Economics of the Non-renewable Resources

• Some Basic Definitions
• Geology and Costs of Extraction
• How much to Produce from a Known Stock
• Flow and Asset Values
• Exploration
• What has actually happened to Resource Prices?

Defining Resources Based on What People and Nature Do

\[
\text{(Stock)}_t = \text{(Stock)}_{t-1} - \text{(Flow)}_{t-1} + \Delta S_{t-1}
\]

- Nonrenewable resource – known amounts then \( \Delta S_{t-1} = 0 \)
- There is no replenishment of the resource – example – minerals
- Renewable resource – known amount then \( \Delta S_{t-1} > 0 \)
- Nature adds more to stock with growth of resource stock – examples – fishery and forest
So with renewable resources:

\[ S_t = S_{t-1} - Q_{t-1} + \Delta S_{t-1} \]

\[ \Delta S_{t-1} = f(S_{t-1}) \]

**Recyclable Resources**

Sometimes nonrenewable resources can be recycled and a portion of resource used in period 0 can be recycled back to contribute to supply for next period so:

\[ S_t = S_{t-1} - Q_{t-1} + \alpha Q_{t-1} \]

\[ \alpha = \text{proportion that is returned through recycling} \]
Reserves versus Amount in a Deposit

- Simple models we will use assume the amount of the mineral deposit is known and of the same quality.

- Reserves are estimated—based on geological AND economic conditions—amount that can be extracted with economic return—means geologist makes assumptions about price of mineral and costs of extraction over the time period for reserve estimate. The same deposit may yield more or less reserves as the expected price or cost conditions change.

Two Different Views of the Geological Availability of Minerals

Figure 5.4, Possible geochemical distributions of abundant and scarce elements. (From B. J. Skinner, "A Mineral Age Alphabet," American Mineralogist vol. 61, 1976, p. 288.)
Socially efficient rate of extraction is to maximize present value of net benefits from using the ore.

\[
\text{Present Value} = \text{Net benefits in year 1} + \frac{1}{1+r} \left( \text{Net Benefits in year 2} \right) \]
\[
= (a+b) + \frac{1}{1+r} (d+e)
\]

Adjust amounts \(Q_1\) and \(Q_2\) until Present Value is the highest.

Figure 5.4. Possible geochemical distribution of abundant and scarce elements.
Socially efficient profile

\[ MWTP_1 - MC_1 = \frac{1}{1+r} (MWTP_2 - MC_2) \]

When firms own deposits and cannot influence price

\[ MWTP_1 = P_1 \]
\[ MWTP_2 = P_2 \]

Competitive market with known deposits will yield efficient outcome

\[ P_1 - MC_1 = \frac{1}{1+r} (P_2 - MC_2) \]

Multiply by (1+r)

\[ (1+r)(P_1 - MC_1) = P_2 - MC_2 \]
\[ (P_1 - MC_1) - (P_2 - MC_2) = -r(P_1 - MC_1) \]

Comparison of Static choice versus Dynamic Choice – dynamic with the *’s; dashed lines are rents in each period
Or

\[
\frac{(P_2 - MC_2) - (P_1 - MC_1)}{(P_1 - MC_1)} = r
\]

\[P_1 - MC_1 = \text{Hotelling Rent}\]

Earn a rate of return by waiting (keep ore in the ground).

Value of a Deposit is Present Value of Rents that are expected to be earned; so two markets connected – market for deposits and market for ore – (Arbitrage opportunity)

Also note if \( MC_t = 0 \)

\[
\frac{(P_2 - P_1)}{P_1} = r
\]

What is comparable \( r \)?

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**Exploration and Sustainability**

In both cases pay attention to the rent;

**Exploration** – the value of a unit of a resource extracted to society is rent; in perfect competition this is \( P_t - MC_t \)

So Exploration takes place until \( \text{Rent}_t = MC \) of Exploration.

**Sustainability** – backstop technology \( p^B \)

When is it best to switch from perspective of social efficiency?

\[
MWTP_t - MC_t = \frac{1}{1+ r} (MWTP_2 - MC_2)
\]

\[
p^B = MWTP_t = MC_t + \frac{1}{(1+ r)} (MWTP_2 - MC_2)
\]
What Has Happened to Prices of Minerals?

More Price Trends for Minerals
(source – Lee, List, and Strazicich, NBER wp#11487, July 2005)
Other Issues to Make Analysis More Realistic

• Multiple Deposits – can different grades be exploited at the same time? – yes with capacity constraints
• Market Structure – is a monopoly a better conservationist?
• Uncertainty – risk premium