Commodity Market Economics

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Environmental and Natural Resource Economics - **December 7, 2024**

Presentation Outline

What are commodities?

- Highly fungible tokens
  - Two distinct copies are identical if they share properties
  - Perfectly substitutable
- General global markets and generally highly volatile
- Specific and valuable physical properties inherent in chemical makeup

Types of Commodity Markets

- Energy commodities
- Base Metals
- Precious metals
- Agricultural commodities

Energy Commodities

- Not derived from a substance but from energy inherent in the substance
- Fundemental to production: capital without energy is a statue, labor without energy is a corpse
- Incredibly influential economically and geopolitically
- The most valuable and heavily traded commodities
- Examples: Natural gas, oil, coal, electricity

Oil Market History

- **Early Beginnings (1850s-1900s):**
  - First commercial oil well drilled in 1859 (Titusville, Pennsylvania).
  - Oil used primarily for kerosene lamps.
- **Rise of the Oil Industry (1900s-1940s):**
  - Development of internal combustion engines increased oil demand.
  - Formation of major oil companies (e.g., Standard Oil).
  - Role of oil in World War I and II as a strategic resource.
- **Post-War Boom (1950s-1970s):**
  - Rapid industrialization and automobile growth fueled demand.
  - Formation of OPEC in 1960 to stabilize prices and control production.
- **Modern Era (1980s-Present):**
  - Oil price shocks (e.g., 1973 and 1979 crises).
  - Role of unconventional sources (shale oil) and renewables.
  - Global challenges: climate policies, geopolitics, and energy transitions.

Natural Gas Market History

- **Discovery and Early Use (1800s-1940s):**
  - Natural gas discovered alongside oil in early drilling.
  - Used locally due to lack of long-distance pipeline infrastructure.
- **Pipeline Expansion (1940s-1960s):**
  - Construction of large-scale pipelines enabled interstate transport.
  - Natural gas became a significant fuel for heating and industrial use.
- **Market Regulation and Deregulation (1960s-1980s):**
  - U.S. Federal Power Commission regulated prices.
  - Deregulation in the 1980s led to the development of spot markets.
- **Globalization and Modern Markets (1990s-Present):**
  - Growth of LNG (Liquefied Natural Gas) trade.
  - Role in electricity generation and transition to cleaner energy.
  - Geopolitical importance of major suppliers (e.g., Russia, Qatar, U.S.).

Base Metals

- Useful for value in production process
- Combination of strength and malleability
- Wide-ranging uses for different kinds of metals
- Can be mixed with other metals to create alloys

Rise of rare-earths

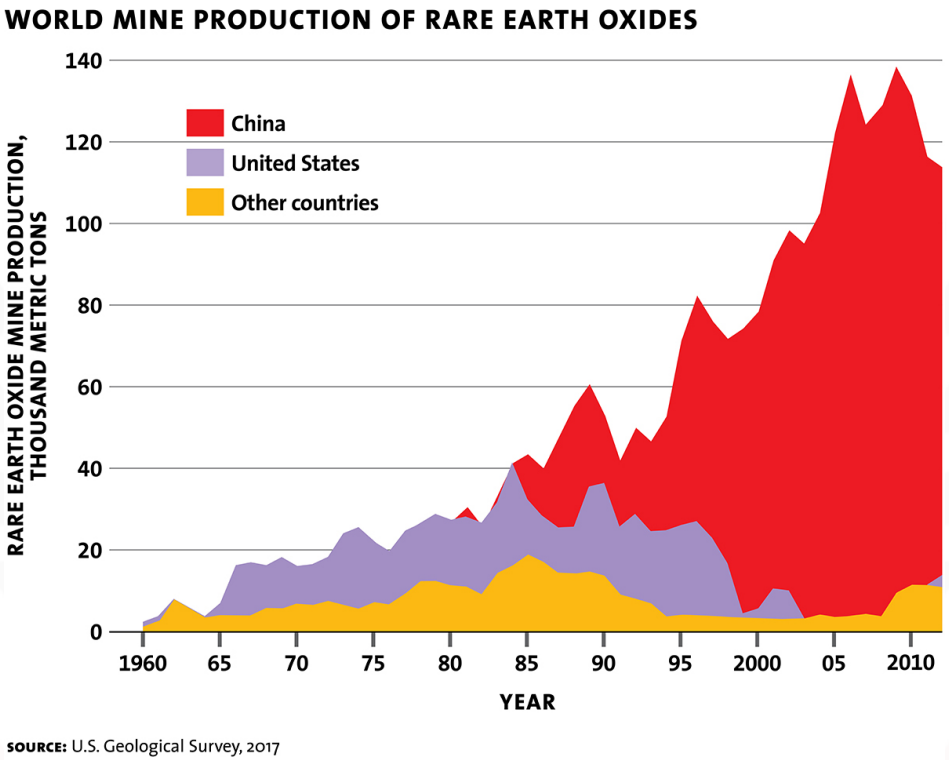

Figure 1: The US is no longer a rare-earth leader

Metals used in Iphone

Figure 2: Iphones are a period table masterclass

Metals used in Battery

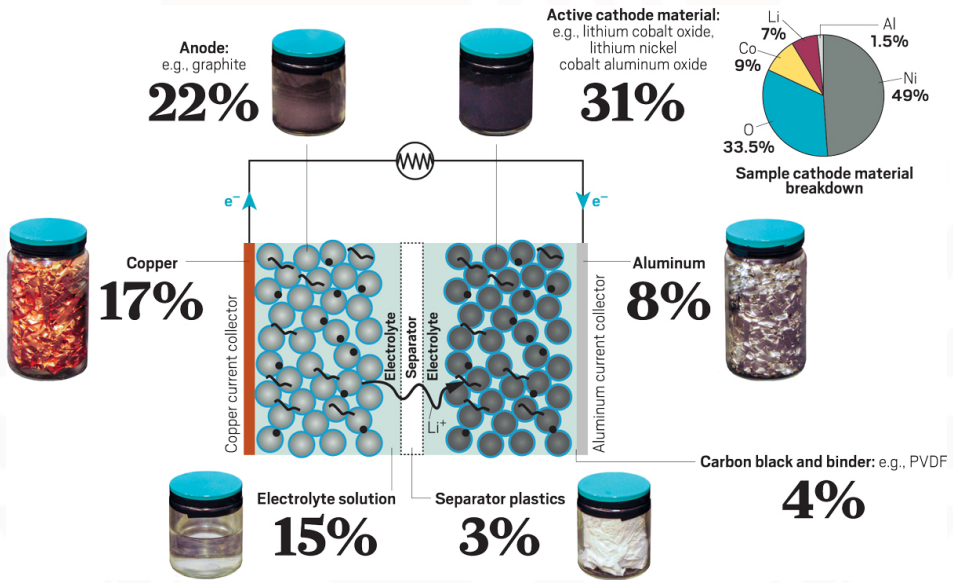

Figure 3: Tesla is a major metals player

Metals and Renewable Transition

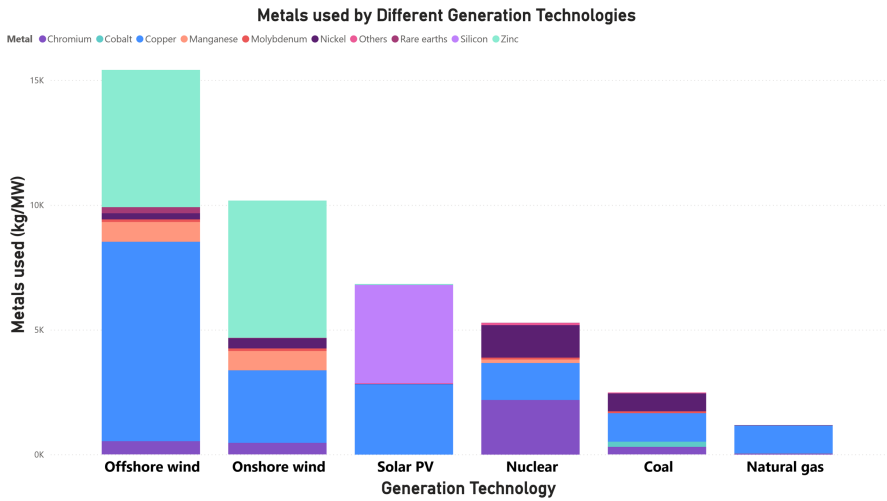

Figure 4: The Energy Transition is an Infrastructure Transition

Environmental concerns of Metals in Transition

- Metals mining is highly environmentally degrading
- Metals are not unlimited resources

Environmental concerns of Metals in Transition

- Metals mining is highly environmentally degrading
- Metals are not unlimited resources
- Are we creating our children's next crisis?

Precious Metals

- Value not tied to physical properties but value placed by society
- Highly rare, durable, practical store of value
- Examples: Gold, silver, platinum
- Why so valuable if largely useless?

Figure 5: Everything you Touch turns to Gold- Imagine Dragons

Agricultural Commodities

- Used for sustenence but also for other purposes
- Perishable and highly dependent on weather patterns creating risk
- Falls into three main categories: grains, softs, and livestock and animal products
- Grains can be divided into cereals (wheat, rice, maize) and legumes (soybeans, lentils)
- Softs examples include coffee, cocoa, fruit, and cotton

Figure 6: Caption

Crops Grown in US

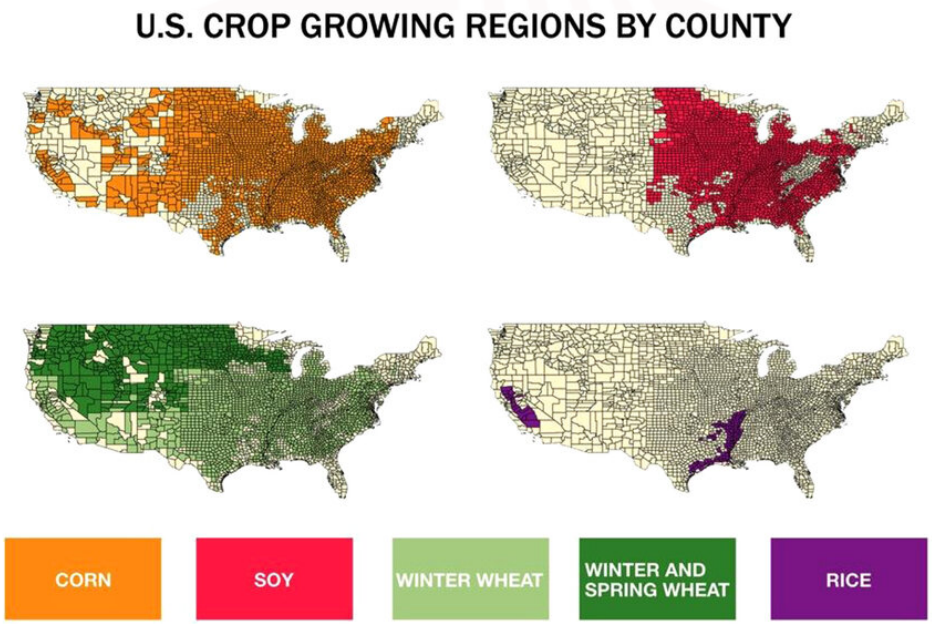

Figure 7: The Midwest is a place where they grow corn and soybeans. If you've hit wheat, you're too far West. If you hit Cotton, you're in the South

Oilseeds Crops Internationally

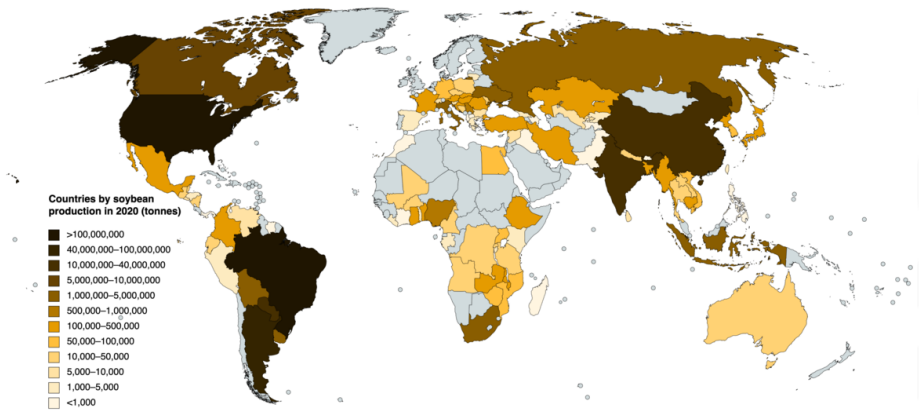

Figure 8: Soybeans are an Instrument of American Foreign Policy

Food Dollar

Figure 9: Where does money spent on food go?

US Agricultural Trading Balance

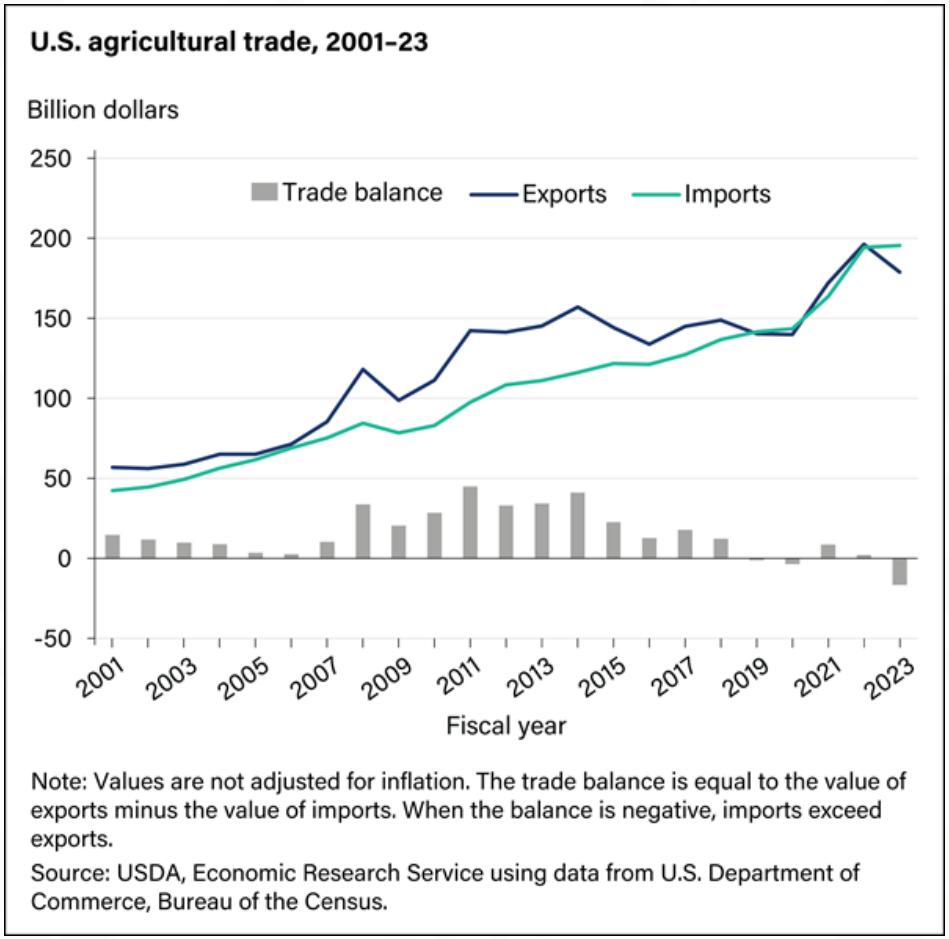

Figure 10: We traditionally have a major commodity export surplus

Features of Commodity Markets

- Volatile and susceptible to long cycles
- Significant contributor to supply chain issues
- Heavily driven by capital investments
- Reliant on physical activities
- Highly risky with generally significant hedging operations

Why Commodity Markets are Interesting

- Really the original market
- Platonic ideal of a market: many features of perfect competition and useful for comparison
- Interesting interaction between physical and financial markets
- Crucial to development of developing countries
- Limited and non-renewable
- Shapes geopolitical environment

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- Shapes geopolitical environment
- Essential for all economic activities

The Great Grain Robbery

Overview: The "Great Grain Robbery" refers to a series of large, covert grain purchases by the Soviet Union in 1972, which significantly impacted global agricultural markets.

Background:

- Poor Soviet harvests in the early 1970s created a massive shortfall in domestic grain supply.
- U.S. agricultural policy at the time subsidized grain exports, making American grain relatively cheap.

The Great Grain Robbery

Key Events:

- Soviet trading companies, acting covertly, purchased approximately 10 million tons of U.S. grain.
- Purchases were executed quickly and below-market prices, without alerting U.S. authorities or the market.
- The scale of the purchases caused a sharp increase in global grain prices when discovered.

Impact:

- U.S. taxpayers effectively subsidized the Soviet purchases through export programs.
- Domestic grain prices skyrocketed, leading to inflation and financial strain for U.S. consumers.
- Highlighted vulnerabilities in U.S. grain export policies and lack of market transparency.

Outlook Programs by EIA, USDA, and USGS

USDA: World Agricultural Supply and Demand Estimates (WASDE)

- **Established:** Enhanced after the Great Grain Robbery.
- **Focus:** Monthly forecasts for global agricultural production, consumption, trade, and stocks.
- **Key Contributions:**
  - Increased transparency in U.S. and global agricultural markets.
  - Provides timely data to prevent manipulation and price shocks.

Outlook Programs by EIA, USDA, and USGS

EIA: Annual Energy Outlook (AEO)

- **Established:** To provide comprehensive energy market analysis and projections.
- **Focus:** Long-term U.S. energy forecasts, including supply, demand, and pricing.
- **Key Contributions:**
  - Guides energy policy and market participants.
  - Models supply chain risks and scenarios.

USGS: Mineral Commodity Summaries (MCS)

- **Focus:** Annual reports on domestic and international mineral production, consumption, and trade.
- **Key Contributions:**
  - Supports critical mineral security and planning.
  - Monitors global supply chain disruptions.

The Role of the Market Balance Sheet in Commodity Markets

Definition:

- A commodity market balance sheet is a detailed presentation of supply, usage (demand), and stocks for a specific period, typically one year.

Components:

- **Supply:**
  - Beginning stocks
  - Production levels
  - Imports
- **Demand:**
  - Domestic consumption
  - Exports
  - Ending stocks

The Role of the Market Balance Sheet in Commodity Markets

Purpose:

- Provides a comprehensive overview of the commodity's market dynamics.
- Assists in forecasting price movements by analyzing supply-demand balances.
- Informs policy decisions and strategic planning for stakeholders.

Example:

- The U.S. Department of Agriculture's World Agricultural Supply and Demand Estimates (WASDE) report publishes monthly balance sheets for commodities like soybeans, detailing supply and usage variables.

Significance of the Balance Sheet

- Highlights potential surpluses or shortages.
- Guides traders and investors in making informed decisions.
- Reflects the impact of external factors (e.g., weather events, policy changes) on the commodity market.

The Balance Sheet: Supply

U.S. Soybeans and Products Supply and Use (Domestic Measure) 1/

SOYBEANS	2022/23	2023/24 Est.	2024/25 Proj. Sep	2024/25 Proj. Oct
		Million Acres		
Area Planted	87.5	83.6	87.1	87.1
Area Harvested	86.2	82.3	86.3	86.3
		Bushels		
Yield per Harvested Acre	49.6	50.6	53.2	53.1
		Million Bushels		
Beginning Stocks	274	264	340	342
Production	4,270	4,162	4,586	4,582
Imports	25	21	15	15
Supply, Total	4,569	4,447	4,941	4,939

Figure 11: Those are Rookie Numbers! Gotta get that yield up!

The Balance Sheet: Demand

Crushings	2,212	2,287	2,425	2,425
Exports	1,980	1,695	1,850	1,850
Seed	75	78	78	78
Residual	39	45	38	36
Use, Total	4,305	4,105	4,391	4,389
Ending Stocks	264	342	550	550
Avg. Farm Price ($/bu) 2/	14.20	12.40	10.80	10.80

Figure 12: Massive soybean export surplus

Why Stocks Matter?

Figure 13: Stock out!

Commodity Market Supply

- Commodity market supply is fundamentally physical
- Goods have to be moved around the world
- Limited product differentiation means almost all competition comes down to cost structures

Hotelling Model: Optimal Production of Nonrenewable Resource Overview

- Demonstrates that equilibrium from a price-taking firm operating
- Consider mine owner optimizing supply of resources from single mine. How to choose how much to extract?
- Cake eating problem. Eat all cake today or save for tomorrow?

Figure 14: Open Pit Mine

Assumptions of Hotelling Model

- Amount of commodity in mine known and fixed
- Commodity perfectly homogeneous with constant marginal cost of extraction
- Producer has perfect control over rate of extraction
- Quantity demand downward-sloping linear function of price
- Single constant interest rate on capital set by market

Economic Implications

- Hotelling's rule provides insight into price paths for exhaustible resources.
- Scarcity increases over time, pushing prices up.
- Model helps inform policy on extraction taxes and sustainability.

Model Assumptions: Mathematically

- Resource is finite and exhaustible (total stock = S).
- Two periods (1 and 2) with discount rate r.
- Price p_t depends on demand function $D(Q_t)$, where Q_t is quantity in period t.
- Profit maximization is subject to inter-temporal constraint on resource use.

Profit Maximization Problem

Objective: Maximize discounted profits over two periods.

$$\max_{Q_1, Q_2} \pi = p_1(Q_1)Q_1 + \frac{p_2(Q_2)Q_2}{1+r}$$

Subject to:

$$Q_1 + Q_2 \leq S \quad \text{(resource constraint)}$$
$$Q_1, Q_2 \geq 0$$

Hotelling's Rule

- Hotelling's rule suggests that the resource price (net of extraction cost) grows at rate r.
- Intuition: Owners allocate resources such that marginal profit in each period is equal in present value terms.

$$\frac{p_1'(Q_1)}{p_2'(Q_2)} = 1 + r$$

- Ensures that the inter-temporal profit-maximizing extraction path is followed.

Solving the Model

1. Derive $p_1(Q_1)$ and $p_2(Q_2)$ from demand functions.
2. Substitute into the profit function and differentiate with respect to Q_1 and Q_2.
3. Solve first-order conditions for optimal Q_1^* and Q_2^*.

Numerical Example

- Assume linear demand: $p_t(Q_t) = a - bQ_t$
- Set parameter values and solve for Q_1 and Q_2.

Example parameters:

$$a = 10, b = 1, S = 10, r = 0.05$$

Multi-Period Hotelling Model

- Extends the two-period model to T periods, allowing for a more realistic representation of resource extraction over time.
- Objective: Maximize the discounted profit stream over T periods.

$$\max_{Q_1, Q_2, \ldots, Q_T} \sum_{t=1}^{T} \frac{p_t(Q_t)Q_t}{(1+r)^t}$$

- Subject to the resource constraint:

$$\sum_{t=1}^{T} Q_t \leq S$$

Hotelling's Rule

- **Hotelling's Rule in Multi-Period Context:** Price net of extraction cost grows at the rate of discount:

$$\frac{p'_{t+1}(Q_{t+1})}{p'_t(Q_t)} = 1 + r$$

- Implications:
  - Prices increase over time, reflecting growing scarcity.
  - Optimal extraction path smooths profits, balancing present and future values.

Relaxing Hotelling Assumptions: Backstop Technology

Backstop Technology:

- A substitute technology or resource available at a fixed price.
- Provides an alternative to resource depletion.

Key Impacts:

- **Price Ceiling:**
  - The resource price cannot rise above the cost of the backstop.
- **Finite Resource Extraction:**
  - Resource owners may accelerate depletion to extract value before substitution.
- **Market Dynamics:**
  - Transition to backstop technology determines long-term market outcomes.

Relaxing Hotelling Assumptions: Variable Mine Quality

Variable Mine Quality:

- Resource deposits differ in extraction cost and quality.

Key Impacts:

- **Cost Heterogeneity:**
  - Low-cost deposits are extracted first.
  - Extraction costs rise over time as higher-cost deposits are utilized.
- **Modified Price Path:**
  - Prices rise faster than the discount rate to reflect increasing costs.
- **Impact on Supply:**
  - Supply curves become steeper, influencing market responses to demand shocks.

Relaxing Hotelling Assumptions: Market Power

Market Power:

- When a single producer or a cartel controls a significant portion of the resource market.

Key Impacts:

- **Price Markups:**
  - Producers restrict output to increase prices above marginal cost.
- **Intertemporal Allocation:**
  - Resource extraction is delayed to maximize present value profits.
- **Reduced Efficiency:**
  - Market outcomes deviate from socially optimal extraction paths.
- **OPEC as a Case Study:**
  - Highlights the role of collusion and strategic behavior in oil markets.

Hubbert's Model of Resource Depletion

- Developed by geophysicist M. King Hubbert to model the production cycle of a finite resource (e.g., oil).
- Predicts that production of a nonrenewable resource follows a bell-shaped curve over time.
- Key Insight: Resource extraction starts slowly, accelerates to a peak, and then declines symmetrically as resources become depleted.
- Often applied to oil fields, where production initially rises with new discoveries and technological improvements, then peaks and declines.
- **Implication**: The peak signals the maximum production rate, after which extraction becomes increasingly difficult and costly.

Mathematical Formulation of Hubbert's Model

- Hubbert's curve is often modeled using a logistic function to represent production $Q(t)$ over time t:

$$Q(t) = \frac{Q_{\text{max}}}{1 + e^{a-bt}}$$

- Where:
  - Q_{max}: total resource available (ultimately recoverable resource)
  - a: parameter determining the curve's shape and midpoint
  - b: growth rate of production, reflecting technological and economic factors
- **Peak Production Time:** Occurs when $Q(t)$ reaches its maximum rate, typically around $t = \frac{a}{b}$.
- **Decline Phase:** After the peak, production decreases as remaining resources become harder to extract, leading to higher costs and lower yields.

Hubbert's Peak

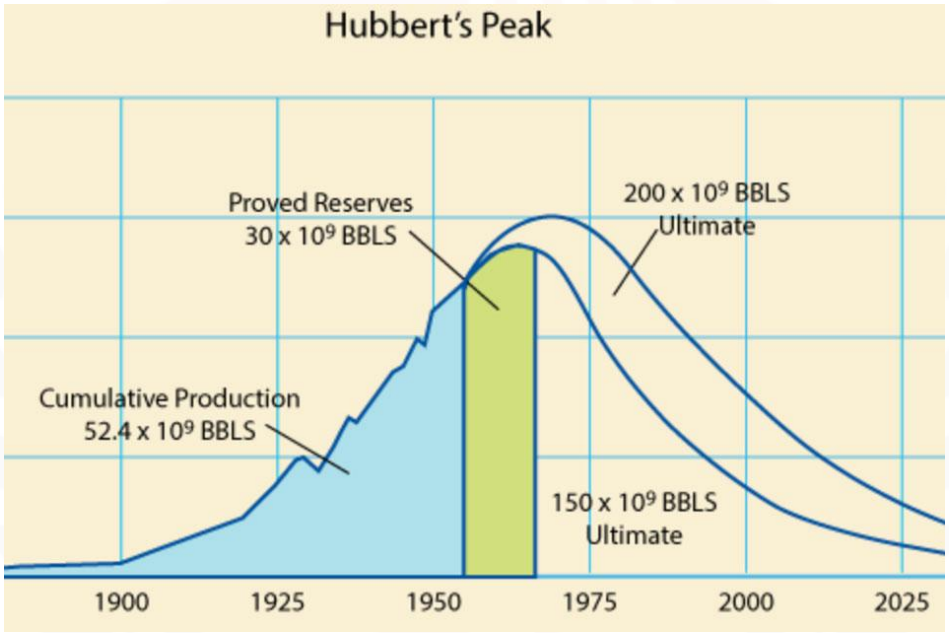

Figure 15: Everyday, your commodity is dying...

Hubbert's Peak and Oil

- Hubbert's peak worked as a model in the US until early 2000's
- Broke down because of shale revolution
- **Markets are incredibly good at reacting to price rises**

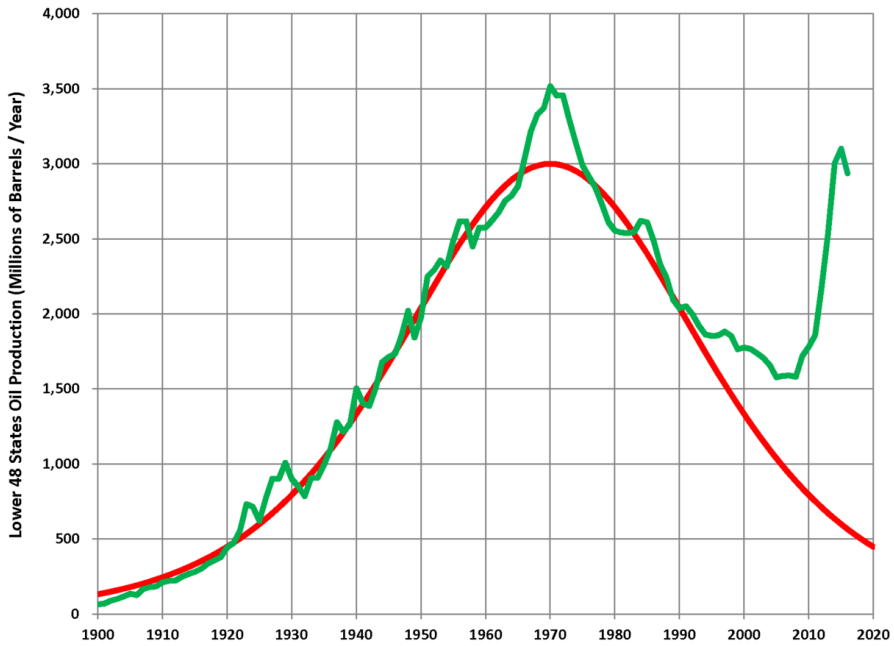

Figure 16: I have not even begun to peak! When I peak, all of Philadelphia will know it!

Industry Cost Curve Method

Overview:

- The industry cost curve is a graphical representation of the supply-side economics of a commodity market.
- It ranks producers based on their production costs, from the lowest to the highest, and plots cumulative production against cost.

Key Components:

- **Cost Categories:**
  - Fixed costs: infrastructure, equipment.
  - Variable costs: labor, raw materials, energy.
  - Capital costs: investments for capacity expansion.
- **Producers' Margins:**
  - Producers with lower costs operate profitably even at lower prices.
  - High-cost producers are vulnerable during price declines.
- **Market Clearing Price:**
  - Price is determined by the cost of the marginal producer (highest-cost producer still active).

Industry Cost Curves

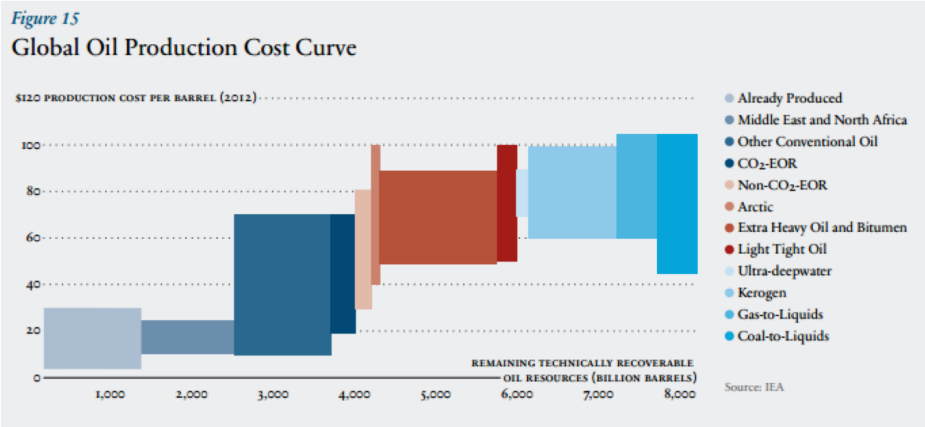

Figure 17: Coal to Oil is not cheap...

Commodity Market Demand

- Commodities are hard to substitute...

Commodity Market Demand

- Commodities are hard to substitute...
- But not impossible!
- Eventually, if bananas cost too much, you eat an apple
- Macro fluctuations also drive demand changes

Distinguishing Demand by Frequency

- Cyclical Demand: Driven by short-term real-business cycle
- Structural Demand: Driven by medium term changes in consumer tastes and business investments in efficiency
- Secular Demand: Driven by long-term factors such as societal-level economic development and technological change

Nerlove's Partial Adjustment Model

Context: Models how firms adjust towards a desired level of output or investment over time.

- In the short run, adjustment to desired levels may be partial due to costs or constraints.
- The desired level of production Y_t^* depends on factors such as price and technology.

Model Specification:

$$Y_t^* = \alpha + \beta X_t + u_t$$

- Y_t^*: Desired output at time t
- X_t: Vector of explanatory variables (e.g., prices, input levels)
- α, β: Coefficients to be estimated
- u_t: Error term

Mathematical Formulation and Partial Adjustment

Partial Adjustment Mechanism:

$$Y_t - Y_{t-1} = \lambda(Y_t^* - Y_{t-1})$$

where:

- Y_t: Observed output at time t
- Y_{t-1}: Output in the previous period
- $\lambda \in (0, 1)$: Speed of adjustment coefficient

Substitute $Y_t^* = \alpha + \beta X_t + u_t$:

$$Y_t = (1 - \lambda) Y_{t-1} + \lambda(\alpha + \beta X_t + u_t)$$

Interpretation:

- λ: Fraction of the gap closed each period. If $\lambda = 1$, full adjustment; if $\lambda = 0$, no adjustment.
- Can be estimated via regression with lagged Y and X_t as regressors.

Energy Demand and GDP Per Capita

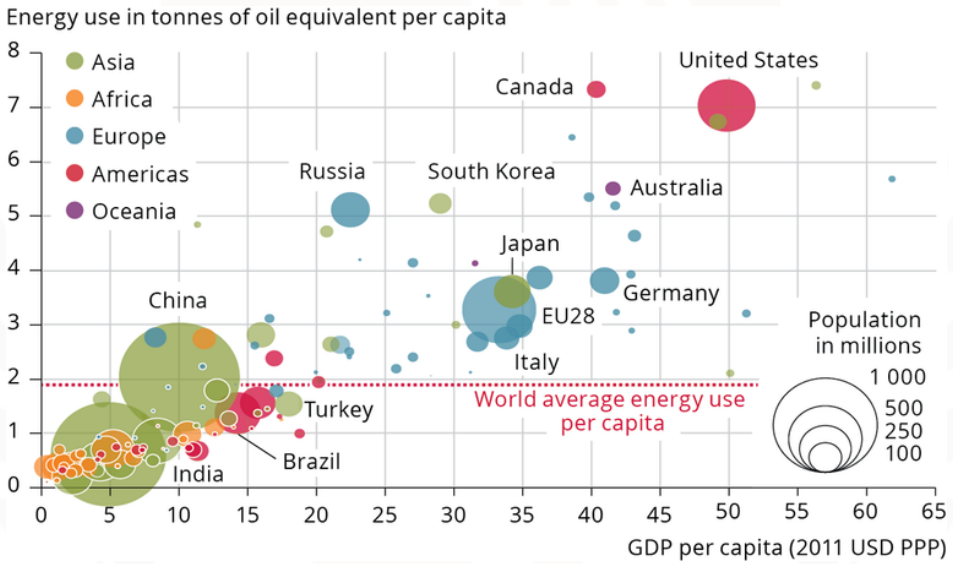

Figure 18: US is a major energy user, but coming down

Commodity Market Equilibrium

Definition:

- The market equilibrium occurs when the quantity supplied equals the quantity demanded at a given price.
- Reflects the balance between producers' willingness to supply and consumers' willingness to purchase.

Key Components:

- **Supply Curve:**
  - Upward sloping, reflecting higher production costs as output increases.
  - Influenced by production technology, input prices, and resource availability.
- **Demand Curve:**
  - Downward sloping, reflecting lower consumer willingness to pay as quantity increases.
  - Influenced by income, substitutes, preferences, and price expectations.

Commodity Supercycles

- Long-run supply highly elastic but short-run supply highly inelastic
- Long lag between commodity price signals and changes in supply
- High demand leads to high prices leads to High supply leads to Low prices leads to low investment leads to low supply leads to high prices...

Commodity Supercycles

- Long-run supply highly elastic but short-run supply highly inelastic
- Long lag between commodity price signals and changes in supply
- High demand leads to high prices leads to High supply leads to Low prices leads to low investment leads to low supply leads to high prices...
- What's the cure for high prices? High prices!

Supercycle Visual

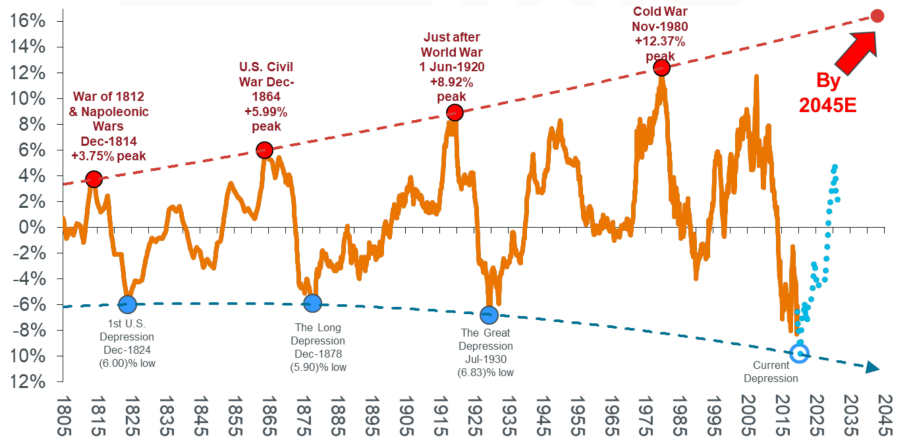

Figure 19: Notice a Trend?

Thank You So Much!

List of References