METHODS

We will estimate a spatial autoregressive error model assuming the error term is spatially correlated:

\[ y = X\beta + \epsilon, \]

\[ \epsilon = \lambda W\epsilon + \mu \]

Where \( \beta \) include 5-year mean temperature, 5-year mean precipitation, yield gap, government compensations, and water availability.

- If the irrigated yield gap is high, then the probability of choosing irrigation over rainfed is higher.
- If water is easily available (surface or underground) the probability of choosing irrigation over rainfed is higher.
- If government payments are high the probability of investment for irrigation will be lower.

Data:
- Yield by county: USDA-NASS (National Agricultural Statistics Service)
- Yield by 5 arc min grid cell: GCWM (Global Crop Water Model)
- Area: Mitra US (Moderate resolution imaging spectroradiometer, Irrigated Agriculture Dataset for the United States)
- Climate: PRISM (Parameter-elevation Regressions on Independent Slopes Model)

RESULTS

- The 1995-1999 mean precipitation has a negative marginal impact on area equipped with irrigation and the impact is significant.
- The 1995-1999 mean temperature has a positive impact on irrigation and it is significant.
- The government payment ratio is significant and has a negative impact on area equipped with irrigation. In other words, high government compensation comes with low irrigated area.
- Including available surface water and ground water is not improving the estimation.
- Coefficients of variation of weather are not able to explain irrigation pattern: the average precipitation and temperature are better in explaining the irrigation distribution.
- There is no significant change in the results by considering a ten year average of temperature and precipitation (1990-1999).

SPATIAL ERROR MODEL

The determinants of area equipped with irrigation (ha) around year 2000 by 5 arc min grid cells in the United States.

Government payment is defined as ratio to total county level crop expenditures.

WHAT ABOUT WATER WITHDRAWAL?

- Looking forward, we are interested in the estimation of irrigation intensity (gallons of water per acre per year) as a short-run response to environmental stressors.
- We will employ new data on simulated soil moisture, which is a more accurate measure of water availability for plant growth than the precipitation averages traditionally used in this literature.
- We will follow Haqiqi et al. (2018) by considering the interaction of heat and soil moisture at 2.5 arc min grid cells.

LIMITATIONS

- We need an all-crop yield index
- We need some nationally consistent data on gridded irrigation expenses
- We need an index for flexibility of change in water use considering water rights
- It will be helpful to consider differences in soil types and soil textures.
Estimating Water Withdrawal Response to Environmental Stresses

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Estimating Water Withdrawal Response to Environmental Stresses

Introduction

We are interested in the estimation of irrigation extent (percent of cropland area equipped for irrigation) as a longer run response to environmental stressors. We propose the following model to explain the extent of irrigation:

\[ l_i = \beta_1 \bar{M}_i + \beta_2 \bar{M}_i + \beta_3 \bar{H}_i + \beta_4 \bar{H}_i + \beta_5 GW_i + \beta_6 SW_i + z_i + \varepsilon_i \]

where, \( l_i \) shows the fraction of cropland which is irrigated at each grid cell calculated from USGS MIRAD-US (Pervez and Brown 2010), \( \bar{M} \) is the historical average soil moisture index from WBM, \( \bar{M} \) shows the historical variation of soil moisture, \( \bar{H} \) is the average harmful degree days calculated based on PRISM, \( \bar{H} \) depicts the historical variation of harmful degree days, \( GW \) is the groundwater availability calculated based on groundwater table depth (Fan, Li, and Miguez-Macho 2013) and groundwater storage (Gleeson et al. 2016), \( SW \) shows the annual surface water runoff and will be calculated from USGS (Reitz et al. 2017), and \( z_i \) is a vector of location specific information including cropland rents from USDA Cash Rents, soil type from Gridded Soil Survey Geographic (gSSURGO) Database (gSSURGO 2017). We will also consider history of extreme heat, extreme soil moisture, and combined extremes (heat and drought) as they affect the crop yields (Haqiqi, Hertel, and Schlenker 2018; Haqiqi et al. 2019). The daily information on the soil moisture content is obtained from grid-based Water Balance Model (WBM) (Grognan 2016; Wisser et al. 2010). This framework suggest a spatial autoregressive error model assuming the error term is spatially correlated. We will estimate it at 5 arc min spatial resolution for continental US for the latest Census of Agriculture.

The decision to irrigate (to invest for irrigation) or to expand irrigation (e.g. more drilling) or to choose the irrigation technology (flood, sprinklers, drip, etc.) requires long-run information. The investment decision may consider the average benefits and costs as well as uncertainty in benefits and costs due to climate variations as discussed in Investment under Uncertainty and Modern Portfolio Theory (Carey and Zilberman 2002; Zilberman et al. 2014). Locations with a history of sufficient soil moisture are less likely to have irrigation equipment. Farmers are expected to invest for irrigation (or increase the irrigation extent) if the expected cost of irrigation does not exceed the associated benefit which flows largely from the yield gap, i.e. the difference between irrigated yield and non-irrigated yield. This yield gap can be determined using growing degree days and precipitation information (Schlenker and Roberts, 2009). These benefits determine the farmers’ willingness to invest for irrigation. However, as this decision is an investment decision in nature, it is required to consider and examine the role of uncertainty. Finally, if water is more easily available (surface or underground) the probability of irrigation is higher (conditional to be located in the same climate region).
References


