Desenvolvimento Sustentável

Hotelling Rule

The Management of Non-Renewable Resources

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NON-RENEWABLE RESOURCES

Types of natural resource stocks:

• Renewable: display a significant rate of growth or renewal on a relevant economic time scale; e.g.: solar, wind, tidal energy, air, forests, fisheries,…

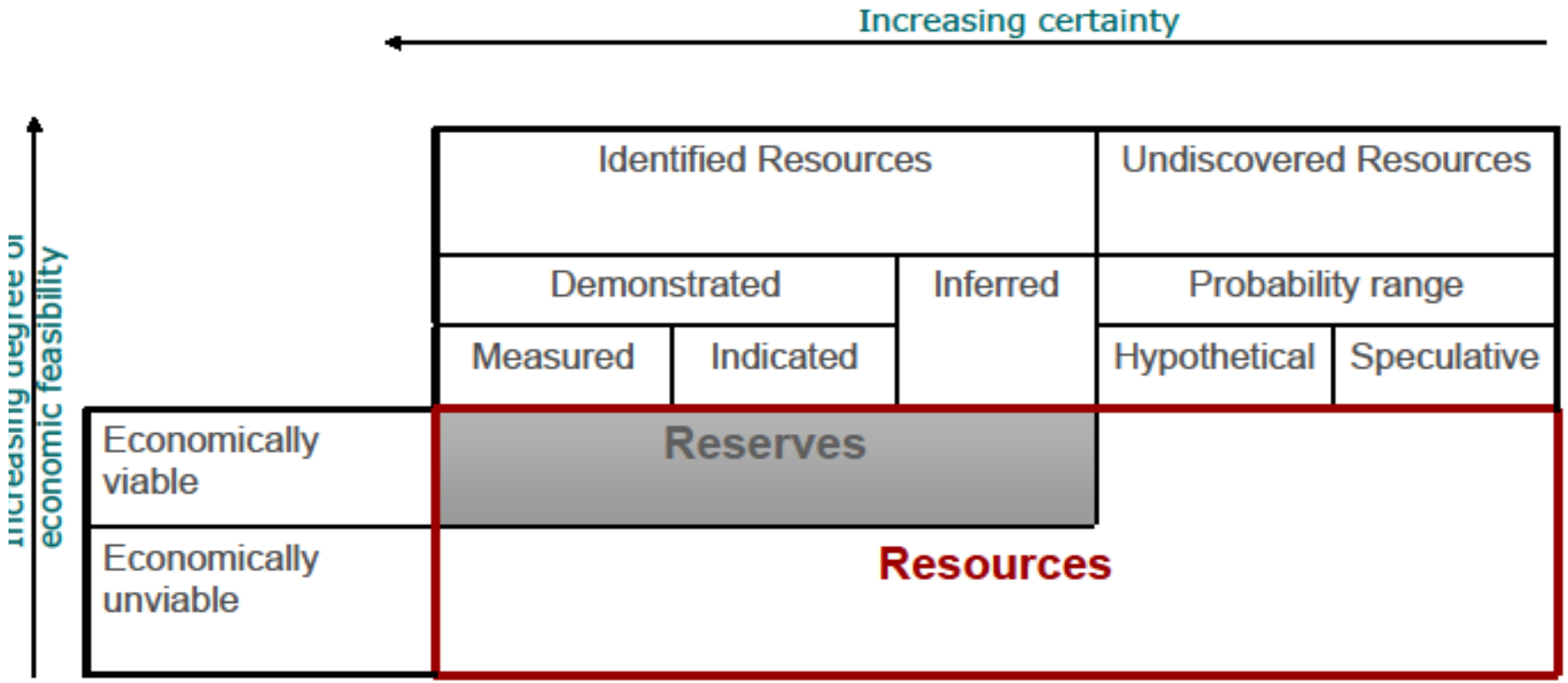
• Nonrenewable; e.g.: oil, coal, natural gas, copper, iron, silver, some plant and animal species,…

• **Resources and reserves**:

- The McKelvey diagram is a graphical classification of mineral resources according to economic viability and certainty of existence.
- Used by the U.S. Bureau of Mines and the U.S.Geological Survey in their definitions of mineral resources and reserves

I. Introduction

Definitions



HISTORY OF ECONOMIC THOUGHT

Classical point of view:

• Malthus (1766-1834): "An Essay on the Principle of Population";

increasing population vs fixed supply of agricultural land will result in starvation

• Ricardo (1772-1823): diminishing quality of natural resources will prevent population growth, despite technological progress that enhances productivity

• John Stuart Mill (1806-1873): technological progress slows down because needs will become satisfied

• **H. Hotelling: "The Economics of Exhaustible Resources," 1931, *JPE* , 39,2**

60’s and 70’s; two points of view:

1. The pessimistic point of view:

- Growing rate of extraction
- Growing demand

2. The optimistic point of view:

The stock varies due to changes:

- Technology: allows for exploiting new reserves at lower costs
- Market mechanism: diminishing returns lead to a price increase
- Substitution

MAIN QUESTIONS

- How should nonrenewable resources be extracted over time?
- Is complete exhaustion (ever) optimal? Is it ever optimal to abandon a mine with extractable reserves?
- Does the time path of extraction by a price-taking firm differ from that of a monopolist?
- How do changes in some parameters (the discount rate, stocks, demand,…) affect optimal extraction over time?

Hotelling's Rule

Perfect Competition – Hotelling's Approach

The '**Hotelling Rule**' emerged naturally from Hotelling's reasoning:

The market will extract a non-renewable resource so that the price rises at the rate of interest.

Intuition: if not, then the price will rise either faster or slower than the rate of interest.

If slower, then it is better to increase extraction and invest in financial instruments that will, by definition, grow at the rate of interest.

If faster, then it is better to decrease extraction, since the price of the resource in the ground is growing faster than the value of financial instruments.

So, **the equilibrium rate of extraction will keep the price rising at the rate of interest.**

Example: suppose a petroleum owner:

- the actual price by barril is 2800$ and the real interest rate is 5%

A) Expectation that the price rise to 3080$ per barril

. If he sells everything and put the money in the banc the welfare rises 5%

. If he does not sell, with the new price the welfare will raise 10%

(3080 – 2800)/ 2800 = 0,10

It does not worth to explore!

B) Expectation : p=2870$

The rise of 70$ implies the rise of welfare of only 2,5%

It seems that selling andd invest everything at a rate of 5% is the best solution

To be in equilibrium , in the market of non-renewable resources >>>>
the price should rise at the same rate as the real interest rate .

HOTELLING RULE

$$\Delta p/p = r$$

The rate of growth of the prices is equal to the rate of interest in the market.

When the equilibrium is reached is indiferent invest in the extraction or in the finance market

- **If prices rise less** everyone wants to sell (**Exploitation**)
  that i, if prices rise less than the rate of interest one prefers to consume in the present and put the money in the banc

- **In the opposite** no-one wants to sell (**conservation**)

Perfect Competition–
Hotelling's Approach Assumptions (1):

- Perfect competition
- No costs of extraction
- Amount of the resource in the ground is known
- Perfect information
- There is a unique interest rate and it is equal to the firms' rate of discount

1. Hotelling's Rules

Perfect Competition-Optimal Control

Problem:

$$\underset{\{Q(t)\}}{Max} \int_0^T P(t)Q(t)e^{-rt}dt$$

$$s.t. \quad \dot{S}(t) = -Q(t)$$

$$S(0) = S_0 \ given$$

Assumptions (2): *S(T)=0*.

(check notes!)

1. Hotelling's Rules

Perfect Competition-Optimal Control

Applying the Maximum Principle, we obtain

$$\frac{\dot{P}}{P} = r,$$

Which can be written as

$$P(t) = P(0)e^{rt}$$