Lecture # 23 – Water as a Scarce Resource

I. Is Water an Exhaustible Resource?

- What makes water a challenging problem?
  - Water demand increasing with rising population
  - Water is a local good
    - Precipitation varies
    - Because water is heavy, it is expensive to move
      - Infrastructure an important constraint
    - Just 9 countries have 60% of world freshwater supplies
      - China and India together have just 10% of world's water
  - As a result, the value of water varies by location
    - Water withdrawals from farming (globally 70%):
      - Britain: 3%
      - US: 41%
      - China: 70%
      - India: 90%
    - Industry uses about 22% of water withdrawals
      - About 60% in rich countries
      - About 10% in other countries
    - Power sector is a major user. Uses water for cooling
      - Over 40% of US withdrawals for power plant cooling
  - The graphs from this section come from the Food and Agricultural Organization of the United Nations and the US Geological Survey.
  - Supply is finite
    - New water cannot be created
    - Over 97% of water is salt water in oceans
    - Of the remaining 2.5%, 70% is frozen
    - Thus, only 0.75% of world's water available for human use
      - Much of this is underground
  - What does it mean to use water?
    - In many cases, water can be reused
      - E.g. using shower water in a garden
    - Water is used when it evaporates or transpires (passing from leaves of growing plants into the atmosphere)

- Whether or not water is an exhaustible resource depends on the source of the water.
    - Surface water -- fresh water in rivers, lakes, and reservoirs that collects and flows on the earth's surface. It can be recharged by precipitation and runoff.
    - Groundwater -- Water that collects in porous layers of underground rock known as aquifers.
        - Although some of the water can be renewed by seeping rain or melting snow, most groundwater has accumulated over several years and cannot be recharged.
        - Therefore, groundwater is an exhaustible resource.
            - 27% of U.S. water withdrawals in 2015 were groundwater

- Note that the total supply of water in the world is more than adequate to meet world demand. However, many areas experience shortages, since the local demand is greater than supply.

- Three problems associated with water availability:
    1. In many areas, water use exceeds the rate at which it is being replenished.
    2. Many activities use water as an input. When it returns to the surface or groundwater, the quality is diminished.
    3. Water is often used for waste disposal. Leads to lower water quality

II. Efficient Use of Water Resources

A. Water as a Resource Flow

- If the flow of a water source (such as a river) is greater than the demand for water, and there are no externalities, there is no resource allocation problem. Price should just cover the marginal cost of withdrawing water.
    - Efficient long run marginal cost (LRMC) should reflect:
        - Cost of transmission, treatment, and distribution
        - Some portion of capital cost of current reservoirs and treatment systems
        - Some portion of capital costs of future facilities that may be needed due to current consumption
    - LRMC may be greater than short-run average cost
        - Because LRMC reflects cost of new supply acquisition
            - New supplies typically costlier to develop than current supplies

- If there is not enough water for every need, the price needs to rise to reflect scarcity.

- Market failures that occur with surface water consumption:
    1. Property rights must be well defined for prices to allocate resources efficiently. However, water is usually a common property resource.
        - In such cases, prices don't work well.
            - More water used by those upstream
        - Even if property rights are well-defined, there may be monopoly problems
            - In most cities, water is distributed by public utilities
    2. Degrading uses of water
        - Water returns to the system with wastes
            - Even wastewater treatment plants cannot treat everything
        - Pollution of water sources
            - E.g. agricultural runoff

- The high fixed costs of water infrastructure also create problems, particularly in developing countries.

B. Water as an Exhaustible Resource

- When the consumption of water is greater than the rate of recharge of the stock, it is an exhaustible resource.
  - Aquifers in the Western U.S. are an example.

- In addition to earlier considerations, the price of water in such cases should include the marginal user cost.
  - As such, for efficiently priced water, revenues may exceed current expenses
    - May be an issue for regulated utilities
  - If there is some surface water available, it may serve as a backstop technology.

- There may also be other externalities with groundwater consumption
  - Ecological damage caused by withdrawing groundwater.
    - Example: heavy water use in southern Florida has caused salt water to move into the aquifer
  - Withdrawals from one user raise the costs of pumping for other users

- What are the barriers to efficient water pricing?
  - Water typically priced at 10-50% of the O&M costs of the system
    - That is only 10-50% of what it is worth in terms of agricultural productivity
    - Thus, water prices would need to rise by 4-100 times to be in equilibrium
  - Barriers to efficient water use and allocation are mainly socially constructed
    - Water prices not determined in markets
    - Water prices do not reflect scarcity
    - Allocation mechanisms highly political
    - Compare to energy, where most resources are privately owned and profits encourage resource owners to consider scarcity
  - Property rights structures for water ignore spatial and temporal externalities
    - In many arid regions, marginal value of water left instream may exceed its value in agriculture and other uses
    - In contrast, external costs of energy are smaller relative to market prices

- Pricing in informal sectors
  - Urban poor in developing countries get water from both the formal sector (public and private piped sources) and informal sector (standpipe operators, water trucks, resold water from those that have piped access)
    - Typically, 50% or more get water from informal sector
    - Provides access to those that would otherwise not have access
      - Informal providers may have local monopolies
      - Evidence suggest these providers sell water at high markups
- Would privatization help?
  - Evidence suggests privatization does increase access for poor households
    - But similar improvements observed in non-privatized control regions, so improvements may not be from privatization
    - Little evidence that private water suppliers less likely to serve poor households
  - Are private monopolies more efficient than public monopolies?
    - A study in the UK found little productivity improvement when privatized water and sewage providers replaced a public utility
    - In US studies, private providers have an efficiency advantage in small utilities
    - Large public utilities appear to be more efficient than large private ones
    - What about prices?
      - Are cost savings passed on to consumers?
      - In both France and Spain, prices are on average higher when utilities are managed by private investors.
      - Prices also increased after privatization in the UK

- Policies to encourage water conservation
  - Would higher prices help?
    - Good estimates of elasticity necessary to know how consumers may respond to price increases
    - Controls include
      - Income
      - Household characteristics (to proxy for preferences)
      - Season
      - Weather
    - Results: residential demand
      - Water demand is inelastic
      - Espey *et al*. (1997): Meta-analysis of 124 studies from 1963-1993
        - Average price elasticity of -0.51
        - Short-run median estimate: -0.38
        - Long run median estimate: -0.64
      - Dalhuisen *et al* (2003): Meta-analysis of 300 studies from 1963-1998
        - Average price elasticity of -0.41
      - Studies suggest price elasticity may increase when price information included on water bills
      - Elasticity may be higher under increasing block pricing than uniform pricing
    - Results: agriculture and industry
      - Here, water demand must be modeled as part of the overall production process
      - Data are hard to get
        - Water usage not often metered
      - Results for industry
        - Demand tends to be more elastic than for households
        - Estimates range from -0.15 to 0.98
      - Results for agriculture
        - Farmers who use surface water usually incur an energy cost to pump water, but don't pay for the water itself
        - Thus, most estimates come from groundwater usage, using energy costs as the price
        - Results
          - Meta-analysis of 24 U.S. agricultural water demand studies from 1968-2004 finds a mean price elasticity of -0.48
            - However, estimates vary widely
              - Often approach zero
              - Elasticities higher in regions with scarce water and higher prices

- If prices cannot be raised, what other policy options are available to encourage conservation?
    - Technology standards
        - Estimated savings from technology standards often smaller than expected due to rebound effect
        - As a result, price increases would be more efficient to reduce water usage
    - Rationing policies
        - Often used in response to short-term crises (CA is a recent example)
            - In 2008, 75% of Australians lived in communities with a water use restriction
        - These restrictions are not efficient
            - Grafton and Ward (2008) estimate restrictions in Sydney resulted in economic losses of $150/household
                - This is about one-half of the annual average water bill
        - Studies suggest that increasing prices instead of mandatory rationing would reduce the economic cost of consumption reductions
            - Mansur/Olmstead (*JUrbanEcon* 2012): study restrictions on residential water use in 11 North American cities
                - Restrictions target uses households are most willing to forgo
                - But, because of household heterogeneity, restrictions impose large welfare costs
                    - Typically, demand for outdoor usage is more elastic than indoor usage
                    - Some households have high willingness-to-pay and would pay more for scarce water
                    - What are the equity implications? For example, Mansur/Olmstead give example of wealthy customers with large lots as being least price sensitive (and thus willing to pay more)
                    - Low income households with small lots not WTP more.
                        - They say that drought pricing *without a lump sum rebate* would be regressive
                        - Extra producer surplus from higher prices could be used to fund a rebate, since utilities typically regulated and cannot have extra profits

III. Allocating Water Across Sectors

- Allocation of water across sectors
  - Since prices do not reflect scarcity and water rights influence consumption, water is likely not efficiently allocated across sectors
  - Differences in prices signal potential gains from trading in the American West
    - Arizona:
      - Farmers in Pima County pay $27/acre-foot
      - Water customers in nearby Tucson pay $497-$3267/acre-foot
    - Texas:
      - Value of water for agriculture in Rio Grande Valley $300-2,300/acre-foot
      - Value of water for urban uses $6,500-$21,000/acre-foot
    - Analysis of water transactions in the west shows prices higher for agricultural to urban transfers than transfers between agricultural users
      - Consistent with differences in value shown above
    - Why is there price dispersion in U.S. markets?
      - Water is a complex, multidimensional commodity (both legally and hydrologically)
      - Few potential traders in many markets
        - Traders that do exist vary in size
      - Lack of information prevents prices from converging
    - Evidence on prices
      - Higher priority water rights sell for higher prices
      - High volume trades have lower per-unit prices
        - Suggests economies of scale
      - Income growth drives up prices
      - Areas with high-valued agriculture have lower quantity of trades
  - How might that be addressed?
    - Informal water markets
      - These are common
      - In developing countries, those with access to groundwater wells and pumps sell water to those without access
    - Formal water markets across sectors have been slow to develop
      - Transaction costs can be high
        - Physical infrastructure for transporting water
        - Legal costs of creating and enforcing contracts and obtaining regulatory permission
        - Carey *et al*. (2002): transaction costs reduce trading and favor trades among closely affiliated farms

IV. The Potential of Water Markets

- Examples of water markets
    - Australia's Murray-Darling river basin
        - Covers 14 percent of Australian land area
        - Until 1980, withdraw rights for irrigation unlimited
        - Water trading introduced in 1983 in South Australia
            - Added to New South Wales in 1989
            - Added to Victoria in 1991
        - Permanent interstate transfers not allowed
            - Temporary trades ensure water can be reallocated to highest value uses as conditions change
        - Significant limitations on inter-regional sales exist
        - Intraregional trading is active
        - Two key features
            - Water usage measured in net terms
                - Return flows to river from unused water accounted for
                - Considers environmental demand and changing land usage
        - National-level policies
            - 1994 National Framework for Water Reform
                - 10-year water reform process
                - Cap on surface water extractions began in 1995
                - Began process of unbundling water rights from land
                - Updated in 2004 to hasten the reform process. Leads to...
            - 2007 National Plan for Water Security/2008 Water for the Future
                - Three key elements
                    - Nationwide investment in irrigation infrastructure
                    - Nationwide program to improve on-farm irrigation and metering technology
                    - Sharing of water savings between irrigators and Australian Government
                        - Intention is to reduce overall withdrawals
                - Included funding to directly buy water entitlements from willing sellers through reverse auctions
                - Implemented through the 2012 Basin Plan
                    - Set Sustainable Diversion Limits (SDLs)
                    - 2018 Amendments increased SDLs

        - How trades work
            - Water entitlement trades involve trade of water access entitlements in the form of a consumptive share of the water resources within a water resource plan area
            - Water allocation trades involve trade of seasonal allocations of water attached to a water entitlement.
            - More allocation trades than entitlement trades
        - Results:
            - 70% of the total nominal water reductions acquired as of 2017
            - Trades appear to have led to higher-value agricultural production
                - More efficient irrigation technologies used
                - Water usage fell more than value of farmed land
            - Saved costs
                - Subsidies to save water 2.5 times more expensive than buy-backs of entitlements
            - However, OECD study suggests system is now over-allocated
            - Environmental impacts not being delivered
            - Monitoring and compliance has been problems
    - Estimates of annual monetary gains from water trades provide evidence that these markets are working
        - Australia
            - Trades are worth $1.8 billion in 2009
            - Gains from trade in a dry year estimated to be $495 million
    - Compare to the US, where the gains from trade are smaller, despite being a larger economy
        - Average annual value of water trading between 1987-2008 about $406 million
            - Over half of this value from trades in California

- While there are large potential gains from trade from trading water rights, implementing markets for water rights is challenging. How might they work in the US? Could they be successful?
    - Challenges include:
        - Markets often localized
        - High transaction costs
- Importance of property rights and institutions
    - Legal/administrative clarity: are water rights clear?
        - Australia has clear water rights
            - Even though rights could be revoked, government has sought to protect existing rights holders.
        - US water rights are not always well-defined
            - Western water rights typically based on prior appropriation and diversion
            - Junior rights may not be guaranteed because of over-allocation of available water
            - Definition of rights vary across states, making transfers across states difficult
            - History of US water rights
                - First property rights were <u>riparian rights</u> -- those with property adjacent to the water had the right to use it.
                - This became inappropriate as population grow and some settlements moved away from the water. The development of mining in the west was a major factor in this growth.
                    - Also, mining began to develop in California
                    - Required water, but mines weren't on the water
                    - Riparian rights didn't provide for water to be diverted

- Led to the prior appropriation doctrine -- the first person to claim water has the property rights.
    - Follows the traditions used in mining.
    - Has been upheld in court decisions and in the Constitutions of several western states.
    - Leads to diversion of water
        - Agriculture flourished in arid areas
    - Initially, these property rights were non-transferable
        - Only for “beneficial” purposes
    - Note that prior appropriation rights discourage conservation (e.g. “use it or lose it”)
        - Because governments can rend rights under public trust doctrine (e.g. for beneficial purposes)
        - Creates uncertain ty about the value of rights
        - Note that environmental flows are a consideration for “beneficial use” (from old reading)
            - However, there is debate about the amount of water needed for environmental objectives
    - No compensation for water rights holders who lose water under the Public Trust Doctrine
        - Leads to long-standing conflicts

- Mobility of water leads to externalities. How can markets address these?
    - Water rights may overlap, as water may re-enter systems as “return flow”
        - Return flows are larger for agriculture than for urban water usage, which is mostly consumptive.
    - Thus, if upstream agricultural users transfer water rights, downstream users of the return flow will be affected
    - Can be avoided by allowing sellers to only sell “consumptive use” (= total diversion minus return flow)
        - This adds to transaction costs, as the actual consumptive use must be calculated
    - Depends on quality of measurement of water usage, which varies in US
        - E.g. Colorado adjudicated rights early and has good records of actual water usage. California does not.
        - Use of new technology, such as hydrologic modeling software, has been used for water quality trading and could help here as well
    - Compared to Australia, externalities are more prevalent in the US
        - Linkages across governments and agencies needed to ensure effective governance when responsibilities are shared
        - Australia does well here
            - Cross-government agreements were the basis of reform in the mid-19990s
        - In US, cooperation is weak, since water management left to the states
            - Leads to high transaction costs
                - Water trades usually require approval of a local irrigation district board, the county, the state, and potentially federal agencies as well.
    - Implications for trading:
        - Transfers within a water basin have fewer externalities, but also limit potential gains from trade.
        - Transfers from agriculture to urban markets more likely to affect downstream users
            - ***Potential trades with the largest gains also have the largest transaction costs!*** How can these be overcome?
                - The reading suggests a need to scale up institutions to allow markets to span jurisdictions, but doesn’t suggest how to do this.

- Can markets be designed to minimize political objections?
    - Rights holders are heterogeneous, and thus have different expectations
    - Farmers with beneficial use requirements typically haven't faced the opportunity cost of water usage. Markets would reveal this opportunity cost
        - But transitioning land from farming may face political opposition
        - Plantinga's blog post suggests how markets can help
            - Comparing areas in California in the Mojave aquifer with and without tradable groundwater rights.
                - Those in areas without rights have open access to groundwater
            - Landowners with property rights face restrictions on usage, but can sell the rights to others, including cities
            - Property values of those just insight the property rights boundary are higher than property value of those just outside the boundary.
        - As restrictions on water usage will be necessary anyway, Ayers' blog post suggests that the ability to trade water rights will help compensate farmers forced to retire because of increasing water scarcity and new restrictions on water usage.
    - What lessons can we learn from other environmental markets?
        - Water quality markets have struggled to match farmers with buyers of permits.
        - Fisheries markets faced opposition from people who could lose economic rents (e.g. the most efficient fishermen). Possible solutions:
            - Allocating quotas based on historical usage
        - In Australia, the quantity of sales in water markets limited to protect communities from reduced water diversions (from old reading)
            - Has reduced water trades
    - Initial allocation and reallocation (are processes transparent?)
        - In Australia, one challenge was to reallocate water rights from existing users to the environment (from old reading)
            - Accomplished through federal government purchases of water rights from willing sellers