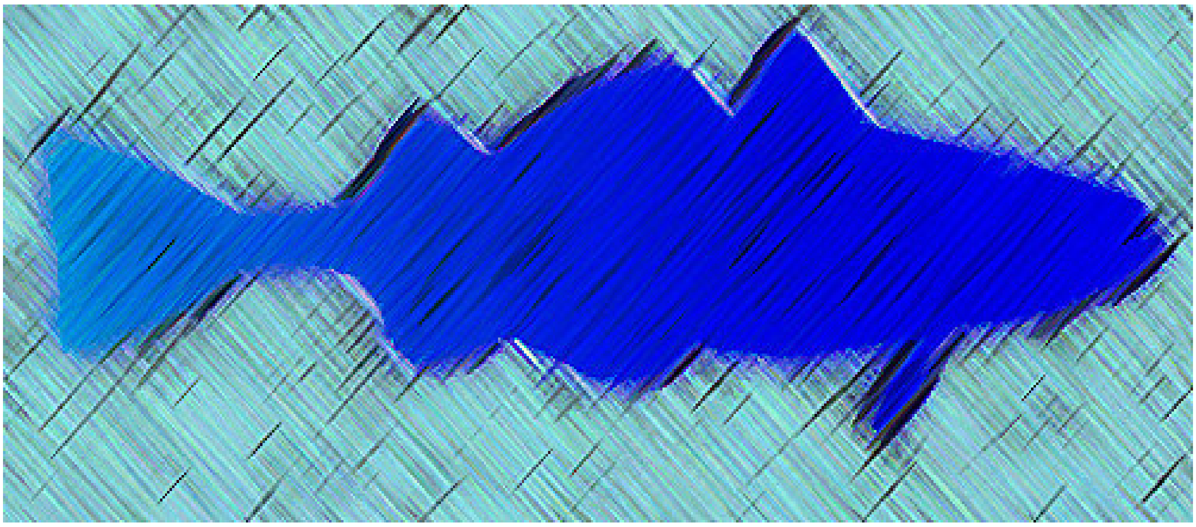
TRAINING COURSE NOTES: ECONOMICS OF NATURAL RESOURCES

BCLME Project LMR/SE/03/03



PRESENTED TO:

Benguela Current Large Marine Ecosystem Programme

BCLME Activity Centre for Living Marine Resources

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THE CONSORTIUM

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EXECUTIVE SUMMARY

We all think we know what natural resources are, but there is room for confusion… clearly not all primary products are 'natural resources'. We would hesitate to describe a litre of milk or even a cow as a natural resource, though we'd have no doubt about using the term to describe a buffalo. Yet we might well describe a tree as a natural resource, even though it was in a plantation. The interesting point is that the central questions we have to ask in the course of any process of primary commodity's production or extraction have a remarkable amount in common. In order to get the best value we can from an existing resource we want to know:

- when to extract it or perhaps how much to extract in each time period,
- how to do the extracting,
- who should be doing it and who should be receiving the benefits of it, and lastly,
- how to ensure that the stream of benefits is sustainable.

We will discover that the answers depend on certain key variables. Some will be characteristics of the resource itself… its richness, rate of regeneration etc, but others, and indeed the most important ones from our point of view, will be things that can be influenced through policy, for example, the interest rate, the nature of property rights, the tax system, the distribution of economic power and, related to it, the institutional structures in the system.

Let's begin with basics. Extraction or harvesting of natural resources is rarely a once off event. It generally occurs over time. If we are to follow conventional economic logic and try to maximise the expected benefits flowing from a resource, then we have to make future and present benefits comparable. After all, if you are offered a choice between R100 today and R100 in ten year's time, there's little doubt that you'd choose the immediate payout, even in a zero inflation world. There are three common reasons given for this:

- **opportunity cost**, if you got the cash today you could put it to work and earn interest
- **uncertainty**, you might not live the ten years needed before you collect
- **myopia**, many people are short sighted and just prefer immediate gratification

All lead to the same conclusion though, if you want to compare income in the future to income at present, then the future funds have to be discounted. The process of discounting (or calculating the present value of future moneys) is simply the reverse of compound interest.

If we are working in discreet time and we invest an amount (the principal) P at a rate of interest r, then after one year it has grown to P(1+r), after two years it'll have grown to $P(1+r)^2$, and after n years to $P(1+r)^n$. These will be the future values of P. For example, if P=100 rands and r=10%, then after three years the principal would be worth $100(1+0.1)^3 = 133.1$ rands.

If you prefer to work in continuous time then the future value will be Pe^{rt}

Suppose however, that you were offered a future payout of 133.3 rands in three year's time. What would the promise of such a payout be worth to you today? Clearly all you have to do is turn the process around and calculate a Present Value . The formula for this is $PV=F\{1/(1+r)^t\}$ where F is the future payout. Clearly the answer is 100 rands.
In continuous time this would reduce to $PV = Fe^{-rt}$
Of course we will generally be dealing with income flows. Where these are constant they appear similar to the stream of earnings from an annuity.

e.g. what is the PV of a constant income stream that pays 800 rands every year for five years, if the interest rate is 10%?

$PV=800+800/(1+r)+800/(1+r)^2+800/(1+r)^3+800/(1+r)^4 = 3,335.89$

If this stream of earnings is running without ever diminishing, then it is effectively the same as a consol i.e. a perpetuity. It's present (i.e. market) value will be

$PV = A/r$ where A is the annual payout and r is the rate of interest. [to generate A dollars a year in annual interest you need to deposit A/r dollars initially]

If the interest were paid "on daily balance" we'd be getting closer to continuous time. In continuous time the interest is immediately added on a second by second basis as it accrues, and the PV of the stream would then be the sum of $800e^{-rt}$ for each of the five years : PV = $800e^{-0.1(1)} + 800e^{-0.1(2)} + 800e^{-0.1(3)} + 800e^{-0.1(4)} + 800e^{-0.1(5)}$
Strictly speaking the present value of the annuity would be:

$$PV = \frac{A(1-e^{-rt})}{(e^r - 1)}$$

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1. NON-RENEWABLES, MINING AND THE THEORY OF OPTIMAL DEPLETION

Imagine that you are the owner of a large asset portfolio, a part of which is large block of gold; a classic non-renewable resource. If you are a rational portfolio manager you will want to be sure that every asset of equivalent risk in your portfolio is earning the same return at the margin. If we assume that financial assets are riskless tax-free bonds, then our block of gold has to compete with the interest that these riskless bonds provide. All it can offer is the promise of rising gold prices in the future. Clearly the expected rate capital gain must match the rate of interest.

Let's now go a bit further. Imagine that you are absolutely certain of the gold price in a year's time. If the gap between that future price and the current price means that the gold price is going to rise at a rate greater than the rate of interest, then you will take cash and buy even more gold. So will every other investor, and the gold price will rise. As it does so the attractiveness of gold as an investment recedes. If the spot price rises high enough, gold will appear no better than any other asset, and should the price rise further, then you'll prefer to sell off some of your gold, and to buy bonds instead. This portfolio balance approach provides us with the major part of the theory of optimal extraction, the "flow" condition. The other portion of the theory simply requires that you can't sell gold that you don't have. Formally it is known as the "stock condition", and simply requires that you cannot mine more of a resource than you actually have available.

To formalise the argument let's make four assumptions:

- the resource market is perfectly competitive
- resource prices are exogenous
- there is a full set of contingent (futures) markets for the resource so that buyers and sellers have full knowledge of future prices (errors in the very distant future are not too problematic due to the effects of discounting)
- resource producers are profit maximisers trying to maximise the present value of their expected profit streams.

Let's now use conventional economics and try to optimise the extraction process.
In any year the extraction process will incur costs. If the average cost is c per unit, and the quantity extracted is Q units, then the total extraction cost will be cQ.
Of course the mine will also get revenue depending on the price (p) it receives per unit extracted. The total revenue will be pQ.
The profit in that year will be pQ - cQ

To optimise one wants to maximise the present value of the stream of profits that the mine will deliver, given, of course, that it can't sell more than it has under the surface of it's property.
i.e. maximise the present value stream:

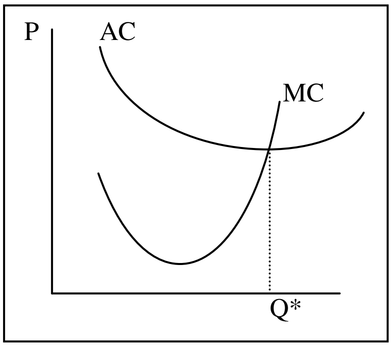
period zero	$p_0Q_0-c_0Q_0$
period one	$(p_1Q_1-c_1Q_1)\ 1/1+r$
period two	$(p_2Q_2-c_2Q_2)\ 1/(1+r)^2$
period three	$(p_3Q_3-c_3Q_3)\ 1/(1+r)^3$
.	. . .
.	. . .
.	. . .
period t	$(p_tQ_t-c_tQ_t)\ 1/(1+r)^t$

subject to: $Q_1+Q_2+Q_3+\ldots..Q_t \leq S$ where S is the available mineral stock.

Clearly the miner only has two variables to play with, the quantity he extracts in any period, and the time he wants his mine to last.

The first order condition of this optimisation is intuitively obvious; the discounted value of the profit earned must be the same in every time period. If the present value of extracting in say period 3 was higher than the PV of extracting in any other time period, them our miner would do he extracting in period 3.
The same intuition gives us a variation on this first order condition. This is the Hotelling flow condition that the profit in each time period should rise at the same rate, this being the rate of interest.

One could rephrase this and say that if we look at the problem backwards, starting on the last day of mining (T) on a site, and moving towards the present, the profit per unit of time will fall at the rate of interest. This leads us to the “terminal” condition.



One approach would be to ask; at the end of the extraction period (in period T), what profit should the mine be making? The conventional answer is to say that one should mine till the profit on the last unit extracted is just equal to the profit on the average unit extracted i.e. till MC=AC, on the diagram this would be when output per unit of time has fallen to Q*.
If this was not the case one would increase the value of the profits by moving resources towards (or away from) extraction on the last period.
This sometimes confuses students seeing it for the first time: remember that as output falls the price of the mineral rises, and the marginal profit rises (MR-MC), this merely asks what happens to the profit on the average unit (AR-AC). Under perfect competition MR=AR=Price, so marginal profit equals average profit when MC=AC.

One can show these results more formally, either using Lagrangean or Hamiltonian analysis.

Using Lagrangians. [there’s a really good two period example on pgs 15/16 of A.C. Fisher, Resource and Environmental Economics, CUP. 1981]

We have the net revenue function and the constrant already, let’s put them together and optimise:

$$L = \sum_{t=0}^{T} [p_t Q_t - c_t Q_t] \frac{1}{(1+r)^t} + \lambda(S -) \sum_{t=0}^{T} Qt$$

Or using continuous time maximise

$$\Pi = \int_0^T e^{-rt} [p_tQ_t - c_tQ_t].dt \quad \text{subject to} \quad \int_0^T Q_t dt \leq S$$

Using Hamiltonians. [again nicely done by Fisher, pgs 32-35]

$$H_{(t)} = e^{-rt}[p_tQ_t - c_tQ_t] - \lambda_t Q_t$$

Let’s turn this into a present value Hamiltonian:

$$\tilde{H} = [p_tQ_t - c_tQ_t] - \lambda_t Q_t - \mu_t Q_t$$

to maximize just take the derivative and set it equal to zero

$\frac{d\tilde{H}}{dQ} = 0$ => $p_t - c'(Q_t) - \mu_t = 0$

=> $\dot{\mu} - r_\mu = \frac{-\partial\tilde{H}}{\partial R} = 0$ where R is the mineral resource base left to the firm at any point in time.

=> $\dot{\mu}/\mu = r$

=> $\frac{d/dt\,[Pt - c'(Qt)]}{Pt - c'(Qt)} = r$ which is Hotelling's flow rule again.

i.e. the rent rises at the rate of interest.

This is fine if you are looking at the rationale of an individual firm which has a mineral deposit as an item on its portfolio. What happens in <u>the industry</u> as a whole though?

Assume N price taking firms in the industry.
R_i is the *i*th firm's reserves
$C_i(Q_{i(t)})$ is the *i*th firm's extraction curve
The market price of the resource is given by an inverse demand function:
$P_t = P(Q_t) = p\sum_{i=1}^{N} q_{i(t)}$

As we saw earlier, the firm's problem is to maximize

$\int_0^T e^{-rt}\,[p_t q_{i(t)} - c_i(q_{i(t)})].dt$ subject to $\int_0^T Q_t dt \le S$

we can now add as constraints that

$R_{i(0)} = S_i$ and $\dot{R}_i = -q_i$

Clearly the firm must know the prices in the near future, so a set of futures markets must exist.

Following Hotelling, one tries to show that in such a "competitive" situation the result will be socially optimal. In other words that the profit maximising firm will extract the ore at the rate that also maximises the discounted social welfare i.e. PV of the combined consumer and producer surpluses.
To simplify things lets get rid of the producer surplus by assuming a horizontal supply curve, i.e. that marginal cost is constant. The consumer surplus is now the area below demand and above MC. i.e. the demand curve is treated as a marginal utility function, so total utility is just its integral - the area underneath it.

If you want to find the socially optimal result you would then have to sum this over all firms (to firm i) and over all time till point T when mining in the industry ends, and discount, and maximise.

Maximise $\int_0^T [U(\sum_{i=1}^{N} q_{i(t)}) - \sum_{i=1}^{N} c_i(q_{i(t)})]e^{-rt}.dt$

i.e. maximise the PV of the difference between MU and MC over time and over all firms.

subject to $R_{i(0)} = S_i$ and $\dot{R}_i = -q_i$

clearly this will fit in perfectly with Hotelling's rule. In a world free of income effects, marginal utility (the Hicks Demand Curve) coincides with the Marshallian Demand Curve. If you're maximising the present value of the net utility above, then you're also maximising the PV of profits in the industry.

2. THE OPTIMAL TIME PATH OF EXTRACTION

Assume a mineral demand curve $P_t = Q_t^{-\alpha}$
(note that this is not a linear demand curve, but an iso-elastic one instead. The intuition of the result that follows is thus automatically clear. A given (i.e. fixed) % change in Q always yields a constant % change in P. If P is to rise at the interest rate (r%) then Q must be falling at the same rate if the elasticity is one at all points, at a faster but constant rate if the demand is elastic etc. The fall in Q needed to achieve an r% decline is getting smaller in absolute terms, while the rise in P needed to achieve its fixed % rise is increasing in absolute terms. The price path is thus growing exponentially and the time path of output is falling asymptotically. This would clearly not be the case with a normal straight-line demand curve.)
Remember that Hotelling's rule strictly speaking refers to the rent earned by a unit of a resource, or to the price that the resource could be sold for while it's still under the ground; nonetheless it tells us that this price rises at a rate equal to the rate of interest. What it doesn't tell us is what the starting price is!

i.e. $P_t = Ae^{rt}$ though we don't yet know the value of A

From the demand function we know that

$$Q_t = P_t^{-1/\alpha} = Be^{-rt/\alpha}$$

In other words if one can just get rid of this arbitrary constant B, one has worked out the quantity being offered in the market at any point in time. To get rid of B, just go back to the stock constraint S. You know that the stock of the mineral will be exhausted at some point. Ideally this will be on the day that the demand for the mineral ceases as the price hits its upper limit; the choke price. This means that the sum of all extraction over time will ideally just equal the stock. One can then work backwards to get the time path of extraction as follows:

$$\int_0^\infty Be^{-rt/\alpha}.dt = S$$

$$\Rightarrow B\int_0^\infty e^{-rt/\alpha}.dt = S$$

$$\Rightarrow B(\frac{-\alpha}{r})(0-1) = S$$

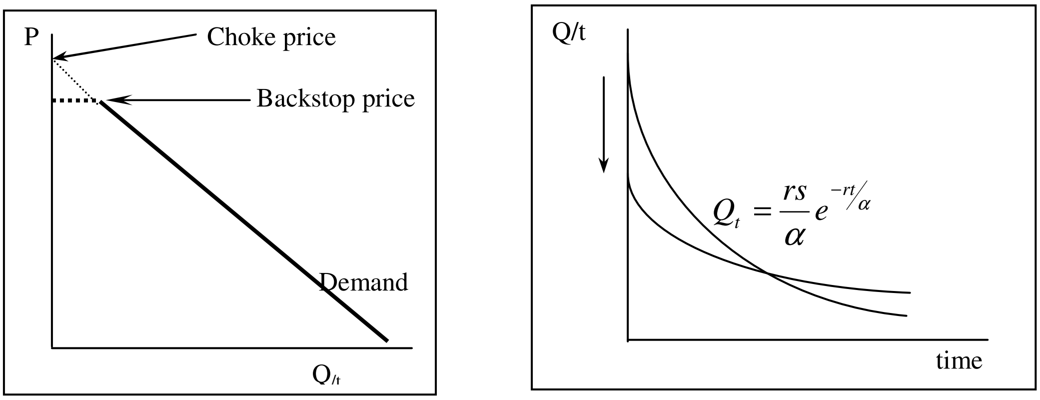
$$\Rightarrow B = \frac{rs}{\alpha}$$

$$\Rightarrow Q_t = \frac{rs}{\alpha}e^{-rt/\alpha}$$

This tells us that the time path of extraction is determined by the rate of interest and by the choke price. The current price and volume of extraction are similarly determined by these, and by the stock of the resource currently available given existing technologies of extraction.

Many texts add that there is likely to be a backstop technology or substitute material available which will come into the market at a price below the apparent choke price. i.e. the demand curve appears truncated before the intercept on the vertical axis. This means that the resource should be completely extracted sooner than would be expected on the basis of a simple demand curve.

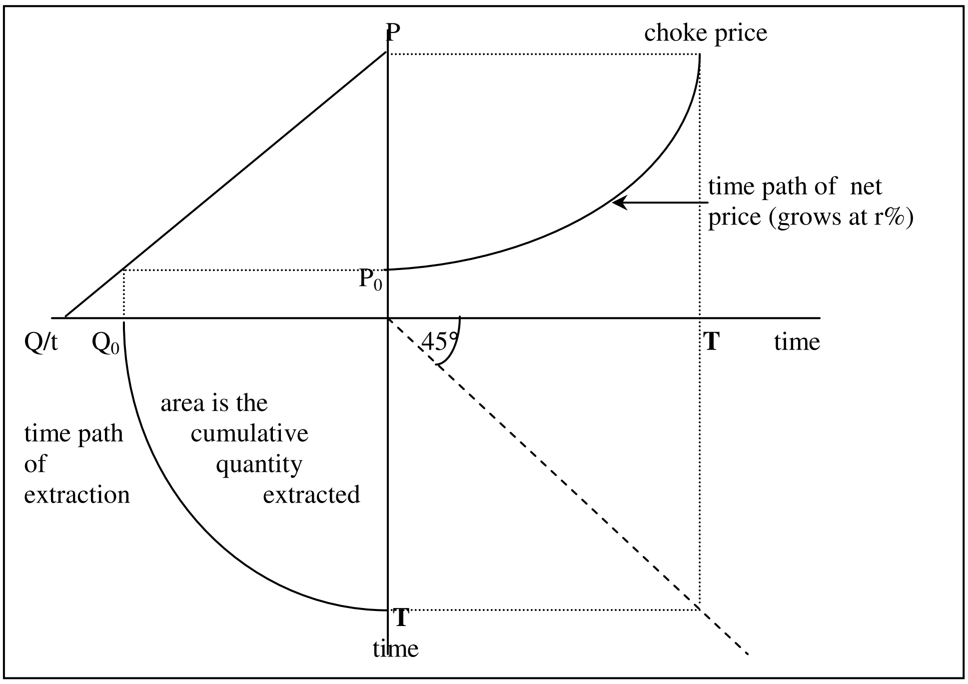
The impact of a backstop technology and associated lowering of the effective choke price, is shown in the diagram below, simplified here to allow for a straight line demand curve



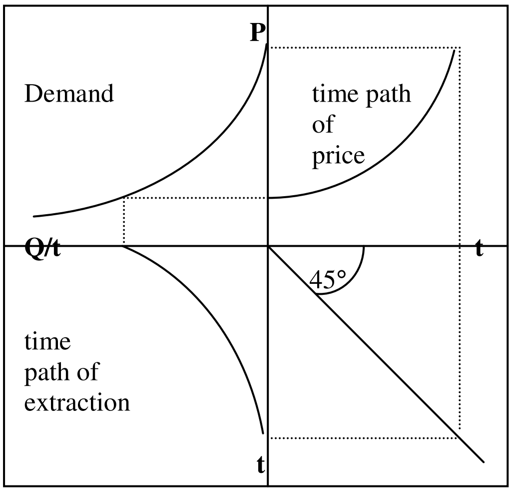
Market demand effect of backstop technology on extraction path

We will now try to explain the intuition that underlies the result we've just seen. A very simple approach is given by Pearce and Turner and provides the basis for what follows:

It uses a four quadrant diagram to link prices, interest rates, extraction and time. Begin by taking a simple **demand** curve. This links price and quantity demanded in any time period. For convenience it is drawn as a mirror image in the top left quadrant. The top right quadrant shows the resource **price** in relation to time. Note that if we think of this as the market price we are misrepresenting Hotelling; strictly speaking it's the price of the unextracted ore, which is the same as the rent that mining it can generate. Following Hotelling's law, we expect this to rise at the rate of interest. The bottom left hand quadrant is just a 45° line to help get around a corner. The last quadrant shows the time path of extraction, i.e. how much has to be taken out in each period of time. At any point in time i.e. at any point along the extraction curve, the area between the path and the axes of the diagram is the cumulative amount that has been extracted.



What the diagram shows is that , assuming low and constant extraction costs, for net price to be rising exponentially, the quantity extracted must be falling at an increasing rate.

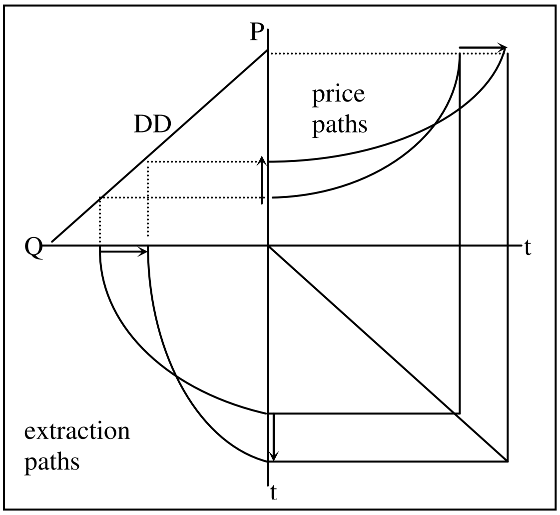


With the iso-elastic demand curve used in the example earlier, the diagram would take on a different shape. This is the shape more commonly seen on diagrams in text-books, it must be remembered that it is a special case!

To check your intuition, ask what happens if:

a) extraction costs rise
b) interest rates rise

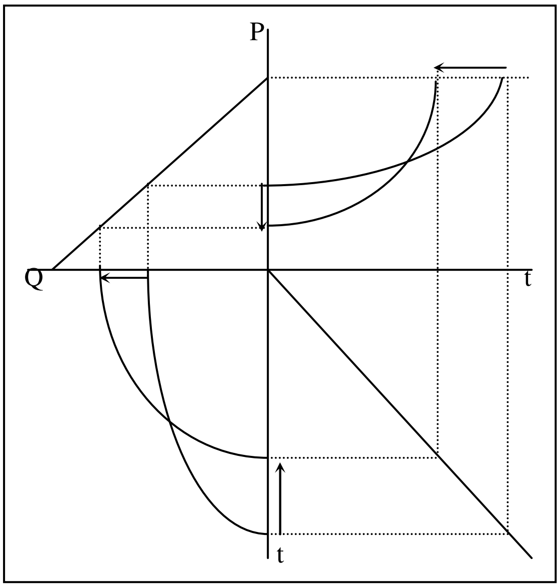
a) First of all ask; 'has the amount of the resource available changed? Clearly not, so the quantity extracted by the time mining ends should be unchanged, and the total area under the quantity function should be identical. Has the interest rate changed? No, so the rent should carry on rising at a rate of r%. Can these two be achieved simultaneously?



Effects of increased extraction costs

The area under the quantity path Remains unchanged, as does the area under the price path. What is happening? Is Hotellings law failing? Remember it is the **rent** that should be rising at a rate of r%. When extraction costs go up, ceteris paribus the rent goes down. The profitability of mining falls, miners have less incentive to extract ore at current prices so market supplies drop and consequently mineral prices rise. This will restore some, but not all, of the rents from each unit of ore extracted. This reduced rent will still be increasing at a rate of r%, but althought he costs are up, and the price of the ore on the market is up, the rent itself has fallen, so the increases are less in absolute terms. This explains the flattening of the price line and the lengthening of the extraction path.

b) An increase in the interest rate is intuitively simpler. Let's simplify to the extreme and assume costless extraction. The price is now equal to the rent. If the rent is to rise at a rate equal to the new interest rate, then it must slope up more steeply. But remember the stock constraint – you can't mine ore you don't have, and you don't want to leave any saleable ore behind when you finish.

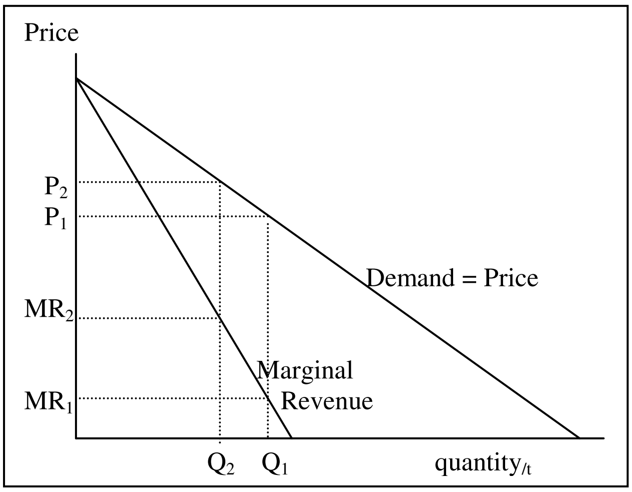


Effects of a rise in interest rates

If the present price of ore didn't change, but the slope of the price path increased, the price would reach the choke point while un-mined ore was still in the ground! The miner must therefore extract More ore now, the present price will fall, there will be less available in the future and prices will consequently rise faster over time.

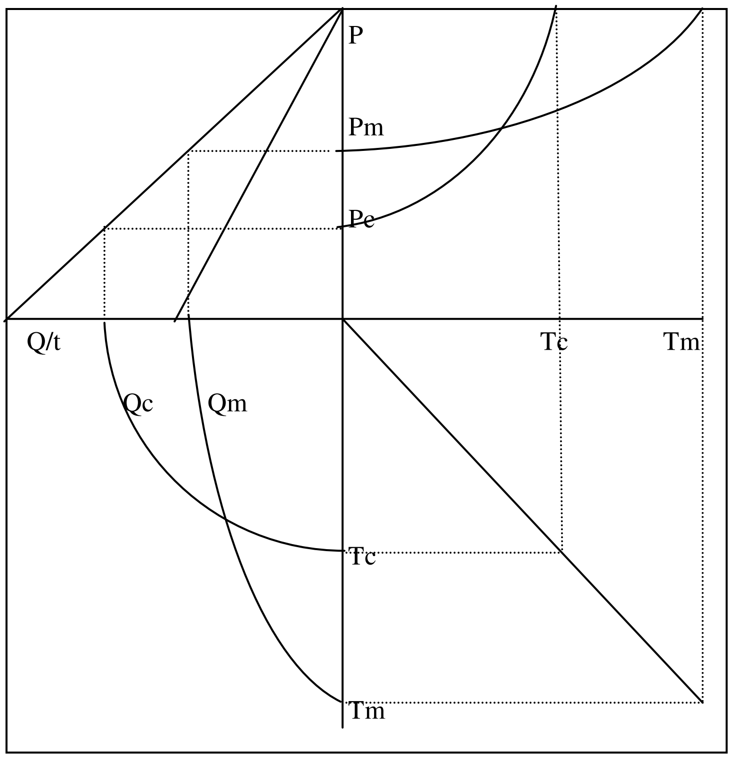
3. THE EFFECTS OF MONOPOLY

Till now we've assumed that the market was competitive, rent was therefore the difference between the price of any unit of a mineral and the marginal cost of extracting it. This changes once we have a monopoly: the rent or marginal profit, is now MR-MC since the monopolist changes the price of the product whenever he alters the quantity he puts on the market.



Let's look at the implications of this for the monopolistic producer. As the diagram shows, the MR curve lies below, and is generally steeper than the demand curve. A given decline in quantity therefore causes a larger percentage increase in rent for a monopolist than for a competitive producer. To show this simply assume a straight line demand curve and costless extraction. A drop in production from Q_1 to Q_2, causes prices to rise from P_1 to P_2, a relatively small increase in percentage terms, while the increase in marginal revenue is MR_1 to MR_2, a relatively large increase in percentage terms. If this were a competitive world, the interest rate would have to equal the percentage change in the rent i.e. $\frac{P_{t+1} - P_t}{P_t} = r$ in our example this would be the percentage increase in price from P_1 to P_2.

If it were a monopoly and the interest rate were the same, the increase in rent would still have to equal the interest rate, but since the rent in the initial time period would be MR1, a drop in production to Q2 would give a percentage increase in rent far larger than needed. In terms of the four quadrant diagram we've been using, we see that the monopolist extracts at a much slower rate, and since he will still want to extract all of the resource (he faces the same stock constraint) the extraction will be over a longer period of time.



A good references is: Devarajan and Fisher JEL, 1981

An important caveat is that the simple result whose intuition is given above, is not universally true. At a pure theory level monopoly does not necessarily help those searching for the key to sustainability in mining. This is seen by solving for the optimal path of a monopoly where the demand function for the mineral is isoelastic.

E.g. assume that the inverse demand function for a mineral is:

$$Q = P^{-1/\alpha}$$

compare the price path under monopoly and under competition.

First let's recap: under Hotelling's law, the percentage change in the mineral rent equals the interest rate. In a world of costless extraction, this would be the percentage increase in that mineral's price per unit extracted. In a competitive market,

if MC = 0, then $\frac{1}{P}.\frac{dP}{dt} = r$

since $P_t = P_0 e^{rt}$

=> $Q_t = (P_0 e^{rt})^{\frac{-1}{\alpha}}$ if we call $P_0^{-1/\alpha} \longrightarrow$ B

then

$$Q_t = Be^{\frac{-rt}{\alpha}}$$

it would now be standard to use the stock constraint to do the solving: i.e. say that by the last day of extraction in time T, the sum of extraction must be less than or (ideally) equal to the current stock of the resource in the mine.

i.e. $\int_0^T Q_{(t)}.dt = S$

and then simply substitute back. BUT…look at the demand curve, being isoelastic it's an asymptote and doesn't ever cut the axes. There is no time T when the resource is exhausted, instead depletion continues in perpetuity, though eventually at infinitesimal rates. We therefore write our stock equation back as:

$$S = \int_0^\infty Be^{-rt/\alpha} = B\int_0^\infty e^{-rt/\alpha} = \left[\frac{e^{-rt/\alpha}}{-r/\alpha}\right]_0^\infty = \frac{-B\alpha}{r}(0-1)$$

Since B = $\frac{rs}{\alpha}$

$$\Rightarrow \quad Q_{(t)} = \frac{rs}{\alpha}.e^{\frac{-rt}{\alpha}}$$

Let's compare this to the monopoly result.

Recall that under monopoly if MC = 0, $\frac{1}{MR}.\frac{d(MR)}{dt} = r$

Since TR = PQ => TR = $Q^{-\alpha}Q$ = $Q^{1-\alpha}$
=> MR = $(1-\alpha)Q^{-\alpha}$ = $(1-\alpha)P$
=> $\frac{1}{(1-\alpha)P}.\frac{d(1-\alpha)P}{dt} = r$

since the (1-α) cancels, one is left with

$\frac{1}{P}.\frac{d(P)}{dt} = r$ This is identical to the competitive result!

Does Hotellings's Law hold in the Real World?
Looking back at the assumptions behind Hotelling's model, it's clear that it refers to an abstract hypothetical state. The first real attempt to evaluate the depletion issue and its impact on prices was Barnett and Morse (1963). More directly linked to Hotelling were Slade (1982) and Halvorsen and Smith (1991). A first class survey of this literature is provided by Berck in Bromley [Ed] (1995). See also p25

4. MINERALS AND MINING IN PRACTICE

There are a number of good books on this side of things, but few that purport to be economic. One worth starting on (now a bit dated, but still very good) is:
Judith Rees, Natural Resources, Allocation, Economics and Policy (2nd ed). Routledge, London. 1990.
A number of points stand out: the first is that the effective cost of mining has to include costs of extraction, refining and marketing a mineral.

Clearly some aspects of these will be self-driven: e.g. the speed with which a deposit is mined will be linked to the average cost of mining it; others are driven by factors beyond the control of man such as the depth and quality of ore bodies. Two local examples will give an indication of physical factors that standard economic models of mining do not capture. In South Africa many reefs are neither horizontal nor vertical, but slope gently downwards. Mining means following a reef and hauling up the ore. This is easy on a vertical shaft, or in following a seam horizontally. The costs rise sharply, however, if one has to mine and haul ore on a slope. A second case is the problems encountered in Zimbabwe mining platinum on the Great Dyke. This is a miner rich ridge that runs like spine down the country. Though rich, much of the Dyke is fragmented and tricky to mine. Despite high Platinum prices, mining was stopped, largely a result of technical difficulties unanticipated by the company.

In reality, however, provided a suitable ore body is present, it is problems such as security, labour uncertainty, poor transport and communications infrastructure and unreliable electricity supplies that raise the real cost of mining and reduce the rewards to it.

The effective cost of mining is further influenced by such policy issues as taxation and licensing restrictions, prescribed worker benefits, availability of skills and environmental regulations.

Over time both demand for a resource and the cost of extracting it are also driven by the technology available. Indeed this often defines in the first instance whether a mineral is a resource or not. The end of the stone age came when the new technology of metal smelting reduced the status of flint and obsidian from resources to merely stones. At the same time it raised malachite from a pretty rock to an economic resource, the source of copper. In more recent times, the technology for the electro-smelting of aluminium gave potential value to bauxite, though this value was only realized when cheap bulk electricity became available. The arrival of cheap aluminium in turn significantly reduced the market for copper. By influencing both the demand (i.e. the price consumers are willing to pay) and the supply (i.e. the extraction cost producers are able to incur while remaining viable in the long run) of minerals, technology effectively drives the extent of economic reserves for any mineral resource.

This leads us to the first practical problem: how to define the level of reserves available? A number of approaches have been used over time, but one which has the advantage of being clearly defined and internationally understood is that used by U.S. Government's Bureau of Mines and referenced by Fisher (p94). This usage provides the following definitions:
"reserves" are the known amounts of a mineral that can be profitably produced at current prices and with current technology. New discoveries and new technologies (as well as changes in demand that are reflected by changes in the price of the product, can influence the extent of economic reserves. These are the stocks of the resource sometimes known as its "proven reserves". As the degree of knowledge of the precise dimensions of the ore body diminishes, so one moves to indicated and then inferred reserves. The extent of the proven reserve of a mineral may be influenced in other ways than via demand and supply. Thus a tax system which imposes a royalty on proven but unexploited reserves, leaves miners with an incentive not to confirm reserves that are believed to exist.

TOTAL RESOURCES

	IDENTIFIED			UNIDENTIFIED	
	DEMONSTRATED		INFERRED	HYPOTHETICAL	SPECULATIVE
	MEASURED	INDICATED			
ECONOMIC	proven reserves	'measured' reserves			
SUBECOOMIC	'paramarginal' or 'conditional' reserves				

5. TAX AND MINING

The evolution of the South African Economy from being mineral and agriculture based to its present service and manufacturing focus allows a measure of latitude in the way mineral extraction is taxed. Clearly this was not always the case, and such latitude is not feasible in the mineral based economies of the region. We will go on to look at the implications for monetary and fiscal policy of being resource dependant. First, however, let's look at taxes alone.

5.1 Features of South Africa's Mining Tax System

1) Capital expenditure allowance
   This allows the immediate write-off of capital expenditure for tax purposes (rather than requiring that capital expenditures be written off over time) the result is to additionally encourage investment in new capital and new shafts when mineral prices are high.

2) Capital allowance
   Firms are allowed to recover the cost of their capital expenditure *plus* interest before being liable for tax.

3) Non-gold mining: tax = 40% (as in regular companies) + 15% tax on distributed earnings (Again induces increased investment when prices are high).

4) Gold Mining Formula %tax payable = $A - \frac{AB}{X}$

[A and B are set as policy constants and X is the profit/revenue expressed in %]

If secondary tax on companies is paid on declared dividends (@ 12.5%) the value of A and B are 37 and 5

i.e. % tax rate = $37 - \frac{37x5}{X}$ = 37 – 185/X

Alternatively if no STC is paid A=46 and B still 5.

i.e. % tax rate = $46 - \frac{46x5}{X}$ = $46 - \frac{230}{X}$

The impact on the ore grade mined can be seen by using an example.

Say that 90 of mine revenue is used up as costs, and 10% of gross mine revenue is profit, i.e. X = 10, then the mine is paying tax at a rate of [46 – 23]% = 23%

If the gold price rises so that profit becomes 20% of mine revenue, the tax rate becomes [46-11.5]% = 34.5%

The tax rate is equal to that paid by normal companies (40%) when X = 38.

If the gold prices rises, a mine can keep its marginal tax down by mining a lower grade of ore. This lengthens the life of the mine, but does so at the expense of other taxpayers!

To get the system into historical perspective a very good article is Kotze, R.M. The South African Gold Mining Position. *SAJE* vol 1. 1933. p133-146.

6. OPTIMAL GROWTH, SUSTAINABILITY AND EXHAUSTIBLE RESOURCES

Hotelling's contribution was to show that a profit maximising mine in a competitive market would extract ore at a rate that was not just privately, but also socially optimal. This result was in line with a neo-classical tradition that began with Jevons, Menger and Walras in the 1870s. Where Hotelling differed was in introducing time. They had talked about the optimal allocation of a given resource at a point in time, he now introduced the allocation of such a resource over a period of time. He did not, however, introduce the idea of optimal growth, merely of optimal extraction! It was only when the first neoclassical growth models were introduced by Solow and by Swan some thirty years later, that neoclassical economics returned to the issue of growth which had been the major concern of classical economists like Adam Smith ,David Ricardo and (importantly for resource economics) Thomas Malthus.

Resource Economics began to translate Hotelling's work into a dynamic growth framework in the 1970s, partly as a result of the somewhat Malthusian "doomsday" literature which began to appear in the late 1960s and early 1970s. The Club of Rome Report (Meadows and Meadows – Limits to Growth, 1972) is normally cited as the classic work of this genre. Like Malthus's original work, it didn't recognise the potential of the modern market to react to resource shortages. It was not as ingenuous a model as sometimes suggested: certainly it did not just extrapolate past resource consumption trends, but used a system of feedback loops. It argued that with continued population growth, output per capita in the 21st century would fall. Importantly it was aggregative in style and did not use a system of changing prices and input substitution. This was where many neo-classical economists found fault with it.

One has to be careful not to write off all neo-Malthusian resource writings: some, especially those by Boulding, Rosenstein-Rodan and Daly, which have been immensely influential, indeed it was these that gave rise to modern Ecological Economics. It shouldn't be surprising, however, that Solow was one of the first writers to concern himself with the significance of apparently fixed resource stocks for growth models which had typically assumed that infinite input flows would be available. It was from these concerns that the modern neo-classical notion of economic sustainability emerged. A notion that has been heavily challenged, but one that remains powerfully influencial.

Let's begin (as Hotelling did) with the issue of utility. If we have a Hicksian demand curve *(i.e. one in which there are no income effects and consequently demand is identical to marginal utility and the marginal utility of money –which is a numeraire- is constant)* then total utility is the area under that demand curve. That utility is maximised under perfect competition. More precisely, the competitive result will be socially optimal given two provisos: there are no externalities, and the discount rate that drives the behaviour of the mine owner happens to be the social rate of discount.

There are thus three clear lines that need to be developed:

- choosing the discount rate
- choosing a welfare function
- extending the model to include the production of final goods from a mix of exhaustible natural resources and reproducible factors including reproducible capital.

6.1 Discounting

The selection of discount rates is treated in a lot of detail in most Cost-Benefit Analysis textbooks, [a somewhat broader view of some issues is also found in Fisher (1981) p67-74].

The key issues involved are as follows:

- the rate of interest is determined through the policy decisions of the reserve bank and government. It does not reflect the demand and supply of loanable funds.
- Depending on currency and period of loan one observes not one, but rather a set of interest rates operating in international financial markets at any point in time.
- The operation of taxation drives a wedge between the private opportunity cost of capital and the rate of interest
- The uncertainty facing an individual, and that facing an economy, will necessarily differ. New technologies may leave existing resources worthless. Moreover, the individual is mortal.
- private time preference may be treated as irrational myopia. On the other hand if a rise in income is expected, MU income would be expected to fall, generating a premium on current consumption

one could also suggest that the whole practice of discounting may be untenable, for example where:

- uncertainty about future preferences means a risk averse decision maker may want to cover all bases and be unwilling to sacrifice future options
- if income rises are expected, and environmental goods are income elastic, then a premium not a discount should be attached to them.
- Ideas of intergenerational justice may seem to preclude discounting

[The last-mentioned problem can be sidestepped by simply introducing a sustainability constraint into all project or policy analysis: i.e. a requirement that the welfare of future generations should not be diminished by a project or policy. In a neoclassical world in which capital can be aggregated and is always valued at its MRP, this is not difficult, one simply maintains the value of the total capital stock (natural plus man-made) – in other words all one needs is a policy in which new investment at least offsets depletion and depreciation in the entire capital stock]

6.2 Welfare functions

Given that welfare depends on consumption, and that consumption depends on production, which in turn depends on the use of inputs, it seems sensible to begin with both a production function and a utility function.

The production function will be the conventional general form, but will only show two forms of capital, reproducible (man-made K) and exhaustible (natural) capital R.

→ Y = f(K,R)

One now wants to find the optimal output path and use of inputs over time.
The idea of optimality requires that we introduce a social welfare function and try to maximize it, in this case:

Maximize $W = \int_0^\infty e^{-rt} U(c_{(t)}).dt$

Subject to: saving = investment = output minus consumption
And to the change in the resource stock in any time period being equal to the amount of the resource actually used in production.

i.e. $\dot{K}_{(t)} = f(K_{(t)}, R_{(t)}) - C_{(t)}$ and

$\dot{S}_{(t)} = -R_{(t)}$

This conventional utilitarian approach follows a method named the Ramsey Model, but with the original approach modified to include natural resources. It therefore gives a variation on the conventional *Ramsey Rule* [the essence of which is that if one wants to get to a 'bliss point' in the future a bit faster, one has to save more now, i.e. give up some current consumption. Optimal saving is reached when the marginal benefit of speeding up convergence to the bliss point is just equal to the marginal current disutility of doing so.]

The state variables, i.e. those in terms of which the model is described, are K and S. The control variables are C and R.

One now sets up the Hamiltonian:

$$H = e^{-rt} U(C_{(t)}) + \lambda[f(K,R) - C] - \mu R$$

The four first order conditions are:

$$\partial H / \partial C = 0 = e^{-rt} U'(C_{(t)}) - \lambda \rightarrow eqn.1$$

$$\partial H / \partial R = 0 = \lambda \frac{\partial f}{\partial R} - \mu \rightarrow eqn.2$$

$$\dot{\lambda} = -\partial H / \partial K = -\lambda \frac{\partial f}{\partial K} \rightarrow eqn.3$$

$$\dot{\mu} = -\partial H / \partial S = 0 \rightarrow eqn.4$$

from eqn. 1 we can extract λ and its time derivative:

$\lambda = e^{-rt} U'(C_{(t)})$ *the time derivative of which is:*

$$\dot{\lambda} - re^{-rt} \frac{\partial U}{\partial C} + e^{-rt} \frac{\partial^2 U}{\partial C^2} . \dot{C}$$

substituting λ for $\dot{\lambda}$ in equation 3 we now get:

$$-re^{-rt} \frac{\partial U}{\partial C} + e^{-rt} \frac{\partial^2 U}{\partial C^2} . \dot{C} = -e^{-rt} \frac{\partial U}{\partial C} . \frac{\partial f}{\partial K}$$

$$=> \frac{\partial^2 U / \partial C^2 \, \dot{C}}{\partial U / \partial C} - r = \frac{-\partial f}{\partial K}$$

Since $= \frac{\partial f}{\partial K}$ is the rate of growth in the marginal product of man made capital, the above equation is stating the Ramsey "Optimal Savings" rule. This is important since it can be shown to be an analogue of Hotelling's law and it will form the basis for the sustainability arguments of Solow and Hartwick:

from equation 2 and equation 3:

$$\lambda\frac{\partial f}{\partial R}-\mu=0$$

and

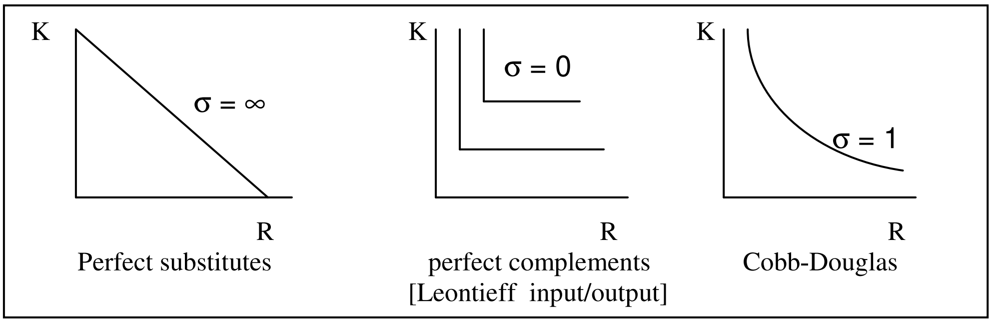
$$\frac{\frac{d}{dt}\left(\partial f / \partial R\right)}{\partial f / \partial R}=\frac{\partial f}{\partial K}$$

We now want to see how the exhaustible natural resources (R) fit into the production process and the search for a sustainability rule.
The first thing one needs to do is assume that there is no upper bound to the average product of the natural resource. If there is an upper bound to the average product of natural resources, then one can't use the substitution of K for R to keep up the level of output.

This is one reason for the popularity of Cobb-Douglas production functions in this section of the literature.
For instance, take a CES production function:

$$Y=[\delta K^{-\rho}+(1-\delta)R^{-\rho}]^{-1/\rho} \qquad \text{where } 0<\delta<1 \ ; \ \rho>-1 \ \& \ \sigma = 1/(\rho+1)$$

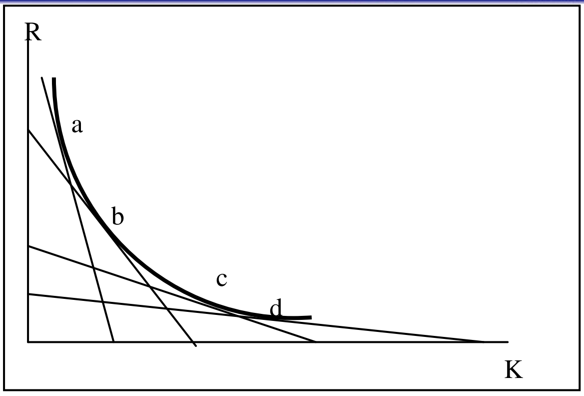
the elasticity of substitution (σ) measures the sensitivity of the factor input ratio to a change in the slope of the isoquant. In the Cobb-Douglas case $\sigma = 1$!



If $\sigma > 1$ then $\rho < 0$ and the isoquants will necessarily cut the axes. This means that either of the inputs can be non-essential: one can produce without one of them if need be. This would make the sustainability problem trivial and this possibility is therefore normally excluded by assumption.

[Of course our historic experience is that many natural resources have become non-essential, no matter how central their place in the economy may have been.]

One can also show that the average product of the natural resource will be upper bounded if $\sigma < 1$ i.e. $\rho > 0$, in this case the neo-classical approach of substituting one factor for another cannot be guaranteed to keep output from eventually falling, unless more complex assumptions are made.
The simple solution for the neo-classical theorist is therefore to use the Cobb-Douglas production function



You may want to look at the intuitive implications of this assumption: initially production is at point a on the isoquant. As the amount of the natural resource available declines, so the use of man made capital increases, and the relative prices of the two factors change: the relative price of natural capital rising as shown by the changing slope of the isocost. Production moves to point b, then to point c and eventually on to d. Note that the slope of the isoquant at each point is the ratio of the marginal products of the two factors. So long as opportunities for substitution continue, output need not fall. The asymptotic shape of the Cobb-Douglas isoquant is thus the key to the issue.

6.3 What Form Does the Utility Function Have to Take?

Most of the key seminal works into sustainability appeared in a special symposium issue of the Revue of Economic Studies in 1974. Two of these will be focused on, DasGupta and Heal's ('The optimal depletion of Natural resources'), and Solow's. The former very briefly, the latter in more detail. They are selected as they represent two common approaches to the issue of sustainability, non-declining utility, and non-declining consumption; approaches that we will see coming up more extensively when we look at sustainability and the practice of national accounting!

DasGupta and Heal's model was utilitarian in approach, using a marginal utility function with a constant elasticity:

=> $-c\frac{u''(c)}{u'(c)}=\eta$ where η is constant and strictly positive

the problem was that their model showed consumption falling over time. This presented a problem from the perspective of intergenerational equity.

ELAB ON THEIR APPROACH

By contrast Solow took a Rawlesian approach, splicing it onto an intergenerational model to guarantee equity over time. i.e. his model tried to maximize the welfare of the worst off generation in foreseeable time. i.e. maximize welfare where
$W= \min[U_1,U_2, U_3, \dots U_t]$ where U_1 is the welfare of generation 1 etc.
Implicitly this means the discount rate is zero since consumption must be constant over time (if it isn't then clearly the welfare of the worst off generation could be increased by redistribution!)

Solow used a simple Cobb-Douglas production function in which natural resources have been included as a factor of production.
$Q = L^gR^hK^{1-g-h}$
As mentioned, this means that the natural resources are necessary, even if in very low quantities.

If population growth is zero clearly consumption per capita is also constant. Also, very importantly, even if there is no technical progress, a finite initial stock of the natural resource can keep output positive over time provided the elasticity of output with regard to man made capital is greater than the elasticity of output with regard to natural resources, i.e. $(1-g-h) > h$

This early model of Solow's had some important policy implications and some interesting theoretical ones: First of all it indicated that sustainability would be impossible if populations were growing without matching technical progress since sustained positive consumption could not be maintained. Secondly one can infer from it that, where population is constant, but there is technical progress, a Rawlesian allocation of resources will not be appropriate … the current generation is entitled to a larger slice of the available resource base.

One now asks: what theoretical policy would such an economy have to follow to achieve sustainability? This was the question answered by Hartwick (AER 1977) in a short article that introduced the "Hartwick Rule" for sustainability.
The answer to the question was already implicit in Solow's RES article; *all net returns from non-renewable resources should be reinvested in renewable capital*.
The key feature of his work, however, was that the result was achieved without having to use a Cobb-Douglas production function or an assumption of zero extraction costs, i.e. Hartwick's result is generalisable.

He begins with a simple identity

$$C \equiv Q - I$$

and then uses the general form of a production function that only involves a depletable natural resource (R) and a man-made natural resource (K) to rewrite it as:

$$C_t = F[K_{(t)}R_{(t)}] - \dot{K} \qquad (1)$$

we know that in a competitive economy man made capital is employed till its marginal product equals the interest rate. We also know that the demand and hence the price of natural resources is a derived demand, their price rises with their marginal productivity and with the price of the goods they produce. If the latter is constant, then, from the equi-marginal principal (and of course Hotelling)

$$\frac{\frac{d}{dt}\left(\frac{\partial F}{\partial R}\right)}{\frac{\partial F}{\partial R}} = \frac{\partial F}{\partial K} = r \qquad (2)$$

the aim is to see if a consumtion path can be found in which consumption does not decline, i.e. where $\dot{C} \geq 0$
Assume that Hartwick's rule holds, i.e. the output generated as a result of natural resource depletion is all invested in man made capital:

$$\dot{K} = R\left(\partial F / \partial R\right)$$

By taking a time derivative of equation (1) we see that

$$\dot{C} = \left[\frac{\partial F}{\partial K}\dot{K} + \frac{\partial F}{\partial R}\dot{R}\right] - \ddot{K} \qquad (3)$$

where

$$\ddot{K} = \dot{R}\frac{\partial F}{\partial R} + R\frac{d}{dt}\left(\frac{\partial F}{\partial R}\right) \qquad (4)$$

if one subtracts (4) from (3) then

$$\dot{C} = \frac{\partial F}{\partial K}\dot{K} + R\frac{d}{dt}\left(\frac{\partial F}{\partial R}\right) \qquad (5)$$

so that, if equation 2 holds

$$\dot{C} = R\left(\frac{\partial F}{\partial K}\frac{\partial F}{\partial R}\right) - R\frac{d}{dt}\left(\frac{\partial F}{\partial R}\right) = 0$$

which satisfies the sustainability objective: this is a non-declining consumption path!

A lot has been written about the Hartwick rule and its relevance, two papers are really worth reading though, Solow (1986) and Dixit et al (R.E.Studs. 1980 p551-556)

Solow (Scandinavian Journal of Economics, 1986) is important for the way it leads into practical sustainability: he shows that keeping to the Hartwick rule means that the total capital base (man made plus natural capital) is being held constant. In a Cobb-Douglas world, keeping the total capital stock constant, but allowing the blend of capitals within it to change, does not affect output. Sustainable consumption is then consuming the "interest" on total capital while leaving the principal intact.

Solow's paper, and the comments on it by Maler and by Svenson, anticipates the question asked by Dixt et al.
is the Hartwick rule sufficient or merely necessary for sustainability?

7. SUSTAINABILITY AND NATIONAL ACCOUNTING

[some standard references on the practical side of sustainability are:
Ahmad Y, El Serafy S. and Lutz E. (eds) *Environmental accounting for sustainable development*. World Bank 1989.
MunasingheM. And Shearer W. *Defining and Measuring Sustainability*. W.B. 1995
Pearce DW and Atkinson G. Measuring Sustainable development. In Bromley D. (ed) *Handbook of Environmental Economics*. Blackwell. 1995]

Neoclassical economists thinking about sustainability normally refer at some stage to Hicks's definition of income. It fits very neatly into the approach described by Solow in the 1986 article described above so it makes a suitable place to begin. Hicks says that ones true income in any time period is the increase in ones stock of wealth after depreciation. Income is the first derivative of wealth. This idea is captured in the definition of national income within the national accounts. It explains environmental economists' interest in the proper calculation of real NNP.

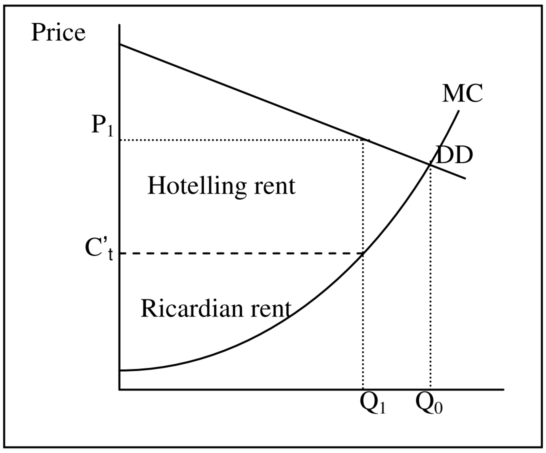
To see the significance of this let's compare two firms, one a widget maker, buys in raw materials and processes them. In doing so it uses up its store of materials and also wears out its machines. For production to be sustainable these must both be replaced. The firm's sustainable income will be its revenue minus its running costs in the period, minus the amount it has to spend to restore its stock of capital (the material inputs used up and machines worn out during that production period). Note that this need not be the same as profit! The emphasis is on the firm being able to do in the next time period just what it did in the period just past, once this requirement is satisfied one asks how much profit there is, and this amount then becomes sustainable income. The firm's contribution to the national income should be this amount, plus the amount it has paid out to its workers or any other owners of factors of production involved in widget manufacture.
The second firm in our example is a mine. How can a mine achieve a sustainable income? The simple way is pointed to by Solow and Hartwick; it takes some of its profits and reinvests them elsewhere. So what is the "sustainable income" of such a mine? Remember that a mine's central asset is a stock of ore. This is extracted and sold. For simplicity assume that extraction costs are

zero. Is the mine's profit then simply equal to its revenue? Not if we follow Hicks's definition of income! The firm is literally selling off the family silver and nothing more. The ore is an asset, the asset is being turned from its natural form into cash, but this is a change of form only, no value has been added yet! The stock of wealth is differently constituted, but it has not increased, therefore income is zero. If we drop the assumption of costless mining then the firm is adding value to the ore during the extraction process. The value of the ore sold is greater than that of the ore before it was extracted. This value added will be spread between the owners of the factors of production involved, and will constitute income to them. Only this amount should be captured in the national income.

If one takes the Hicksian view that sustainable income is the return on natural resources after the stock of wealth has been left non-declining. Extracted resources are converted to cash and held as financial assets yielding a return. Those return then providing the basis for sustainable consumption. In these terms sustainable consumption (c_t) is the return on wealth (W_t)

$$c_t = \frac{r}{1+r} W_t = \frac{r}{1+r} [W_{Rt} + W_{Ft}]$$

The sustainable consumption depends on the present value of all current and expected future resource extractions. In theory, the actual current resource rent only matters as a contribution to this flow!



Because the firm is a mine it does not produce output Q_0 where MC=DD, but output Q_1 where there is a Hotelling rent. The implication can be seen in the diagram alongside, where we now assume that there are positive extraction costs. The Ricardian rent is distributed as conventional profit, the Hotelling rent is the amount that has to be reinvested according to Hartwick's rule. (C'_t is the marginal cost in period t. See Brekke K.A. *Economic Growth and the Environment*. 1997)

The "gross" statistics commonly used in national accounting (GDP, GNP etc) have numerous deficiencies as measures of a national economy. They have even more deficiencies when used as surrogates for national welfare (one of the best known papers on this is Tobin and Nordhaus, 1972 which introduced the "measure of economic welfare" as a theoretical concept). To move from GDP to NDP one subtracts capital depreciation – the real problem is capturing the depreciation on all capital, including that on natural resource stocks. There is now a move in many countries to try to capture the full value of depreciation, including the loss of all natural capital (eg mining, loss of topsoil, loss of forests etc) in a set of satellite accounts. The US Bureau of Economic Analysis has introduced a variety of satellite accounts. The integrated economic and environmental accounts focus on changes in the stock of natural resources. There are others including transport accounts, travel and tourism accounts, and personal savings accounts. [see Moulton BR. 'Getting the 21st century GDP right. What's underway'? *AER* 2000. P&P. 253-258].

At a practical level the introduction of natural resource depreciation into the national accounts introduces numerous problems. Two classical approaches are Repetto's approach of subtracting resource rents (which means that without new discoveries mining contributes nothing to GDP), and El Serafy's "User-Cost" technique which does allow for the inclusion of some rents into

National Income. [For a simple summary of these with examples, see Brekke p37-62] Note that neither conforms exactly with the equation above!

Back to the underlying theory now: Weitzman (QJE 1976, p156-162) explains why the focus should be on NNP. He begins by asking, "why measure investment when sustainability should involve either non-declining flows of consumption or levels of wealth?" He answers this by showing that the PV of the flow of all future consumption (which is an appropriate welfare measure) is proxied by NNP. In this literature one regularly sees a reference to real NNP as the present value Hamiltonian of future consumption, and this is precisely what Weitzman does here. Investment is treated as an intermediate good whose end purpose is the attainment of an infinite time series in consumption. This is the key concept in all neoclassical notions of sustainability!

The model assumes on consumption good, the amount of it consumed in any time period (t) being $C_{(t)}$.
There are also n capital goods, the stock of the ith one being $K_{i(t)}$
$\boldsymbol{K_{(t)}}$ is a vector of the stock extant in period t of all types of capital $K_{i(t)}$……..$K_{n(t)}$
Investment in any time period is the net change in the capital stock.
$\boldsymbol{I_{(t)}}$ is the vector of investments into these forms of capital in period t. $I_{i(t)}$ ……$I_{n(t)}$

$$I_{i(t)} = {dKi}/{dt}(t)$$

for convenience the labour force is kept constant (if one wanted it variable there'd be no problem arranging to keep the capital/labour ratio constant). Further assume a production possibilities set:

$S(K_{(t)})$

and assume that the price of the i^{th} investment good is Pi
where there is a vector of capital good prices: $\boldsymbol{P} = Pi$ ………Pn
the consumption good being used as numeraire.

The real NNP function used by Weitzman is:

$$Y(K,P) = \max[C + PI] ......where.....[C,I] \in S(K_{(t)})$$

Weitzman now assumes competition and a fixed rate of interest (r)
The feasible competitive trajectory ($C^*_{(t)}$,$K^*_{(t)}$) is one for which there is a set of investment prices $P_{(t)}$ such that:

(i) $$Y(K_{(t)}, P_{(t)}) = C^*_{(t)} + P_{(t)} {dK^*}/{dt}$$

(ii) $$\frac{dY}{dK} \Big| = rP_{i(t)} - \frac{dP}{dt}(t)$$

(i) simply says that production is maximizing NNP, i.e. prices of capital goods are equal to their marginal rates of transformation into the consumer good
(ii) is the intertemporal efficiency condition of a competitive capital market with perfect foresight. To make this clearer, because future production can be sold in a future market, the condition has to include the present value of future capital gains (discounted back at rate r)

(i) and (ii) emerge as conditions for the solution of the problem:

maximize the present value of consumption $\int_0^\infty (C_t e^{-rt} dt$

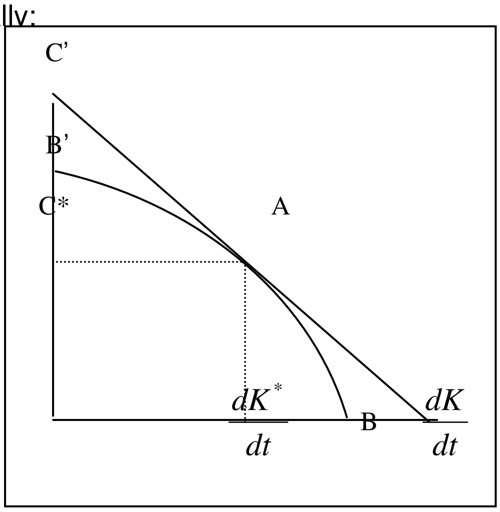
subject to consumption and investment being elements of the production possibilities set as already assumed.

The present value Hamiltonian will be

$$C_{(t)} + P_{(t)}\frac{dK}{dt}(t)$$

note that there is no λ since the price of the consumption good is already being used as numeraire

One can represent the problem diagrammatically:



The diagram shows the production possibilities set (BB') with the straight line tangent to it showing the price of an extra unit of investment in capital in terms of the extra consumer goods that would have to be forgone.

If there were no net investment, i.e. one was on the vertical axis, the maximum amount one could consume without running down the stock of capital would be C'. This would be C* + P(dK*/dt) and clearly fails as it is beyond B', which is the production possibility set's limit since P(dK*/dt) is the area C"AC*. However, Weitzman shows that welfare generated by an economy consuming at the optimal rate (at point A) would be the equivalent of this.

The optimal control path from time t on in perpetuity is: $\int_t^{\infty} C(s)e^{-r(s-t)}ds$

where s is just a constant of integration. Ultimately this gives:

$$\int_t^{\infty}[C^*(t) + P(t)\frac{dK^*}{dt}(t)]e^{-r(s-t)}ds$$

This means that the welfare equivalent will actually be C', even though this is a point outside the PPF. This apparent paradox comes because the appropriate measure of welfare is taken to be the current value Hamiltonian of C+I. This also provides the key to the logic behind the neo-classical idea of sustainability.

Hartwick 1990. Introduces exhaustible resources in the corrections needed in green national accounts. This is taken further in Hartwick 1992.

Satellite Accounting in South Africa

The United Nations Handbook, *Integrated Environmental and Economic Accounting 2003*, is available on
unstats.un.org/unsd/environment/seea2003.htm

There are two national accounts discussion papers available on the Stats SA website: http://www.statssa.gov.za.
Go to Papers & Schedules (left hand side) then Discussion papers.
1 = Natural resource accounting : mineral accounts for South Africa, 1980-2000 ;
2 = Natural resource accounting : water accounts of the upper Vaal Water Management Area, 1991-2000.

8. TESTING HOTELLING: ARE NATURAL RESOURCES BEING EXHAUSTED?

The modern literature on sustainability was largely a result of the outcry that followed the Club of Rome Report (Meadows et al, 1972), but an influential earlier report had already suggested that the problems they pointed to were exaggerated. Barnett and Morse's (1963) report "Scarcity and Growth" found that real resource prices were roughly constant over a period from 1870 to 1957, despite a many-fold increase in effective demand for them.

The first thing to ask is whether this means that there is no real resource scarcity, or that Hotelling's Law doesn't hold? Barnett and Morse were looking at prices of refined minerals. If extraction costs had been falling through technical advances in extraction processes, then Hotelling rents could have risen even though mineral prices were constant. The Barnett and Morse findings do not, therefore, say anything about Hotelling's Law. They are, however, important if one is thinking about practical sustainability issues. [Kula E. *History of Environmental Economic Thought*. Routledge. 1998. Has a good chapter on scarcity, Barnett and Morse, etc which is easy going and provides a useful summary. Their whole book is worth the read too!]

Heal and Barrow recognised the problem that Hotelling's law requires that it is the value of ore in the ground that should be rising at the interest rate and not the price of refined metal. Nonetheless they too tested using the price of refined metals. They did so, however, using a model that allowed arbitrage between natural resources and other inputs. The model used is as follows:

Assume P=current mineral price & Y=current income from mining the mineral while P' & Y' are weighted averages of previous prices and incomes.

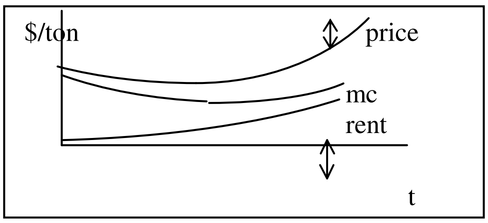
A time lagged supply model is used, i.e. current production of a mineral depends on the prices and incomes it yielded in preceding years: S=S(P',Y')
The demand for a mineral allows for arbitrage:

$$D = P^{\eta(p)} Y^{\eta'(y)} \left[\frac{\tilde{P}/P}{\tilde{O}/O} \right]^{a'}$$

Where η(p) is price elasticity and η(y) is income elasticity and a' is a constant. O represents the prices of other assets, and ~ indicates that the prices are taken at future dates.
In actually testing this they used monthly price data from 1965 to 1977 and as a growth rate the OECD index of industrial production.

[Their approach is easily replicable and would make an interesting basis for analysis using African data, especially in cases where there is a near monopoly of the mineral as is the case with platinum or chrome].

A better known article testing the Hotelling model is Slade (JEEM, 1982) which is well written up in an appendix of Hartwick and Olewiler's textbook. She monitored mineral prices (corrected for inflation) and noted first that they did not follow the exponential trend suggested by Hotelling. She attributed this to changing costs of extraction due to declining ore quality (increasing costs) and improvements in technology (decreasing costs). She does not actually argue that she has proved or disproved Hotelling's rule, she is content instead to simply say that a price function with a quadratic form as shown above, goes as far as is possible while consistent with Hotelling.



The real problem is that Hotelling's law describes the hypothetical prices of ore bodies still in the ground. Observation shows the price of extracted minerals in the market. An effective approach to this conundrum was offered by Halvorsen and Smith (QJE 1991). Unfortunately the data they used was Canada's aggregated mining production. A researcher wanting an interesting paper could follow their path, but use figures from a single mineral. As suggested in the note on Heal and Barrow's paper, sectors such as platinum and chrome lend themselves particularly well. If access can be had to the data, there is the potential for a truly publishable paper here).
In order to get the Hotelling prices of the ore bodies, Halvorsen and Smith work backwards. They imagine mining as an optimisation problem and use duality theory. The Lagrange multiplier is thus a shadow price. The model is elegant, but assumes perfect certainty and perfect arbitrage. These assumptions, and the use of aggregate data, are flaws that could be corrected!

9. RENEWABLE RESOURCES FISHERIES

The early fisheries models treated the fishery as a source of Ricardian rents. As in Ricardo's land model, the best fishing grounds are exploited first, the next best will be exploited second, the third best after that, and so on. Each time a fishing ground is exploited till the rents on it are just equal to those in the next available new ground. i.e. under open access, fishing grounds are exploited in such a way that Ricardian rents are equated over them. This approach has been heavily criticised, but it provides the basic answer to the question: "why if the seas offer so much wealth, are fishermen so poor?"

This simplistic approach was replaced by bio-economic models following the popularity of Clark's book *Mathematical Bio-Economics* (1976). The following stylised model is a basic one that follows the approach he uses in the opening chapters of the book. It must be stressed that the modelling of fisheries is a far more sophisticated activity than this model suggests. Some of the alternative approaches to fishery modelling will be dealt with briefly later. This one has the advantage that, though simple, it can be used to to illustrate most economic problems associated with fisheries' policy. A more accessible and very useful text is his later (1985) book, '*Bioeconomic Modelling and Fisheries Management*'

9.1 The Simple Single Species Static Model

Let X_t be the stock of some fish specie at time t.The rate at which this fish stock increases depends on how many fish there are already: this drives the amount of food, space, breeding opportunities, spread of disease etc. i.e.

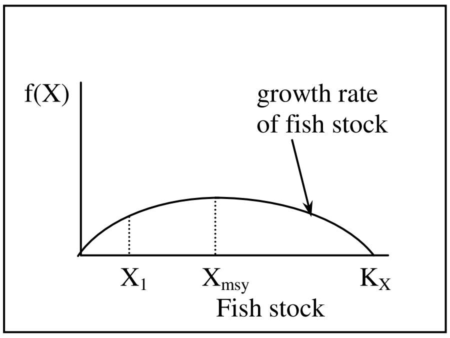
$$\frac{dX_t}{dt} = f(X)$$

Where f(X) is a function of size growth rate, birth rate and death rate.

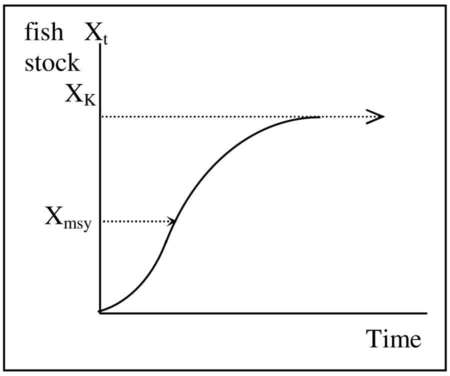
In this simple model we assume that f(X) is a logistic function

$$f(X) = rR\left(1 - X/K\right)$$

Where K is the carrying capacity at which the fish stock will tend to settle if there is no extraction.



The vertical distance between the horizontal axis and the curve shows the instantaneous growth rate of the fish stock at that level of X.



The same function can be shown in terms of time as a standard logistic curve
One can also visualise it as a sustainable harvest function since it shows what amount can be extracted at each stock level while keeping that stock unchanged. Thus at X_K, the sustainable harvest is zero. At X_1 it is the vertical distance to the curve shown by the length of the dotted line. At X_{msy} it is the vertical distance to the f(X) curve, which is there at its turning point. This amount is the maximum sustainable yield. It would also be the slope of the logistic function at its point of inflexion.

A sustainable harvest or yield is found when the harvest matches the instantaneous growth rate of

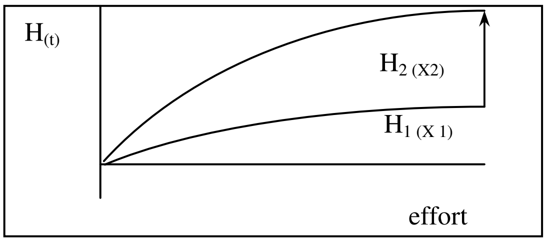
$$dX/dt = f(X) - H = 0$$

the fish stock, i.e when

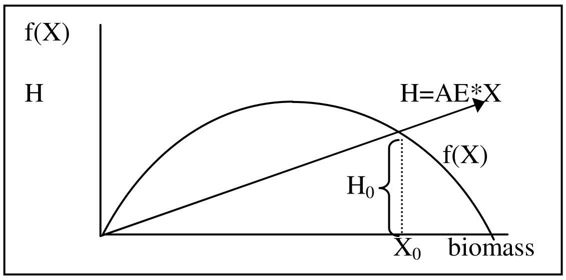
We haven't yet looked at the harvest technology though.

In this model we will assume that the more fish there are in a given area, the easier and therefore the cheaper it is to catch them. The harvest of fish in any period of time will therefore depend on two things, the effort made to catch them and the biomass of fish there.

$H_{(t)} = G(E_{(t)}, X_{(t)})$
or
$H = AEX$
where A is an index of the specie's catchability.

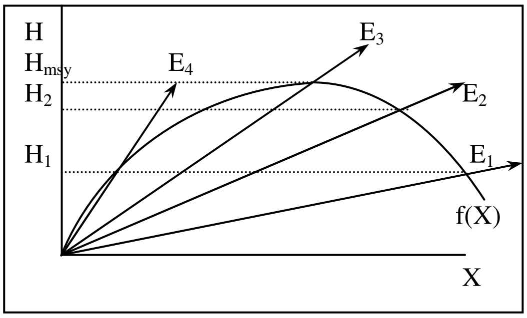


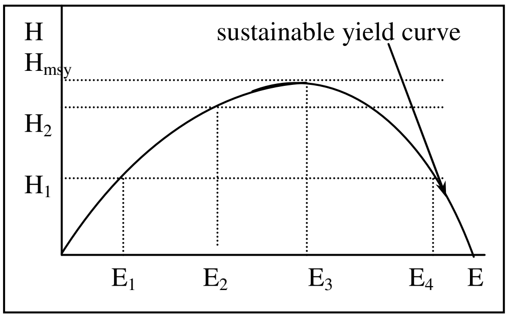
This means that any increase in the fish stock will shift the harvest function upwards.



If the effort is fixed, eg. the size of the fishing fleet is set at E* then the sustainable harvest will be H_0 and the stock X_0 Any other level of harvest would be unsustainable: the stock would be either rising or falling. Similarly, with that level of effort, any stock other than X_0 would be unsustainable; the biomass would be either rising or falling.

Given the hypothetical logistic function for any fishery, one can therefore obtain a biomass growth function, f(X), and from this obtain the sustainable harvest and biomass that would pertain at each possible level of effort.

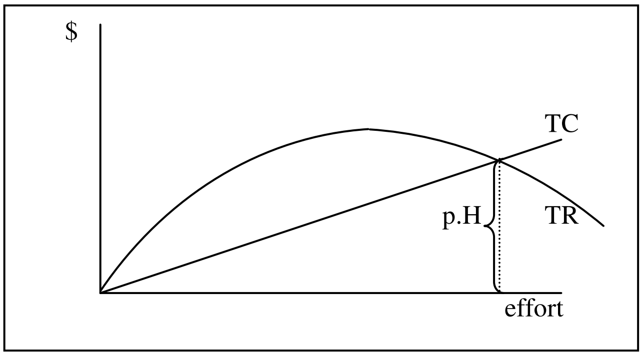




Note that as E rises, X is falling. On the second of the graphs above, the origin shows zero effort and hence a totally *un*exploited fishery.

The sustainable yield curve can be converted into a sustainable revenue curve. If fish prices are fixed then revenue is simply the harvest multiplied by the price of fish. The two curves would thus be effectively identical. Similarly, to introduce costs one could simply take the amount of effort and multiply by the unit cost of that effort.

TC = c.E

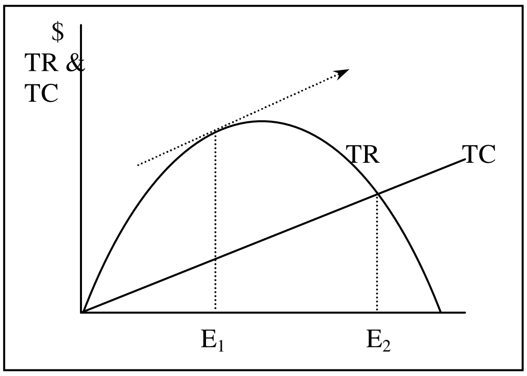


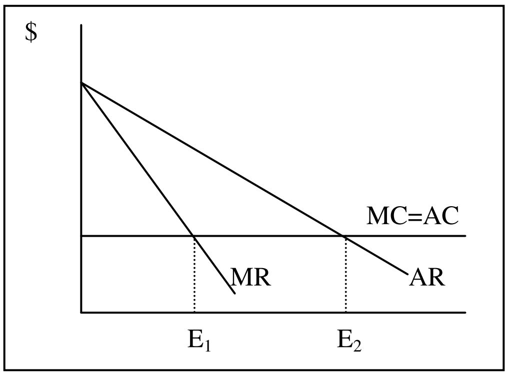
If the latter is constant then the cost curve is effectively identical to the effort curve.

If a fishery is subject to open access then equilibrium will be reached where TR = TC since there will be a rent available to new entrants for as long as TR>TC.

This gives us one of the first results in the fisheries' literature: the tragedy of open access (Gordon's model –JPE 1954, 62p124-142- fits this as can be seen below)

The first point to note is that even though we have assumed the fishery is a price taker, the total revenue function keeps the shape of the harvest function and therefore looks like that of a monopolist.





Since TR = H.P_{fish} =
AR = APP_{effort}.P_{fish} and MR = MPP_{effort}.P_{fish}

It is clear that under private management the optimal output would be with effort level E_1, while under open access the rents would be dissipated and equilibrium reached at E_2. The reason that open access leads to excessive entry is that new entrants capture the average catch, not the marginal one and therefore have an incentive to enter for as long as AR>MC.

An important intuitive feature of this model is the insight it gives us into the *'stock effect'*. Each new entrant increases the effort needed by existing fishermen hoping to maintain their catches intact. Alternatively, a new entrant lowers the revenues of existing operators. Formally:

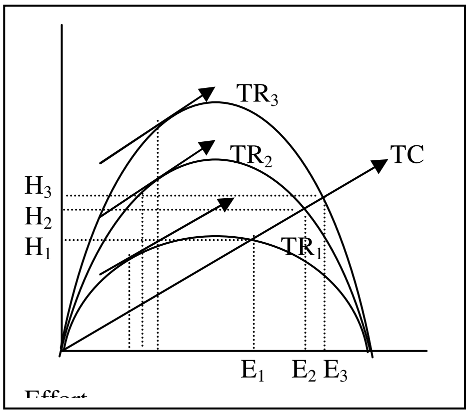
$$H = AP_E \cdot E$$

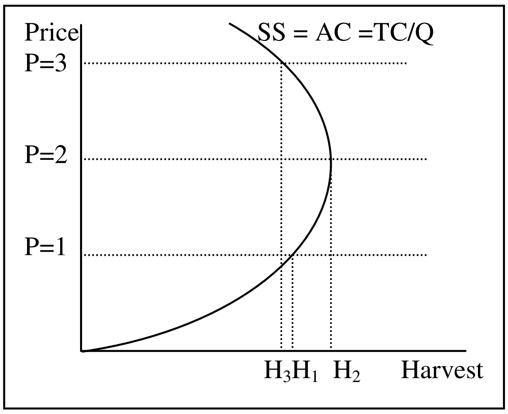
$$dH/dE = AP_E + \frac{dAP_E}{dE} \cdot E$$

the second section of the equation above is the stock effect and is negative.
This can be taken further if the new entrants add congestion costs (Mohring costs).

Note that the open access result not only shows rent dissipation, but could also be bionomically inefficient if the same revenue could be obtained with less effort [this happens if the open access harvest is greater than the MSY]. Note too that the value of a fish today and of a fish in the future is the same. The discount rate is ignored or treated as zero!

One can show the effects of changing fish prices on the steady state harvest by deriving the fishery supply curve.





The backward bending AC (supply) curve under open access means that high prices induce additional effort (investment in the fishery) and lead to overfishing which, by reducing the fish stock also lowers the sustainable yield. This implies a basic inefficiency – too much effort is causing the supply curve to bend back.

If the property rights to the fishery are fully allocated optimal effort requires MC=MR.

$$\frac{dR}{dE} = \frac{dC}{dE} ......where.... \frac{dC}{dH} = \frac{dC}{dE} \cdot \frac{dE}{dH}$$

Again, without any discounting we still find a harvest that is below the MSY.

9.2 Dynamising the model

So far we haven't mentioned the rate of interest. As we will see this can make a crucial difference to the outcome of the model.

To see how let's take the case of a private fishery with zero extraction costs and examine the behavior of the owner as portfolio manager. Let's begin by assuming only two assets, fish and bonds. The opportunity cost of a fish left swimming in the sea is the interest it could be earning if had been caught, sold and the proceeds used to by a bond.

Start with an untouched fishery at its full carrying capacity (K). Being at capacity the sustainable yield is zero. The static ideal would be to mine the fishery till the maximum sustainable yield is obtained (since MC=0 the MSY would also be the static profit maximizing harvest). But say the cash obtained from mining the fishery to a stock level of say X_1 is used to buy a bond. This would provide a yield of $r \cdot P(K\text{-}X_1)$

Where P is the price of fish and (K-X_1) is the amount by which the stock is mined.

The remaining stock of fish will now give a sustainable yield of $P \cdot f(X) = P \cdot H$

Total income from the fishery is therefore:

$$r \cdot P(K\text{-}X_1) + p \cdot H + X_1 \Delta P$$

where the last term indicates any capital gains (or losses) from changes in the value of the remaining fish stock.

Maximising this we first reorder it:

$$rPK + P \cdot f(X) - (rP - \Delta P)X$$

The first term shows the income the entire stock of fish could generate if it were harvested to extinction and the proceeds invested. The second term shows possible sustainable income if the stock of fish is positive and the third term includes capital gains.

Intuitively we expect that the risk adjusted returns on all assets in an optimal portfolio will be equal. Unsurprisingly then, a first order condition for this maximisation will be

$$(rP - \Delta P) = P \cdot f'(X)$$

$$\Rightarrow f'(X) + \Delta P / P = r$$

This means that even though there are no extraction costs (by assumption) so MC is constant at zero, the optimal harvest will not be the MSY unless r = 0 *and* there is no prospect of capital gains or losses. The fishery manager will deplete the stock till the sustainable harvest of the fishery gives rate of return equal to the rate on financial assets. With positive interest rates we therefore expect the fishery manager to extract beyond X_{msy}.

Clearly this behaviour will be less conspicuous if the marginal costs of harvesting fish are positive and increasing. This is the stock externality we encountered earlier.

We can see how these two forces will work in opposite directions by using a simple two period model.

Call the PV of portfolio profits over two periods PVπ.

$$PV\pi = P \cdot H_t(E_t, X_t) - cE_t + \frac{1}{1+r}\left[P \cdot H_{t+1}\left(E_{t+1}, X_{t+1}(E_t X_t)\right) - cE_{t+1}\right]$$

i.e. TR in t MC in t PV of TR in t+1 PV of MC in t+1

(stock in t+1 depends on harvest in t hence X_{t+1} is a fn of harvest in t)

$$\frac{\partial PV\pi}{\partial E_t} = P \cdot \frac{\partial H_t}{\partial E_t} - c + \frac{1}{1+r} P \cdot \frac{\partial H_{t+1}}{\partial E_{t+1}} \cdot \frac{\partial H_{t+1}}{\partial X_{t+1}} \cdot \frac{\partial H_t}{\partial E_t}$$

one wants to know is how effort in period t affects the PV of the entire income stream. i.e.

marginal user cost

marg value of harvest marg cost

in equilibrium an additional unit of effort would not increase or decrease PVπ.
So set the above equal to zero: this shows that the marginal value of the fish harvest in equilibrium is equal to the marginal cost of harvesting plus the user-cost of the fishery in the following year.

9.3 Interpreting the dynamic optimal control rule

One can now easily see the optimal extraction of fish as a variant of Hotelling's rule.
If we call (P-c) the net price V, and introduce a social discount rate δ, we can express the optimal outcome as follows:

$$\frac{\dot{V}}{V} = \delta - f'(X) + \frac{C_X}{V}$$

% capital gain marg stock effect (physical growth of stock) stock externality (costs rise as stock falls, harvest in yr t increases costs in yr t+1)

If (as before) we assume zero harvest costs, then the stock externality falls away and

$$\dot{V}/V = \dot{P}/P = \delta - f'(X)$$

or

$$\delta = \dot{P}/P + f'(X)$$

The higher is the discount rate, the faster the stock is depleted. Similarly if the private discount rate (interest) is higher than the social rate, depletion will increase. Expectations of rises in the future price of fish would move the stock closer to X_{msy}.

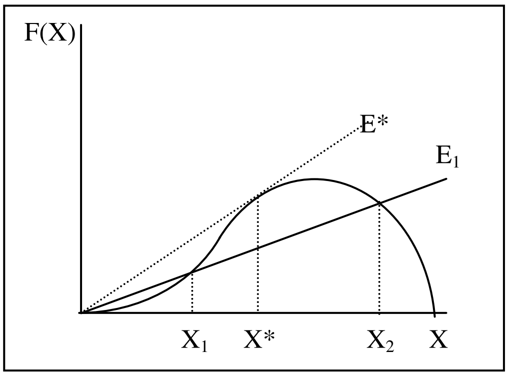
For as long as δ>f'(X) there is an incentive to mine the resource.

Introducing the cost of harvesting: the more stock dependent are costs, the less the likelihood of the resource being exhausted. This becomes important when we look at the different types of fish and how they are caught.
Think for a moment about the implications for schooling fish like anchovies, species that come together in mating aggregations at fixed spots (eg Orange Roughy or the East coast squid) and those that are spread less densely (eg Cape Hake)
What do you think will be the features of those fish or marine mammals that are more likely than most to become commercially extinct?

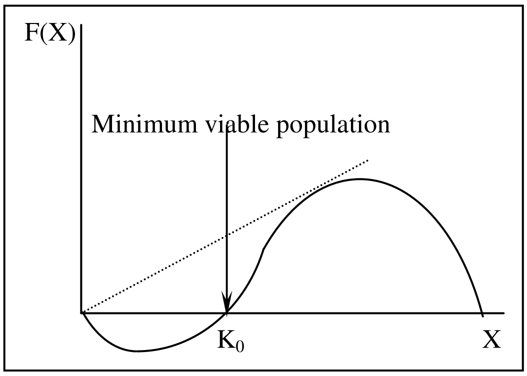
9.4 Going beyond the Schaefer Model

A useful start in bringing an element of realism into fisheries is to talk about "potential yield" rather than "sustainable yield". The latter implies that one is sure of the stock and its rates of growth. In reality many fisheries are prone to severe fluctuations, especially species that are short lived. Where year class strength and recruitment rates naturally fluctuate it is difficult to maintain a level of stock abundance without the catch fluctuating. And maintaining a fixed catch rate is likely to destabilize the population even further. One way around this is to think in terms of a "potential yield" i.e. of the greatest average annual yield that can be obtained over a long period of time. At a policy level this means adopting a precautionary approach to setting harvest limits. Note that commercial species such as Pilchard and Anchovy (which are prone to such natural fluctuations) have had historic collapses in the past. Importantly these could not have been anticipated using existing data and modeling techniques (Butterworth, 1980).

A further problem of the Schaefer model is its assumption that the yield curve is convex. If it is concave to the origin as shown in the two cases below, the predictions of the model become more tenuous. This is the problem of "depensation". The normal convex Schaefer curve exhibits "compensation" i.e. dX/dt, the growth rate of the stock is a *de*creasing function of X the stock size. 'Depensation' implies that over some range the growth rate is an *in*creasing function of the stock. An extreme case of this is 'critical depensation' in which f(X)<0 at low stock levels.

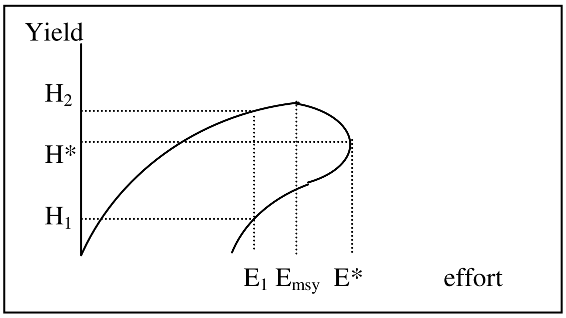


depensation



Critical depensation

Depensation is important because it introduces the possibility of multiple equilibria. The result is a bifurcation of the
Yield-Effort function when Effort
Is at E*. The policy implications
are important:
i. the kind of incremental
adjustments one can use to
fine tune harvests if there is
a conventional Schaefer curve



are no longer certain. If the population is at X*, even a small increase in effort above E* can lead to population collapse.

ii. hysteresis: if E>E* and the population begins to collapse, managers may insist that effort be reduced below E*, but population may keep falling because we are now in a region of unstable equilibria.

iii. This suggests the possibility of extinction; however the likelihood is that a fishing ban or the cessation of harvesting for commercial reasons will occur first. However, it could be a problem if the resource exhibits 'critical depensation'. This would mean that any drop in the population below the critical level (K_0) would be irreversible regardless of subsequent cuts in effort.

9.5 Policy implications of the Simple Model

Unregulated fisheries tend to open access. We've seen that this is inefficient. What does the basic model suggest about the different approaches to rectifying this?

Ideally one wants to control the *effort* used in harvesting. Just regulating the take is no guarantee that it will be extracted efficiently. The ideal is efficient use of economic resources to harvest a stock that is being kept at it's optimal level while avoiding adverse effects on income distribution. A tall order!

Tools available include:

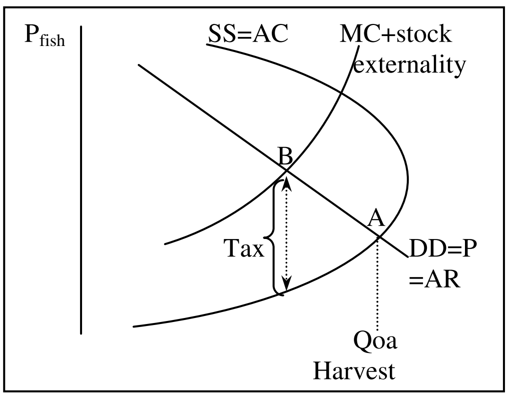
- Taxes – on harvest or on effort
- Quotas - on harvest or effort
- Licensing – of vessels or fishermen themselves
- Assignation of property rights – especially tradable permits such as ITQs

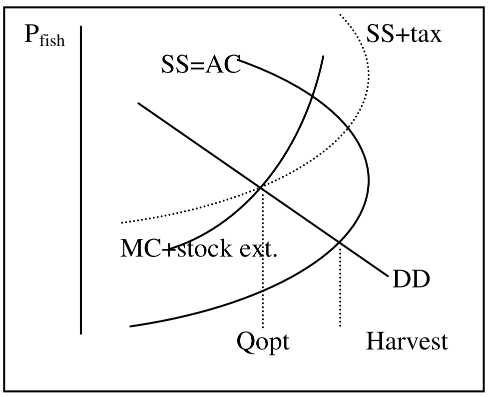
For simplicity let's look at a static case (or assume r = 0) with full certainty. Intuitively your economics will have suggested that in such a situation control through a tax is just the dual of control through a quota. That they will have identical effects on the harvest, though the implications for income distribution and profitability of the industry will be different. We will discover that this is not in fact true: it only holds when the quota is fully tradable in the market. In such a case the difference between a tax and a quota is simply whether the property is right is fully allocated to the state or fully allocated to the fisherman.

9.5.1 Taxing for Optimality

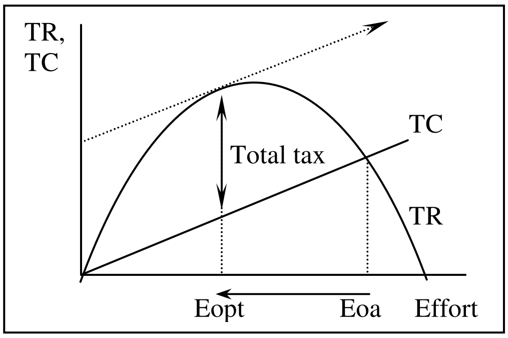
In an optimally run fishery P = MC + stock externality
i.e. P = C' + C'/f'(X)

under open access, however, P = AR = AC = CE/H





To move the harvest from the open access level Qoa to the private optimum Qopt, one imposes a tax as shown. This shifts the effective average cost (SS) curve up as shown, and the equilibrium moves from A to B.
This assumes no tax shifting: a reasonable assumption since individual fishermen are generally price takers. In an oligopolistic market (as many African commercial fisheries are) this simple approach would not be valid!

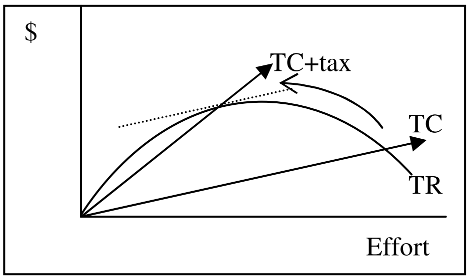


Note that the tax is extracting the entire rent. This will reduce the effort in the fishery and therefore increase efficiency, but will also have an income distributional effect!

Monitoring a tax is easier if the fishery involves large scale formal processing plants or if the tax can be charged at the point of sale. It is tricky when the fishery is artisanal and sale is informal (as would be the case were a tax imposed on say the Cape Snoek fishery)

The real practical problem is setting the appropriate level of tax given that the price of fish will rise as the harvest falls, as well as being subject to irregular demand shocks. More importantly, many major commercial fish species (especially short lived species such as anchovy, sardine and squid) are prone to natural population collapses which are difficult to predict in advance of a fishing season. Taxes are typically set for long periods of time and are not easily adjusted in response to natural events.

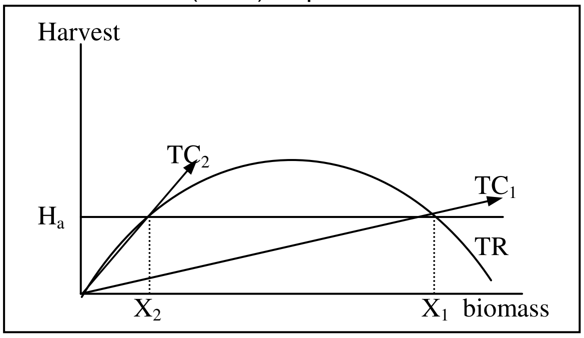
Lump-sum taxes such as that described above are often favored by economists as 'non-distortionary'. They may appear as taxes on fish landing or as license fees (permit charges) which also cause a parallel shift of the total cost curve but leave marginal costs unaffected.



An alternative would be a tax per unit effort, e.g. taxing nets, boats, meters of boat length, tonnage etc. These have been widely used and are distortionary. They are the source of many of the failures in fishery management through taxation. A further problem of taxes on effort is the *identification* of the effort. Many aspects of effort are substitutes: vessel length and tonnage, engine size, net size, labour employed, technology used etc. may each substitute for one another. Taxing one merely biases towards use of others while maintaining the dissipation of rents.

9.5.2 Quotas on Catch or Effort

The basic quota here is the Total Allowable Catch (TAC) imposed on an entire fishery. If a harvest quota of H_a is set it can be reached using two levels of effort and at two levels of biomass. Ideally one wants the higher biomass and the lower level of effort (X_1 and TC_1). The policy is therefore to close the fishery as soon as the stock has fallen to X_1 i.e. as soon as H_a has been harvested.



Such simple quota systems face a basic problem: rent dissipation is still present even at the optimal harvest. The quota described is at an industry wide level. The reduced harvest means fish prices rise and the open access situation still pertains. Individual fishermen therefore have an inducement to overcapitalize – they want to get in first before the industry quota is reached and fishing has to stop. There is also an incentive for fishermen to use large refrigerator vessels even though a fresh fish market may be more economically justified. Both problems have been observed in the west-coast fisheries of Canada and the United States.

It appears that a solution would be the allocation of quotas to individual fishermen as exclusive rights. Unless these are sub-divisible and tradable, however, they too present problems. Firstly efficiency requires that larger vessels get larger quotas, and that the vessels with the lowest marginal costs get the first allocations. This raises all manner of social problems. The traditional approach has involved "grandfathering" in other words allocating permit on the basis of historic capacity and catches. There is a risk with any allocation process, however, that rent seeking behaviour by participants can yield anomalous results. This has been a real problem in South Africa in the past few years, and in Zimbabwe with the allocation of permit to catch Kapenta on Lake Kariba.

The inefficiencies of simple quota systems can be eliminated in theory if the quotas are subdivivisible and tradable (ITQs), an approach that was popularised in New Zealand and Australia and has spread rapidly (including locally). Nonetheless, rent seeking remains a problem. There are numerous good readings on this issue. Two good recent ones on quotas vs tariffs are Weitzman M. "Landing fees vs. harvest quotas with uncertain fish stocks" *JEEM* 43 (2) March 2002 p325-338. and the discussion at the end of the article by Danielsson in JEEM 43(1) Jan 2001. p20-33. Even if you don't want to slog through the formal components, the discussion section in Weitzman's paper is partularly worth reading for its policy implications.

9.5.3 Marine reserves and restricted areas

Some fish species (especially demersal fish) breed in one area and as populations expand they move out and colonise surrounding areas. Others tend to breed in select areas and are particularly easy to capture when in spawning aggregations. In both cases it makes sense to set aside areas in which there is either no fishing or in which fishing is restricted to fixed times of year.

9.5.4 Eliminating Subsidies

One of the major sources of the international overcapacity of fishing fleets is that they have been historically subsidised. Southern Africa is rare in having effectively unsubsidised fleets. The exclusive economic zone supposedly allows nation states to keep foreign vessels out. However West African (and until recently Namibian) waters have been heavily fished by subsidised foreign fleets. One would expect a first step in fishery regulation to be the removal of such vessel and industry level subsidies. There are numerous readings on the problem, most of which suggest that subsidy removal is not as easy as it sounds.

Recommended reading : Branch and Butterworth's submission to SA Govt on methods to manage South Africa's fisheries. Notice how they differentiate between methods suitable for deep sea, inshore and artisanal fisheries.

9.5.5 A Further Dose of Reality - Multiple Species Fisheries

Outside of aquaculture (which is closer to plantation forestry in its modelling, since the aim is to determine the optimal rotation rate of the stock being farmed) there are few true single species fisheries. One reason is the presence of by-catch in nets and on long-lines. Another is that the species harvested generally interact naturally with others (which may also be commercial species, or may affect them. This partly explains the concern with predator-prey models in fisheries economics. Certainly it makes regulation of fisheries far trickier.

One problem is the risk of 'high-grading'. Fish caught in nets are normally killed when the nets are lifted. If a vessel has a quota of some number of tons of 'fish' it pays them to sort through the catch and throw back the portion of the catch that brings in low prices, and keep fishing, raising the average value of fish landed. This is possible since quotas tend to be measured when fish are landed, not when captured!

Vessels have some control over the species they catch. Depth of trawl, mesh size, position and time of day can all influence the predominant catch. One response to high grading is therefore to set quotas by specie. Any by-catch that the vessel has no quota for then has to be returned, even though the fish is dead. This prevents vessels targeting valuable 'by-catches'.
For a fuller analysis of these issues see: Clarke C.W. 1985 *"Bioeconomic modelling and fisheries management"* ch. 5.

9.5.6 Alternative modelling approaches

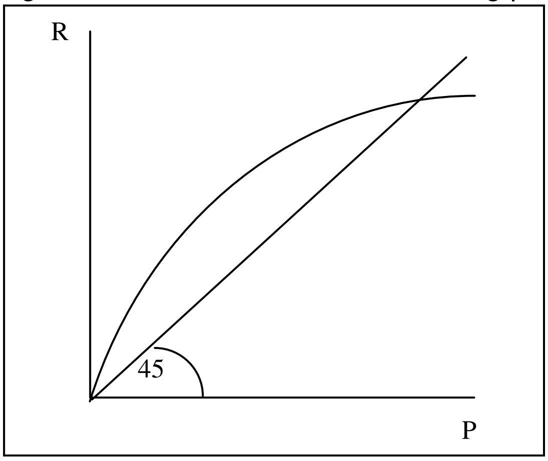
In your reading you may come across a number of alternative modelling approaches. For completeness we mention a few of these.
A basic problem with all fisheries modelling is data quality. We actually know very little about existing fish stocks at any point in time. This is one reason for the popularity of modelling approaches such as the spreadsheet techniques found in Bleloch A. and Starfield.A. 1986 *Building Models for Conservation and Wildlife Management*. The book is easy reading and seriously recommended.

When modelling population growth zoologists often use Leslie Matrices. These are based on the age structure of a species and the fecundity rate and mortality rate of each age group. A commonly found alternative approach used more widely in the fisheries literature is the Beverton-Holt model which uses a similar age-structured approach. The last term you should be aware of is the Von Bertalanffy function, which describes the rate of mass increase experienced by an individual member of a specie. Useful summaries of these are found in both of Clark's books.

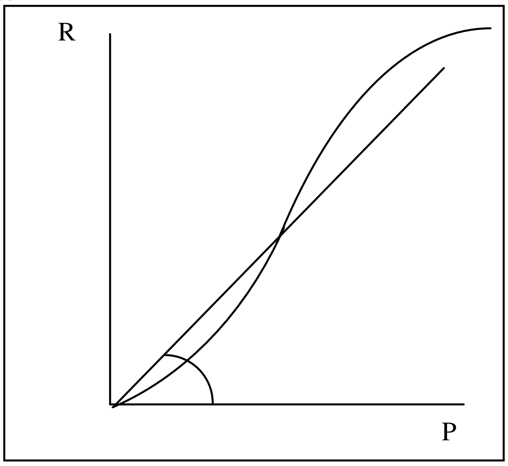
The basic stock-recruitment model assumes that the number of recruits to a population in any time period, depends on the number of breeding adults in an earlier time period (the gap between the two periods depending on how long it takes for a newborn fish to reach a size where it is considered a recruit). In a simple case where one year's newborn is next year's recruit:

$X_{t+1} = f(X_t)$	without any harvesting
$R_{t+1} = f(P_t)$	recruitment is a fn of parent stock
$P_{t+1} = R_t - H_t$	the recruits left after harvesting become next year's parents

This can give us either compensating or depensating results. In the diagrams below, the 45 degree line shows all recruits becoming parents.



Compensating



Depensating

An important point is that this basic stock/recruitment ratio often doesn't appear! This is a key feature of Beverton & Holt, Ricker and similar more advanced approaches.

9.5.7 Beverton and Holt's basic compensation model

B and H began with a basic observation that needed explaining. The result of overfishing for many species is not initially falling population, but falling age and size of the average fish. This was particularly true of demersal species with high fertility rates since with a fertile species so many eggs are laid that the population in the next year rather depends on how favourable natural conditions are for survival of the eggs and fry.

Call N_t the population of newly hatched fish in period t.
Assume a density dependent mortality rate

$$\frac{1}{N}\frac{dN}{dt} = -(\mu_1 + \mu_2 N)$$

note that if the mortality were independent of the density of young then we'd see

$$\frac{1}{N}\frac{dN}{dt} = -\mu_1$$

μ_1 and μ_2 are constants related to k_1 and k_2 below.

For the time period t=0 to t=T

$$N_T = S(N_0) = \frac{k_1 N_0}{1 + k_2 N_0}$$

We can now introduce a *'fertility'* constant α which relates the number of newborn larval fish to the adult population.

$$N_0 = \alpha P_0$$

This gives us Beverton and Holt's recruitment relationship

$$N_T = \frac{k_1 N_0}{1 + k_2 N_0} = \frac{\alpha P_0}{1 + bP}$$

Clark gives a straightforward example to show how this relationship can give a constant population despite overfishing.

For this model to demonstrate *de*pensation, mortality has to *de*crease as population level rises. This sounds intuitively unlikely, but there are a number of cases where it is found. The major ones are schooling fish and fish that move along a fixed path every year.

Schooling is a survival mechanism: even though large numbers of predators follow schooling fish, an individual is more likely to survive as one of a shoal that it would be alone. Fish moving along preset routes (migrating salmon moving upriver to spawn, sardines on the E. Cape/Natal sardine run route etc) face the same situation: the number of predators is finite, as is the time spent in the migration. A certain number of fish will be consumed by these predators, but the remainder will get through. The greater the amount by which the migrating fish stock exceeds the number lost to predation, the lower the mortality rate. Note the important caveat: if the population falls below the number expected to be lost to predation, the population may not easily recover. This may be one reason for the collapses observed in populations of schooling fish subject to their own population cycle and also to commercial harvesting.

Beverton and Holt developed the model further by introducing age cohorts. The value of fish depends on both the number and the size. They had shown that the average size rather than the population might be the variable affected by overfishing. Introducing a cohort based approach they showed that in trawl fisheries the mesh size (and implicitly other ways of targeting larger fish such as depth and place of trawl) could become tools usable to optimize a continuing yield.

This cohort based approach becomes the basis of the next section: determination of optimal rotation rates in forestry.

10. OPTIMAL ROTATION RATES IN SILVI-, AQUA - AND MARICULTURE

When renewable resources are farmed their rate of growth is generally independent of their population size (unlike say a natural fishery). Also growth tends to refer to the way individuals expand in size rather than (or in addition to) the rate at which a population breeds.

In much of the world natural forests (like fisheries) like fisheries, would be open access resources but for state intervention. What has tended to happen is that naturally occurring forests are taken as property by the state, which rents out the right to harvest them, charging a fee known as 'stumpage'. The real world determinants of the system, the allocation of cutting permits, determination of stumpage charges, determination of what is to be cut and how, tend to be institutional matters. This does not mean that they are free of controversy. The Canadian softwood lumber industry, for example, has been criticized by the US government as subsidized (hence their call for duties against Canadian lumber exports), by local operators as inefficient since it is forced to incur social-engineering costs: to support local communities the gov't insists that timber be milled close to the place where it is felled rather than being milled where costs are least. The enviro-activists say that clear-cutting is silting streams and destroying habitats, while loggers claim that the biggest clear-cuts are actually those involving trees subject to heavy infestations of spruce and mountain-pine beetles which would otherwise kill the trees and eventually destroy the value of the wood. In much of Asia cutting rights are features of political rent seeking, the externalities of which are now making themselves felt. The 'Yellow Wind' that reaches Korea and Japan from China, the river silting in Indo-China, and the air-pollution in Malaysia and Indonesia, have all been attributed to excessive and poorly regulated harvesting of local forests.

We will not go into the institutional aspects of natural forest harvesting now. Rather we will begin with the problem facing the manager of a farm which has been given over to cultivating plantation trees (silviculture). The same model will do equally well for the farming of fish/mussels/abalone/oysters etc in ponds or cages (aquaculture & mariculture)

Let's begin with a basic problem. Imagine that you plant a tree and want to know when to cut it. To simplify let's make some assumptions:

- planting, maintaining, cutting and marketing are costless
- the land has no alternative uses and will never be replanted
- the tree grows every year, but at a declining rate
- the timber price per cubic metre doesn't vary with tree age
- timber is the only use of the tree.

The intuitive answer is easily reached. The tree is an asset in a portfolio. So long as it offers a return greater than the interest rate (its opportunity cost) it stands. Once its growth rate is less than the interest rate, it should be felled. If V is value, then formally:

Maximize PV of $V_{(t)}e^{-rt}$

f.o.c will be: $V't / Vt = r$

Let's now start dropping some of the assumptions. What happens if harvesting is no longer costless?

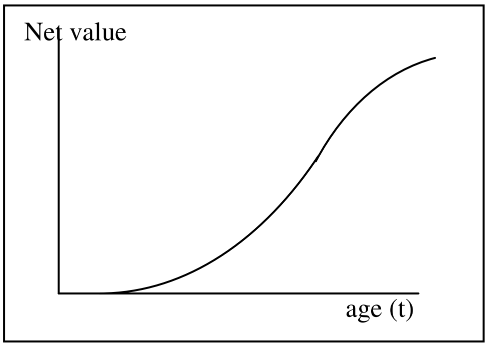
If harvest costs are C, one wants to maximize $PV = (V_{(t)} – C)e^{-rt}$

The net growth rate must now equal r

i.e. $V'(t) / V(t) – C = r$

Let's now change the assumption of zero opportunity cost: now assume instead that after the tree is cut it will be replaced by new sapling of the same sort. This introduces an opportunity cost similar to the 'user cost' or Hotelling rent we saw in the theory of mining since the ground a tree stands on could be used to plant a sapling (with a faster growth rate and therefore a higher internal rate of return).

So as not to trivialize the result let's say that very young trees have no value as timber, and that the older the tree the more valuable its timber per cubic metre up to some limit.



The net value of a tree therefore follows a logistic path as shown.

To make the calculation easier let's assume that the rotation period is constant: i.e. that each successive tree planted on the same spot will live for exactly the same amount of time. What we want to maximize is the present value stream:

Max PV = $[V(T_1) - C]e^{-rt} + [V(T_2 - T_1) - C]e^{-rt} + [V(T_3 - T_2) - C]e^{-rt} + [V(T_4 - T_3) - C]e^{-rt} + \ldots. \; [V(T_n - Tn_{-1}) - C]e^{-rt}$

A constant rotation period means: $T_1 = (T_2 - T_1) = (T_3 - T_2) = (T_4 - T_3)$...etc

This means $T_2 = 2T_1$, $T_3 = 3T_1$ etc, so each tree gets to live exactly T_1 years.
Formally: $Tk = kT$
The maximization can therefore be written:

$$MaxPV = \sum_{k=1}^{k=\infty}[V(T) - C]e^{-rt} = \frac{[V(T) - C]}{(e^{rt} - 1)}$$

this is the PV of the income stream from the site and is called "site value". Note what this means for the first order conditions: now

$$\frac{V'(T)}{V(T) - C} = \frac{r}{1 - e^{-rT}}$$

known as the Faustmann Formula.

It means that

$$V'(T) = r[V(T) - C] + r\left[\frac{V(T) - C}{e^{rt} - 1}\right]$$

growth of tree in value terms — interest earned if tree is felled & sold — opp. cost of interest on site value

i.e. cut the trees every T years, this being when the marginal increase in the value of the tree in the ground just equals its opportunity costs. The opportunity costs being the interest the tree could be earning if it were cut and sold, and the interest the land used could be generating if it were sold (given that the price of land is the PV of the net profits it can generate).

Is this of any use in analyzing the problems of natural forests? It does reinforce one insight. Open access means a Nash equilibrium where everyone rushes in to cut. As Dasgupta points out in his book, Hardin's views on the tragedy of the commons were overly gloomy. Rents will be dissipated, but the forest need not disappear. Open access means the logger's time horizon is NOW. i.e. $r = \infty$. One should cut trees as soon as the value of the timber covers the costs of cutting and marketing them. If costs are not covered, one should stop cutting immediately.

If, on the other hand, $r = 0$ and the trees are privately owned, the forester will want to simply maximize the sustainable yield from the plantation. He will want the greatest average annual yield i.e. $[V(T)-C] / T = \max$.

The last aspect is externalities: if trees in a plantation are seen as say a recreational resource, and a patch of clear-cut land is seen as a dis-amenity, then the socially optimal rotation rate will be longer than the privately optimal one. At this point one can introduce issues like irreversibility: ask yourself whether the decision to stop logging old-growth forests in parts of North America is theoretically justified by the belief that these forests were needed if some species were not to become extinct.

This question will lead us into the issue of biodiversity.

11. BIO-DIVERSITY

Key readings: Pearce D.W. and Moran D. "The Economics of Biodiversity" in Folmer H and Tietenberg T.(eds) *The International Yearbook of Environmental and resource Economics 1997/98*. Edward Elgar. P82-113
Solow A. Polasky and Broadus offered a measure of diversity as did a trio of papers by Martin Weitzman: *QJE* 1992 p363, *QJE* 1993 p157 and *Econometrica* 1998 p1279-98
Land economics has had good recent coverage, and Smith R.B.W and Shogren J. *JEEM* March 2002 p169-187 is relevant to a problem facing conservationists in S. Africa at the moment; how to induce conservation behaviour among farmers whose land has fallen into 'mega-reserves'.
Brock, W A. & Xepapadeas, Valuing Biodiversity from an Economic Perspective: A Unified Economic, Ecological, and Genetic Approach. *AER*; Dec2003, Vol. 93 Issue 5, p1597,

Before getting into any of the modern rigorous stuff though, try to find something by Aldo Leopold, the founder of the modern American conservation movement
There are a few biodiversity literature web sites for those interested in the area. The WWF biodiversity library can be accessed at http://biodiversityeconomics.org/
Over the years two good ones are those set up by Stephen Polasky and by Thomas Tietenberg. Check their personal websites for the latest addresses.

"Biodiversity" is another of those words (like sustainability) that everyone uses but for which no precise definition has been widely agreed. If one looks at the Western Cape of South Africa, for example, an extraordinary number (over 6000) of different plants are reportedly endemic to the area. Does this mean that the area is a "bio-diversity hotspot" and should be preserved before other botanical areas of the country? First it would seem so, but there is a counter argument: it seems that most of the plants found in the area fall into half a dozen families. They may have separate identities, but they tend to have lots of very close relatives which only experts could tell apart.

Problems of definition aside, we need to ask why bio-diversity is important, and in particular why it should be an issue for study by economics? This is the easiest question, so we'll start there:

We are told that Economics describes the allocation of scarce resources between competing wants. It is also the study of opportunity costs. We know that the greatest threat to biodiversity is loss of habitat… generally to economic activities. Clearly the opportunity cost of expanded production has, in some places, been the extinction of species. Moreover, though some resources are available for the preservation of species, these are finite and have to be allocated between species, each needing them to survive. Lastly, bio-diversity loss is effectively irreversible. The logic of Krutilla (Conservation Reconsidered. AER 1967) and Arrow and Fisher (…) suggests that special consideration is needed before embarking on irreversible acts. Even at the most basic level, setting aside land for conservation areas, a choice is being made as to which species are most important.

There are two common approaches to biodiversity conservation:

i. at an individual species level
ii. at a habitat wide level

Although much of the literature still addresses the former, real practice tends to be at the level of the latter. The former asks how we identify species which are worth conserving – "which gives the greatest expected marginal biodiversity preservation per unit of money spent?" Not an easy question to answer, so there are a number of reasons for preserving species at the habitat wide level.

a) there are economies of scale in preservation of whole habitats
b) information on the value of individual species is incomplete
c) information on species inter-relationships is incomplete

d) there are non-diversity benefits to habitat preservation (e.g. recreational benefits) - transferable development rights are one aspect.

For now we can use as a loose definition of biodiversity: *the extent of variation between existing species (both plant and animal).*

The problem with such a definition is that to be effective it requires a measure of genetic or characteristics distance. This isn't easy to achieve.

Scientific measures of diversity (eg Shannon or Simpson) combine richness and evenness (S & E).

Shannon index *(H)* adds up proportional abundances of each species (i.e. abundance of species / total abundances).

$$H = -\sum_{i-1}^{S} p_i \ln(p_i) \quad \text{where } p_i = n_i / N$$

$$H = \ln(S) + \ln(E)$$

A key article is Solow, Polasky and Broadus 1993(JEEM 24, p60-68). They have a pure diversity measure and a preservation measure. Their diversity measure is just half of the Shannon measure. The preservation measure uses a simple measure of genetic distance combined with the probability that extinction will occur without intervention.

Begin with the basic assumption that biodiversity necessarily declines if any of species becomes extinct.

Let T be the set of species being considered i.e. $T=\{S_1....S_n\}$

Let Ij=1 if species j is extinct and Ij=0 if species j is in existence

X is the set of preserved species X = {Sj : Ij = 0}

Y is the set of extinct species Y = {Sj : Ij = 1} T = X U Y

The diversity index is I = {I1....In}

Assume that there are conservation resources (C) that can influence the pattern of future extinctions, their influence, however, is not certain, but probable, being seen through a joint probability density function Pc_I

Metrick and Weitzman insert further economic factors:

D_i = uniqueness of i

U_i = utility of i

ΔP_i = effect of spending on the probability of survival of i

C_i = cost of achieving ΔP_i

Gives priority ranking

$R_i = [D_i + U_i].(\Delta P_i / C_i)$

Polasky and Solow (JEEM 1995) introduced the idea of valuing a collection of species that are imperfect substitutes for each other.

Their idea was taken further by Brock and Xepapadeas (AER 2003) who stress the utility approach even further: they focus on the potential economic value of diversity, trying to put everything into a welfare framework by following some very different work of Weitzman's on NNP. Their aim is to illustrate the trade-off between productivity and ability to withstand infection or parasitism in common food crops. This ability explains the value of preserving a broad genetic base among food crops.

Monetary and Fiscal Policy and Natural Resource Rents
http://www.imf.org/external/np/fad/2004/grrt/eng/

APPENDIX 1: TAXATION

1.2.1 Background

1.2.1.1 The current system of mining tax

The taxation of mining activities follows the normal rules of taxation, subject to the following particular features:

a) Income
A mining company may derive income from mining operations and non-mining operations. Different rules and tax rates are applied according to the nature of such income. Differences also apply according to whether the mining income is derived from gold or other operations.

b) Deduction of expenditure
A mining company incurs a wide range of expenditure. Some of this is in the nature of current expenditure (deductible in terms of the general deduction formula), and some in the nature of capital expenditure. The capital expenditure provisions of the Income Tax Act provide for the immediate deduction of capital expenditure and of expenditure on prospecting and incidental operations. Capital expenditure includes expenditure on shaft sinking, mine equipment, development, general administration and management. Some assets such as housing for residential accommodation, motor vehicles for private use of employees, and some railway lines and pipelines qualify only for a partial annual redemption.

c) Ring-fencing
The Income Tax Act applies a ring-fence to the taxable income of a mine, by restricting the deduction of its capital expenditure to the taxable income from mining on that mine. In certain circumstances the ring-fence may be breached by up to 25% of taxable income to allow a company to apply a portion of its expenditure on one mine against the taxable income of another of its mines.

d) Capital allowance
To encourage high capital investment during times of inflation, the Income Tax Act provides, in the case of gold and natural oil, for a capital allowance, calculated as a percentage per annum of total expenditure, which is transformed into a deduction against current capital expenditure.

e) Environmental funds
Mining companies are required by law to make financial provision for mining-related environmental rehabilitation. If in the form of a trust fund, the Income Tax Act permits the deduction of this provision from income, and exempts from tax the receipts and accruals of registered environmental funds established to hold these provisions.

f) Tax rate and formula tax
Non-mining income, as well as mining income not derived from gold mining is taxed at the flat company rate. Income from gold mining is taxed on a formula basis. The effect of the formula is that gold mines which are marginally profitable pay tax at a lower rate than the normal company rate, or no tax at all, and more profitable gold mines pay tax at a rate greater than the normal company rate. The intention of this is to encourage the mining of marginal orebodies, while retaining an overall tax rate for the gold industry at approximately the same rate as the standard company rate. The formula tax, therefore, has the effect that a gold mine can continue to operate at marginal profit levels without paying tax until it regains profitability sufficient to attract tax. In this way it preserves employment in an industry which has a large number of employees and is prone to fluctuations in profitability.

g) Royalties

For purposes of this chapter, royalties are not regarded as a tax and are discussed in section 1.3.

h) Other
No severance tax is imposed. Mining companies are liable, in certain circumstances, to the secondary tax on companies. Indirect taxes paid by mining companies include value-added tax, regional services levies, transfer duties, customs and excise duties and donations tax. (In the case of value-added tax, a mining company does not pay the tax on its export sales, since all exports are zero-rated, and the mine is entitled to a refund in respect of all input taxes paid by it.)

1.2.1.2 Aspects of exploration and mining which have a bearing on mining tax

Any mining taxation system needs to recognise the following aspects:

a. The risk to reward ratio in exploration is high, and mining itself is attended by a high degree of geological, project and market risks.

b. Particularly in big-scale and deep-level operations large amounts of capital are required. This capital is at high risk over long periods.

c. Mining companies are usually required to provide their own infrastructures because of the remote location of mineral deposits.

d. Mining involves the realisation of a wasting asset and the mine has little or no residual value. Continuing investment is therefore necessary in exploration, the acquisition of rights to mine and the development of new mines. All these activities form an essential part of the mining business cycle.

e. Increasing the cost of mining from whatever sources, has the effect of increasing the cut-off grade of ore, thus reducing the life of a mine and sterilising mineral resources.

f. Legitimate expenses should be treated in an appropriate way, the efficient use of resources should be encouraged and not retarded, and the system should not be subject to frequent change, change at short notice or change with retrospective effect.

g. In view of international competition for investment funds, the tax system should be designed to assist in attracting and retaining investment in South Africa.

1.2.2 Intent
Government will maintain and promote a stable legal and fiscal climate that does not inhibit the mining industry from making the fullest possible contribution to the national, provincial and local economy.

1.2.3 Policy Requirements

1.2.3.1 Views of the investment community and mining companies

i. There must be a consistent and stable fiscal regime that compares favourably with those in other jurisdictions.

ii. The tax system should be such as to allow for attractive returns on capital.

iii. The tax system should recognise, through appropriate measures, the risks inherent in mining, such as high capital commitment, long lead times, geological uncertainty and cyclical and volatile markets.

iv. Mineral beneficiation projects share many of the risks referred to above.

v. Mines should be taxed on profits and not in a way which increases costs.

vi. The total tax burden is highly relevant to investment decisions so the levels and structures of national, provincial and local taxes, levies and imposts should be assessed in their entirety. The industry should be consulted when decisions regarding mining taxation are to be made.

vii. The tax system should not discourage, in particular through ring-fencing, the use of the financial strengths of an existing company to invest in the establishment of new mines.

viii. Severance taxes should not be imposed.

1.2.3.2 Other views

i. The mineral industry should make its rightful contribution to tax revenues, both through taxes and royalties.

ii. The tax system should encourage the adding of value to raw materials.

iii. Levies and taxes should be used to fund environmental rehabilitation of land affected by past and current mining activities.

iv. Inter-sectoral equity in terms of taxation should be achieved.

v. Consideration should be given to using tax measures to improve access to mineral rights.

vi. The tax system should promote the optimal utilisation of South Africa's mineral resources.

vii. The tax system should be used to empower the provinces to influence the economic development process and to deal with the effects of downscaling.

1.2.4 Government Policy

i) In developing mining tax policy, Government is committed to ensuring that the tax regime will be consistent and stable and that the aggregate rate of tax will be internationally competitive.

ii) The Katz Commission is investigating mining tax in South Africa. The Commission's recommendations will need to be considered in conjunction with the policy options set out here. It is understood that the Commission will be considering a number of tax issues, for example:

a. redemption of capital expenditure in mining;

b. capital allowances for gold mining;

c. ring-fencing;

d. tax deductions for exploration;

e. a tax on mineral rights; and

f. the extension of the gold-mining formula taxation to other types of mining.

APPENDIX 2: MINERAL RIGHTS AND PROSPECTING INFORMATION

1.3.1 Background

1.3.1.1 Nature and content of mineral rights

i) The South African system of mineral rights has developed over many years to its present state under a dual system in which some mineral rights are owned by the State and some by private holders. The State controls the exercise of prospecting and mining rights under the administrative system of prospecting permits and mining authorisations referred to below.

ii) Under common law, ownership of the land includes ownership of the minerals in the land. The law developed in such a way that the right to minerals in respect of land can be separated from the title to the land, for example upon original grant of the land or by subsequent transactions. The owner of land from which mineral rights have not been separated may separate the mineral rights from the land ownership by ceding them to another person or by reserving them to himself or herself. The mineral rights are then held under separate title which may include all the minerals in the land concerned or only a particular mineral or minerals.

iii) Mineral rights constitute rights in land. They are officially registered by the State, and are a form of property protected under the Constitution.

iv) Mineral rights are tradeable. They have been and continue to be the subject of considerable financial investment that has resulted in the acquisition and registration of rights by prospectors and miners over relevant areas of interest.

v) Mineral rights represent a parcel of rights including the rights to prospect and mine together with ancillary rights to do what is reasonably necessary in order to effectively carry on prospecting or mining operations. The holder of mineral rights may grant subordinate rights to prospect under a prospecting contract or grant subordinate rights to mine under a mineral lease or may sell or otherwise dispose of the rights.

vi) The mineral rights owner is compensated by the exploiter of the minerals for the depletion of the non-renewable resource through the payment of royalties. It is generally accepted that in principle royalties are charged on production or revenue.

1.3.1.2 Ownership of mineral rights

i) The two main categories of owners of mineral rights are the State and private holders. Unfortunately, the current deeds registry system does not provide reliable overall figures indicating what percentage of the mineral rights is owned by each of these categories of holders. Statistics kept by the Department of Minerals and Energy since 1993 indicate that with the exclusion of the coastal zone and sea areas, the mineral rights in respect of which prospecting permits and mining authorisations have been issued are divided in the proportion 1/3 state-owned and 2/3 privately owned. This does not necessarily imply that for the country as a whole, including the coastal zone and sea areas, mineral rights are held in these proportions, but illustrates that the private sector is a substantial holder of mineral rights. A distinguishing feature of the South African mining industry at present is that almost all privately-owned mineral rights are in white hands.

ii) In the former TBVC states and self-governing territories mineral rights were largely owned by those states and territories but, for the purposes of prospecting and mining legislation, administered as if they were privately owned. It has been estimated that mineral rights in respect of some 19 million hectares, which represent 15% of the land area of the Republic, fall into this category, including mineral rights held by Government in trust for specific tribes and communities.

This category also includes those mineral rights which vest in the Lebowa Minerals Trust under the Lebowa Minerals Trust Act, 1987, and the Ngonyama Trust under the Kwa-Zulu Ngonyama Trust Act, 1994. In terms of the present Constitution, mineral rights in this category vest in the State except for those held by the abovementioned two trusts as well as mineral rights held in trust for specific tribes.

iii) The acquisition of mineral rights by the governments of the TBVC states and the self-governing territories was a result of the implementation of the South African Development and Trust Act, 1936, which provided for the vesting of these rights in the SA Development Trust (SADT) on behalf of Blacks. In terms of the Constitution of Self-governing Territories Act, 1971 and various statutes, these rights were transferred to the governments concerned.
Provision was also made for the vesting of trusteeship in the South African Government in cases where land together with mineral rights held by communities was incorporated into the jurisdictional areas of the governments of the TBVC states and the self-govering territories as well as land together with mineral rights which fell outside the jurisdictional areas of the aforementioned governments.

iv) The State is the owner of mineral rights in various areas of surveyed and unsurveyed State land as well as in privately-owned land where mineral rights have specifically been reserved to the State. Under prior legislation the latter class of land was known as "alienated State land" in respect of which prospecting rights together with the exclusive right to obtain mining rights were vested in the landowners or their nominees. According to section 43 of the Minerals Act, such rights were replaced with similar rights for a period of only five years which ended on 31 December 1996.

v) Mineral rights in certain rural areas, situated mainly in Namaqualand and in the Northern Cape (governed by the Rural Areas Act, 1974), are regarded as state-owned for the purposes of the minerals legislation. However, management boards in those areas exercised through the years extensive authority in respect of the granting of prospecting and mining rights. These management boards have after April 1994 been replaced by transitional local councils.

vi) Provision has been made in the Constitution read with the Restitution of Land Rights Act, for relief to persons or communities who were dispossessed of rights in land under any racially discriminatory law after 19 June 1913. Mineral rights are rights in land and can therefore be subject to the Act.

vii) There is an active market and continual movement in mineral rights, some 6 000 mineral cessions and prospecting contracts having been registered in deeds offices in South Africa for the five year period from 1991 to 1996.

1.3.1.3 Provisions for intervention by the State

In addition to the modes of acquisition of mineral rights referred to in paragraph

1.3.1.1 iv) above, the State can intervene under section 17 of the Minerals Act to grant prospecting rights in circumstances where an intending prospector cannot trace the holder of the mineral rights or where an heir has not taken cession of the mineral rights in an estate. According to section 24 of the Minerals Act, mineral rights and other rights in land may be expropriated in the public interest against compensation payable by the person requesting expropriation. It is therefore possible to expropriate the right to prospect and the right to mine. Under the current law, the State may, by virtue of section 18 of the Minerals Act, conduct an investigation on any land to establish the presence, nature and extent of minerals in or on that land, provided that such an investigation is in the national interest.

1.3.1.4 Other jurisdictions

i. South Africa and the USA are two of the few major mining countries which have a dual system of public and private ownership of mineral rights. In most other countries the right to minerals is vested in the State. However, in some countries, of which Chile and Australia are good examples, the state system is such as to allow a mining company *de facto* permanent title to such rights.

ii. In jurisdictions where mineral rights are publicly owned, a system of licensing is usually applied which provides security of tenure sufficient to attract exploration and mining. Many countries, notably in South America but increasingly elsewhere, which employ licensing systems for publicly-owned mineral rights, have successfully attracted large and continuing investment in exploration and mining.

1.3.1.5 The exercise of prospecting and mining rights in South Africa

i. In South Africa, the mineral right owner is not permitted to prospect or mine for minerals without having obtained a prospecting permit or mining authorisation from the State. These licences are not transferable. They are aimed at controlling prospecting and mining, having regard to considerations of health and safety, environmental rehabilitation and responsible extraction of the ore. Conversely, a prospecting permit or mining authorisation cannot be granted unless the applicant is the holder of the relevant mineral right or has acquired the holder's consent to prospect or mine.

ii. Reconnaissance work can and does take place without the necessity to hold a permit, provided the work does not fall within the definition of 'prospecting' in the Minerals Act.

1.3.1.6 Records of prospecting work

i. According to section 19 of the Minerals Act, the holder of any prospecting permit or mining authorisation is obliged to furnish certain prospecting information to the State within one year after completing the digging of any excavation or drilling a borehole for the purpose of prospecting. The information must be kept confidential by the State. When 15 years have elapsed from the date of the completion of the excavation or borehole concerned, the State may disclose the information unless any person with a pecuniary interest in the excavation or borehole satisfies the State that his or her interest will be prejudiced by such disclosure.

ii. In most other jurisdictions confidentiality against disclosure to third parties of basic prospecting information furnished to the State is afforded during the currency of the prospecting licence or for very short periods. In such jurisdictions, where public ownership of mineral rights prevails, the policy is directed at assembling a public record of exploration work as a resource for future exploration.

1.3.2 Intent

Government will:
i) promote exploration and investment leading to increased mining output and employment;

ii) ensure security of tenure in respect of prospecting and mining operations;

iii) prevent hoarding of mineral rights and sterilisation of mineral resources;

iv) address past racial inequities by ensuring that those previously excluded from participating in the mining industry gain access to mineral resources or benefit from the exploitation thereof;

v) recognise the State as custodian of the nation's mineral resources for the benefit of all;

vi) take reasonable legislative and other measures, to foster conditions conducive to mining which will enable entrepreneurs to gain access to mineral resources on an equitable basis; and

vii) bring about changes in the current system of mineral rights ownership with as little disruption to the mining industry as possible.

1.3.3 The Present System: Views For and Against

Many differing views have been expressed in support of or against the current arrangements in respect of mineral rights and prospecting information.

1.3.3.1 Private ownership

i. Proponents of private ownership maintain that:

a. It has been and remains ideally suited to effective utilisation of South Africa's distinctive ore bodies, for example, by providing the absolute security of tenure necessary in the development of very deep gold mining along the West Wits line. The capacity to retain mineral rights securely for the development of new mining ventures when these become possible is a positive feature of private ownership.

b. Holding of mineral rights is a critical parameter in the valuation of a mining company by international investors. The company is valued according to its future potential ("blue sky") which depends on an ongoing flow of new projects derived from such mineral holdings.

c. Private ownership of mineral rights based in the law of property is preferable to a pure licensing system of rights based in administrative law and involving administrative discretion. Private ownership affords the absolute long-term security of tenure that attracts investment in exploration, mining and marketing.

d. South Africa has the ability to produce at a level far exceeding the world's ability to consume several commodities such as manganese, chrome, platinum and vanadium. Mineral rights in such commodities are held as part of long-term mining plans. Owners have a record of having expanded production in line with growth in demand and have also invested substantial funds in new product development and other forms of promotion to foster market growth.

e. Private ownership is consistent with a market economy and with an international trend towards reducing the direct role of Government in the mining industry.

f. Private ownership encourages trade in and utilisation of mineral rights, as is evident from the figures referred to in paragraph 1.3.1.2 above.

ii. Critics of private ownership of mineral rights argue that:

a. Minerals are part of the nation's endowment so that the State is the rightful custodian of this endowment.

b. South Africa (along with the USA) is out of step with other major mining countries, where public ownership of mineral rights has led to successful exploration and mining industries.

c. Private ownership of mineral rights suppresses exploration activity as well as the opportunity for alternative views to be taken of the economics of mining an unexploited ore body.

d. It allows hoarding of mineral rights. As such, the system is a barrier to entry against potential investors.

e. Complex and fragmented mineral right holdings and the multiplicity of owners in South Africa militate against new investment by prospective new entrants who encounter difficulty and cost in identifying holders of mineral rights and obtaining mineral rights.

f. The system is inaccessible to small-scale miners, and inhibits the development of a vibrant junior mining sector.

g. Private ownership of mineral rights limits equal and equitable access to mineral rights and resources.

1.3.3.2 State ownership

i) Those in support of the transfer of privately-held mineral rights to the State contend that:

a) Transfer of mineral rights to the State will release mineral terrains for new entrants, which will stimulate private sector activity.

b) State control of mineral rights will remove difficulties in cost and delays surrounding fragmented mineral right holdings.

c) A system of state-owned mineral rights would enable the State to enforce the submission and release of exploration information, thereby avoiding duplication of exploration activities.

d) State ownership of mineral rights is more prevalent in the world than is private ownership of mineral rights.

e) State ownership will prevent the hoarding of mineral rights and allow equal and equitable access to potential investors, in particular small-scale miners.

ii) Contentions raised against a transfer of mineral rights to the State are that:

a. Transfer of mineral rights to the State will require the payment of compensation, which would be an inappropriate use of the State's limited financial resources.

b. The blanket transfer of mineral rights to the State could easily lead to administrative difficulties in a system not geared to the management of mineral rights, extensive delays and hence a loss of investor confidence that could seriously damage the South African mining industry.

c. There is no indication that the transfer of mineral rights to the State will automatically result in more successful exploration and mining. It is argued that in South Africa there is evidence to the contrary in that state ownership of mineral rights has made these rights subject to policies that have impeded rather than promoted mineral development. As indicated above, it has been estimated that two-thirds of the mineral rights in respect of which prospecting and mining activities are conducted are privately held. Management of deposits that will be brought to account in the future requires a long-term perspective attuned to changes in technology and markets that is more likely to be found in the private sector.

d. State ownership based in a system of administrative law offers less security than a system of private ownership based in the law of property, and is susceptible to inefficiency and corruption.

e. A bias towards state ownership would run counter to the Government's philosophy and policy on competition and privatisation.

f. Prospecting information and mineral rights are separate forms of property. Ownership of the latter does not automatically confer title to the former.

1.3.3.3 Disclosure of prospecting information

In relation to prospecting information there are broadly two contending views. On the one hand, it is argued that more data on prospecting results should be made publicly available as a resource for future exploration efforts by new prospectors and prospectors with new techniques. Against this it is held that prospecting data are the product of effort and investment by prospecting companies, the data constitute property that can be bought and sold and an incentive should be provided for the prospecting effort to be undertaken by protecting the confidentiality of the data for a reasonable period. As a further complication, contentions in support of the public release of prospecting data after fixed periods ignore the nature of prospecting programmes that do not have a readily determinable point of completion.

1.3.4 Tax on Mineral Rights

i) One view is that a tax should be imposed on privately held mineral rights to open access to such rights. Such a tax would not be payable by operating mines or where the retention of mineral rights is part of a long-term mining strategy that is in the national interest, or where there is active exploration taking place. If the owner of the mineral rights is unable or unwilling to pay a mineral rights tax, the rights may either be sold to a willing purchaser or at no cost to the owner be transferred to the State.

ii) Opponents of such a tax reject the view that the rights would be better utilised if transferred to the State. They have also contended that it would be contrary to the Constitution to use a tax to induce taxpayers to surrender assets to the State without payment for these assets. In addition to questions about the constitutionality of such a tax, and whether it will achieve its objective, opponents of such a tax contend that there are practical difficulties in applying such a tax; for example, how could this be done equitably across a range of mineral rights where commercial values may differ greatly and which may be held by a multiplicity of holders? They argue that the tax would be contentious, wrongly burden the holding of rights intended for future use, raise the investment threshold, delay investment decisions, generate uncertainty about mineral right holdings and require considerable administrative effort. It could become a source of litigation, for example in so far as its application to property held in trust is concerned. In addition, such a tax directed at a policy purpose, as opposed to revenue generation, would be inconsistent with the guiding principles articulated by the Katz Commission and hence detracts from the evolving coherence of the country's fiscal policy.

iii) It is also contended that, if a tax on mineral rights were introduced, expenditure on market development (such as R & D on possible new products and promotion of long-term growth in the market) incurred by the taxpayer should be allowed as a credit against the tax liability, in addition to the current value of past prospecting-related expenditures. Proponents of this view observe that ownership of mineral rights affords the long-term predictability of security of tenure on which major commitment to future development depends.

1.3.5 The Need and Capacity for Change

Whilst the Government recognises that the system currently in place has some positive features, it concludes that the *status quo* must be changed with a view to achieving the policy objectives set forth in paragraph 1.3.2 above. Government believes that changes will be implemented on an incremental basis. Notwithstanding changes to the current mineral rights dispensation, the State shall guarantee security of tenure.

1.3.6 Government Policy

1.3.6.1 Ownership of mineral rights

i) Government recognises the inherent constitutional constraints of changing the current mineral rights system. However, in terms of the Constitution the State is bound to take legislative and other measures to enable citizens to gain access to rights in land on an equitable basis. In addition, it empowers the State to bring about land rights (including mineral rights) and other related reforms to redress the results of past racial discrimination. Furthermore, article 2(1) of the UN Charter of Economic Rights and Duties of the State grants to States full permanent sovereignty, including possession and disposal, over all its natural resources. Government therefore does not accept South Africa's current system of dual state and private ownership of mineral rights.

ii) Government’s long-term objective is for all mineral rights to vest in the State for the benefit of and on behalf of all the people of South Africa.

iii) State-owned mineral rights will not be alienated.

iv) Government will promote minerals development by applying the "use-it or lose-it"/"use-it and keep-it" principle.

v) Government will take transfer of mineral rights in cases where a holder(s) of mineral rights cannot be traced or where mineral rights have not been taken cession of and are still registered in the name of a deceased person(s).

1.3.6.2 A new system for granting access to mineral rights

As a transitional arrangement in persuance of the objective stated in section 1.3.6.1 ii above, the following new system for granting access to mineral rights will apply:

i) The right to prospect and to mine for all minerals will vest in the State.

ii) Government will develop detailed legislative proposals for the introduction of the new system of access to all mineral rights. In developing such proposals provision will be made for:

a) Guaranteeing the continuation of current prospecting and mining operations in accordance with the "use-it and keep-it" principle;

b) a transitional period to allow holders of prospecting, mining and mineral rights to licence the operations referred to in (a) above, as well as extensions which are necessary to provide for the continuation of such operations;

c) a transitional period to allow holders of prospecting, mining and mineral rights to licence *bona fide* intended prospecting and mining operations in cases where (a) and (b) above do not apply;

d) a general notification to allow holders of prospecting, mining and mineral rights to substantiate in respect of areas other than those contemplated in (a), (b) and (c) above, why licences for prospecting and mining should not be granted to another party in accordance with the "use-it and keep-it" principle;

e) Granting of prospecting and mining licences to applicants without the consent of the holders of prospecting, mining or mineral rights who have not been licensed in terms of (b), (c) and (d) above;

f) Security of tenure by granting prospecting and mining licences for specified periods which are capable of cancellation or revocation only for material breach of the terms and conditions of the licence;

g) Registerable prospecting and mining licences which will be transferable with the consent of the State;

h) The holder of a prospecting licence to be entitled to progress to a mining licence on compliance with prescribed criteria;

i) Annual minimum work and investment requirements to discourage the unproductive holding of prospecting and mining licences;

j) a retention licence which may, upon written application, be granted to an applicant in cases where the applicant, having explored the area and established the existence of an ore reserve which is, at the time of completion of the exploration programme, considered to be uneconomical due to prevailing commodity prices (market conditions) or where the exploitation thereof might lead to market disruption not in the national interest. Such licence will enable the holder thereof to retain the reserve without the commitment to minimum work and investment requirements. The licence will be granted for a limited period in respect of the property concerned;

k) Precluding the granting of a prospecting or mining licence over an area in respect of which a currently valid prospecting retention or mining licence is held for the same mineral;

l) Predetermined standard terms and conditions, for all prospecting and mining licences;

m) the reduction, as far as possible, of discretionary powers by applying standard requirements or objective criteria;
n) Payment of prospecting fees or royalties by the holder of the prospecting or mining licence to the registered holder of mineral rights. Such prospecting fees or royalties will be determined by the State after consultation with the registered holder of the mineral rights. In determining such fees and royalties, prospecting fees and royalties payable to the State will be used as a guide. The quantum of prospecting fees and royalties will be internationally competitive and will not inhibit the initiation of new projects;

o) payment of a surface rental, determined by the State after consultation with the landowner, by the holder of a prospecting or mining licence to the registered land owner; and

p) the processes of considering the granting of a prospecting or mining licence and the approval of an environmental management programme to run concurrently and to grant the prospecting or mining licence and approve the environmental management programme simultaneously.

iii) Persons, including their successors in title, or assigns or nominees, who could lay claim, under section 43 of the Minerals Act, 1991, to the exclusive right to prospect for a mineral to which the right was reserved to the State, shall after the lapsing of the period that ended on 31 December 1996, or the approved longer period, no longer be deemed to be the holder of such right.

1.3.6.3 Reconnaissance work

A non-exclusive permission for broad-based, non-destructive exploration will be implemented. Such permissions will be for a limited period in respect of the area required. A reconnaissance permission will not entitle the holder thereof to a prospecting or mining licence.

1.3.6.4 Disclosure of prospecting information

It will be a condition of any prospecting licence or reconnaissance permission that all information and data from prospecting shall be submitted to the State after completion or abandonment of any particular prospecting activity. The State will release such information to the public at any time from the date of submission of such information unless the prospector retains a prospecting retention or mining licence in respect of the land concerned or an application therefor is pending. Such information submitted to the State will be used to create a national exploration data base.

1.3.6.5 Data base of mineral rights holdings

Government will through the Departments of Land Affairs and Minerals and Energy seek to obtain the aditional resources which will be necessary in order to compile a readily-accessible data base.

1.3.6.6 Disincentive for non-utilisation of mineral rights

Government will investigate the feasibility of imposing disincentives which would be intended to discourage the non-utilisation of privately-owned mineral rights. Such disincentives will not apply in respect of areas where currently valid prospecting, retention or mining licences are held. Such investigation, which will be undertaken by the Department of Minerals and Energy in association with the Department of Finance, will take into account the findings of the Katz Commission.

APPENDIX 3: ENVIRONMENTAL MANAGEMENT

2002 WHITE PAPER

Chapter Four:

The Constitution provides that everyone has the right to an environment that is not harmful to their health or well-being and to have the environment protected for the benefit of present and future generations. This must be done through reasonable legislative and other measures that will prevent pollution and ecological degradation, promote conservation and secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.

To be able to meet the development needs of the people while ensuring that the integrity of the environment remains unimpaired, it is essential to integrate environmental impact management into all economic development activities. This is in the interest of Government's overarching goal of sustainable development.

4.1 Background

i) Mining activities impact on the environment to varying degrees. Three important areas identify themselves for policy and regulation:

a) the environmental impact of exploration;

b) the environmental impact over the life of a mine including mine closure and financial assurances for mine site rehabilitation;

c) maintaining rehabilitation measures where mining activity has ceased.

ii) South African society and the economy are characterised by the inequitable distribution of wealth and resources. This has resulted in the basic needs of the majority of South Africans not being met. To satisfy the needs of all South Africans, the utilisation of the mineral resources of the country, within a framework of responsible environmental management, is essential.

iii) Development in South Africa requires the optimum and environmentally sustainable use of all the natural resources of the country. A balance must therefore be attained between a cost-effective and competitive mining industry and the imperative to protect the environment.

iv) The complex nature, both underground and above ground, of on- and offshore mining operations requires a dedicated approach and specific skills from controlling authorities. Adequate personnel who are qualified in the earth, biological and environmental sciences and who have been subjected to specialist training relevant to environmental management and mineral extraction are therefore required by the controlling authority.

v) Government will have to ensure that the costs of environmental impacts of the mining industry are not passed over to the community. This calls for:

a) a co-ordinated and integrated environmental management approach to the planning, management and use of all natural resources;

b) an increased public involvement to ensure pro-active and informed decision-making;
c) the implementation of effective and affordable measures and standards for environmental impact management, the prevention or efficient management of water, soil and atmospheric pollution, and the rehabilitation of areas affected by past mining operations; and

d) ongoing research with a view to improving and strengthening the measures, standards and practice applied to managing the impacts on the environment and to control pollution.

vi) Under the Minerals Act, prospecting and mining operations may not be conducted without an environmental management programme (EMP) having being approved by the authorities. To assist prospecting and mining companies to comply with this requirement, the Environmental Management Programme Report (EMPR) process was developed and has been approved for use in the mining industry. The EMPR covers a description of the pre-mining environment, a motivation for and detailed description of the proposed project, an environmental impact assessment, and an indication of how the impacts will be managed. Adequate consideration must be given to alternative methods of mining. The EMP, furthermore, requires adequate provision for financial guarantees for rehabilitation and arrangements for monitoring and auditing.

4.2 Intent

Government, in recognition of the responsibility of the State as custodian of the nation's natural resources, will ensure that the essential development of the country's mineral resources will take place within a framework of sustainable development and in accordance with national environmental policy, norms and standards.

4.3 Policy Requirements

4.3.1 Views of employers

i. A balance should be maintained between encouraging economic development and preserving high standards of environmental management.

ii. Subject to the site-specific nature of the operation, uniform standards of environmental management should be applied across mining operations of varying scale so that all mining is conducted in an environmentally responsible manner. Artisanal mining, which has frequently caused severe environmental damage in other countries, should not be treated more leniently.

iii. In principle, there should be no area, other possibly than those which have been sterilised by proclaimed townships, where prospecting and mining are prohibited, but the degree of sensitivity of the area must affect the standards of environmental control exercised by the mining operation. Should an economically viable ore body be discovered in a sensitive area, approval to mine should be subject to the full assessment of environmental impacts provided for in the Minerals Act, in which the "no project" option can be considered.

iv. Cognisance should be taken of the stage of economic development of the country in framing environmental regulations. Environmental protection legislation that follows the example of highly developed countries should be adopted with caution. Prospecting and investment in mining have on occasion been substantially diminished as a direct result of ever-higher standards.

v. Mining should be granted precedence in land use, while taking cognisance of environmental factors.

vi. Appropriate environmental standards should be set for different stages of mining so that low impact activities, such as prospecting, are not burdened with cumbersome regulations.

vii. The interdepartmental consultation required for approval of environmental management programmes should be facilitated and expedited through a "one-stop shop" approach in which the Department of Minerals and Energy acts as a lead agent and liaises with other departments, provincial authorities and interested and affected parties.

viii. Delays in obtaining environmental approvals should be eliminated through improved administration.

4.3.2 Views of small-scale miners

i. Government support should be provided for the education of small-scale miners on environmental management.

ii. Intensive environmental management services should be provided in areas where there is a high concentration of small-scale miners. Measures should include providing technical and environmental management assistance and simplifying the procedures for complying with environmental management regulations. Explicit budgetary allocations should be made for this purpose.

iii. Rehabilitation procedures should be made more affordable by devising a more flexible system for providing the necessary rehabilitation moneys.

4.3.3 Other views

i. Conservation areas including parks, reserves, wilderness areas, and cultural and archaeological sites should be protected.

ii. The rehabilitation of defunct and derelict mines which are a risk to the environment, public safety and human health should be provided for by appropriate regulation.

iii. The environmental damage caused by the mining industry should be managed and contained irrespective of the size of the mine.

iv. It should be ensured that the rehabilitation of land for post-mine use is carried out to standards that permit its use for the purpose set out in the EMPR and that closure be granted only after satisfying that there are no foreseeable residual impacts that will be inherited by parties acquiring such land.

v. Communities directly affected by mining should be enabled to participate in environmental impact assessments studies at the planning stage.

vi. South Africa should comply with international environmental standards to meet international obligations.

vii. Concerns that the DME lacks capacity to enforce existing environmental provisions should be addressed.

viii. Environmental management for the minerals industry should be improved by expanding the scope of EMPRs, which presently address the physical environment, to include assessment of the impact on the social environment.

ix. A conflict of interest between the promotion of the minerals industry and the enforcement of environmental standards within the DME should be prevented by providing a clear separation of powers.

x. Land-use decisions should be based on economic efficiency and mining should not enjoy a claim to precedence.

4.4 Government Policy

Government will ensure that the following principles are adhered to:

i) In order to achieve integrated and holistic environmental management throughout South Africa, Government requires compliance with a single national environmental policy and governance within a framework of co-operative governance. While Government has appointed the national Department of Environmental Affairs and Tourism as its lead agent for this role, the DME will, in support of the lead agent and in accordance with national principles, norms and standards, develop and apply the necessary policies and measures to ensure the mining industry's compliance with the national policy on environmental management and other relevant policies such as the national water policy.
Similarly, due recognition will be given to the Department of Water Affairs and Forestry as lead agent for the national water resource.
The processes of considering the granting of a prospecting or mining licence and the approval of an environmental management programme will run concurrently and the granting of the prospecting or mining licence and approval of the environmental management programme will take place simultaneously. The DME, in consultation with the relevant State Departments, will develop procedures to accommodate their requirements. These procedures will provide for decision making in consultation with such Departments.

ii) During decision-making, a risk-averse and cautious approach that recognises the limits of current environmental management expertise will be adopted. Where there is uncertainty, action is required to be taken to limit the risk. This will include consideration of the "no go" option.

iii) The polluter-pays principle will be applied in the regulation and enforcement of environmental management. The mining entrepreneur will be responsible for all costs pertaining to the impact of the operation on the environment. Where for reasons such as the demise or incapacity of a mining entrepreneur, no responsible person exists or can be identified to address pollution emanating from past mining operations, the State may accept responsibility or co-responsibility for the rehabilitation required. Government may require that any person benefiting from such rehabilitation should contribute to the cost involved in such proportions as may be negotiated.

iv) A consistent standard of environmental impact management will be applied and maintained irrespective of the scale of the mining operation. Special attention will be afforded to the education and the provision of guidelines for mining entrepreneurs concerning environmental management, especially for small-scale miners. Furthermore, intensified attention and guidance will be provided in areas where high concentrations of small mining activities occur.

v) Equitable and effective consultation with interested and affected parties will be undertaken pro-actively to ensure public participation in the decision-making process and the *audi alteram partem* (hear the other side) rule shall apply to all decision-making. The decision-making process shall provide for the right to appeal. Access to information shall be in accordance with the requirements of the Constitution.

vi) Mining companies will be required to comply with the local Development Objectives, spatial development framework and Integrated Development Planning of the municipalities_within which they operate and will be encouraged to promote social participation by conducting their operations in such a manner that the needs of local communities are taken into consideration. On closure of a mine, every opportunity must be taken to ensure the continued availability of useful infrastructure.

vii) Clear guidelines on the process and sequence of events for implementation of environmental management procedures and decision-making will be provided.

viii) The principles of Integrated Environmental Management (IEM) will be applied to environmental management in the mining industry. These must be amplified to include cradle-to-grave management of environmental impacts in all phases of a mine's life, effective monitoring and auditing procedures, financial guarantees for total environmental rehabilitation responsibilities, controlled decommissioning and closure procedures, procedures for the determination of possible latent environmental risks after mine closure and the retention of responsibility by a mine until an exonerating certificate is granted.

ix) The building of capacity to -

a) effectively implement environmental management measures;

b) monitor occurrences of pollution; and

c) monitor compliance with the requirements of the national environmental management policy.

x) The principle of multiple land use will be adhered to in planning decisions, and contending options will be assessed and prioritised on economic, social and environmental grounds.

xi) The mining industry will be required to reduce pollution and encouraged to promote a culture of waste minimisation and creative recycling and re-use of waste products.

xii) Problem areas in environmental management will be identified pro-actively with a view to the co-ordination of research there into.

Mineral Leasing

Up until now, Prospecting Fees and Royalty Payments have been payable where prospecting or mining operations involving State owned Mineral Rights have been taking place. The rates for prospecting and level of royalties for mining have been laid out in a document approved by Director-General of the Department of Finance, in terms of the Public Finance Management Act, 1999 (Act No. 1 of 1999). Until the promulgation of the Money Bill, the present rates as reflected in the Treasury document will be payable.

One of the focal points of the New Act is that all Mineral resources belong to all South Africans and that the State is the custodian of these resources. The result of this is that after the transition period provided for in the New Act, prospecting fees and royalties will be payable whenever a potential resource is to be prospected or a proven resource is to be mined, whether these rights were previously State or privately owned.

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