have been unable to provide policymakers with the practical tools needed to form tax policy. When models are too complex to give analytic solutions, simulation provides a practical alternative.[33] By describing individual events in the system rather than its overall behavior, the simulation model shows how risks are shared under alternative contract terms. The cash flow model used can include standard investment items such as exploration and development costs as well as quantities extracted, price and operating costs. Changes in the time path of real prices as well as in inflation should be incorporated as parameters that can be changed at the user's discretion. To simplify the initial analysis, it is assumed that the geological composition of the deposit and investment costs are known with certainty,[34] that real relative prices are constant,[35] that price and cost uncertainty do not increase with time, and that there is no inflation. For purposes of clarity, the instruments are analyzed one at a time to avoid any interaction between instruments that can complicate the analysis. In the reported simulations, an instrument that is preferred by one of the parties for a given set of project

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33/ Deacon (1990) uses a simulation model to examine the welfare loss of different taxes in the petroleum industry in the U.S.

34/ Allowing for uncertainty in development costs flattens the distribution of returns (NPV).

35/ When the price follows a Brownian motion (increasing uncertainty over time), the variability of returns (NPV) to both parties increases, but the rankings remain unchanged. It is important to differentiate between the time path of nominal and real cost. It is assumed in many projects that real relative prices have no time trend (for example, the real price of copper over the past 120 years [Gordon et al. 1987]) and thus only nominal adjustments are made. This assumption is neither general nor satisfactory for many inputs and outputs, labor in particular. A constant real wage is tantamount to assuming that real GDP increases only at the rate of population growth. While a convenient assumption for steady state theoretical analysis, a constant real wage is not consistent with the historical development of most economies.

assumptions is also preferred under alternative project assumptions. This is not a general result, but may nevertheless seem somewhat surprising. It is partly explained by the fact that the parties are assumed to prefer lower variance in expected net present value rather than lower variance in the profile of a project's cash flow over the years.[36]

50. As noted earlier, the extraction profile is determined exogenously. The reason for this is that, in order to analyze risk sharing, it is necessary to hold constant the total risk to be shared. This in turn requires total extraction to be held constant as changes in the total volume of output can change both the marginal and total risk of the project.[37]

51. A stylized mining project cash flow is generated by the model. Large capital costs are assumed to have been incurred and known at the time of analysis. Operating costs, however, are uncertain. Probability distributions are, therefore, specified for both prices and costs. For purposes of the current illustration, a joint normal distribution is selected with no autocorrelation through time but with positive covariance.[38] The latter assumption is consistent with basic microeconomic theory (an

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36/ It is with respect to variance of cash flow for a given project that the instruments differ most in terms of risk sharing capability. In a model where the variance of cash flow appears, it is more likely that a change in raking between instruments would occur when project assumptions change. This obviously warrants some theoretical clarification between further simulations are performed.

37/ It is easy to demonstrate that the total variance of a project increases with total extraction if production exhibits decreasing returns to scale.

38/ In the general model, autocorrelation (in real terms) and covariance (either positive or negative) can be introduced.

increase in the price of oil will generally be expected to lead to an increase in the price of oil drilling equipment.[39]

52. The total cash flow is then divided between the two parties to the contract using a risk simulator. In this study, it is assumed that the government seeks to obtain 40 percent of the expected net present value of the project. This value may be interpreted as the amount in present value terms that a risk neutral resource owner might be paid today for the mineral rights. Thus, 40 percent of the present value is essentially the minimum opportunity cost of a risk neutral resource owner.

53. The rate of each instrument is then calibrated so that the government receives the specified share of the expected value. The royalty rate is determined by dividing the present value of the government's share by the expected present value of total receipts. The rates for the RRT must be determined iteratively in the context of the simulations. These contract terms create autocorrelation in the distribution of cash flows that arises from the provisions that losses can be carried forward and that no payments are made in situations where the present value is zero. For these reasons, it is necessary to make an initial estimate of the rate and to revise the rate through iterations until the contracting parties receive their respective shares.[40]

C. Results

54. Two simulations are presented to provide a preliminary illustration of the methodology and ranking system. The only difference

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39/ The covariance is assumed to be contemporaneous for present purposes even though it may occur with a lag in actual situations. When zero covariance is assumed, the total variability to the project decreases, but in this case the relative rankings between agents remains the same.

40/ A brief description of the model and simulation procedure is contained in Appendices 2 and 3.

between the simulations is the probability of negative present values. The probability of a negative net present value is 26 percent for Case #1 and 42 percent for Case #2 (see Figure 1).[41] The contract rates are reported in Table 1 for each case, along with summary statistics in Tables 2 and 3.

55. The use of a constant mean provides a convenient and practical benchmark for determining rates for the different instruments in light of their respective risk sharing features. That is, given the parameters of the model, if the government wants 40 percent of a project's expected NPV, then it must set the royalty rate at three percent or the RRT rate at 32 percent when there is a 26 percent chance that the project will fail, and at one percent or 13 percent respectively if the probability of failure increases to 42 percent. The higher the probability of failure (negative NPVs), the lower will be the mean NPV and the lower will be the rate required to capture 40 percent of it. The rate changes are non-linear with respect to the probability of failure.

56. It is interesting to note the relatively low rates necessary for the government to accrue 40 percent of the net present value for all three contract terms. The royalty consistently has the lowest rate as it is computed from the largest base (sales). The free equity type of income tax rate is also low (nine percent in Case #1) relative to expectations. There are a number of reasons why such a low rate can generate sufficient revenue to accrue 40 percent of the net present value. First, revenues accrue only when the base is greater than zero. The government has no losses of its own to recoup and so this lowers the rate. Second, the opportunity cost of

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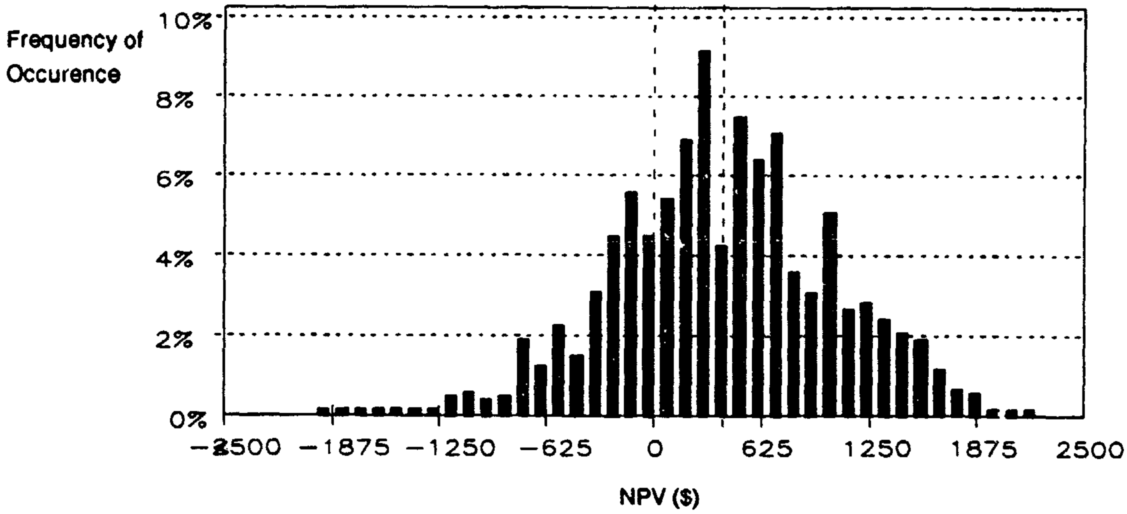
41/ In the simulations reported, the higher probability of failure arises from higher initial costs. It is possible with the model, however, to have the higher probability of failure arise from other causes, such as greater uncertainty over time with respect to prices and operating costs, for example.

Figure 1: Expected Value of Project Returns (NPV) Given Different Probabilities of Failure

a) Case 1
26 Percent Probability that NPV < 0
Expected Value = $400



b) Case 2
42 Percent Probability that NPV < 0
Expected Value = $100

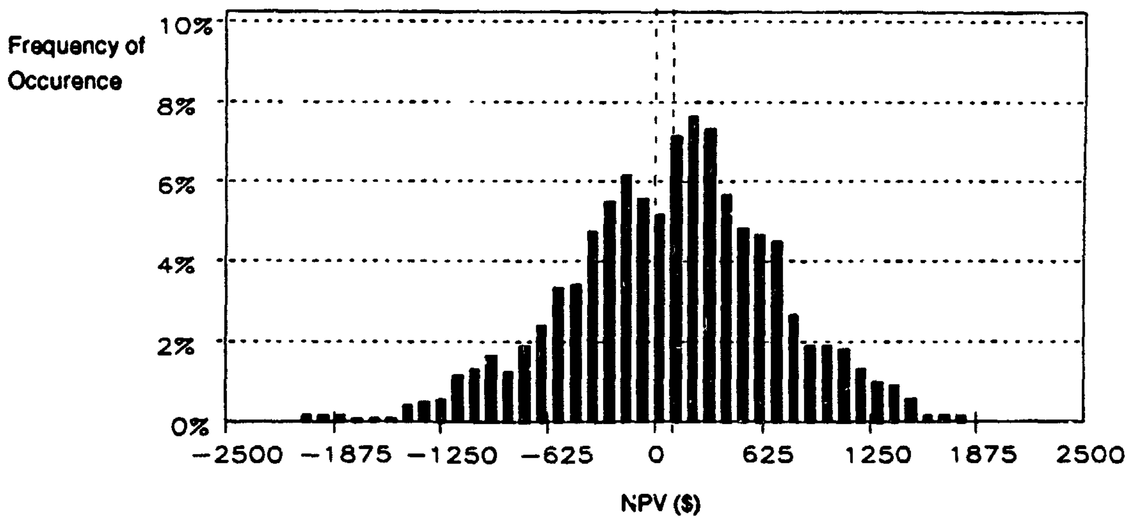


Table 1: Comparison of Rates When Government Receives 40% of Project Cash Flow

	Case 1	Case 2
Project NPV	$400	$100
Prob. NPV < 0	26%	42%
Output Royalty	3%	1%
Income Tax	9%	2%
Resource Rent Tax	32%	13%

Table 2: Summary Table

Case 1

		Expected NPV	Prob. NPV ≤ 0
Mining Project		$400	26%
Share of NPV received by:			
Royalty	Government	$160	0%
	Firm	$240	33%
Income Tax	Government	$160	0%
	Firm	$240	33%
Resource Rent Tax	Government	$160	26%
	Firm	$240	26%

Notes:
-exclusive use of one tax/payment instrument.
-the government and firm share the NPV of the project 40/60.

Table 3: Summary Table

Case 2
(higher exploration costs)

		Expected NPV	Prob. NPV ≤ 0
Mining Project		$100	42%
	Share of NPV received by:		
Royalty	Government	$40	0%
	Firm	$60	44%
Income Tax	Government	$40	0%
	Firm	$60	44%
Resource Rent Tax	Government	$40	42%
	Firm	$60	42%

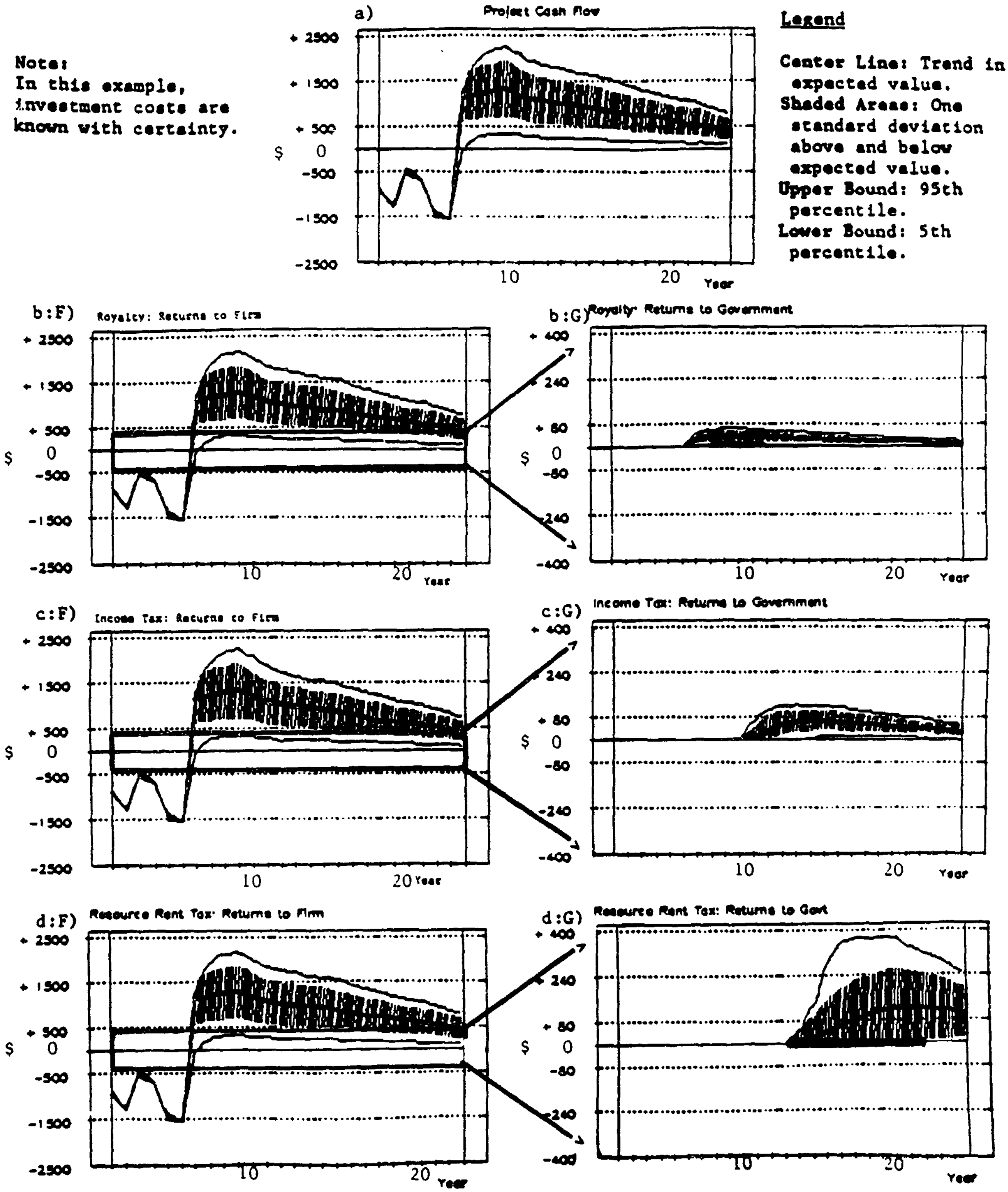
Notes:
-exclusive use of one tax/payment instrument.
-the government and firm share the NPV of the project 40/60.

capital is not incorporated. This further increases the effective base. The RRT has the highest rate of the three instruments but it is significantly lower than the 40 percent NPV share (32 percent in Case #1). Unlike the income tax base, the base for the RRT incorporates the opportunity cost of capital, which defers the accrual of positive cash flow for the government. However, like the income tax, the government only receives positive cash flow if the base is greater than zero. This will reduce the rate below 40 percent as the rate is based only on expected positive outcomes.

57. In Case #2, the initial costs are higher. Thus, there is a shift in the expected value of the overall distribution of outcomes with no change in the overall variability of project revenue. The royalty rate is lower in Case #2 as would be expected given that a lower present value needs to be collected. Both the income tax and the RRT rates decrease dramatically. Higher investment costs imply higher loss offsets that increase the period of zero government revenues. However, the effective base falls by less than the present value of expected revenue for government. This decreases the rate.

58. The time profiles of revenue to the government under the three instruments are dramatically different though their mean NPV is identical. Positive cash flow accrues to the government under both the royalty and the income tax in every state of the world simulated (see Figures 2b and 2c). A royalty is paid on extraction regardless of whether the net present value is positive or not. Thus, this result is to be expected. It is also to be expected that there will be a positive cash flow to the government under the income tax in all cases. Book accounting and the non-incorporation of the opportunity cost of capital combine to increase the base of the charge.

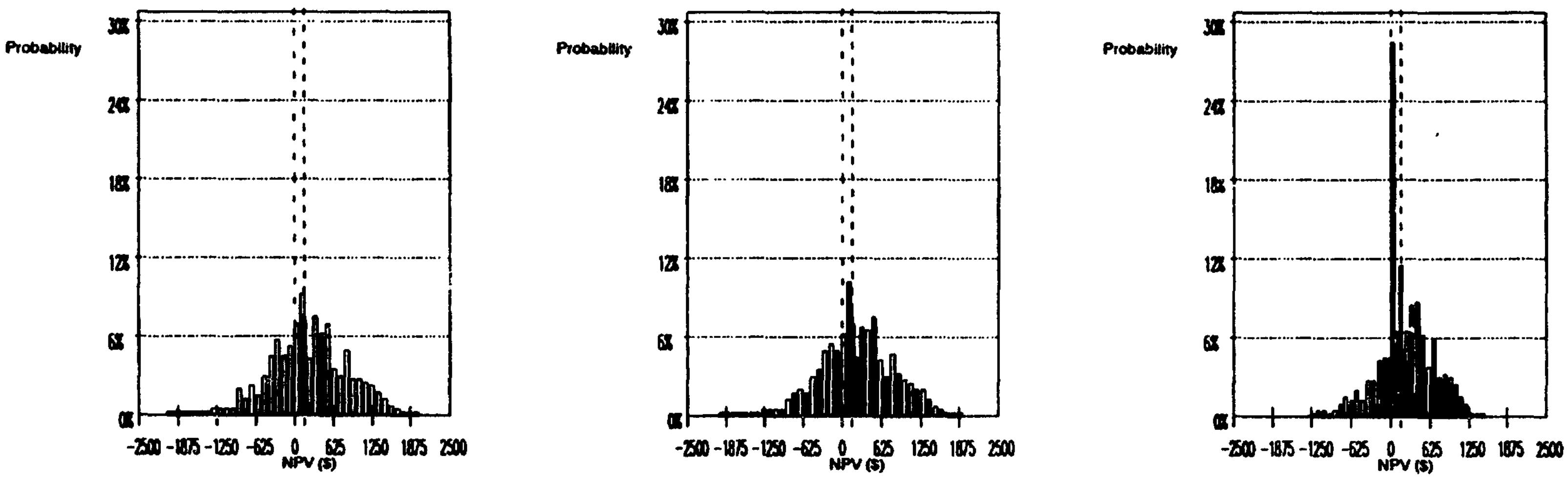
Figure 2: Time Profile of Returns Under Uncertainty



The effective base of the income tax is cash flow adjusted for depreciation. The summation of cash flow can be positive even when the present value of the project is negative. This benefit to the government accrues at a cost to the firm as it increases the probability that the firm will have negative present values. For instance, in Case #1 (Table 2), the probability of a negative present value for the firm increases to 33 percent under the royalty and the income tax, compared to 26 percent under the RRT. Under the RRT, the government and firm each have the same risk as the overall project. Unlike the royalty and income tax, which have no downside risk for the government, under the RRT the government collects no cash 26 percent of the time in Case #1 and 42 percent of the time in Case #2 (Table 3). In other words, the downside risks to the government increase dramatically under the RRT relative to the other two instruments (solid line with zero revenue in Figure 2d), whereas the risks to the firm do not increase as dramatically under the royalty and income tax compared to the RRT.

59. An examination of the distribution of outcomes under each scheme reveals that the income tax of the free equity type and the royalty are remarkably similar (see Figure 3). Two factors combine to yield this similarity. First, the covariance between revenues and the present value is high. Second, the positive covariance between prices and costs increases the positive relationship between revenues and present values. The covariance effect can be illustrated by the simple case of one period where costs are a linear function of prices with no supply shocks. If the probability of negative present values is zero, then the distribution of the income tax and the royalty will be identical. This is true because profit is merely a linear function of price shocks, which implies that for

Figure 3: Variations in the Returns to Government and Firm with the Same Expected Value Across Instruments



a) Royalty on Output

b) Income Tax of the "Free Equity" Type

c) Resource Rent Tax

<u>Legend</u>
White Area: Uncertainty in Firm's Returns
Black Area: Uncertainty in Government's Returns

Note: Case in which there is 26 percent probability that project NPV < 0.

the same revenue the income tax and the royalty would be perfectly correlated yielding identical distributions.

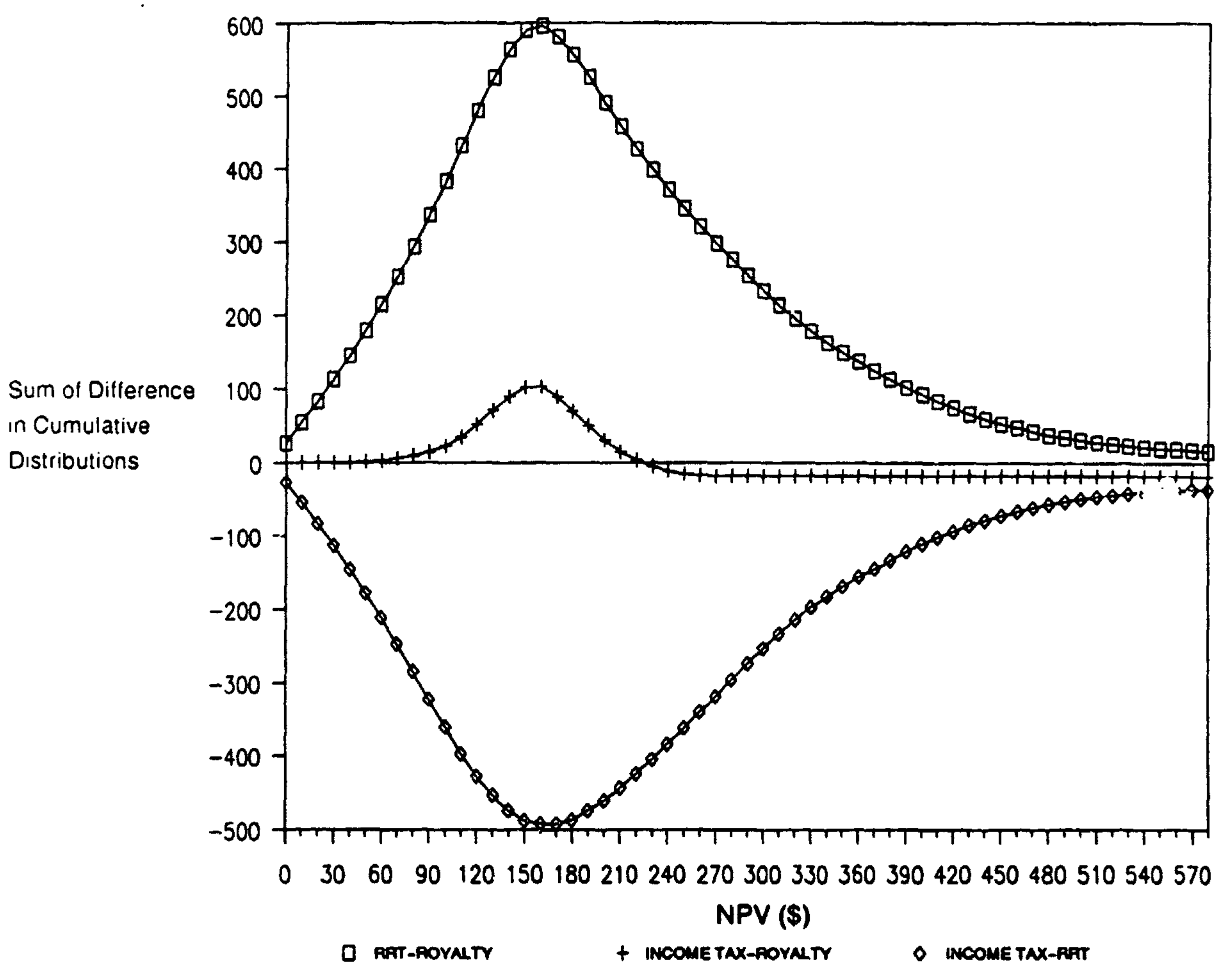
60. Figure 3c illustrates more clearly that under the RRT, downside risks to the government are much higher relative to the other contract terms as the probability of a zero NPV is much higher. By contrast, for the firm, the RRT has both lower downside and lower upside potential compared to the other instruments, which implies that the mass of the frequency distribution is more concentrated.

61. Since distributions for the various instruments are very dissimilar, it is necessary to compute the differences in the cumulative distributions both for the government and the firm to determine if one instrument can consistently be preferred over another. The results are depicted graphically in Figures 4a through 5b. The graphs show that the government will rank the royalty higher than either the income tax or the RRT, and rank the income tax higher than the RRT. However, the exact opposite ranking is found for the firm.[42] That is, the firm would prefer the RRT to the income tax and the income tax to the royalty. Furthermore, these rankings are the same across cases. These results are consistent with theory[43] and with logic. Given a specific total risk to be shared, an instrument that creates lower variability for one party will of necessity shift more variability onto the other party. Thus there is a natural conflict of interest between the parties with respect to risk, holding their respective mear constant.

42/ Recall the definition of second order dominance found in equation #1 as a measure of the cumulative differences. The graphs should be read with this in mind and with respect to the legends presented on the graphs.

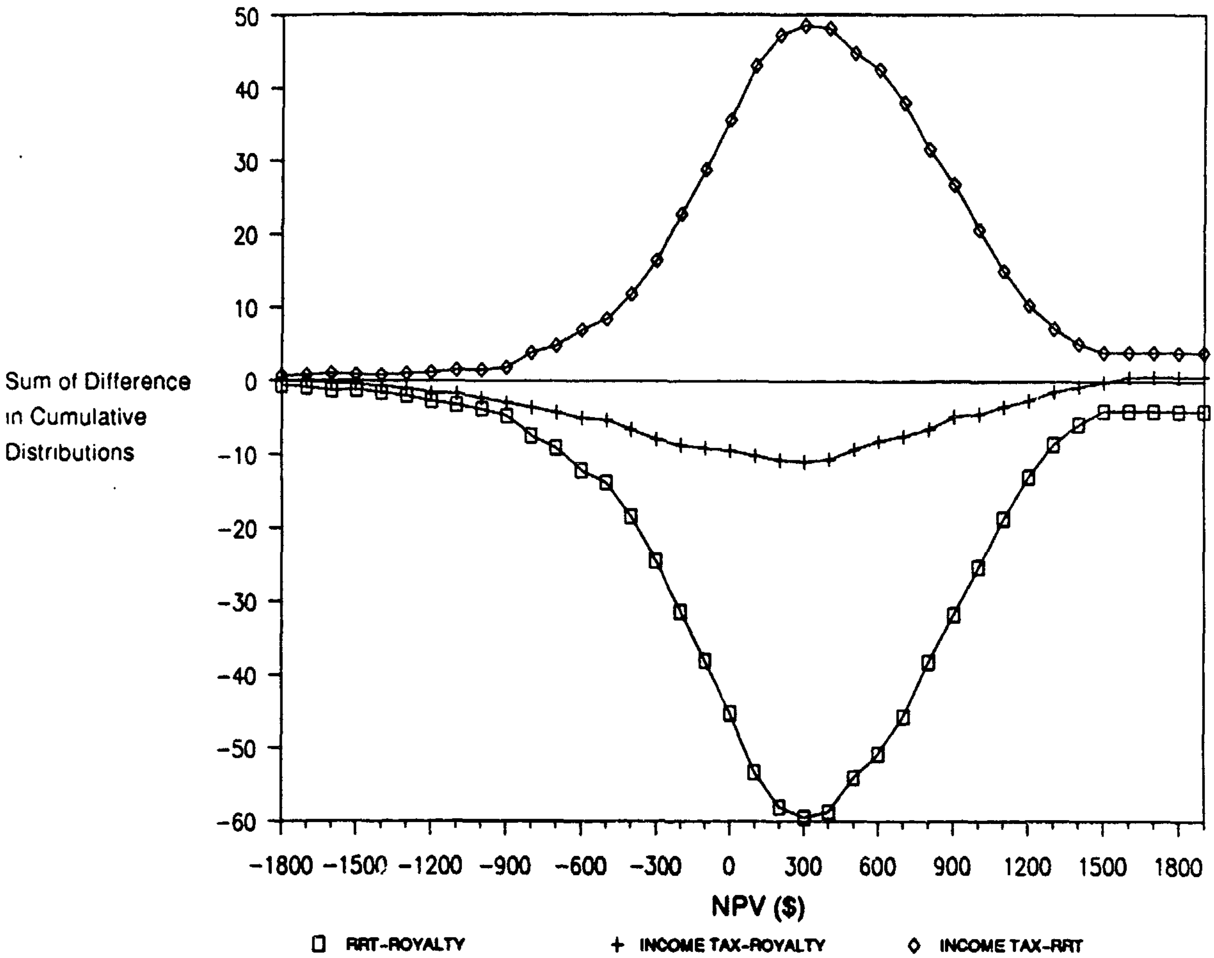
43/ See Conrad (1988) and the references therein.

Figure 4a: Difference in Cumulative Probability Distributions for Government.



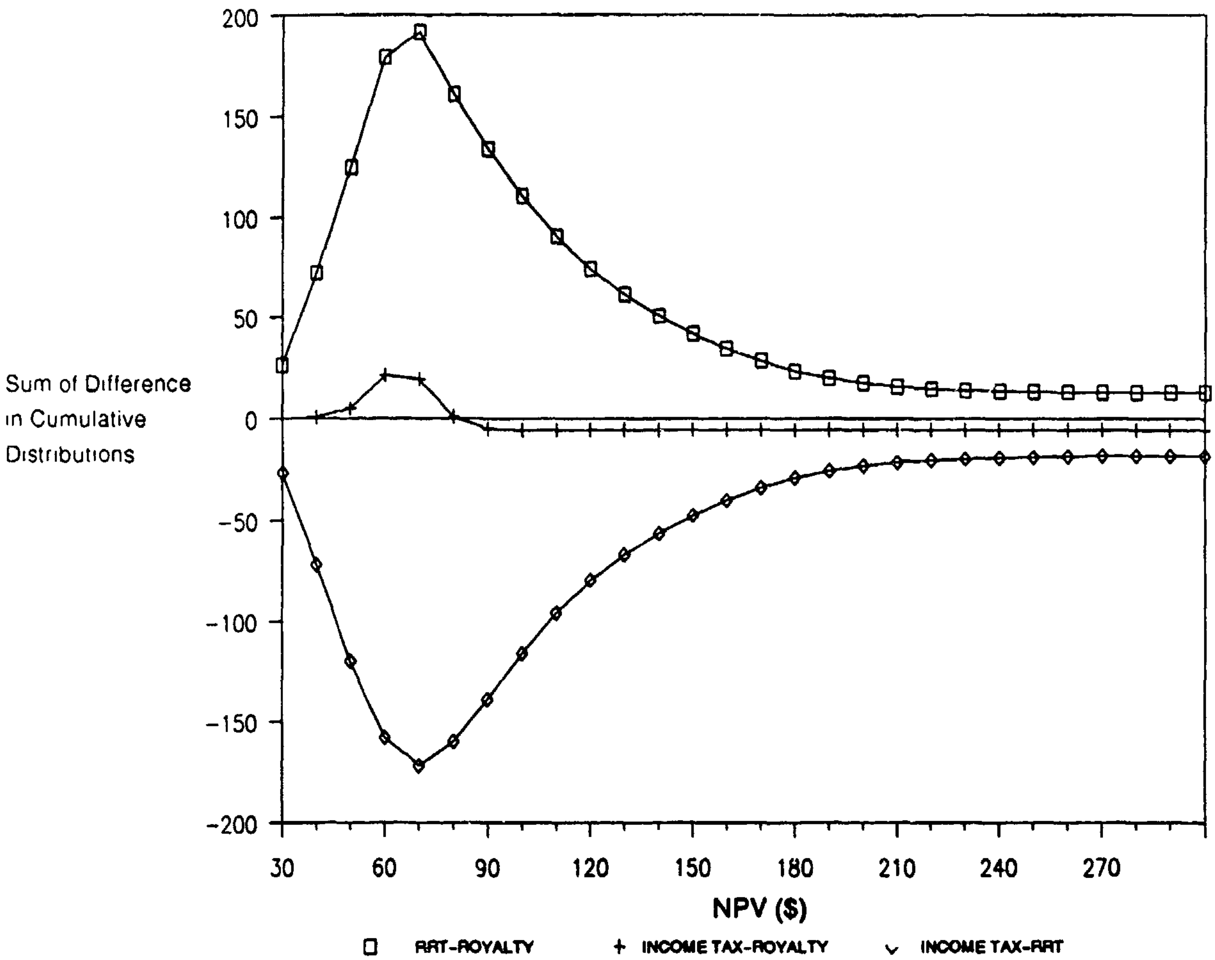
Note: Case in which there is 26 percent probability that project NPV<0.

Figure 4b: Difference in Cumulative Probability Distributions for Firm.



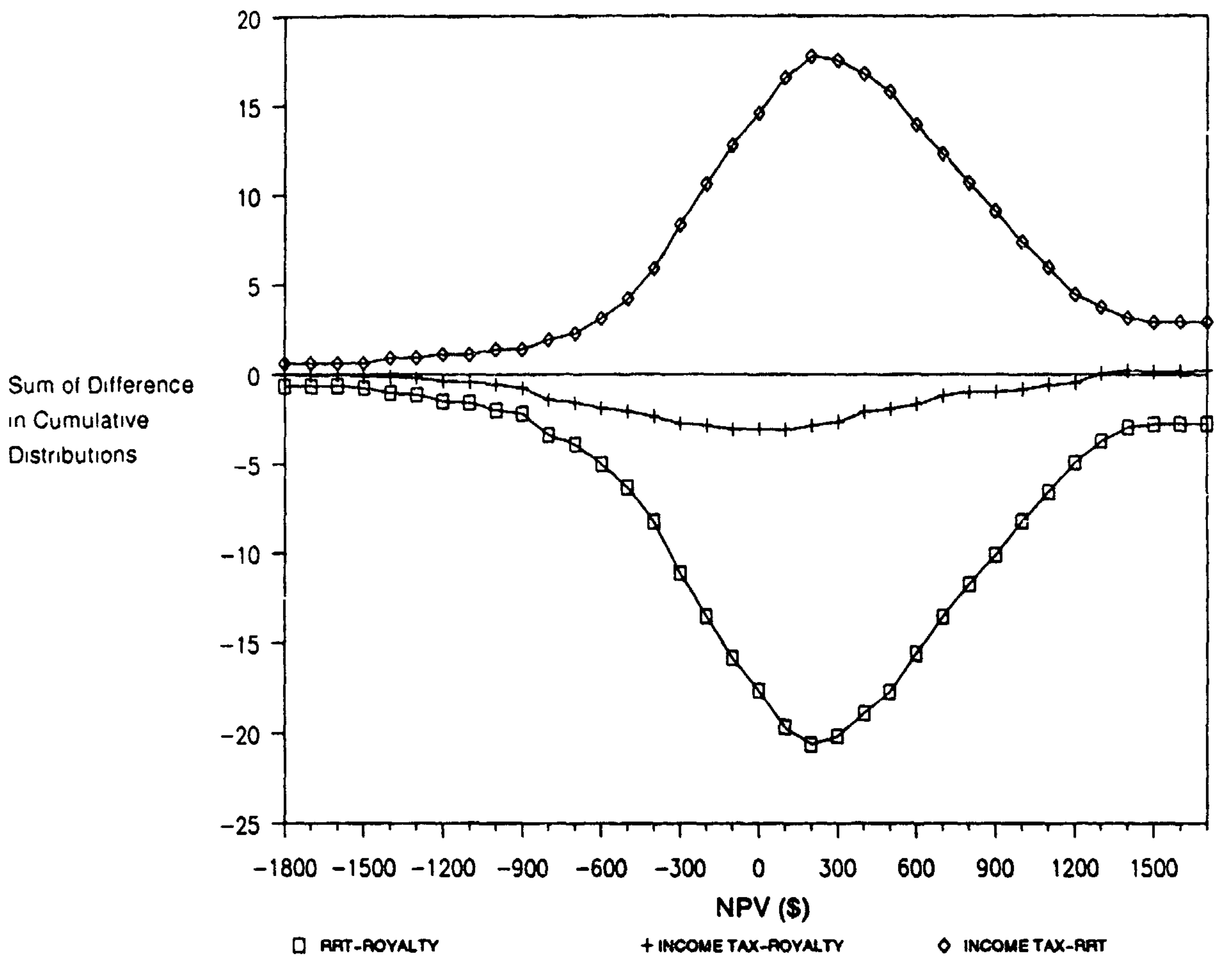
Note: Case in which there is 26 percent probability that project NPV<0.

Figure 5a: Difference in Cumulative Probability Distributions for Government.



Note: Case in which there is 42 percent probability that project NPV<0.

Figure 5b: Difference in Cumulative Probability Distributions for Firm.



Note: Case in which there is 42 percent probability that project NPV<0.

62. This implies that ranking revenue instruments according to risk sharing features will vary between parties with different risk preferences and wealth. That is, it will be necessary, in general, for contracting parties to trade mean expected values for risk in reaching mutual agreement regarding contract terms. Thus there is no reason to expect that in actual situations one instrument (or one set of contract terms) will be consistently preferred to another by both parties.

D. **Summary**

63. The illustrative results are presented with two objectives in mind--first, to illustrate how alternative rankings might be developed, and second, to illustrate the practical potential of relatively simple techniques.

64. Applying these techniques to the stylized cash flow model enables one to demonstrate numerically a familiar result from the literature; namely, if both parties are risk averse, they will not necessarily have the same ranking of schemes, holding the mean returns constant. Therefore, in general, gains are to be had if the contracting parties are prepared to trade mean expected value for risk. This implies that no single instrument (or set of contract terms) can be a priori advocated as superior for mineral dependent developing countries. Each country has different endowments (portfolio of initial assets) and faces different risks. These factors must be taken into account when selecting instruments and determining rates. In some cases, where assets are not and cannot be diversified, royalties may be justified and should not be systematically de-emphasized as they are now. In other cases, where the asset base is diversified, RRTs may be more appropriate. However, governments that employ the RRT should be aware that there is a significant probability that

their mineral endowments will be extracted and that their economies will be forced to adjust to the changes in comparative advantage brought about by mineral extraction without them ever receiving a positive payment. It is common to report mean values when evaluating the net present value of mineral projects. However, all parties should be aware that the probability is zero that the mean value will occur. Recognition of risk is important and should be incorporated into the analysis.

65. The last statement highlights the second contribution of this work which is to demonstrate that it is now possible for governments to engage in this type of risk analysis at little cost. The decrease in the relative cost of computer power and programs makes it economically possible for governments (and donors) to perform detailed and precise risk analysis using microcomputers and spreadsheet programs. Government policymakers can run the types of simulations discussed in this paper for the unique circumstances of their country and measure the alternative distributions of outcomes. This should give them a better understanding of the nature of revenue variability under different contract regimes.

66. The results reported in this paper are illustrative and preliminary, but they point to areas in which more work will be necessary. First, the module should be tested in a specific case or two. This will provide an opportunity to refine extraction profiles to reflect actual situations more accurately, to estimate empirically variations in prices and costs that are to be incorporated and to rank other instruments. Second, there is a need to develop simulation methods for arriving at specific contract terms (by trading means or pricing risk). Third, the variance in the cash flow over time should be considered in addition to the variance in NPV to reflect the concerns of the parties more accurately.

Fourth, there may be a need to determine and incorporate the way in which alternative mineral payment/tax policies affect the overall variability in the economy, both in terms of total government revenue and intersectoral effects.[44] Incorporating empirical and institutional effects such as these should make it possible to demonstrate the power of these simple methods in applied situations.

44/ For example, as noted earlier, it has been observed that the discovery of significant mineral endowments increased the real exchange rate in developing economies. This increase tends to depress the profitability of traditional exports. However, this change will work in reverse as the reserves are depleted (or as mineral prices fall).

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Appendix 1

Description of Principal Mineral Tax/Payment Arrangements

Bonus Bid

This type of arrangement is equivalent to the outright sale of the mineral reserves (or a mining tract). The resource owner bears no risk in this case. In a private ownership economy, such arrangements can be enforced via contracts because the sale of the private ownership rights legally transfers title of the land and reserves to the producer. The seller has no claim after the sale. A national government that holds the mineral rights is in a somewhat different situation as the bonus bid arrangement is equivalent to selling part of the country to a third party. Sovereign risk is another problem. Firms know that the government can observe the outcome of exploration and production. The government may be inclined to nationalize or impose other charges if exploration is successful. For these reasons, bonus bids are seldom used except to lease public tracts to private firms for exploration purposes. The value of the bid can be determined by an auction if there is sufficient competition among bidders or by the determination of a reservation price by the owner of the tract.

Fixed Fees

The opposite case in terms of risk sharing is the fixed payment to the contractor, or a service fee arrangement where the contractor's return is independent of the profitability of the enterprise.

Cost Plus

A special case of fixed fees is a cost plus arrangement that places 100 percent of the risk of the project onto the government while the firm is simply hired to explore for and extract the mineral. This scheme is particularly prone to incentive problems, since the government pays the firm for expenses, but finds that it is extremely costly to monitor the efficiency with which the firm carries out exploration, development and resource extraction. This can result in inefficient extraction decisions as there are no incentives to reduce costs. To partially mitigate this problem, a regressive cost sharing arrangement can be introduced in which the government reimburses a smaller amount of the costs as the costs increase.

Royalty

A royalty can be levied either on output or on extraction. Royalties (or severance taxes) on output are one of the most popular forms of payment schemes due mainly to their administrative simplicity. A royalty on output can be levied on an "ad valorem" basis (a percentage of price) or on a "specific basis" (per unit of output). Royalties on output can induce high grading and change the intertemporal extraction profile of the firm, often resulting in the premature closure of a mine. For this reason, they can be distortionary and undesirable. The advantage is that they generate revenue for the government as soon as production starts.

A royalty on extraction is a charge on the mineral as an input into production. If the elasticity of substitution between inputs is zero, there will be no substitution in the use of inputs and the charge can be approximated by a charge on output at a lower rate (proportional to the input share in the value of outputs). If input substitution is possible, the charge can result in efficient use of the resource. Administratively, a royalty on extraction can be difficult because of valuation problems, given that there is often no market price for these inputs. Procedures such as net-back pricing or reference prices can sometimes be used to approximate the value of the mineral.

Production Sharing

Under production sharing arrangements, the government and firm share in the value or the quantity of resource produced. In this case, the firm may provide financial, technical and managerial know-how to establish mining operations in exchange for a certain portion of the production to cover costs, while buying the remainder of the product on a prearranged basis. The contractor bears all of the risk during the exploration and development phases (although the government has an interest in keeping costs low), while the government shares in the risk once production commences.

Profit Sharing

Another type of sharing arrangement is profit sharing (equity sharing or "participation"). This arrangement usually provides for the government to collect its revenues in the form of dividends. If the government purchases its shares, it takes risks like any other shareholder. Alternately, the use of "free" equity, in lieu of purchased equity, can be justified on the grounds that the country and investor bring two different but necessary types of capital into the operation--the country brings the resource itself and the firm brings the physical capital and expertise. However, this analogy is limited. The nongovernmental investor sees "free equity" as a reduction of his return on the physical capital over and above the reductions incurred if he is also subject to income and output payments. In effect, free equity is perceived as a means of increasing the country's returns beyond those generated through other fiscal instruments. This can increase incentives to employ transfer pricing methods. The returns from equity participation for the government will accrue, if at all, only after a considerable period of time. This occurs because, in general, a significant portion of the physical capital must be recovered and debt repaid before any dividends are declared.

Cash Flow Tax

A cash flow tax ("Brown Tax") is based on the difference between cash receipts and allowable expenses within a period. The government shares in the risks by subsidizing losses at the same rate that gains are taxed. Under this tax, all exploration, development and operating costs are fully recoverable, resulting in a zero marginal effective tax rate on the returns to investment. The cash flow tax introduces no distortions and is suitable for collecting economic rent, but may not be best where parties are risk averse. Because of the requirement that governments share fully in the up front risks of a project, the Brown Tax has not been used in practice. A more practical version of the cash flow type taxes is the resource rent tax.

Resource Rent Tax

The resource rent tax (RRT) carries losses forward at the rate of interest when the net assessable receipts are negative, and it provides the resource owner with positive revenues only in periods when the accumulated net assessable receipts are positive. The government does not collect any revenue if the net present value of the project is zero or negative. This scheme allows a threshold rate of return to the investor on a project before any traditional taxes are payable. As such, it is conceptually prior to any regular income tax (and a deductible cost from it). Otherwise, after uncertainty is eliminated, firms would effectively be guaranteed a return higher than the opportunity cost of the capital used (similar to the problem of overcapitalization in public utilities). This would result in a reduced value of the resource and a transfer of resource rent from the government owner to the firm.

Income Tax

Many developing country governments rely heavily on income related charges in the mineral sector. The regular income tax is often superseded by an income tax with special features to address the particular problems in mining. Two relatively common adjustments to income taxation are provisions of: (i) immediate expensing of exploration and development costs; and (ii) a depletion allowance. The rapid writeoffs are intended to encourage exploration and to compensate for risks and wasted costs associated with necessary but unsuccessful ventures.

The provision for immediate expensing, interest deductions and special allowances can result in such low marginal effective tax rates that the sector is de facto subsidized relative to other sectors after correcting for risk.

Appendix 2

Mineral Project Cash Flow Model

The stylized mineral project model consists of an investment with a known fixed outlay (exploration and development costs aree certain) and an unknown net present value (operating costs and gross revenues are uncertain through the lifetime of the project). Using standard probability distributions for output prices and operating costs, a series of simulations are performed to generate the project's cash flow. For each scenario, the net present value (NPV) of three sets of returns are calculated: (1) total project returns; (2) the share accruing to the government; and (3) the share accruing to the firm. The latter two vary by instrument whereas the first return is a function of the project's probability of failure (NPV < 0). Expected NPV refers to the mean value resulting from repeated simulations.

Assumptions

- There is a single project with a finite life.
- The geological size and composition of the deposit is known with certainty.
- The extraction profile is determined exogenously.
- Exploration and investment costs are known and fixed.[1/]
- The price of the output is uncertain and determined on the world market.[2/]

1/ This is equivalent to evaluating the effect of different instruments on a project's cash flow after exploration and investment costs have been incurred.

2/ The project output is assumed to be small relative to the rest of the world. Therefore, changes in production have no effect on international prices of the commodity.

- Operating costs are uncertain and positively correlated with output price.
- All instruments generate the same fixed proportion of the expected net present value of the project's cash flow for the government.
- Losses cannot be used to offset income from other sources.
- There is no inflation.

Model Structure

Observed project revenue in year t, R_t, is determined by multiplying the stochastically generated price by the quantity produced in year t. The quantity produced in year t is determined by the exogenously given extraction profile. Variability in the value of the output (gross revenue) is, therefore, attributable solely to the variability in price.

The observed price in a given year, P_t, is:

(1) $P_t = E(P_t) + \alpha_t$

where $E(P_t)$ is the expected price and α_t is the price shock.

Operating costs, C_t, are assumed to be positively correlated with output price.[3/] Operating costs in year t have the following structure:

(2) $C_t = \{1 + \beta[P_t/E(P_t)-1]\}\ [E(C_t) + v_t]$

where $E(C_t)$ is the expected operating cost per barrel, and v_t is the direct, randomly generated shock, normally distributed $(0,\sigma_c^2)$. β is the parameter (which could be based on an estimated regression coefficient) relating price to cost.

Capital costs in a given year, K_t, are known:

3/ For example, in most realistic cases when the price of oil increases, so does the price of drilling equipment. This is equivalent to assuming the latter is not perfectly price elastic.

(3) $K_t = K^e_t + K^d_t$

where K^e_t are costs incurred in year t for exploration and development which are written off immediately ("expensed"), and K^d_t are depreciable capital costs incurred in year t.

The project cash flow, CF_t, is derived by subtracting operating and capital costs from the total revenue generated by the project:

(4) $CF_t = R_t - C_t - K_t$

The interest rate, i, is used to discount project costs and benefits. The observed net present value of the project cash flow, NPVCF, is calculated by summing the discounted cash flows in each year:

$$(5) \qquad NPVCF = \sum_{t=1}^{T} \frac{CF_t}{(1+i)^t}$$

The expected NPVCF, ENPVCF, is the mean of the observed NPVCF generated by the series of simulations. The government receives a constant share of the ENPVCF:

(6) $G = \delta(ENPVCF)$

where δ is the share the government receives and G is the government's expected share of the project.

Bases and Rates of Tax/Payment Instruments

1. Royalty in the Form of an Ad Valorem Tax on Output

The base for the ad valorem royalty tax is the project's gross revenue in a given year, R_t. The rate of the royalty, θ, is determined by dividing the government's expected share of the project G by the expected NPV of project revenue, $ENPV(R_t)$:

$$(7) \qquad \text{Royalty rate} = \theta = \frac{G}{ENPV(R_t)}$$

The observed government NPV and firm NPV under the royalty are the following:

(8) Observed Government NPV = $\theta(NPV(R_t))$

(9) Observed Firm NPV = $NPVCF - \theta(NPV(R_t))$

ii. <u>Income Tax of the "Free Equity" Type</u>

The base for this type of income tax is:

(10) $R_t - C_t - K^*_t - D_t + L_{t+1}$

where R_t = project revenue in year t

C_t = operating costs in year t

K^*_t = capital costs in year t which are fully expensed

D_t = depreciation written off in year t, according to a selected method of depreciation[4]

L_{t+1} = loss carry forward, according to the following rule:

Loss Carry Forward Rule:

(11) For all $NCF_t - L_t \geq 0$: No loss carry forward

(11a) For all $NCF_t - L_t < 0$: Carry forward L_{t+1} into next period,

where $L_{t+1} = |NCF_t - L_t|$

NCF_t = cash flow net of depreciation

The rate, τ, for the income tax is calculated by dividing the government's revenue share by the taxable base, that is, cash flow minus losses carried forward.

(12) Income Tax rate $= \tau = \dfrac{\delta(NPVCF)}{NPV(NCF_t - L_t)}$

4/ Straight line method, double declining balance or sum-of-years' digits, for example.

τ is applied in each period that $NCF_t - L_t > 0$. The gross cash flow minus the payments to the government in each period yield the after tax flows to the firm.

(13) Observed Government revenue in period t = τ $(NCF_t - L_t)$ when $(NCF_t - L_t)>0$,

= 0 when $(NCF_t - L_t)\leq 0$

(14) Observed Firm cash flow in period t = CF_t - Government share in period t

iii. Resource Rent Tax (RRT)

The base for the resource rent tax is cash flow (equation (4)) with a loss carry forward provision. All capital costs (such as exploration investment) are expensed, and losses are carried forward at the rate of interest. Hence, the taxable base is determined according to the following rule:

Loss Carry Forward Rule:

(15) For all $CF_t - L_t \geq 0$: No loss carry forward

(15a) For all $CF_t - L_t < 0$: Carry forward L_{t+1} into next period,

where $L_{t+1} = |CF_t - L_t|(1+i)$

CF_t = gross cash flow in period t

L_t = stock of loss carry forward in period t

i = Interest rate

The resource rent tax rate, ϕ, is applied in each period that $CF_t - L_t > 0$. The after tax flows to the firm in each period are equal to the total cash flow minus the payments to the government in that period.

(16) Observed Government revenue in period t = $\phi(CF_t - L_t)$ when $(CF_t - L_t)>0$,

= 0 when $(CF_t - L_t)\leq 0$

(17) Observed Firm cash flow in period t = CF_t - Government revenue in period t

The rate for the RRT must be determined iteratively in the context of the simulation, due to the combined effect of the loss carry forward property and the fact that the government receives no revenue when the base is zero (this can be a significant time period when losses are large in the initial stages of the project). The RRT rate is determined by the following:

$$(18)\quad \phi = \frac{G}{NPVCF'}$$

where $NPVCF'$ = NPV of years when $CF_t - L_t > 0$

As the probability of negative project NPV increases, the RRT rate will decrease. At first glance this may seem counterintuitive, but it makes sense as losses reduce the expected NPV of project cash flow. The lower the probability of failure, the higher will be the expected NPV of project cash flow and the higher will be the rate required to capture G.

Appendix 3

Model Parameter Values

Parameters for Case 1 [5]:

Project life	= 25 years
Interest rate [6]	= 6 percent
Total Production	= 700 barrels
Expected Oil Price	= $16.50/barrel
Operating Costs	= $1.50/barrel
Exploration Costs	= $3.50/barrel
Development Costs	= $4.00/barrel
Depreciable Capital Costs	= $0.50/barrel

Government share of NPVCF = 40 percent

Time Profiles:

Years 1-3: Exploration costs are incurred.

Years 4-6: Development and depreciable capital costs are incurred.

Year 6: Extraction begins and is spread over a 15 year period (with production at its maximum rate during the second and third years (8.79 percent) and declining for each successive year).

Simulation Procedure

A Lotus 1-2-3 add-in program called "@RISK" is used. Using @RISK, the price and operating cost parameters are represented by probability distributions which are used during the simulation.[7]

The expected price of oil, $E(P_t)$ is $16.50 per barrel and is constant for

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5/ In case 2, exploration costs are increased to $4.00/barrel.

6/ The nominal and real interest rates are equivalent since there is no inflation in the model.

7/ The Latin Hypercube method of sampling was used, however, the Monte Carlo method can also be used.

the life of the project. The simulated price in year t follows equation (1) in Appendix 2.[8] The price shock, α_t, is normally distributed (0, 6.8)[9], consistent with the historical oil price trend. P_t is multiplied by the quantity extracted in each year to get project revenue, R_t.

Expected operating costs, $E(C_t)$, are \$1.50 per barrel for the life of the project. Actual operating costs are calculated according to equation (2) in Appendix 2. The regression coefficient, β, is set to 0.5. This is motivated by the assumption that operating costs, as well as the other variables in the model, are demand determined. The independent shock, v_t, is normally distributed (0, 0.5). After being subjected to the independent shock, the cost is then multiplied by the covariance effect as shown in equation (2).

Once NPVCF has been determined according to equations (4) and (5), it is multiplied by δ, the fixed percentage of the expected NPVCF the government receives. The tax rates are calculated and applied to each base as shown below.

8/ In an alternative scenario, price follows a uniform distribution. This year's price falls within a range of x percent higher or lower than last year's price.

9/ The second number in the parentheses refers to the standard deviation.

	Base	Loss Carry Forward Provision
Instrument:		
Royalty	R_t	None
Income Tax	$R_t - C_t - K^e_t - D_t + L_{t+1}$	Without interest
Resource Rent Tax	$CF_t + L_{t+1}$	With interest

R_t = project revenue in year t

CF_t = cash flow in year t

C_t = operating costs in year t

K^e_t = capital costs in year t that are fully expensed

D_t = total depreciable capital written off in year t, according to depreciation method. For straight line depreciation:

$$D_t = \sum_{j=0}^{T} d^d_{tj}$$

where $d^d_{tj} = K^d_t/n$ if $t \le j+n$
or $= 0$ if $t > j+n$

j = year in which asset K^d_t is written off

K^d_t = depreciable capital incurred in year t

n = tax life of the asset

L_{t+1}= loss carry forward, when applicable

Tax/Payment Rates for Case 1 and Case 2

	Case 1	Case 2
Output Royalty	3%	1%
Income Tax	9%	2%
Resource Rent Tax	32%	13%

Appendix 4

Glossary of Terms[10]

Cumulative Frequency Distribution

A cumulation of the frequency (progressively adding bar heights) across the range of a frequency distribution. A cumulative distribution can be an "upwardly sloping" curve, where the distribution describes the probability of a value less than or equal to any variable value. Alternatively, the cumulative curve may be "downwardly sloping", where the distribution describes the probability of a value greater than or equal to any variable value.

Economic Rent

The return to a factor over and above that needed to induce the allocation of the factor to a given activity. Thus, changes in economic rent (for example through taxation) will not affect the allocation of resources at the margin.

Expected Value (Mean)

The sum of all values in the set, divided by the total number of values in the set.

Frequency Distribution

Constructed from data by arranging values into classes and representing the frequency of occurrence in any class by the height of the bar. The frequency of occurrence of a class relative to total occurrences represents the probability of occurrence (hence it is also called probability distribution).

Iteration

A recalculation of the model during a simulation. During each iteration, all uncertain variables are sampled once according to their probability distributions, and the model is recalculated using these sampled values. The number of iterations desired is specified when using the @RISK program.

Latin Hypercube Sampling Technique

A relatively new stratified sampling technique used in simulation modeling. Stratified sampling techniques tend to force convergence of a sampled distribution in fewer samples than in a Monte Carlo sampling technique. Stratification divides the cumulative curve into equal intervals on the cumulative probability scale (0 to 1). A sample is then randomly selected from each interval of the input distribution, thus recreating the input distribution.

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[10] Some definitions taken from @RISK User's Guide (1989).

Mean Variance Analysis

Mean variance analysis has been extensively employed in risk analysis. It describes attitudes to risk in terms of the mean and variance of income. Its use is appropriate when the distribution of income is normal, or when all assets together have normally distributed returns. This type of analysis is not appropriate when distributions are not normal or when the actor's choice changes the form of the distribution of returns (trying to reduce the weight in the tail of the distribution).

Monopoly Rent

Monopoly rent can arise for any number of reasons: barriers to entry, technological innovation, etc. For example, the structure of the market can generate monopoly rents in two ways. First, the oligopolistic nature of the intermediate demanders (the multinationals--MNCs) can give rise to the existence of excess profits for the sole (monopsonistic) supplier. Second, it is possible, as OPEC price increases have demonstrated, to increase monopoly rents, even for an oligopolistic supply structure, by in effect "taxing" competitive final demanders. The extent to which the intermediate demanders (MNCs) are able to shift the tax onto the final demanders depends on the degree of competitiveness of the final demand market and on the existence of substitutes. Where substitutes are few and markets at the final demand stage are competitive, the tax will be more easily shifted to the final consumer. Thus, the two kinds of monopoly rent differ in who eventually bears the burden of the tax.

Natural Resource Rent

Natural Resource Rent arises due to the exhaustible nature of minerals. The rent increases as total stocks (reserves) diminish. This type of rent arises even when the resource is of uniform quality and distribution. In addition, changes in the size of this rent affects behavior at the margin. Thus, it is a price not an economic rent.

Opportunity Cost

The amount of a good that must be given up in order to produce another good, or the value of the next best alternative. Intertemporally it represents the value of goods today (current) in terms of goods foregone tomorrow (in the future). Intersectorally it represents the value of goods in one sector in terms of goods foregone in other sectors.

Probability Distribution

A probability distribution or probability density function is the statistical term for a frequency distribution constructed from an infinitely large set of values where the class size is infinitesimally small. See frequency distribution.

Quasi-Rent

Since the mining industry is highly capital-intensive and its capital is immobile in the short-run, capital in the sector enjoys a sizeable quasi-rent. As a result, in the short run, taxation of capital is not likely to discourage the use of capital as much as taxing labor is likely to discourage the use of labor (which is often more mobile). However, in the long run taxing capital can discourage investment. In addition, other relatively scarce factors in mining such as managerial and technical know-how also enjoy quasi-rents.

Ricardian Rent

Ricardian rent arises from quality differences. It is normally associated in agriculture with differential fertilities or location of land--the marginal land generating zero rent even though it has a positive price associated with its scarcity value. In the mineral sector it arises due to differences in quality of ores, pressure of oils and gases, location, or ease of mining.

Risk

Risk measures the probability and severity of loss. The notion of risk epresupposes a lack of predictability, but it acutally arises from a well understood probabilistic process. For example, the risk associated with a bet on a fair coin toss is known with certainty; the risk has no uncertainty, although the outcome of the toss is uncertain.

Shadow Price

The social opportunity cost of goods and services estimated for the economy as a whole.

Skewness

Skewness is a measure of the shape of a distribution. It indicates the degree of asymmetry in a distribution. Skewed distributions have more values to the one side of the most likely value, that is, one tail is longer than the other. The higher the skewness value, the more skewed will be the distribution.

Standard Deviation

The standard deviation is the square root of the variance.

Stochastic

Stochastic is a synonym for uncertain.

Stochastic Dominance

First Order Stochastic Dominance: An asset is said to be stochastically dominant over another if an individual receives greater wealth from it in every (ordered) state of nature. This is known as first order stochastic dominance and applies to all increasing utility functions including linear functions.

Second Order Stochastic Dominance: Second order stochastic dominance not only assumes utility functions where marginal utility of wealth is positive, but also that total utility must increase at a decreasing rate, that is, the utility function is concave. Hence, under second order stochastic dominance, individuals are assumed to be risk averse.[11]

User Cost

The payment which is collected by the owner of an endowment based on its scarcity value.

Uncertainty

Uncertainty refers to lack of definite knowledge or a lack of sureness. Here, the lack of predictability arises from insufficient knowledge.

Variance

The variance measures how widely dispersed values are in a distribution, and is a measure of risk in symmetric distributions. It is calculated as the average of the squared deviations about the mean. The variance is the square of the standard deviation.

Windfall Rent

Windfall rents (gain) are largely due to sudden increases in demand in the presence of low short-run supply elasticities. Taxing these rents is neutral intertemporally only if windfall losses are subsidized.

11/ See Copeland and Weston (1980).

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