Water Resources

Understanding the economic impacts of climate change on irrigated agriculture has proven critical to date because water allocation institutions complicate the relationship between climate signals and decision-making at the individual level. Climate and weather determine water availability, which governs which crops are grown and when.

• Water rights are complex and vary across states
  - Across the U.S. West, surface water is allocated amongst users according to the doctrine of prior appropriation ("first in time, first in right")
  - Irrigators hold unabstracted water rights, each with a priority date that corresponds to the first date on which water was diverted for beneficial use.
  - In the event of a water shortage, senior water rights (those established earliest) are safeguarded first; junior water rights may be curtailed.

• Irrigators with junior rights face greater uncertainty in water availability than do those with senior rights, all else equal.

Because water availability is not known with certainty at planting, irrigators with junior rights will likely make different production choices than those with senior rights.

• Planting potatoes or sugarcane, high-valued crops that cannot survive a missed irrigation application, is risky given the prospect of curtailment. Irrigators with junior rights may be more likely to plant drought resilient, low-value crops.

• Changes in the mean, variance, and timing of water inflows, along with population growth and urban expansion, have begun to test water rights institutions in never-before-seen ways.

Study Region


Watershed Management:

• The Snake River Basin (in green) with Idaho and Oregon water rights for irrigation by project or farm

APPROACH

Integrate remote sensing data into an econometric analysis of factors that affect land-use decisions by agricultural producers, with a focus on the allocation of land between irrigated and dryland production.

Objective 1: Develop a micro-economic theoretical framework linking climatic variability and water rights to agricultural land-use decision-making

Assume that a risk-neutral producer uses a vector of inputs X to produce a single agricultural commodity. The commodity can be produced with irrigation or on dryland. The irrigated and dryland production functions are given by:

\[ y - y_f(x_s) \quad \text{and} \quad y = y_f(x) \]

where y and y_f denote total irrigated and rainfed yield per unit area, x_s is a vector describing the land allocation to irrigated and dryland production, and x is the allocation of water to irrigated production.

A producer who operates under uncertainty chooses a land and water allocation to maximize profit for the growing season:

\[ \max_{x, y} f(x, y) \] where W is available to the producer and \( x \) is the total amount of land available for agricultural production.

The problem of facing a producer having the choice of two water rights curated to receive water deliveries in the amounts "x" in the Western US. The University of Illinois Press. The theoretical framework yields three testable hypotheses: (1) all producers reduce irrigated production in a dry year; (2) a relative junior irrigator allocates less land to irrigated production in any year, regardless of inflows; (3) in a dry year, a junior irrigator reduces irrigated acreage by a greater amount than a senior irrigator.

Objective 2: Develop an empirical econometric model to explain observed land-use changes in the Snake River Basin

Our empirical strategy exploits the spatial discontinuities created by water rights rules. Under the Alaska-Soldotna Treaty, for example, the effect of water rights scarcity on land-use decision-making, the economic analysis is given by:

\[ Y = \alpha + \beta_1 x + \beta_2 x^2 + \beta_3 x^3 + \beta_4 x^4 + \beta_5 x^5 + \epsilon \]

where \( x \) denotes the individual farm and \( y \) the year. Model variables and data sources are defined in Box 2.

Objective 3: Merge remote sensing data from MODIS and Landsat to generate a panel dataset of agricultural land-use observations

NASA remote sensing data provide the dependent variable in the econometric model (the observed outcome of a decision-making process), which will be summarized in the proportion of land irrigated within the geopolitical boundaries of each farm.

We will distinguish between irrigated and dryland agriculture by examining the dynamics of decision-making over the course of each growing season:

• Land use data are at a spatial resolution consistent with individual decision-making units (farms) and the length of the time series allows us to capture changes in climate as well as weather. But the coarse temporal resolution and cloud cover problematics are:

We will use MODIS and Landsat data in a complementary way following Ozdogan, Michael (2006). MODIS NDVI will be used to identify differences in the spectral signatures of irrigated and dryland land use in the growing season (Figure 5). The NDVI threshold will be used to identify the earliest irrigation and dry farming dates, respectively.

Validation and ground-truthing will include comparisons of MODIS and Landsat data to assess the accuracy of MODIS data and the effect of climate, weather and water rights on land use.

Preliminary Analysis

• A preliminary analysis was undertaken for the State of Idaho, including the Upper, Middle, and Lower Snake, Kootenai-Pend Oreille-Spokane, Bear, and South Snake Lake Basins (Cobourn et al., in review).

• The dataset spans 45,364 unique water rights designed for irrigation and four growing seasons (2007–2010).

• Land-use decisions are summarized by USDA-NASS Crop Data Layers:
  - Rainfall data at a spatial resolution of 56 meters describes each producer’s choice of crops.
  - A spatial sampling technique is used to describe how land is allocated across 12 major crops within the boundaries of each farm.

• Water-use decisions are only captured using as some crop cannot be grown under irrigation and some have requirements.

• Other variables included in the model are the mean and standard deviation of the seasonal water forecast (at the time of planting), long-run water availability, water rights priority dates, the trend and standard deviation of growing degree-days, soil type, and distance from nearest surface waterway.

FINDINGS

• Producers with access to a stable natural water supply tend to plant lower valued crops.

• Junior irrigators plant lower-valued crops than farms with earlier priority dates, but the effect diminishes after 1906.

• Farms with junior surface water rights are more responsive to an anticipated water shortage than farms with senior surface water rights. Junior and senior groundwater irrigators do not respond differently to an anticipated water shortage, which indicates that access to groundwater protects irrigators from uncertainty in inflows.

References


