Exhaustible Resource Extraction

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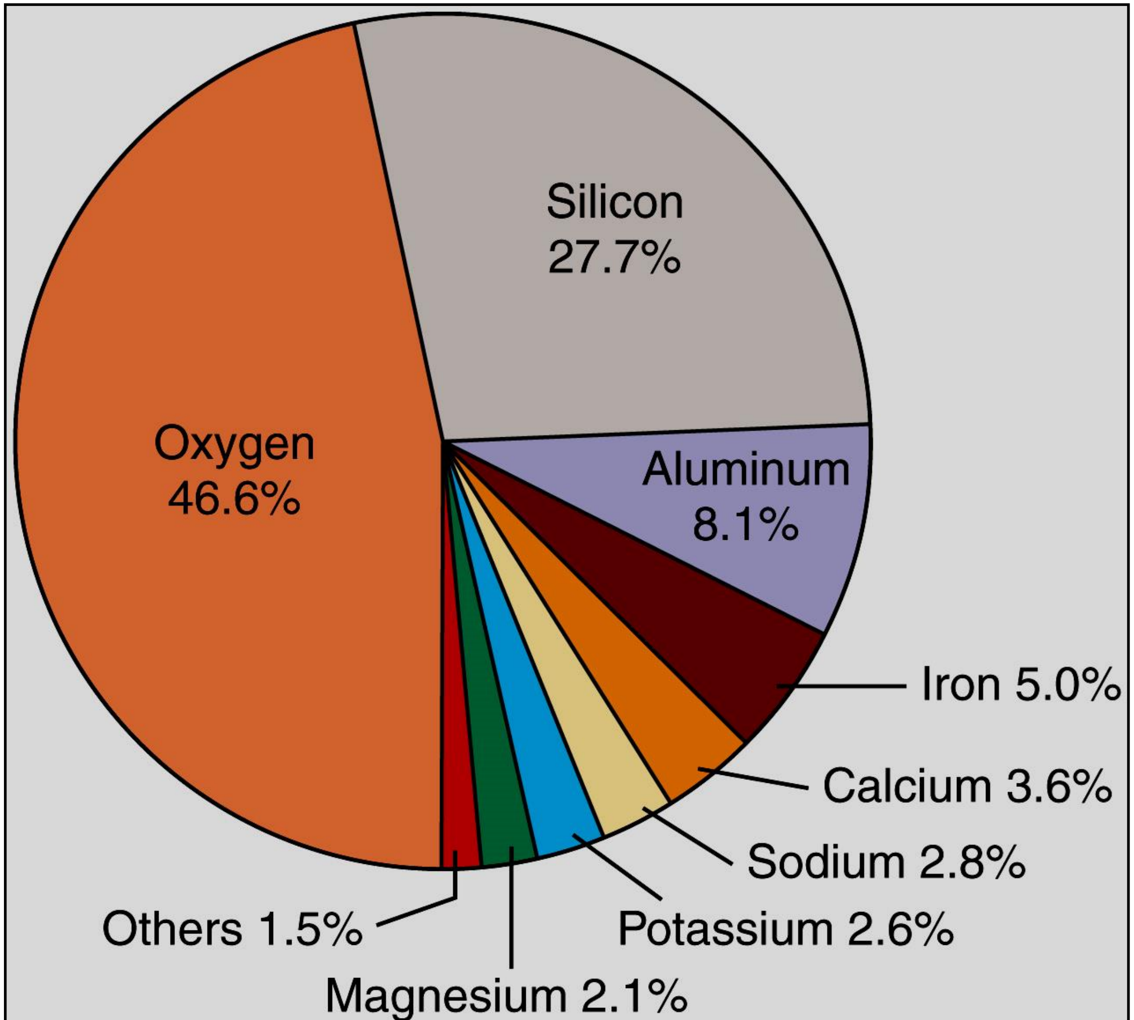
Key Issues

- How Are Resources Being Depleted?
- An Economic Model of Exhaustible Resource Mining

Mineral Resources

- Earth has 92 natural elements
- About 99% of the Earth's crust is comprised of only 8 of these…
  - Oxygen, silicon, aluminum, iron, calcium, sodium, potassium, magnesium

Mineral Resources



Mineral Resources

- These 8 common elements combine with 1000’s of rare elements to form +/- 3,000 different minerals
- The key here, however, is this:

- **Each mineral is potentially a resource, if people find a use for it.**

Mineral Resources

- Minerals are valued primarily for their mechanical or chemical properties
  - **As technologies evolve, so too do the related values of mineral resources**

Mineral Resources

- As with energy resources, mineral resources are ***NOT*** uniformly distributed around the world…

Mineral Resources

- Minerals are either *metallic* or *nonmetallic*
- *Weight-wise, 90% of minerals that humans use are nonmetallic!!*
  - *Metallic minerals have other, economic-based value…*

Nonmetallic Minerals

- 90% of nonmetallic mineral extraction is used for:

- Building materials
  - Building stones / large stones
  - Coarse gravel
  - Fine sand

Nonmetallic Minerals

- Nonmetallic minerals are also used for fertilizer
  - Phosphorous
  - Potassium
  - Calcium
  - Sulfur

Nonmetallic Minerals

- Gemstones
  - A small percentage of nonmetallic minerals in weight, these minerals have high value
    - Especially for their color and their brilliance…
    - Also, diamonds play an important role in industry

Metallic Minerals

- Metallic minerals:
  - Contain properties that are valuable for making
    - machinery, vehicles, weapons, and other essential elements of an industrialized society…

Metallic Minerals

- Ferrous (metals) - IRON
  - Refers to iron ore and other alloys used in the production of iron and steel
- Nonferrous (metals) - ALUMINUM
  - Used to make products other than iron and steel

Ferrous

- Why is **iron** such a valuable resource?
  - Good conductor of both heat and electricity
  - Attracted by a magnet and able to be magnetized
  - Malleable into all sorts of useful shapes

Important Ferrous Metals

- Abundant Supply
  - Manganese
  - Chromium
  - Titanium
  - Magnesium
  - Molybdenum
- Limited Supply
  - Nickel
    - 100 years
  - Tin
    - 50 years
  - Tungsten
    - China – 90% production, 50% reserves

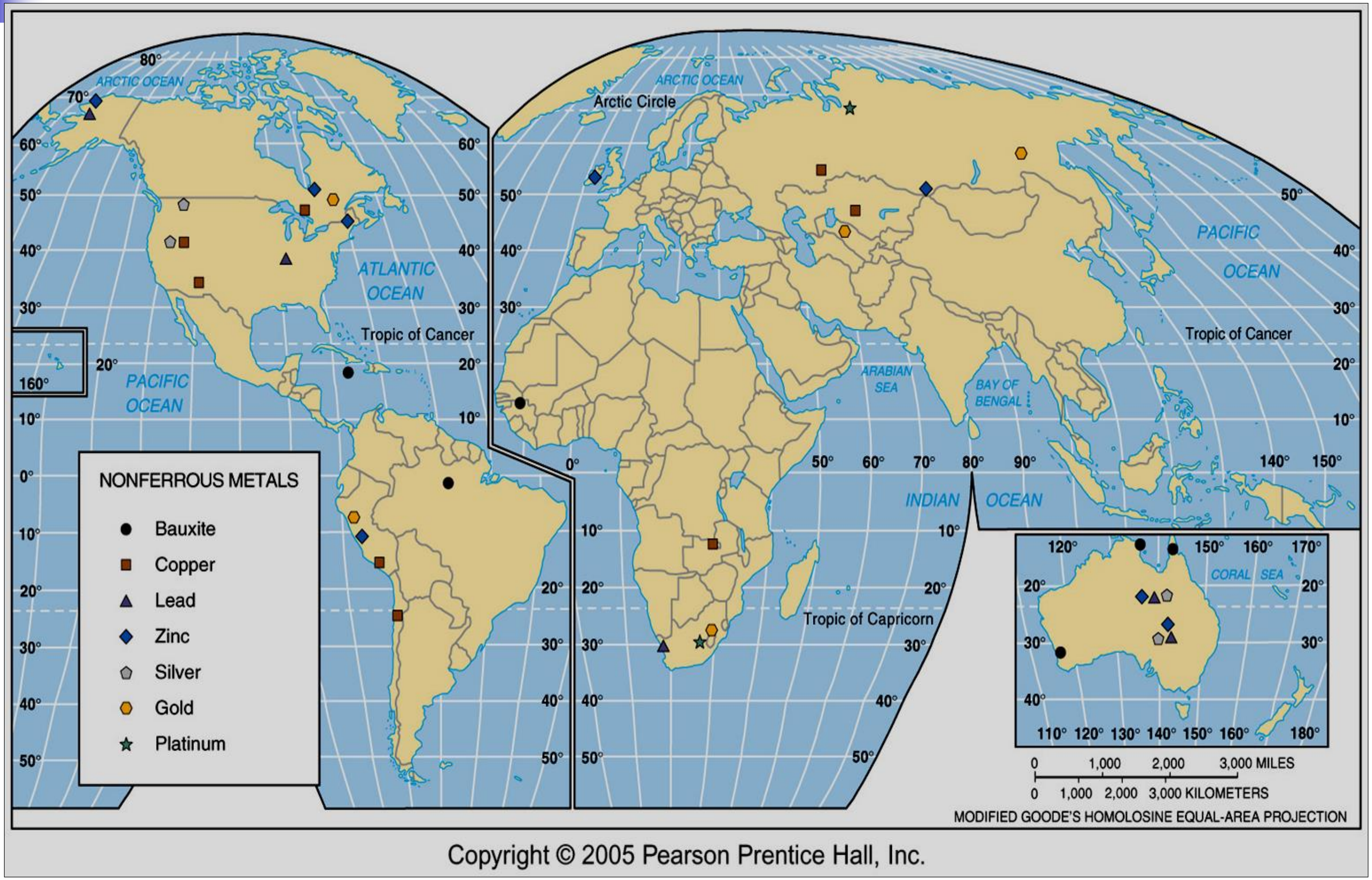
Nonferrous

- Why is **aluminum** such a valuable resource?
  - Light and Strong
  - Non-magnetic
  - Resistant to corrosion
  - Huge supply
  - As well as being malleable, ductile, and a decent conductor…

Important Nonferrous Metals

- Copper
  - 60 years supply
- Lead
  - 25 years…
- Zinc
  - 45 years…
- Silver
- Gold
  - Prized for beauty and durability
  - Not just jewelry
- Platinum
  - S. Africa – 90% reserves

Nonferrous Metal Production



Economics of Exhaustible Resource Use

Intertemporal Production Decisions---Depletable Resources

- Firms' production decisions often have *intertemporal* aspects---production today affects sales or costs in the future.

Intertemporal Production Decisions---Depletable Resources

- Scenario
  - You are given an oil well containing 1000 barrels of oil.
  - *MC* and *AC* = $10/barrel
  - Should you produce the oil or save it?

We need:

$[P_t^{oil};\ P_{t+1}^{oil} \ldots;$ cost of storage ("in situ"); cost of extraction; r (interest rate)$]$

Intertemporal Production Decisions---Depletable Resources

2 period example

$P_t - c = \text{Rent}_t$

$P_{t+1} - c = \text{Rent}_{t+1}$

- Scenario
  - P_t = price of oil this year
  - P_{t+1} = price of oil next year
  - c = extraction costs
  - r = interest rate

"Rent tomorrow" "Future Value of Rent Today"

Decision Rules

$$\text{If } (P_{t+1} - c) > (1+r)(P_t - c) : \text{Keep the oil in the ground}$$

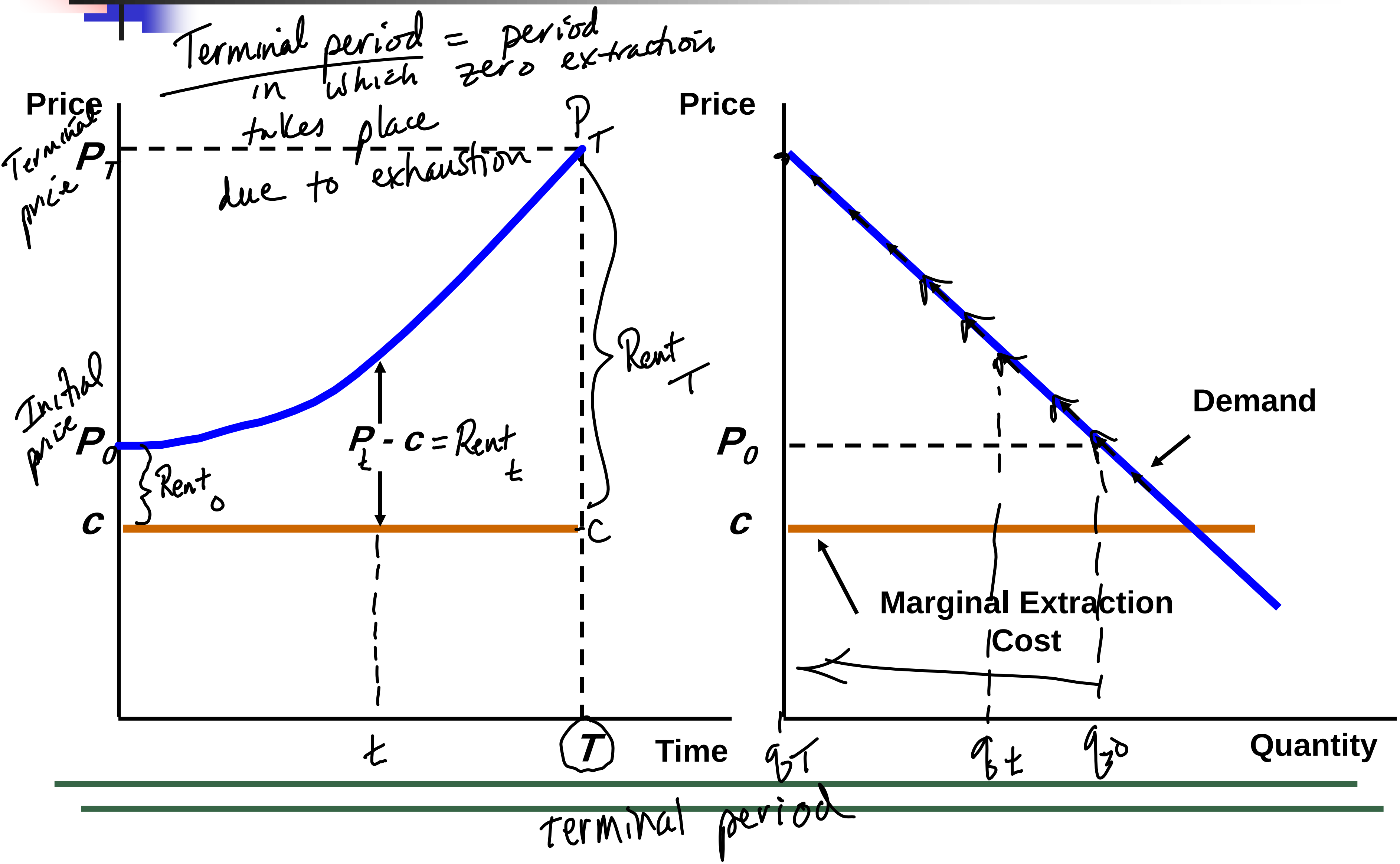
$$\text{If } (P_{t+1} - c) < (1+r)(P_t - c) : \text{Sell all the oil now}$$

$$\text{If } (P_{t+1} - c) = (1+r)(P_t - c) : \text{Indifferent}$$

Intertemporal Production Decisions---Depletable Resources

- Do not produce if you expect its price less its extraction cost to rise faster than the rate of interest.
- Extract and sell all of it if you expect price less cost to rise at less than the rate of interest.
- What will happen to the price of oil?

Price of an Exhaustible Resource



Price of an Exhaustible Resource

- In a competitive market, *Price* - *MC* must rise at exactly the rate of interest.
- Why? Hotelling's Theorem
  - How would producers react if:
    - *P* - *C* increases faster than *r*? Keep in situ
    - *P* - *C* increases slower than r? extract all now

Price of an Exhaustible Resource

- Notice
  - $P > MC$
    - Is this a contradiction to the competitive rule that $P = MC$?
      - *Hint:* What happens to the opportunity cost of producing an exhaustible resource?

Price of an Exhaustible Resource

"lambda"

- $P = MC$
  - MC = extraction cost + user cost
  - User cost = P - marginal extraction cost

MC_e (extraction cost) λ (user cost) opportunity cost

Yes ⇒ $P > MC_e$ but $P = MC_e + \lambda$

Price of an Exhaustible Resource

- How would a monopolist choose their rate of production?
  - They will produce so that marginal revenue revenue less marginal cost rises at exactly the rate of interest, or
  - $(MR_{t+1} - c) = (1 + R)(MR_t - c)$

Price of an Exhaustible Resource

Resource Production by a Monopolist

- The monopolist is *more conservationist* than a competitive industry.
  - They start out charging a higher price and deplete the resources more slowly.

How Depletable Are Depletable Resources?

$\left(\frac{\lambda}{P}\right) \left(\frac{MC_e}{P}\right)$

Resource	User Cost/Competitive Price	
Crude oil	.4 to .5	.5 – .6
Natural gas	.4 to .5	
Uranium	.1 to .2	
Copper	.2 to .3	
Bauxite	.05 to .2	
Nickel	.1 to .2	
Iron Ore	.1 to .2	
Gold	.05 to .1	

How Depletable Are Depletable Resources?

- The market structure and changes in market demand have had a very dramatic impact on resource prices over the past few decades.
- Question
  - Why would oil and natural gas have such a high user cost ratio compared to the other resources?

The End