Lecture # 21 –Energy Pricing

I. Optimal Extraction of an Exhaustible Resource

- Three classifications of exhaustible resources:
    1. current reserves -- known reserves that can be profitably extracted at current prices. Also known as proved reserves.
    2. potential reserves -- reserves that could be recovered at higher prices.
    3. resource endowment -- the entire geological supply of resources (including those not yet discovered).
- Decisions to use exhaustible resources are dynamic decisions, because future availability of the resource depends on what is used today.
- Thus, exhaustible resources should be treated as an asset.

A. The Costs of Extraction

- There are two costs to using a resource, such as oil, today:
    - Extraction cost
        - How much does it cost to obtain the resource?
        - Obviously, only sell if P >= MEC (marginal extraction cost).
    - User cost -- the opportunity cost of not having the resource to sell in the future
        - As a result, the price of the resource will be greater than the MEC.
- The owner of a resource, such as oil, has two options to make money for next year:
    - Sell all the oil now, and invest the profits at interest rate i.
    - Wait and sell the oil next year.
- Case A: Expected profit next year rises less than the rate of interest:
    - Present value of marginal profits next year is less than current value this year:
        - P_1 - MEC > (P_2 - MEC)/(1+i)
    - The owner of the oil is better off selling the oil now and investing it.
    - Leads to lower prices now (greater supply) and higher prices next year (lower supply).
- Case B: Expected profit next year rises faster than the rate of interest:
    - Present value of marginal profits next year is greater than current value this year:
        - P_1 - MEC < (P_2 - MEC)/(1+i)
    - The owner of the oil is better off waiting to sell the oil next year.
    - Leads to higher prices now (lower supply) and lower prices next year (higher supply).

- Prices adjust whenever one option (case A or B) looks better. Thus, equilibrium is reached when the expected profit from the sale of the oil rises at the rate of interest.
    - P_1 - MEC = (P_2 - MEC)/(1+i), or
    - (1 + i)(P_1 - MEC) = (P_2 - MEC)
    - With a constant marginal extraction cost, this simplifies to:
        - $P_2 - P_1 = \Delta P = i(P_1 - MEC)$
        - *Intuition*: profit received from extracting the resource rises at the rate of interest
- <u>Marginal user cost (MUC)</u> -- the present value of the opportunity cost of the last unit of oil used not being available in the next period.
    - P(t) = MUC(t) + MEC(t)
    - If marginal extraction costs are constant, the marginal user cost rises at the rate of interest.
    - This implies that the present value of marginal user cost remains the same!
        - The market is maximizing the present value of welfare (including consumer surplus) over time.
    - Note that the price of a resource is greater than the MEC. Thus, higher prices are not, by themselves, evidence of abuse of market power.
        - Rather, they simply represent <u>economic rent</u> due to scarcity.
        - The mathematical example shows how the marginal user cost increases as scarcity is more of a problem.
        - For those who would like more practice working with these concepts, you can download the spreadsheet I used in class by [clicking here].
- Changes in the marginal extraction cost
    - Up to now, we have assumed the MEC is constant.
    - If marginal extraction costs rise over time, the marginal user cost will fall.
        - Intuition: MUC represents the opportunity cost of using the resource now. If it will be more costly to use the resource in the future, the opportunity cost is not as high.

B. Backstop Technologies

- This theory describes how the price should change over time. But what price should we start at?
  - We want to run out of the resource at the highest price that people are willing to pay.
  - This is the backstop price. It is determined by a backstop technology.
  - A <u>backstop technology</u> is a technology that is available in vast quantities at the backstop price.
    - E.g.: solar energy
    - Note that the backstop price is constant, since the backstop technology is not exhaustible.
  - Note that, if several fuels are available, we will begin by using the one with the cheapest extraction cost, and continue, using up each fuel, until the backstop technology is reached.
    - Note that, if these prices do not account for negative externalities, such as pollution, all of the dirty fuel supplies are used up!
  - Technological innovation on the backstop technology could lower its price and speed the transition.
    - However, if the backstop won't be usable for many years, markets might not support this research.

II. Energy Prices Over Time

- Theory predicts that energy prices should rise over time. That has not happened.

- Factors leading to higher prices
  - Higher demand, particularly in emerging economies
  - Risk premium
    - Concerns over security and corruption in oil producing nations raise the risks of future shortages.
  - Lack of refining capacity
    - Even if more oil comes into the U.S., there isn't additional capacity to refine it into gasoline more quickly.
    - Price volatility reduces investment.

- Factors leading to lower prices
    - Demand for oil and gasoline in many richer countries is falling, as more consumers use hybrid and electric vehicles
    - Resource scarcity
        - If a resource is not scarce, the user cost is near zero, so the price is set at the marginal costs of extraction.
            - Scarcity rents become a factor as demand increases, leading to slowly rising prices.
        - Concerns about peak oil were first raised during World War I
            - US crude oil proved reserves grew from 22 billion barrels in 2000 to 36.3 billion in 2014
        - New discoveries have limited the importance of scarcity in oil prices.
            - Current reserves in our model at the beginning of class change with market conditions
            - Exploration increases when energy prices are higher
    - Competitive markets
        - Changes in the role of OPEC play a key role in oil prices. The supply of non-OPEC oil has increased
        - Complexity of oil markets leads to boom and bust cycles
            - Effective spare capacity, both upstream (exploration/drilling) and downstream (refining) matters
                - Prices rise when spare capacity is low, because any shock will leave the market unable to react
                    - Note how, like in our basic pricing model, concerns about the future of the market matter
        - The quality of oil also matters. This has caused complications for energy markets.
            - Two dimensions
                - Density: ranges from light to heavy
                    - Measured using American Petroleum Institute (API) gravity formula
                - Sulfur content: ranges from sweet (low sulfur) to sour (high sulfur)
            - Light sweet crudes used for gasoline
            - Heavier and sourer crudes best suited for diesel fuel and heavy fuel oils
                - It is costlier to refine heavier crude oil into gasoline
                - Requires additional refinery units (e.g. crackers, cokers, and hydrotreaters)
            - Conventional US oil is generally light sweet crude with API less than 40.
            - Light oil is usually more expensive, because it requires less refining to produce high-quality products such as gasoline.

- Shale oil has even higher API, and is thus even lighter
  - Thus, not always a perfect substitute for conventional oil, as these differences can affect the quality of refined products.
  - But, it is well-suited for gasoline.
- The model assumes constant marginal costs
  - Over time, technical progress has reduced the marginal cost of many resources.
  - Technological change has lowered extraction costs.
    - Lower extraction costs increase economic reserves => lower MUC as well.
  - Technological change changes expectations of future costs
  - Technological change lowers the cost of backstop technologies
  - Higher prices in recent years have made it feasible to extract energy from places with higher extraction costs.

- Hydraulic fracturing of shale oil is an example of technological change
  - Shale oil depends on three technological advances:
    - horizontal drilling
    - microseismic imaging
    - hydraulic fracturing
  - What is fracking?
    - Causes cracks and fissures in the rock formation that allow crude oil to escape
    - Fracking is occurring at known resource sites. It isn't that new resources were discovered, but that more became economical to access.
  - Possible costs of fracking
    - Water resource impacts
      - Water used could reduce flows of rivers and streams
        - Quantities of surface water used are small
        - But most water usage concentrated during the fracturing process
          - If this occurs when water is scarcer (e.g. summer), may have an impact
      - Surface water pollution
        - These costs may be significant
      - Groundwater pollution
        - Determining causal effects often difficult.
      - Groundwater depletion not an issue in eastern U.S., but could be an issue in semi-arid areas
        - Little data on this yet
      - Increased seismic activity

- Surge in fracking stimulated by high oil prices after 2003, which made the technology competitive
  - Since then, the cost of the technology has fallen.
  - Energy companies become more efficient as gain experience and drill more wells.
    - Advances include extending horizontal section farther:
      - Requires more water and sand, but makes wells more productive
- Projected continued growth in US oil production comes entirely from shale oil
- How has shale oil and gas affected prices?
  - Reduced US oil imports
  - Increased US exports of refined products
  - Building infrastructure to export natural gas
    - More pipelines (e.g. to Mexico)
    - Facilities for liquefied natural gas
  - Reduces volatility
    - Shale wells take longer to drill and reach production
    - But they produce more per well and have less variation in production
    - Thus shale oil and gas is more responsive to market prices
      - More so for natural gas, for which the market is primarily North America
      - Oil, in contrast, is a global market
- Increased use of natural gas from shale reduced emission from US power plants