EFFICIENCY OF PRACTICAL RESOURCE RENT TAX SYSTEM:
THRESHOLD RATES AND INCOME TAXES

by
Arvind Virmani
April 1986

Development Research Department
Economics and Research Staff
World Bank

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ABSTRACT

An abstract pure profit or rent tax for a known resource is easy to define and analyze. The challenge is to (a) design a tax-contract system which is relatively efficient in extracting rents when the existence and size of the resource is uncertain, and (b) implement the system under the government's informational problems and practical limitations. The Resource Rent Tax has been proposed as a practicable method of taxing resource rents under uncertainty. The proposed system is composed of several elements each of which can move it away from a pure profit tax. The paper studies the impact of these on efficiency in the context of uncertainty about the size of the resource and its existence.
1. **INTRODUCTION**

An abstract pure profit or rent tax for a known resource is easy to define and analyze (see e.g. Dasgupta and Heal, 1979). The challenge is to (a) design a tax-contract system which is relatively efficient in extracting rents when the existence and size of the resource is uncertain, and (b) implement the system under the government's informational problems and practical limitations.\(^1\) The Resource Rent Tax (RRT) has been proposed as a practicable method of taxing resource rents under uncertainty (Garnaut and Ross, 1975, 1979).\(^2\) The proposed system is composed of several elements each of which can move it away from a pure profit tax. Yet the impact of these on efficiency has either not been studied at all or been analyzed only for a known resource.

There are three distinguishing elements of the system as defined by Garnaut and Ross. (1) Full expensing (100% depreciation) of all costs and their unlimited carry forward at a specified interest rate.\(^3\) This element of the system is similar in many respects to a corporate pure profits tax (Stiglitz (1973, 1976), King (1977)). (2) A progressive rate structure, where

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1. Even after the firm has resolved most of the resource uncertainty through exploration, the government may still be uncertain. Given the inherent asymmetry in information once exploration begins, it is not difficult to conceal information or provide selective (misleading) data. A system in which the government becomes a full partner in the exploration could break this asymmetry. Brazil introduced such a participation system but could not attract the oil majors.

2. Systems based on value of resource present in the tract after exploration, or those which allow government to determine this value, appear to be impractical in many countries, for reasons given in the previous footnote.

3. Interest paid on loans is not deductible.
the tax brackets are defined in terms of rates of return to capital (multiple thresholds). (3) A standard income tax imposed before or after the resource rent tax.

The central difficulty with the first element is in determining the firm discount rate for the project or the "supply price of investment". If the specified rate or first threshold is different from the discount rate the tax is no longer a pure profit tax (Sumner (1978) Dowell (1980)). The sensitivity of system efficiency to positive errors in guessing the discount rate is numerically studied in the paper. As governments generally want firms to bear the exploration risk, the full loss offset feature is seldom operative. This will be the basic case studied here.

If the discount rate was precisely known and the threshold rate set equal to it, the tax rate could in principle be 100%. Rates close to 100% will have strong disincentive effects on operation of fields whose internal rate of return is higher than the threshold rate. The second element of the system requiring progressive tax rates which approach but never reach 100% will minimize disincentives. It may also create efficiency losses. Another justification for a progressive RRT is that it will help mitigate any

4. Their analysis is for a known resource.

5. Rates as high as 25% have been recommended, for instance, in Papua New Guinea. These appear to be quite high when compared to the borrowing rates of the oil majors.

6. If foreign firms are involved, losses from unsuccessful exploration can seldom be offset against income from other sources within the country. New domestic firms have the same problem.

7. A graduated system of threshold rates which encompass the "true" discount rate with high probability could also alleviate the difficulty of determining the precise discount rate of interested firms.
sovereign risk perceived by firms.\textsuperscript{8} Both the efficiency and sharing properties of multiple rate systems will be studied and compared with those for single rate systems.\textsuperscript{9}

The final element of the RRT tax-contract package is a conventional income tax. If an income tax already exists, the issue is whether it should be applicable to resource firms. In the case in which firms are foreign, a home income tax will be applicable (to foreign source income) to them. If the host income tax can be credited against home tax liability, this will have a different impact than if it is merely deductible. Though the combined effect of a tax-contract system can be quite different from that of a system considered in isolation, this has not been studied. It will be shown how the distorting effects of an income tax can be countered by proper specification of the threshold rate.

2. **THE MODEL**

The formal analysis is based on standard firm optimizing behavior under uncertainty. Firms maximize expectation of after tax net present value (EATNPV) from the tract under consideration. The presence and form of any income taxes and the contract system to be used is known before exploration begins. At that time, the existence of the resource and its size conditional on existence is uncertain. This uncertainty is assumed to be completely

\textsuperscript{8} The argument is usually made in terms of "shorter pay back period" and a higher share to government from large fields.

\textsuperscript{9} Though sovereign risk will not be formally analyzed in this paper, I will draw on a simple model of sovereign risk to relate the progressivity results to this issue.
resolved during the exploration phase, during which a fixed cost is expended. At the beginning of the exploration phase the firm must decide whether to lease the tract, and the resource tax rate it is willing to pay. If a resource is discovered, the firm determines the optimal extraction path for this (now) known resource at the start of the development-production phase. Based on this it also decides whether the resource is worth exploiting.10/

Analytical solution of even the simplified model given in Table 1 involves nonlinear conditions which do not yield unambiguous comparative statics. A simulation procedure has therefore been used to obtain numerical results for petroleum resources. The most important assumption is that the second stage optimization determines the peak production level. The entire future time path of output then follows from the geologic conditions determining oil pressure and flows in the reservoir (Figure 1). Development and operating costs are linked to peak production as both depend on the number and pattern of oil wells over the field. Development costs per unit of peak production also decline with resource size.11/

The market for resource leases is assumed to be essentially competitive. All firms are assumed to be identical and have identical costs, information and expectations. If firms compete in terms of the resource

10. In the home income tax case exploration costs can be completely written off on nonproduced fields. In this case there will be a discontinuity at the zero production point.

11. The basic programming model used is the Gen II version of Kalter, Tyner and Hughes (1981), kindly supplied to me by Prof. Tyner. The RRT system was introduced into this framework, along with several other changes. For more detail and justification of assumptions, see Virmani (1985).
Table 1: Firms' Maximization Procedure With No Income Taxes

First Stage: \( \text{EATNPV(RRTR)} = E[-C_e(i) + \text{PRRD ATNPV}(S) + (1 - \text{PRRD}) \text{TAXW}] \)

Second Stage: \( \text{ATNPV}(S) = \text{Max ATNPV}(Q_o, S) \), where

\[
\text{ATNPV}(Q_o, S) = Q_o \left[ -C_d(i) + \int_0^T (p-c) e^{\alpha t} dt + (1-\text{RRTR}) \int_0^T (p-c) e^{-\alpha t} dt \right] + \int_0^T (pe^{-\alpha t} - c)e^{-\alpha t} dt
\]

\( a = \text{To}/(1 - \text{delta}), \quad p(T)e^{-\alpha t} - c(T) = 0, \quad S = Q_o(\text{To} + 1/a), \quad Q_o \int_0^T (p-c)e^{-\alpha t} dt = Cd(r) - Ce(r) = 0 \).

Competition leads to an adjustment in RRTR so that \( \text{EATNPV(RRTR)} = A \)

Final: \( \text{EPVGRV} = E[\text{RRTR}^* Q_o \left( \int_0^T (p-c) e^{-\alpha t} dt + \int_0^T (pe^{-\alpha t} - c)e^{-\alpha t} dt \right)] \)

\( S \) = Size of reserve discovered, \( Q_o = \text{Peak production capacity} \),

\( F \) is the expectation operator. Expectation is taken over all random variables (focus is on lognormal resource distribution).

\( C_e(x) \) = Exploration costs discounted at rate \( x \), where \( x = i \) or \( r \),

\( i \) = Firm discount rate, PRRD = probability of resource discovery,

\( r \) = Threshold rate or interest rate for cost carry forward.

\( \text{TAXW} \) = Tax write-off available if no resource is discovered.

\( \text{RRTR} \) = Resource rent tax rate with respect to which firms compete,

\( A \) = Pure profits which competitive firms need to enter into a resource contract (normally assumed zero).

\( p \) = Output price, assumed to grow at a constant rate.

\( c \) = Unit operating cost, assumed to grow at a constant rate.

\( Tr \) = Time at which resource rent tax becomes applicable.

\( C_d(x) \) = Development cost per unit of peak production \( Q_o \), discounted at rate \( x \), where \( x = i \) or \( r \).

\( \text{delta} \) = Fraction of stock for which production is steady.
Figure 1: Production Profile After Field Development

\[ S = Q_o (T_o + 1/a), \quad a T_o = \text{Delta} 1 (1-\text{Delta}) \]

\[ S \] = Reserve Size, \( Q_o \) = Peak Production Level,

\[ T_o \] = Length of time for which production is steady at peak level.

\[ a \] = Rate of decline of oil production after \( T_o \).

\[ T_r \] = Time at which resource rent tax becomes applicable.

(\( T_r \) could occur in declining portion)

\[ \text{Delta} \] = Exogenous parameter measuring the proportion reserves over which an almost steady flow of oil is obtained.

Note:

1. There is also a production build-up period which is not shown here or in Table 1.

2. This profile is used as an approximation to the inserted logistic profile which is believed to most accurately represent oil flow from water and gas drive reservoirs.
rent tax rate (RRTR), this will result in a rate which reduces the EATNPV to zero. Any fixed positive number (A, say), with positive values indicating that firms' share part of the expected rent, is consistent with the analysis.  

A number of single and multilevel resource rent tax variants are defined. Each is formally treated as a separate system. Application of the above procedure yields an owner government revenue profile for each system. The expectation of the present value of (host) government revenues (EPVGRV) is then an index of the ex ante efficiency of the system. Thus efficiency is viewed from the selfish perspective of the contracting parties. As comparisons are done under a wide range of exogenous conditions, it is useful to measure efficiency losses relative to a base system. A participation system in which the host government shares in everything except exploration costs is used as the base system. 

Many informal analyses of contractual systems focus on the share of ex-post returns received by the government (GOVPER) and how these vary with size of field. A simple model of sovereign risk suggests that this risk could be reduced if the share of rents received by government approaches one for very large fields (Virmani, 1985). A summary measure of ex ante

12. This could be due, for example, to factors which have been ignored in the analysis, such as differential costs or different valuation of the field. These aspects are formally considered in the bidding literature (Riley and Samuelson (1981)).

13. In the context of the present model, this system is neutral when no other taxes are present.

14. GOVPER(S) = PVGRV(S)/PROJPV(S),
progressiveness (CORR) was defined and used to compare system variants from this perspective.

\[
\begin{align*}
\text{RATIO}(S) &= \frac{\text{PVGRV}(S)}{\left[\text{PROJPV}(S) - \text{PVGRV}(S)\right]} \quad \text{AND,} \\
\text{CORR} &= \frac{\text{COV}(\text{RATIO}, \text{PROJPV})}{\left[\text{VAR} (\text{RATIO}) \times \text{VAR} (\text{PROJPV})\right]} , \quad \text{where} \\
\text{PVGRV}(S) &= \text{the present value of government revenue for field of size } S, \\
\text{PROJPV}(S) &= \text{the total present value of the field of size } S, \\
\text{COV} &= \text{covariance} \\
\text{and } \text{VAR} &= \text{variance of the terms in the respective brackets.}
\end{align*}
\]

3. SIMULATION RESULTS FOR SINGLE RATE SYSTEMS

As income taxes are invariably ignored in analysis of resource contracts the paper starts with this case. Five RRT variants each with a single threshold rate \((r)\) lying between 6% and 15% are considered.\(^{15}\) The discount rate \((i)\) in the base simulations is assumed to be 6% for both firms and the government. Lower and higher discount rates are also considered, as were different rates for the host government. Table 2 shows (columns 2, 6 and 10) the relative efficiency losses for three different values of the probability of finding a resource \((\text{PRRD})\).\(^{16}\) The efficiency of the RRT declines

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15. A threshold of 4% was found to be similar to a simple income tax type and a production share system. For the latter, see Virmani (1986).

16. The effect of varying PRRD is the same as that of varying \(A\) from zero. Recall that changing \(A\) changes the share of rents expected to go to the firm.
### Table 2: Efficiency Losses for Single Rate RRTs (No Income Taxes)

<table>
<thead>
<tr>
<th>System</th>
<th>.01</th>
<th></th>
<th></th>
<th>.15</th>
<th></th>
<th></th>
<th>.2</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Efficiency Loss (%)</td>
<td>Mean $T_0$ (Years)</td>
<td>Tax (%) RRTR CORR</td>
<td>Efficiency Loss (%)</td>
<td>Mean $T_0$ (Years)</td>
<td>Tax (%) RRTR CORR</td>
<td>Efficiency Loss (%)</td>
<td>Mean $T_0$ (Years)</td>
<td>Tax (%) RRTR CORR</td>
</tr>
<tr>
<td>RRT06 (r=6%)</td>
<td>0.0</td>
<td>4.3</td>
<td>66</td>
<td>0.10</td>
<td>0.1</td>
<td>4.4</td>
<td>78</td>
<td>*</td>
<td>0.4</td>
</tr>
<tr>
<td>RRT07 (r=7%)</td>
<td>0.0</td>
<td>4.1</td>
<td>66</td>
<td>0.12</td>
<td>0.5</td>
<td>4.1</td>
<td>79</td>
<td>.10</td>
<td>0.5</td>
</tr>
<tr>
<td>RRT09 (r=9%)</td>
<td>1.0</td>
<td>3.8</td>
<td>67</td>
<td>0.43</td>
<td>2.3</td>
<td>3.4</td>
<td>80</td>
<td>*</td>
<td>4.1</td>
</tr>
<tr>
<td>RRT12 (r=12%)</td>
<td>3.9</td>
<td>3.4</td>
<td>69</td>
<td>0.49</td>
<td>9.6</td>
<td>1.5</td>
<td>84</td>
<td>.74</td>
<td>10</td>
</tr>
<tr>
<td>RRT15 (r=15%)</td>
<td>10.0</td>
<td>1.7</td>
<td>73</td>
<td>0.73</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
</tbody>
</table>

* Missing Values

**Definition**

$\delta$ = Interest rate at which costs can be carried forward/ (Threshold) internal rate of return above which resource rent tax applies.

**Base Case Values**

PRICE: INITIAL $28, RATE OF GROWTH = 3%, DEVELOPMENT COST = $30

DELTA = 0.425, DISCOUNT RATE OF FIRM AND HOST GOVERNMENT = 6%

DEVELOPMENT COST DISTRIBUTION: 4th to 8th year (6%, 9%, 45%, 19%, and 19% of total)

INFLATION = 7%, MEAN FIELD SIZE = 100 Million barrels, STANDARD DEVIATION = 100 million

BUILD UP PERIOD: 9th and 10th Year (50% and 75% of Peak); DEPRECIATION: 15 years straight line

EXPLORATION COST: 68 million, EXPLORATION COST DISTRIBUTION: First 3 years (14%, 43%, and 43% of total).
unambiguously with a rise in the threshold rate for all three values of resource discovery probability.

As an illustration consider a discovery probability of 0.1. As the threshold rate rises above 6%, initially there is not much effect on efficiency. At some point before 9% efficiency begins to fall, and between 12% and 15% it declines rapidly. Thus the rate of change in efficiency with the threshold rate increases with the rate.\(^\text{17}\) The source of this inefficiency is an acceleration in the rate of extraction which is summarized in the mean of To (column 3). The period of steady output To is inversely related to peak production and the speed with which extraction takes place. Mean To measures the average To over all potential field sizes, and is 4.2 years when there are no taxes. This indicates that higher thresholds distort production towards earlier periods, and this distortion increases with the threshold.\(^\text{18}\)

Consider, for a given field, the effect of an increase in the threshold rate above the discount rate. With unchanged development and production profiles (and tax rate), the effect is to postpone the time at which the resource rent tax becomes applicable. In a competitive market the tax rate must rise to compensate the government for the fall in revenue (column 4 headed tax). The joint effect of these is to change the effective intertemporal pattern of taxation to one which rises more steeply over time.

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17. This is graphically represented in Figure 3 below.

18. This is the average picture. The plot of To against reserve size shows that it has a very strong (relative) peak for field sizes for which the internal rate of return is equal to the threshold rate. This peak will occur at different field sizes for different variants, and there will be field sizes for which the ranking of To is different from the average picture.
This will induce a shift in extraction from later to earlier periods in an effort to reduce tax liability (see e.g. Dasgupta and Heal). Accelerated production involves higher peak capacity. Though costs per unit of capacity do not change initial costs cumulated to the start of production are much higher. This, in turn, increases the period over which no tax applies. The net effect is a fall in marginal cost of raising peak production relative to the marginal benefit from postponement of tax liability. Optimal peak production is therefore higher.

Columns 2, 6 and 10 of Table 2 show that the efficiency losses for every system increase with resource discovery probability. Higher discovery probability means that the expected value of the tract is higher. In a perfectly competitive market, firms' expectation of returns from the tract are unchanged at zero. The tax rate must rise (columns 4, 8 and 12), increasing the distortion. More strikingly the spread between the efficiency of different systems also increases. This is consistent with conventional tax analysis where the distortion increases as a square of the tax rate. A related point of note is that the critical threshold at which efficiency losses accelerate falls with tax rates. In the context of the present model, a reduction in resource discovery probability (PRRD) is equivalent to allowing firms a share in pure profits (a rise in A above zero). Thus a move from the right columns to the left columns also shows the effect on efficiency of raising firm's share while keeping PRRD unchanged at 0.2.

19. The RRT06 system is not exactly neutral because of a small difference in the way in which discounting was introduced (continuous time versus discrete). Its effective threshold rate is therefore slightly lower than the discount rate resulting in a small (average) deceleration of extraction.
The efficiency loss depends on the difference between the discount rate of the firm and the threshold rate, rather than on the latter's absolute level. This is best seen by considering the effect of changes in the discount rate on the relative efficiency of the systems (Table 3). Consider the RRT09 system for PRRD=0.15 or the RRT15 system for PRRD=0.1. As we move from a discount rate of 9% to 6% efficiency falls by a much smaller amount than in moving from 6% to 4%. In both cases the gap between the threshold rate and the discount rate is increasing, but the effect on efficiency accelerates with the gap. These results are completely analogous to those obtained for changes in the threshold rate. 20/  

Table 3: Comparative Efficiency Losses (%) for Different Discount Rates  
(No Income Tax)  

<table>
<thead>
<tr>
<th>Discovery Probability</th>
<th></th>
<th>.1 Discount Rate (1)</th>
<th></th>
<th>.75 Discount Rate (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>System</td>
<td>4%</td>
<td>6%</td>
<td>9%</td>
<td>4%</td>
</tr>
<tr>
<td>RRT04 (r=4%)</td>
<td>0.0</td>
<td>*</td>
<td>*</td>
<td>0.0</td>
</tr>
<tr>
<td>RRT06 (r=6%)</td>
<td>0.0</td>
<td>0.0</td>
<td>*</td>
<td>0.0</td>
</tr>
<tr>
<td>RRT09 (r=9%)</td>
<td>1.2</td>
<td>1.0</td>
<td>0.0</td>
<td>10.4</td>
</tr>
<tr>
<td>RRT15 (r=15%)</td>
<td>18.9</td>
<td>10.0</td>
<td>2.0</td>
<td>*</td>
</tr>
</tbody>
</table>

* Missing Values  

20. Changing the government discount rate while holding the firms discount rate constant has no effect on the efficiency ranking of the systems considered. The spread between the systems is however inversely related to the government's discount rate.
Figure 2(a): COMPARATIVE VARIATION OF HOME GOVERNMENT SHARE WITH RESERVES
(no home income tax)

Figure 2(b): COMPARATIVE VARIATION IN RATIO WITH RESERVES
(no home income tax case)
Figure 3: THE EFFICIENCY-PROGRESSIVENESS TRADE OFF
FOR SINGLE RRT SYSTEMS WITH DIFFERENT
CUMULATION RATES

Note: Threshold or cumulation rates (r) are shown as fractions.
The progressiveness of the system as defined by CORR (Table 2, page 9) is also positively related to the threshold rate. The variation in government's share of ex-post rents with the resource discovered is shown in Figure 2. Broadly speaking the lower threshold systems yield a higher share to the government at field sizes below about 2 to 2.5 times the mean. The government share is lower for lower threshold systems above those field sizes (ignore 2RRT). What may be most relevant to the problem of sovereign or nationalization risk is the government's share for very high value fields (Virmani 1985). Even the most progressive system RRT15 reaches a government share of only 70% at a field size six times the mean. It does not seem likely that an RRT system will solve a serious sovereign risk problem.

If the progressiveness of a system is relevant to contracting decisions this can not be seen in isolation from system efficiency. The trade off between efficiency and progressiveness, as shown in Figure 3, appears to have two distinct segments. As the threshold rate is increased above 6%, progressiveness increases relatively rapidly while efficiency falls slowly. This segment seems to end at a threshold rate of about 9%. If the threshold rate is increased beyond this point, efficiency falls much more rapidly with little gains in progressiveness. The 'critical' threshold rate is therefore about 1.5 times the discount rate.

4. INCOME TAXES AND EFFICIENCY OF SINGLE RATE SYSTEMS

As noted in the introduction the combination of an RRT and an income tax can be far from a pure profits tax. To understand the impact of income taxes it is best to start with a single tax. Practically there are two possibilities. One is that an existing (host country) income tax applies to
natural resource firms. This is likely to be true only if all firms are domestic. The other is if all firms are foreign, subject to an income tax in their home country, and contractually excluded from paying the host income tax. In this paper, there are two ways in which the home and host income tax treat firm income differently. The home income tax allows current expenditures before the start of production to be immediately written off against other profits. It also allows investment expenditures during the exploration phase to be written off if the field is not developed for production.

Formally it is assumed that a host income tax at a rate of either 30% or 45% is applicable to resource firms. Table 4 summarizes for the RRT06 and RRT15, the impact of increasing tax rates (from zero). The efficiency of RRT06 deteriorates slowly with income tax rates, while that of the RRT15 system improves dramatically. The improvement of RRT15 is so great that for each income tax rate considered, the RRT15 is now superior to the RRT06. Further the relative efficiency of RRT15 for each discovery probability declines with income tax rates beyond 30%. This suggests that RRT15 will be most efficient in the presence of an income tax of the order of 15%.

The explanation for these results lies in the influence of the income tax. The effect of a pure income tax type of contract system which is shown in the last line. The standard income tax has an effect on extraction which is the opposite of that for a RRT with a threshold rate higher than the firm

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21. One cannot conclude from this that deliberate introduction of a combination income tax-high RRT system will be superior to an RRT system with threshold rate equal to the discount rate and no income tax. Equal efficiency may, however, be achievable.
### Table 4: Efficiency Losses for RRT Systems in the Presence of Host Income Taxes (No Home Income Tax)

<table>
<thead>
<tr>
<th>Discovery Probability</th>
<th>0.1</th>
<th>0.15</th>
<th>0.2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Efficiency Loss (%)</td>
<td>$T_0$ (Years)</td>
<td>Tax/Share (%)</td>
</tr>
<tr>
<td>RRT, CRAT=6%, PHI=0</td>
<td>0.0</td>
<td>4.3</td>
<td>66</td>
</tr>
<tr>
<td>RRT, CRAT=6%, PHI=30%</td>
<td>0.6</td>
<td>5.2</td>
<td>48</td>
</tr>
<tr>
<td>RRT, CRAT=6%, PHI=45%</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>RRT, CRAT=15%, PHI=0</td>
<td>10.0</td>
<td>1.7</td>
<td>73</td>
</tr>
<tr>
<td>RRT, CRAT=15%, PHI=30%</td>
<td>0.4</td>
<td>5.0</td>
<td>52</td>
</tr>
<tr>
<td>RRT, CRAT=15%, PHI=45%</td>
<td>0.8</td>
<td>5.4</td>
<td>34</td>
</tr>
<tr>
<td>INCOME TAX</td>
<td>1.7</td>
<td>5.8</td>
<td>60</td>
</tr>
</tbody>
</table>

### Table 5: Comparative Efficiency Losses in the Presence of Home Income Taxes (Rate = 45%)

<table>
<thead>
<tr>
<th>Discovery Probability</th>
<th>0.1</th>
<th>0.15</th>
<th>0.2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Efficiency Loss (%)</td>
<td>$T_0$ (Years)</td>
<td>Tax/Share (%)</td>
</tr>
<tr>
<td>RRT, CRAT=6%</td>
<td>3.6</td>
<td>5.7</td>
<td>60</td>
</tr>
<tr>
<td>RRT, CRAT=9%</td>
<td>3.4</td>
<td>5.5</td>
<td>61</td>
</tr>
<tr>
<td>RRT, CRAT=15%</td>
<td>3.6</td>
<td>5.8</td>
<td>64</td>
</tr>
<tr>
<td>RRT, CRAT=20%</td>
<td>6.5</td>
<td>5.3</td>
<td>71</td>
</tr>
<tr>
<td>RRT, CRAT=25%</td>
<td>15.7</td>
<td>4.4</td>
<td>87</td>
</tr>
<tr>
<td>RRT, CRAT=6%</td>
<td>5.1</td>
<td>7.1</td>
<td>80</td>
</tr>
<tr>
<td>RRT, CRAT=9%</td>
<td>4.8</td>
<td>7.3</td>
<td>81</td>
</tr>
<tr>
<td>RRT, CRAT=15%</td>
<td>4.4</td>
<td>7.3</td>
<td>86</td>
</tr>
</tbody>
</table>
discount rate. Thus the extraction accelerating effect of RRT15 is countered by the extraction slowing effect of the income tax. The net distortion is consequently lower, and the efficiency of the total tax-contract system higher. Corresponding to any given RRT variant, there will be an income tax rate which virtually eliminates the (relative) efficiency loss. This 'critical' income tax rate will be positively related to the difference between the threshold and discount rates, and to the probability of resource discovery.

Table 5 presents the results for a wider range of RRT systems for the home income tax case (with a rate of 45%). The results for this case are very similar to those given above except that efficiency losses appear to be much higher. This is merely an artifact of scaling in terms of the base system. As home income tax revenues do not enter our efficiency criterion (EPVGRV), which is consequently lower for all systems including the base system. The same absolute efficiency loss would appear as a higher percentage loss. Because of its better loss offset features, the home tax also has, for the same tax rate, a smaller extraction slowing effect than the host tax. This

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22. The effect of an income tax (IT) is similar to the effect of an RRT with r less than i. For analysis of the IT, see Virmani (1986).

23. Conversely, corresponding to any given income tax, there will be a threshold rate (actually gap r-i) which will eliminate the efficiency loss. This is suggested by the results for the home income tax.

24. Or equivalently be negatively related to the firms share of expected pure profits for given discovery probability.
means that the effects of a home tax at rate 45% will be similar to those of a host tax at a much lower rate.25/

The impact of a home income tax can be determined by comparing tables 1 and 4. With no income taxes, system efficiency deteriorates monotonically with increasing threshold rate (relative to the discount rate). In the presence of an income tax there is an initial subsegment in which efficiency is positively related to the threshold rate.26/ Thereafter, the negative relationship reasserts itself. For any given income tax rate, there appears to be an optimal threshold rate (discount rate gap, r-i). This 'optimum' rate rises with discovery probability (PRRD) going from about 9% at PRRD=0.1, to about 15% at PRRD=0.2.27/ It appears that as this 'optimum' threshold rate rises, the rapidity with which efficiency deteriorates with thresholds above this rate also increases.

The relationship between threshold rates and system progressivity (CORR) is unaffected by the introduction of an income tax. Higher threshold systems are still more progressive than lower threshold ones (Table 5). The absolute progressiveness is however reduced, because of the regressive effect of the income tax. The tax contract system is now regressive for the 6% threshold RRT.

25. From the previous results, this appears to be less than 30% and could be as low as 15%.

26. All systems in this segment are regressive. The host income tax results suggest that the length of this subsegment increases with the income tax rate.

27. Or equivalently, rises with government share of rent.
The comparative picture is best summarized by the efficiency progressiveness diagram (PRRD=0.1 in Figure 4). Except for the initial increasing efficiency portion (i.e. systems having negative CORR) this diagram is remarkably similar to the no tax one (Figure 3). It has an initial segment for which progressiveness rises rapidly with the threshold rate, with only a small loss in efficiency. After this efficiency falls rapidly as the threshold rate rises with little change in progressiveness. The critical threshold rate constituting the turning point is now 2.5 times the discount rate compared to 1.5 times (15% compared to 9%).

The most important influence of the income tax is therefore to reduce the sensitivity of the resource rent tax to errors in judging the correct "supply price of capital". The presence of an income tax broadens the range of threshold rates over which mistakes in rate setting have relatively little cost to the government.28/

We turn briefly to a consideration of the situation in which both sets of income taxes exist simultaneously, and the firms are foreign. The main issue here is the treatment of foreign source income by the foreign firms' home government. Under a credit type system, as prevails in the USA, income taxes paid to a foreign government are credited against the home income tax liability. The effect is similar to the home tax case considered above, with the applicable tax rate taken as the maximum of the two rates. The host government collects a much greater share of the resource rent by setting an

28. As noted earlier the results for the home tax case apply broadly to the host case and vice versa.
Figure 4: EFFICIENCY–PROGRESSIVITY TRADE OFF UNDER HOME INCOME TAX
(at Rate of 5%)
income tax rate equal to that of the home government.\textsuperscript{29/} The comparative efficiency effects are virtually unchanged. The threshold rate could be adjusted along the lines shown earlier to obtain an efficient system.

A deduction type treatment of foreign income tax payments, adds another layer of taxes to the tax-contract system. This means that for the firm to satisfy its expected zero profit condition contractual tax rates (RRTR) must be lower. The extraction accelerating effect of each RRT system is therefore reduced. Threshold rates can be even higher than before, without bringing about substantial efficiency losses. In terms of Figure 4, the critical threshold rate is much higher if a host income tax is imposed on top of an existing home tax rate (of 45%). There is no reason, however, to deliberately introduce a host income tax and an appropriately higher threshold in this situation.\textsuperscript{30/}

5. MULTILEVEL RRT SYSTEMS

So far only single threshold RRT systems have been considered. One objective of the RRT was to introduce greater progressiveness by the use of multiple threshold levels. In this section two-level systems are considered. Even with two thresholds a large number of choices open up with

\textsuperscript{29/} This assumes that the home government accepts the income tax as being a genuine one applicable to all firms, rather than one constructed purely to transfer revenues from home to host coffers.

\textsuperscript{30/} This is unlikely to increase efficiency, and may worsen it in comparison to a situation in which there is no income tax applicable to the resource producers.
respect to combinations of threshold rates to be considered. Two sets of threshold rates, $r_1 = 6\%$, $r_2 = 15\%$, and $r_1 = 9\%$, $r_2 = 15\%$ are tried.

There are still two more parameters to be dealt with and one must be fixed before firms' compete with respect to the other. Alternatively, the ratio between the two must be fixed and the firms allowed to compete with respect to the absolute level. We adopt the first alternative and fix the first level tax rate (RRTR1). Firms are therefore assumed to compete with respect to the second rate (RRTR2). Several system variants defined in terms of different RRTR1s are considered (10\%, 20\%, 30\% and 40\%).

As before we start by considering the no income tax situation. Table 6 shows the results for the (6\%, 15\%) bi level systems. With resource discovery probability at 0.1, the efficiency loss for these systems is worse than for all single rate systems except RRT15. Among the bi level systems efficiency improves as the first level tax rate (RRTR1) is increased. The tax column shows that this is associated with a decline in the competitive tax rate applicable after the second threshold of 15\% is reached. The net result is a lower ex-post marginal tax on high value fields which carry a much greater weight in the ex ante efficiency. Another way to view the bi level system is as a weighted average of the two single threshold ones. As the RRT06 system is far superior to the RRT15 system, the efficiency of the double rate system improves as more weight is put on the former.

The progressiveness index CORR (Table 6) for the bi level systems are a bit of a surprise. Contrary to conventional thinking, multiple thresholds do not produce a more progressive system. The progressiveness indices for the bi level systems are intermediate between those for RRT06 and RRT15, and increase marginally with the first level rate (RRTR1). Bi level systems are
### Table 6: Comparative Efficiency Losses for DOUBLE RRT Systems (No income taxes; r1=6%, r2=15%)

<table>
<thead>
<tr>
<th>Discovery Probability</th>
<th>Efficiency 0.1</th>
<th>Efficiency 0.15</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Efficiency Loss (%)</td>
<td>$T_o$ (Years)</td>
<td>Tax/Share (%)</td>
</tr>
<tr>
<td>RRTR1=0.20</td>
<td>8.6</td>
<td>2.4</td>
<td>65</td>
</tr>
<tr>
<td>RRTR1=0.30</td>
<td>8.5</td>
<td>2.7</td>
<td>59</td>
</tr>
<tr>
<td>RRTR1=0.40</td>
<td>5.7</td>
<td>2.9</td>
<td>51</td>
</tr>
</tbody>
</table>

**Single**

- **RRT12**
  - Efficiency: 3.9
  - $T_o$: 3.4
  - Tax/Share: 69
  - CORR: 0.49
  - Marginal: .49

- **RRT15**
  - Efficiency: 10.0
  - $T_o$: 1.7
  - Tax/Share: 73
  - CORR: 0.73

---

1/ Marginal tax rate when both levels apply.

**RRTR1** = Rate of tax applied after the first threshold ($r1 = 6\%$) is reached.

**Tax (RRTR2)** = Rate of tax applied after second threshold ($r2 = 15\%$) is reached.

---

### Table 7: Comparative Efficiency Losses for Double RRT Systems (No income taxes; r1=9%, r2=15%)

<table>
<thead>
<tr>
<th>Discovery Probability</th>
<th>Efficiency 0.1</th>
<th>Efficiency 0.15</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Efficiency Loss (%)</td>
<td>$T_o$ (Years)</td>
<td>Tax/Share (%)</td>
</tr>
<tr>
<td>RRTR1=.10</td>
<td>10.8</td>
<td>1.9</td>
<td>70</td>
</tr>
<tr>
<td>RRTR1=.20</td>
<td>9.2</td>
<td>2.3</td>
<td>65</td>
</tr>
<tr>
<td>RRTR1=.30</td>
<td>10.1</td>
<td>2.1</td>
<td>60</td>
</tr>
<tr>
<td>RRTR1=.40</td>
<td>7.0</td>
<td>2.7</td>
<td>51</td>
</tr>
</tbody>
</table>
much less progressive than RRT15 and only slightly more progressive than RRT12.

The efficiency progressiveness trade-off is illustrated in Figure 5. Two of the bi level systems appear to be (pareto) inferior to single rate systems in both dimensions. That is a single-level RRT system with threshold rate between 12% and 15% will be superior to the bi level systems with RRTR1 of 20% or 30%. Even the system with RRTR1 = 40% falls on the trade off line joining RRT12 and RRT15 suggesting that a single level system can be found which replicates its efficiency and progressiveness. The results for PRRD=0.15 are similar. The bi level systems' efficiency is marginally better than RRT12's, but still worse than RRT09's. Its progressiveness index is also likely to lie between the two. Multiple thresholds do not appear to have any advantages over single rate systems, but could easily result in (pareto) inferior systems.

The results for the other set of bi level systems is however mixed. Compared to the (6%, 15%) systems both efficiency losses and progressiveness are higher for the (9%, 15%) systems (Table 7). As the RRT09 system was less efficient and more progressive than the RRT06 system, this is to be expected. The results for discovery probability 0.1 are very similar to those obtained earlier. Systems with first level tax rate RRTR1 equal to 10% and 30% are pareto inferior while the other two systems appear to lie on the trade

31. It is conceivable that a bi level system with RRTR1 less than 40% will lie outside the trade-off line for single rate systems. In this case, marginally higher progressivity may be achievable relative to a single threshold system with a rate of 12% to 13%.

32. At higher probabilities the efficiency of these systems is likely to drop drastically as it does for RRT12.
Figure 5: EFFICIENCY-PROGRESSIVITY TRADE OFF FOR SINGLE AND DOUBLE RRT SYSTEMS
(no income taxes)

R1=.2: \( r_1=6\%, \ RRTR1=20\%, \ r_2=15\%, \ RRTR2=\text{variable} \)
R1=.3: \( r_1=6\%, \ RRTR1=30\%, \ r_2=15\%, \ RRTR2=\text{variable} \)
R2=.4: \( r_1=6\%, \ RRTR1=40\%, \ r_2=15\%, \ RRTR2=\text{variable} \)
off line. At a discovery probability of 0.15 the results are different. There is a substantial increase in the progressivity of the systems with little or no loss in efficiency. This is also true in comparison to the RRT12 system (efficiency loss 9.6% and CORR .74 from Table 2).

The overall conclusion for the no income tax situation is as follows. A carefully chosen multiple level system can bring about some improvement in system progressivity without sacrificing efficiency. It is, however, more difficult to identify such a system. Mistakes can easily result in a system which is both less efficient and less progressive than an appropriate single rate system.

The results for the case with a home income tax (45% rate) are very similar. All systems in the (6%, 15%) set have efficiency losses in the range of those for single threshold systems with rates between 6% and 15% (Table 8). This is true for both discovery probabilities shown. The same efficiency results are also found for the (9%, 15%) bi-threshold systems (Table 9). Only one bi level system (RRTR1 = 40%) is found to have a smaller efficiency loss than any single rate system (PRRD=0.1 in Table 8).

The efficiency improvement is due almost solely to the ex-post effect of the system on fields with internal rate of return above 15%. In the single threshold RRT15 system the period of steady production increases sharply for these fields. That is, extraction is slowed down and peak capacity lower. As is apparent from Figure 6, this sharp change in the ex-post extraction pattern over different field sizes is considerably reduced. This is because a tax is already in operation for fields with internal rates of return between 6% and 15%. The difference in tax rates for fields with 15% return and those with
Table 8: Efficiency Losses for Double RRT Systems (home income tax at 45%, \(r_1=6\%, r_2=15\%\))

<table>
<thead>
<tr>
<th>Discovery Probability</th>
<th>0.1</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>System</td>
<td>Efficiency Loss (%)</td>
<td>(T_o) (Years)</td>
<td>Tax/Share (%)</td>
</tr>
<tr>
<td>RRTR1=.20</td>
<td>3.4</td>
<td>5.5</td>
<td>54</td>
</tr>
<tr>
<td>RRTR1=.30</td>
<td>3.4</td>
<td>5.5</td>
<td>47</td>
</tr>
<tr>
<td>RRTR1=.40</td>
<td>3.3</td>
<td>5.4</td>
<td>37</td>
</tr>
<tr>
<td>Single Rate</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>RRT09</td>
<td>3.4</td>
<td>5.5</td>
<td>61</td>
</tr>
<tr>
<td>RRT15</td>
<td>3.6</td>
<td>5.8</td>
<td>64</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Discovery Probability</th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>System</td>
<td>Efficiency Loss (%)</td>
<td>(T_o) (Years)</td>
<td>Tax/Share (%)</td>
</tr>
<tr>
<td>RRTR1=.20</td>
<td>4.6</td>
<td>7.3</td>
<td>82</td>
</tr>
<tr>
<td>RRTR1=.30</td>
<td>4.6</td>
<td>7.3</td>
<td>80</td>
</tr>
<tr>
<td>Single Rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RRT09</td>
<td>4.8</td>
<td>7.3</td>
<td>81</td>
</tr>
<tr>
<td>RRT15</td>
<td>4.4</td>
<td>7.3</td>
<td>86</td>
</tr>
</tbody>
</table>

RRTR1 is the rate of tax applied after the first threshold (\(r_1=6\%\)) is reached.

Table 9: Efficiency Losses for Double RRT Systems (home income tax at 45%, \(r_1=9\%, r_2=15\%\))

<table>
<thead>
<tr>
<th>Discovery Probability</th>
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<th></th>
<th></th>
<th>0.2</th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>System</td>
<td>Efficiency Loss (%)</td>
<td>(T_o) (Years)</td>
<td>Tax/Share (%)</td>
<td>CORR</td>
<td>Efficiency Loss (%)</td>
<td>(T_o) (Years)</td>
<td>Tax/Share (%)</td>
</tr>
<tr>
<td>RRTR1=.10</td>
<td>3.6</td>
<td>5.8</td>
<td>60</td>
<td>0.57</td>
<td>4.6</td>
<td>7.4</td>
<td>85</td>
</tr>
<tr>
<td>RRTR1=.20</td>
<td>3.5</td>
<td>5.6</td>
<td>55</td>
<td>0.57</td>
<td>4.5</td>
<td>7.2</td>
<td>82</td>
</tr>
<tr>
<td>RRTR1=.30</td>
<td>3.4</td>
<td>5.6</td>
<td>48</td>
<td>0.57</td>
<td>4.5</td>
<td>7.2</td>
<td>80</td>
</tr>
<tr>
<td>RRTR1=.40</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>4.5</td>
<td>7.0</td>
<td>76</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RRT09</td>
<td>3.4</td>
<td>5.5</td>
<td>61</td>
<td>0.39</td>
<td>4.8</td>
<td>7.3</td>
<td>81</td>
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<tr>
<td>RRT15</td>
<td>3.6</td>
<td>5.8</td>
<td>64</td>
<td>0.57</td>
<td>4.4</td>
<td>7.3</td>
<td>86</td>
</tr>
</tbody>
</table>
Figure 6: VARIATION IN FLAT PRODUCTION PERIOD WITH RESERVES
(home income tax=45%)

Figure 7: EX-POST VARIATION IN HOST GOVERNMENT SHARE WITH RESERVES
(home income tax=45%)
marginally higher return is much smaller for the bi level system. The
distortion in the extraction pattern is therefore much less.

The bi level (6%, 15%) system with first level tax rate RRTR1 equal
to 30% is the only one which is clearly more progressive than the single
systems (0.64 instead of 0.58, Table 8). Figure 7 shows the underlying
variation in government share with resource discovery. Though RRT15 is more
progressive than the bi level system at large field sizes, the latter makes up
for this at lower sizes. As noted earlier progressiveness at large value may
be more relevant for the sovereign risk problem. RRT15 may therefore still be
preferred in situations in which sovereign risk is a serious problem.

The efficiency progressiveness diagram (PRRD=0.1 in Figure 8)
suggests that some gains in progressiveness may be possible. The RRTR1=30%
system is not only more progressive but also marginally more efficient than
RRT15. The bi level system with RRTR1 = 40% has a marginally lower progres-
siveness than RRT15, but has a slightly higher efficiency. Thus the (6%, 15%)
bi level systems appear to be able to shift the efficiency progressivenes
frontier out when income taxes are present.

6. SUMMARY OF CONCLUSIONS

The most difficult element of a resource rent tax is the
determination of the discount rate that firms will apply to the natural
resource tract. This determines the interest (or threshold) rate at which
firms should be allowed to carry forward exploration and development costs.
Though the borrowing rate that oil firms face on international capital markets
Figure 8: EFFICIENCY-PROGRESSIVENESS TRADE OFF FOR SINGLE AND DOUBLE RRT SYSTEMS
(home income tax=45%)

Note: Threshold rates for single rate systems are given in fractions. Bi level system’s rates shown are the first threshold tax rates, i.e.
R1=.2: \( \frac{r_1}{r_2} = 6\%, \ RRTR1=20\%, \ r_2=15\%, \ RRTR2 \) variable; R1=.3: \( \frac{r_1}{r_2} = 6\%, \ RRTR1=30\%, \ r_2=15\%, \ RRTR2 \) variable;
R1=.4: \( \frac{r_1}{r_2} = 6\%, \ RRTR1=40\%, \ r_2=15\%, \ RRTR2 \) variable.
is fairly well defined the "supply price of capital" for risky investment is not. The sensitivity of contract system efficiency to errors in setting the threshold interest rate was explored in the context of resource uncertainty. As against the usual measures of efficiency in a situation of known reserves this required a definition of ex ante efficiency.

The comparative efficiency loss of the resource rent tax was found to be related in a logistic pattern to the difference between the threshold and the discount rate. There was a considerable range of (positive) values of this gap for which efficiency losses did not increase significantly. In a situation without income taxes the threshold rate could be as much as 50% higher than the discount rate before efficiency deteriorated rapidly.

In the presence of an income tax the pattern was only slightly different. One difference was the appearance of initial subrange in which efficiency seemed to improve marginally. The other difference was that sensitivity declined further. The range of insensitivity was positively related to the applicable income tax rate(s). In a situation in which foreign firms are subject solely to a home income tax of 45% the threshold rate could be as much as 150% higher than the discount rate. The position was similar with a home tax less than the host tax when the latter allows crediting of foreign source income. In a situation in which a host income tax is applicable, and firms are either domestic or are foreign firms subject to a deduction type system, the insensitive range was even larger.

The range of insensitivity narrowed with an increase in the probability of discovering a resource. This was true both with and without any income taxes. The analysis suggests that a similar narrowing would take place if the mean of the resource distribution (conditional on discovery) was
increased. The insensitive range broadened if the firm could keep part of the
expected pure profits (or rents).

The progressiveness of the resource rent tax was also found to be
positively related to the gap between the threshold rate and the discount
rate. The relationship between the two was closely related to the efficiency
loss pattern. Progressiveness increased very rapidly in the first segment,
and very slowly in the second. The boundary between the two segments is at
approximately the same critical gap. This was true whether an income tax was
applicable or not. With income tax applicable, the initial subsegment of
increasing efficiency appeared to consist solely of regressive systems. Given
these patterns of change with threshold rates the efficiency progressiveness
frontier shows the trade-off involved in choice of a threshold rate.

Examination of the ex-post (discovery) shares of the government in
returns showed the reasons for the progressiveness. Government share usually
increased rapidly around field sizes whose internal rate of return is equal to
the threshold rate. The government share rises very slowly at large field
sizes (values). Thus even for the most progressive system encountered this
share did not rise above 70%. This suggests that the sovereign risk problem
cannot be solved by using a resource rent tax without significant loss of
efficiency. If serious nationalization risk is perceived by firms, a service
contract may be a better solution.

Introduction of even one more threshold level opens up a Pandora's
box of permutations and combinations with which system variants can be defined
and compared. Some of these were explored in the present study. The ef-
ficiency progressiveness frontier provides the best means of comparison. In
the presence of income taxes, some of the bi level systems were found to lie
beyond the frontier constructed from single threshold systems. Thus small
gains in either efficiency or progressiveness (or both) could be obtained by
using multiple thresholds. Such systems were harder to identify in the
absence of income taxes. In both cases there were many bi level variants
which fell well inside the frontier. The likelihood of bi level systems being
both relatively inefficient and less progressive than single threshold systems
is therefore quite large. Even more fine tuning is likely to be required if
more than two threshold rates are used.
REFERENCES


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King, Mervyn A. "Public Policy and the Corporation." 1977.


APPENDIX: SENSITIVITY ANALYSIS

Selected single threshold resource rent tax variants were subjected to a range of parameter changes. Exogenous geological and economic parameters were changed by 30% or more, often in both directions. The basic results of the previous analysis were found to be quite robust, though precise bounds on the range of insensitivity were not derived. The tables showing some of the results of the sensitivity analysis for the no income tax are shown below.
Table A1: Efficiency Loss for Different Value of Mean Field Size

<table>
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<tr>
<th>System</th>
<th>70 mi</th>
<th>100 mi</th>
<th>130 mi</th>
<th>70 mi</th>
<th>100 mi</th>
<th>130 mi</th>
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<td>*</td>
</tr>
<tr>
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<td>10.0</td>
<td>8.8</td>
<td>11.4</td>
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</table>

Table A2: Efficiency Loss for Different Values of Development Cost

<table>
<thead>
<tr>
<th>Cost</th>
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<th>$20</th>
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<tbody>
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<td>RRT,ACRAT=.06</td>
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<td>0.0</td>
<td>0.8</td>
<td>0.1</td>
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<td>*</td>
<td>0.4</td>
<td>0.1</td>
</tr>
<tr>
<td>RRT,ACRAT=.09</td>
<td>0.6</td>
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<td>0.1</td>
<td>2.5</td>
<td>2.3</td>
<td>1.1</td>
<td>3.0</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>RRT,ACRAT=.15</td>
<td>5.1</td>
<td>10.0</td>
<td>17.8</td>
<td>4.6</td>
<td>*</td>
<td>17.0</td>
<td>4.4</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

Table A3: Efficiency Loss for Different Rates of Growth of Oil Prices

<table>
<thead>
<tr>
<th>Discovery Probability</th>
<th>0.1</th>
<th></th>
<th>0.15</th>
<th></th>
<th>0.2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate of Price Change</td>
<td>0.01</td>
<td>0.03</td>
<td>0.04</td>
<td>0.01</td>
<td>0.03</td>
<td>0.04</td>
</tr>
<tr>
<td>RRT,CRAT=.06</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>1.6</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>RRT,CRAT=.09</td>
<td>0.6</td>
<td>1.0</td>
<td>0.0</td>
<td>5.1</td>
<td>2.3</td>
<td>0.2</td>
</tr>
<tr>
<td>RRT,CRAT=.15</td>
<td>11.1</td>
<td>10.0</td>
<td>11.4</td>
<td>8.7</td>
<td>*</td>
<td>11.5</td>
</tr>
</tbody>
</table>

* Missing Values
### Table A4: Efficiency Loss for Different Values of Inflation Rate

<table>
<thead>
<tr>
<th>Discovery Probability</th>
<th>0.1</th>
<th>0.15</th>
<th>0.2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.04</td>
<td>0.07</td>
<td>0.10</td>
</tr>
<tr>
<td>RRT, CRAT = .06</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>RRT, CRAT = .09</td>
<td>0.6</td>
<td>1.0</td>
<td>0.2</td>
</tr>
<tr>
<td>RRT, CRAT = .15</td>
<td>11.3</td>
<td>10.0</td>
<td>9.0</td>
</tr>
</tbody>
</table>

### Table A5: Efficiency Losses for Different Patterns of Development Cost

<table>
<thead>
<tr>
<th>Discovery Probability</th>
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<th>0.15</th>
<th>0.2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1/</td>
<td>2/</td>
<td>1/</td>
</tr>
<tr>
<td></td>
<td>Accelerated</td>
<td>Base</td>
<td>Accelerated</td>
</tr>
<tr>
<td>RRT, ACRAT = .06</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
</tr>
<tr>
<td>RRT, ACRAT = .09</td>
<td>0.1</td>
<td>1.0</td>
<td>*</td>
</tr>
<tr>
<td>RRT, ACRAT = .15</td>
<td>12.1</td>
<td>10.0</td>
<td>11.2</td>
</tr>
</tbody>
</table>

1/ .25,.25,.20,.15,15  
2/ .08,.09,.45,.19,.19

* Missing Values


159. Export Incentives and Export Growth in Developing Countries: An Econometric Investigation by Bela Balassa, Evangelos Voloudakis, Panagiotis Fylaktos, and Suk Tai Suh, February 1986.


