

## Classes of Natural Resources

A. Nonrenewable, or Exhaustible – e.g. coal deposit, oil deposit, body of iron ore (the subject of Ec. 471)

B. Renewable – a resource that is capable of growth, or regeneration, e.g. a forest, a fishery resource

The use of the term “Exhaustible” can be misleading -often impossible to physically exhaust category A natural resources. Many category B natural resources can in fact be physically exhausted -examples

## ECONOMIC BASE of a REGION (e.g. British Columbia)

-goods and services produced by the Region that are sold primarily beyond the Region's borders

All other productive activities in the Region are seen as being dependent on this BASE.

The Economic Base of the Region that is British Columbia is heavily oriented towards Natural Resources –forestry in particular.

## Natural Resources as Capital

Capital is any asset that is capable of yielding a stream of economic returns through time – as opposed to a consumer good or service.

Real capital vs. financial capital

All natural resources, non-renewable and renewable, fall within this definition of real capital

The World Bank 2005 publication: ***Where Is the Wealth of Nations?*** – based upon the fundamental idea that society's income through time is produced by its stock of real capital, which consists of:

- I. Produced capital (person made capital)
- II. Natural capital
- III. Intangible capital (human and social capital)

Traditional national income accounting only recognizes produced capital. The World Bank and others call for “green accounting”

Development seen by the World Bank as a process of real capital portfolio management through time (portfolio – a set of assets).

## Natural Capital vs. Produced Capital (person made capital)

- a. Natural capital assets come as endowments of nature
  
- b. Can be optimal –within limits –to deplete, to disinvest in, Natural capital
  - deliberate disinvestment of Produced capital never discussed. No nation is ever seen as having more than enough Produced capital.

Our ability to manage these resources is affected by the existence, or lack of existence, of resource property rights. The property rights, if they exist, may either be private, or public (i.e. state), property rights. As a first step, we must define what we mean by property rights.

## Property Rights – Text definition

**“A bundle of characteristics that convey certain powers to the owner of the right”**

### Key characteristics

I. Exclusivity

II. Enforceability

III. Transferability

IV. Divisibility

Characteristics I and II are crucial

-the Text's example of a farmer holding a deed to farm land.

Absence of property rights:

***“common pool” resources***

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## Sustainable Harvesting and Resource Investment: A Crude Example

### A Forest

At the end of period  $t$ , the volume of wood in the forest is estimated to be equal to  $X$  cubic metres.

If no harvesting (logging) were to occur in the forest over the following period:  $t + 1$ , the volume of the wood in the forest at the end of period  $t + 1$  would be estimated to be equal to:  
 $X + Y$  cubic metres.

The additional  $Y$  cubic metres accounted for by the net natural growth of the forest.

Suppose now that, over  $t + 1$ ,  $Y$  cubic metres was extracted from the forest due to harvesting, i.e. logging. The volume of wood in the forest at the end of  $t + 1$  would, other things being equal, be  $X$  cubic metres:  $(X + Y) - Y = X$

In theory,  $Y$  cubic metres could be extracted from the forest, period after period, with the volume of wood in the forest remaining stable. We would talk about harvesting the forest on a “**Sustainable Basis**” - “cropping the growth”, or “skimming off the growth”.

If the harvest over  $t + 1$  should be less than  $Y$  cubic metres, we would have positive investment in the forest. The forest asset, measured in terms of volume of wood, would increase.

If the harvest over  $t + 1$  should exceed  $Y$  cubic metres, we would have negative investment in the forest asset – also known as disinvestment.

If the forest was harvested on a “sustainable basis” over  $t + 1$ , i.e. the harvest over the period equal to  $Y$  cubic metres, then the investment in the forest asset is equal to zero – neither positive nor negative.

-Size of the sustainable harvest will be influenced by the size of the forest (measured in cubic metres of wood).

***Sustainable Yield*** (or harvest) – a concept that we shall see coming up over and over again.

## The Theory of Capital vs . The Theory of Investment

Theory of Capital – about determining the optimal Stock of capital.

Theory of Investment –concerned with flows –

positive investment – building up a stock of capital through time.

negative investment (disinvestment) - reducing a stock of capital through time.

The Theory of Investment is designed to tell us how rapidly we should approach the optimal stock of capital. Should the *rate* of investment be fast or slow.

The economist's Theories of Capital and Investment lie at the heart of Natural Resource Economics, as applied to both renewable and non-renewable natural resources.

Before we can say anything about the Theories of Capital and Investment, we have to review the concepts of Present Value and Future Value

## The Interrelated Concepts of Present Value and Future Value

Present Value (PV) used to express the current, or present day, value of an asset (or return) to be received at a certain future date.

Future Value (FV) relates to value of an asset, if held, at a certain date in the future.

Key link between PV and FV provided by the **interest rate** – also referred to as the **rate of discount**.

Example:

\$1,000 held to day - Present Value

Suppose that the relevant annual rate of interest is 5.00% (no compounding within the year)

At the end of one year, the \$1,000 will be worth:

$\$1,000(1+0.05) = \$1,050$ , which is the Future Value (1 year) of the original \$1,000

Denote the relevant interest rate in decimal terms as:  $\delta$ .

In general terms: Future Value (1 year) is:

$$FV = PV(1 + \delta)$$

and

$$PV = \frac{FV}{(1 + \delta)}$$

in our example, we have  $\delta = 0.05$

Suppose now that I am to receive \$100 at the end of 1 year. Then:

$$PV = \frac{\$100.00}{(1 + 0.05)} = \$95.24$$

Suppose that I was to receive the \$100 in two years time, what then would the PV of the \$100 be? We would have:

$$PV = \frac{\$100}{(1 + 0.05)^2} = \$90.70, \text{ why?}$$

To generalize, let R be the amount to be received at a future time t. Then:

$$PV = \frac{R}{(1+\delta)^t}$$

The present is:  $t = 0$ .

Now suppose that we were to receive a series of equal payments of \$100.00 from  $t = 1$  to  $t = 5$ , and continue to suppose that  $\delta = 0.05$

$$PV = \frac{\$100}{(1+0.05)^1} + \frac{\$100}{(1+0.05)^2} + \frac{\$100}{(1+0.05)^3} + \frac{\$100}{(1+0.05)^4} + \frac{\$100}{(1+0.05)^5} \approx \$432$$

$R = \$100$  is now the amount to be received period after period.

When  $R$  is constant, period after period, we can generalize and express  $PV$  in equation form as:

$$PV = \frac{R}{\delta} \left( 1 - \frac{1}{(1+\delta)^n} \right)$$

where  $n$  is the last period in which  $R$  is received. In our example, we have  $n = 5$ .

## Two Extreme Cases

a)  $n=1$

b)  $n=\infty$

a)  $PV = \frac{R}{(1+\delta)}$

b)  $PV = \frac{R}{\delta}$

## Some Investment Decision Rules

To begin, a bond that pays interest forever and ever, and is never redeemed, is called a *Perpetual* (example – Consols – Britain, late 19<sup>th</sup> Century).

The value of such a security is equal to the PV of the stream of interest payments over time.

Consider such a *Perpetual* and suppose that  $R = \$100$ , and that  $\delta = 0.05$

Since,  $n = \infty$ , we can say that:

$$PV = \frac{\$100}{0.05} = \$2,000$$

When would it pay me to buy the security? – clearly, it would pay me to buy the security, if the cost was less than \$2,000.

If the cost is \$1,500, BUY. If the cost is \$2,500, IGNORE.

If the cost is \$2,000, I will be on the margin of indifference.

Denote the cost of a marginal investment – addition to the stock of capital - as **C**

An investment decision rule, which provides an answer to my Theory of Capital question:

Invest up to the point that:

**C = PV**, where **PV**, in this case, is the present value of the stream of economic returns from this marginal addition to the stock of capital, from  $t = 0$  to  $t = \infty$ .

In the case of the *Perpetual* bond, we have

$$\mathbf{PV = \$2,000.}$$

So invest up to the point that  $\mathbf{C = \$2,000}$

In the bond market, the price of the bond (C) would, in fact, be driven up, or down, to  $C = \$2,000$

Next, the yield, rate of return, or “own rate of interest” on a marginal investment.

In all of the cases that we shall come to deal with, the period by period return from a marginal investment (positive) will be constant and go on forever, just like our *Perpetual* bond. This will greatly simplify life for us.

Denote the yield on a marginal investment as  $y$

We have:  $y = \frac{R}{C}$

Suppose that we have, as before:

**C = \$2,000; and R = \$100**

then:

$$y = \frac{\$100}{\$2,000} = 0.05$$

or  $y = 5.0\%$

A condition for capital asset portfolio equilibrium is that all assets of a common risk class be found to offering the same yield, or rate of return.

It is reasonable to suppose that this common rate of return is the same as our discount (interest) rate,  $\delta$

The gives us another Investment Decision Rule.

If  $y > \delta$ , go on investing in the capital. Invest up to the point that:

$$y = \delta$$

In our case, where  $R$  is constant and goes on forever and ever, it is easy to show that the two Investment Decision Rules are identical:

$C = PV$ , our first Investment Decision Rule; but

$$PV = \frac{R}{\delta}$$

hence:

$$C = \frac{R}{\delta}$$

$y = \delta$ , our second Investment Decision Rule; but

$$y = \frac{R}{C}$$

thus we have:

$\frac{R}{C} = \delta$ , which, upon re-ordering terms, is:

$$C = \frac{R}{\delta}$$

We shall encounter just these sorts of Investment Decision Rules in our discussion of the economics of fisheries management, and of the economics of forestry management.

The stocks of capital will be seen to consist of stocks of fish and stands of trees.

## **Fisheries**

Some distinctions;

Marine vs. Inland Fisheries

Capture (wild) Fisheries vs. Aquaculture

Types of Fishery Resources

I. True fish:

a. Finfish ,e.g. Pacific salmon, Pacific halibut

b. Shellfish, e.g. shrimp, crab

II. Sea mammals, e.g. seals, whales

III. Marine plants – seaweed, e.g. kelp. Irish moss

We will confine our discussion to marine (ocean) capture fisheries – reasons for.

World marine capture fisheries have a total annual harvest of approx. 80 million tonnes, with a “first” value in excess of US\$80 billion.

Employment, direct and indirect, over 120 million, world wide.

(Source: Food and Agriculture Organization of the UN [FAO])

These fisheries are overwhelmingly base on Type I resources.

### Difficulties in the Economic Management of Capture Fisheries

1. The fish, and their interaction with the surrounding aquatic environment, are very difficult to observe.

-species interaction:

(a) competition for food resources

(b) predator-prey relationships.

2. The fish are, in most instances, mobile. Some species may travel over several thousand kilometers during their life cycle – the example of Pacific salmon

The consequence has been, in the past at least, that it is/was very difficult ,or more to the point, very costly to establish effective property rights to these resources, be the property rights private or public.

Capture fishery resources historically seen as the classic example of “common pool” resources.

By the middle of the 20<sup>th</sup> century, the “common pool” nature of these resources was being seen to lead to serious problems – overexploitation and severe economic waste.

“Everybody’s property is nobody’s property”

Today, the environment –oceans, atmosphere –have similar problems.

BUT – up until the end of World War II, “common pool” nature of capture fishery resources did not seem to matter all that much, other than in a few isolated cases.

Thomas Huxley, one of the greatest biologist of 19<sup>th</sup> century Britain, stated in 1883 that the great ocean fishery resources of the world are “inexhaustible”. The best fisheries management, he argued, is no management at all.

This view was enshrined in international law, in the form of the doctrine of the Freedom of the (High) Seas – goes back to the 17<sup>th</sup> century.

Legal distinction between coastal state Territorial Sea and the High Seas. (coastal state –state with significant marine coast line, e.g. Canada, vs. landlocked state ,e.g. Austria)

Coastal state exercised full property rights within the Territorial Sea, but the Territorial Sea was very narrow, historically 3 miles – roughly 4.8 kilometers. Everything else constituted the High Seas.

Under the doctrine of the Freedom of the Seas, fishery resources in the High Seas are open to exploitation by all - fishery resources true “common pool”.

Justification: up until the 19<sup>th</sup> century too costly to exploit these resources extensively. The resources were protected by economics. The natural capital was “free” capital.

The economic protection of these great ocean fishery resources was undermined by advances in fisheries technology, which lowered harvesting costs – economic protection was beginning to fray, even as Huxley spoke in 1883 – e.g. shift from sail to steam. All of this took time

-the two World Wars and fish stocks in the North Sea.

First major attempts to regulate ocean fishery resources through international agreements – very limited success.

Following World War II, coastal states began extending their jurisdictions over ocean resources unilaterally. UN intervened to try and put some order into the process. Convened the First UN Conference on the Law of the Sea in 1958, and a second conference in 1960. The two conferences did little about capture fisheries management.

The Third UN Conference on the Law of the Sea was held between 1973 and 1982. This conference revolutionized the management of world capture fisheries.

The Conference brought forth the 1982 UN Convention on the Law of the Sea.

-Under the 1982 UN Convention, coastal states, such as Canada given the right to establish 200 nautical mile (370 km., approx.) Exclusive Economic Zones (EEZs). Within the EEZ the coastal state, to all intents and purposes, has property rights to the fishery resources contained therein. Whether the coastal state can make these property rights effective is a different matter.

-The EEZ regime is now almost universal. Canada has EEZs off its Atlantic and Pacific coasts – Arctic EEZ not fully settled.

-Estimated in 1982 that, if EEZ regime became universal, the EEZs would encompass 90% of the commercially exploitable capture fishery resources of the world - massive reduction in Freedom of the Seas, as applied to fisheries, or so it seemed in 1982.

The EEZ regime has mitigated the “common pool” problem of world capture fisheries, but it certainly has not eliminated it. Many coastal states find that their intra-EEZ property rights are difficult to implement. Still have overexploitation and economic waste within EEZs.

Furthermore, because of the mobility of most capture fishery resources, many of the fishery resources cross the EEZ boundary into EEZs of neighbouring coastal states, or into the remaining High Seas –the Shared Fish Stock problem, which we shall discuss at a later point.

It was assumed by many in 1982 that High Seas fishing would be at most a minor problem. This assumption has proven to be dramatically wrong. UN forced to convene another international conference to deal with the problem – biggest problem – fishery resources crossing the EEZ boundary into the High Seas – so called Straddling Stocks

Common pool characteristics of fishery resources now invariably lead to overexploitation and economic waste.

Contrast fishery resources with forestry resources. Trees are visible and stationary. Relatively easy to establish and enforce property rights – private or public.

On the other hand, the environment –narrowly defined –has common pool problems similar to fisheries.

In any event, overexploitation of world capture fishery resources continues to be a serious problem, although one that is hopefully leveling off.

FAO based figure, which is bit dated, but still gives a clear idea of the problem.

### Some More Description

Classes of Finfish Species:

A. Demersal Species (groundfish, or whitefish), e.g. cod, halibut

B. Pelagic Species, e.g. herring, tuna

C. Anadromous Species, e.g. salmon

### Classes of Gear in Capture Fisheries

1. Lines and hooks

2. Traps and pots

3. Encirclement gear

4. Entanglement gear

Historically, Pacific salmon was the most important species harvested by the B.C. fishing industry. This has now changed. Demersal species (groundfish) are now the most important, followed by shellfish

## **Bioeconomics**

Every respectable Economic Model of the fishery has a Biological Model as its foundation.

If the biological model is misspecified, the economic model built upon the biological model will, at best, be worthless

So close is the link between biology and economics in fisheries economics that we now talk in terms of

## ***Bioeconomics***

This Fundamental Proposition requires a brief overview of biological models of fishery –

-a still useful 49 year old source, by two famous marine biologists, R.J. Beverton and M.B. Schaefer

Schaefer and Beverton (1963), *"Fishing Dynamics- Their Analysis and Interpretation"*

The focus is on a stock of fish of a particular species (a single species model), in particular region  
-stock measured in terms of weight – **biomass**.

-concentrate, not on the total biomass, but on:  
**Fishable Biomass**. Later, we will talk simply about the biomass, but what we will be referring to is really the *fishable biomass*.

-through time Fishable Biomass (FB) will increase, due to:

- (a) recruitment
- (b) growth of individual fish in FB

-through time the FB will be depleted due to:

- (i) natural mortality
- (ii) fishing mortality

-a diagrammatic representation

Now let  $x$  denote the FB. The % rate of growth of  $x$  can be represented as follows:

$$(I) \quad (dx/dt)/x = z(x) + g(x) - M(x) - f(E) + \eta,$$

where  $z$ ,  $g$ ,  $M$  and  $f$  denote the rates of recruitment, growth of individual fish in FB, natural mortality and fishing mortality respectively. Note that  $z$ ,  $g$  and  $M$  are assumed to be functions of  $x$ .

$f$  is seen as a function of  $E$  – fishing effort, which we can interpret as a combined flow of labour, produced capital and ancillary services devoted to harvesting (often measured in standardized vessel days).

$\eta$  denotes a noise term, with mean = 0

Setting  $\eta = 0$ , a Steady State ,i.e.  $(dx/dt)/x = 0$ , will have been achieved when:

$$(II) f(E) = z(x) + g(x) - M(x)$$

refer to the Right Hand Side (R.H.S.) of Eq. (II) as the “net natural rate growth of the FB” . Eq.(II) then just says that a steady state will be achieved when the rate of fishing mortality is equal to the net natural rate of growth of the stock (FB)

Now take (II) and multiply both sides by  $x$ , so that we have:

$$(III) f(E)x = [z(x) + g(x) - M(x)]x$$

implying that, at the steady state, the harvest –  $f(E)x$  is equal to the net natural growth of the stock – essentially skimming off the growth of the resource. But this Steady State situation means that the resource is being harvested on a “sustainable” basis.

Beverton and Schaefer tell us that, ideally, biologists would like to be able to estimate all of the parameters in (I), for given fishery resources, but that this has proven to be very difficult – no evidence that these difficulties have vanished over the intervening 49 years.

Simplifications required. Two broad approaches:

A. Beverton – Holt – attempts made to measure the parameters in context of a discrete time model, but it is usually assumed that the period by period rate of recruitment remains constant. Then focus on behaviour over time of individual sets of recruits – cohorts or year classes.

For analytical purposes, economists find that the B-H type of model is just what they want in analysing the management of aquaculture resources. The B-H model is used extensively in capture fishery management.

In developing analytical economic models of the management of capture fisheries, however, B-H models create intractable difficulties – reasons for. Having said this, it will be seen that economists do in fact make extensive use the B-H models in empirical analysis of such fisheries

In developing analytical models of capture fisheries, economists look to the second approach:

B. “General Production” models, in which key parameters are merged – what mathematicians call “**lumped parameter**” models.

Perhaps the most famous of such General Production models is the one developed by M.B .Schaefer, in the early 1950s. The Schaefer model provides the foundation for most of the economic models of the fishery that we will be examining, so let us take a close look at it.

## The Schaefer Model

We have:

(1)  $dx/dt = F(x, \mathbf{A})$ , where  $x$  denotes the biomass, and  $\mathbf{A}$  denotes the aquatic environment, assumed to be constant. Hence (1) can be re-written as:

$$(1a) \quad dx/dt = F(x)$$

- it is assumed that  $F(x)$  corresponds to the “logistic” law of population growth (19<sup>th</sup> century Verhulst model population growth)

$$(2) \quad dx/dt = F(x) = rx [1 - x/G],$$

where  $G$ , a constant, is the “carrying capacity”, or natural equilibrium biomass level (biomass cannot grow forever), and where  $r$  is the “intrinsic growth” rate.

Let us note the following: The %, or proportional, growth rate of the biomass is  $- F(x)/x = r[1 - x/G]$

$$\lim_{x \rightarrow 0} F(x)/x = r$$

thus  $r$  is the *maximum %* growth rate

Now introduce harvesting. We have:

$$(3) \quad dx/dt = F(x) - h(t)$$

The harvest production function is given by:

$$(4) \quad h = qE^\alpha x^\beta, \text{ where } q, \text{ a constant, is the "catchability" coefficient, a constant, an index of the state of fishing technology, and where the exponents, } \alpha \text{ and } \beta, \text{ are constants}$$

Note that this production function looks a lot like the Cobb-Douglas production function that we are familiar from Ec. 201/301:  $Q = AK^\alpha L^\beta$ , where  $Q$  is the quantity of output, where  $A$  is a constant, and where  $\alpha + \beta = 1$ .

-a critical assumption in the Schaefer model is that the fish are uniformly spread throughout the relevant aquatic environment, regardless of density. This amounts to assuming that  $\alpha = \beta = 1$  – unlike the Cobb-Douglas production function.

In any event, with  $\alpha = \beta = 1$ , by assumption, we rewrite (4) as:

$$(4a) \quad h = qEx$$

This assumption has, as we will see, important policy implications

By the way, what is the rate of fishing mortality in the Schaefer model? It is, simply:  $qE = h/x$

-a diagrammatic representation of the Schaefer model, and the concept of sustainable harvest, or yield, and Maximum Sustainable Yield (MSY).

We next have to consider the relationship between fishing effort ( $E$ ) and sustainable yield (harvest). This we need for the first economic model of the fishery.

Consider the following diagrams.

The diagrams show the relationship between  $E$  and sustainable yield, or harvest for two possible rates of  $E$ ,  $E_1$  and  $E_2$ . We could carry out the same procedure for every other possible rate of  $E$ .

Fortunately, we do not have to. From the Schaefer model, we can develop a functional relationship between  $E$  and sustainable harvest (yield), which we shall denote as:  $h_s$ .

We start off by returning to our harvest production function:

$$(I) h = qEx$$

We note that, if harvesting is taking place on a sustained yield basis, then it will be the case that:

$$(II) h = F(x),$$

recalling that  $F(x) = rx[1 - x/G]$ ,

we can (II) re-write as:

$$(IIa) qEx = rx[1 - x/G]$$

Associated with any sustainable harvest there will be an equilibrium, steady state, level of the biomass,  $x$ .

From (IIa) we can derive an equation for  $x$ , representing the equilibrium, steady state, level of  $x$ , given a particular  $E$ :

$$(III) x = G[1 - (q/r)E]$$

Now substitute for  $x$  in Eq. (I) [the harvest production function], from (III), and we have an equation for sustainable harvest (yield),  $h_s$ :

$$(III) \quad h_s = qE\{ G[1 - (q/r)E]\}$$

$$= qGE - (q^2G/r)E^2$$

$$(IIIa) \quad h_s = uE - vE^2,$$

where  $u = qG$ ,  $v = q^2G/r$ , and where  $u$  and  $v$  are obviously constants

-a diagrammatic representation

The concept of “Biological Overfishing”.  $E > E_{MSY}$ ,

which will cause the biomass to fall below  $x_{MSY}$

-more diagrams

## **The H. Scott Gordon Economic Model of the Fishery and Resource Rent Dissipation**

This model, which appeared in 1954, marks the beginning of modern fisheries economics.

It is a “static” economic model, because this was the best that Gordon could do with the tools available to him at the time.

While it has drawbacks, because of its static nature, it has important lessons, and continues to have a major influence on policy makers. Moreover it provides the foundation for the dynamic economic model of the fishery that we will examine later.

Basically what Gordon does is to take the Schaefer based fishing effort (E) sustainable yield (harvest) relationship that we have discussed and add in prices and costs to make it an economic model.

-consider the following diagram

### **Key Assumptions Underlying the H. Scott Gordon Model**

1. Demand for harvested fish is perfectly elastic.  
Hence, price for harvested fish,  $p$ , is a constant.

2.  $p$  provides a perfectly adequate measure of MU of harvested fish to society
3. Supply of E is also perfectly elastic. Hence, the unit (average) cost of E,  $b$ , is a constant. Moreover,  
 $b = MC_E$ . Also note that the total cost of E is simply:  
 $TC_E = b.E$
4. There is no discrepancy between private and social cost of E.
5. The fishing industry is perfectly competitive.
6. Human and produced capital in the fishery are both “perfectly malleable”, meaning that they can be easily and costlessly moved in and out of the fishery.

The implication of assumptions 2. and 4. combined is that we are living in a First Best World.

### Some Further Definitions:

Value of the Marginal Product of E ( $VMP_E$ )

Total Revenue with respect to E:

$$TR_E = (\text{Sus. Yield}).p$$

$$\frac{d(TR_E)}{dE} \equiv VMP_E$$

Value of the Average Product of E ( $VAP_E$ )

$$VAP_E = \frac{TR_E}{E}$$

Marginal Cost of E ( $MC_E$ )

$$TC_E = b.E$$

$$MC_E = \frac{d(b.E)}{dE} = b$$

Average Cost of E ( $AC_E$ )

$$AC_E = \frac{b.E}{E} = b$$

Note that  $MC_E = AC_E$

Next note it will always be the case that  $VMP_E < VAP_E$ , except when  $E = 0$ .

$$TR_E = p.h_s = p[uE - vE^2]$$

Thus  $VMP_E = p[u - 2vE]$  (do the differentiation)

$$VAP_E = \frac{TR_E}{E} = p[u - vE]$$

Resource Rent defined – Joan Robinson

“The essence of the conception of *rent* is the conception of a surplus earned by a particular --- factor of production over and above the minimum necessary to do its work. The conception of rent----is closely connected with the ‘free gifts of nature’—the essential characteristic of which is that they do not owe their origins to human nature”

Joan Robinson, *The Economics of Imperfect Competition*

The rent associated with the “free gifts of nature” (natural resources) we term **Resource Rent**.