Concepts and methods for assessing economic impacts from climate change on water resources

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Introduction

- Long-run changes in climate and water supply
- Persistent changes in temperature and precipitation
- Changes in surface and groundwater supplies

Influences

- Falling groundwater tables and rising pumping costs
- Higher evapotranspiration rates and rising irrigation costs
- Increases in water competition and demand
- Greater user-restrictions to domestic water users

Estimating water's economic value

- Water's instrumental value in providing goods and services
- Food, drinking, health, cleaning, manufacturing, waste removal, navigation, etc.

Changes in willingness-to-pay

- (nonpublic good) Commercial water demand and cost schedules: e.g, municipal water rates
- Valuing water in crop production, industrial, household use, and flood risk reduction (Young and Loomis, 2014)
- (public good: externalities, non-rivalry) Water quality, wetland, recreation
- Non-market methods with stated or observed preferences

Two approaches

- Hydro-economic models: watershed-based models
- Reduced-form hedonic estimation: the capitalization of climate variables in land values

Hydro-economic models

- Spatially disaggregated, intertemporal watershed models
- Incorporating water sources and supply functions, water use and demand functions

Goal

- Optimize water use and storage decisions
- Optimize patterns of interregional trade
- Examine climate change impacts on drought (Hurd and Coonrod, 2012) and endangered species (Ward and Pulido-Valazquez, 2008)

Hydro-economic models

Assumptions

- Water move freely between users, ignoring transaction costs and institutional barriers to water transfer
- Optimizing over time permits "perfect foresight", anticipating future climate patterns and inflows.

Hydro-economic models: Present Value of Net economic Benefit

- Choose flows F_{nt}, diversions W_{nt}, and aquifer pumping rates R_{nt} to maximize

$$PVNB = \sum_t dt \sum_n (\sum_i [B_{nit}(W_{nit}) - C_{nit}(W_{nit})]$$
$$+Q_{nt}(S_{nt}) + H_{nt}(R_{nt}) + E_{nt}(F_{nt}) - D_{nt}(F_{nt})$$

- t, n, i represents time periods, river nodes and consumptive uses
- B_{nt}, C_{nt} define benefits and costs as function of diverted water W_{nt}
- Q_{nt} and H_{nt} generate value from water stored S_{nt} and released R_{nt}
- E_{nt} and D_{nt} are environmental services and damages of flow F_{nt}
- Subject to *Flow-balance constraint* and *Storage-balance constraint*

Reduced-form hedonic estimation: the Ricardian approach

- The climate-irrigation model: (Mendelsohn and Dinar, 2003)

$$V = \int_t [\sum_i P_i Q_i(X, F, Z, G, H, S_{sw}) - \sum_j R_j X_j - R_H H] e^{-rt} dt$$

- V stands for the per hectare farmland value, expressed as the present value of net economic returns
- Q_i is the total quantity of crop i produced
- A vector of j inputs X_j purchased at prices R_i
- F, Z, G, H, S stands for climate variables, soil quality, economic conditions, irrigation technology, and surface water supply

Reduced-form hedonic estimation: the Ricardian approach

- The climate-irrigation model: (Mendelsohn and Dinar, 2003)
    - Rising marginal value of water as temperature rises
    - Include interaction terms to test sensitivity to climate variables, such as temperature and precipitation changes

Regional empirical results

- California
  - Scarcity costs: \$360 million/year from lost of agricultural production and urban water shortages
  - Operating costs: \$384 million/year
  - Additional policy costs: \$250 million/year from limiting interregional water transfers
  - Other papers also examines the capitalization of various water characteristics in land values such as access to multiple sources and reliability

Regional empirical results

- Columbia river and Pacific Northwest
    - Significant reductions in snowpack and shifts to earlier peak runoff could cause 43% losses to summer irrigation by 2080s.
- Rio Grande
    - An estimated total economic loss of approximately 0.2% of GDP, combining agricultural and urban sectors
- Colorado River
    - Hydro-economic model combined with incremental climate change scenarios, the losses approached nearly $1.4 billion under 2.5 degree Celcius with 10% reduction in precipitation. (Hurd et al, 1999a)