NBER Proposal
Economics of Research and Innovation in Agriculture

Project Title: Water Prices, Water Markets, and Incentives to Adopt Agricultural Technology

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With climate change, many of the world's most productive agricultural regions will experience increased water scarcity. Global climate models predict drier futures in many Mediterranean climate regions and an increase in extreme drought events in California (Polade et al. 2017; Swain et al. 2018). Historically, in many regions, the agricultural costs of drought have been mitigated through increased reliance on groundwater. However, as agricultural regions worldwide have increased their reliance on groundwater for irrigation, groundwater levels have declined (Famiglietti, 2014). Increases in water scarcity and water variability coincide with the need to feed a rapidly growing population.

A critical element in meeting the food needs of the future in a more water-constrained world is agricultural innovation and investment in water-saving technology and drought-tolerant crops. Understanding the factors that influence and spur the development and adoption of new agricultural technologies is the broad focus of this proposal. We will investigate this topic through the lens of irrigation. Specifically, we will evaluate how changes in water prices and the establishment of water markets impact water use, crop choice, and irrigation technology. Results from this research will speak to the importance of water prices and water markets in inducing the adoption of irrigation-efficient technologies, and directly inform discussions on sustainable agriculture in a changing climate.

The first portion of this project will develop a theoretical model of farm-level decision making to illustrate the channels through which water markets affect investment in irrigation technology. While previous literature makes clear that higher water prices increase drip and sprinkler irrigation adoption (Caswell and Zilberman, 1985), we will focus on the how the presence of a water market affects investment incentives of farmers. Building off the work by Carey and Zilberman (2002) and Dinar and Letey (1991), we will show how different features of a water market affect investment incentives.

In the absence of trade, more efficient irrigation technology is one of the only channels to increase the water supply. This is because new water-saving technology leads to less evaporation and water loss in the system, and a subsequent increase in the quantity of water reaching the crops. Trading provides another avenue through which to increase water supplies and incentivize investment in water-saving technology. In the presence of a water (permit) market, water-saving technology may increase permit supply or decrease permit demand. Using a theoretical model of water use and trading, we will define optimal investment without trade and see how optimal investment changes with the introduction of a trading regime. The theoretical model will provide insights regarding investment incentives and crop choice.

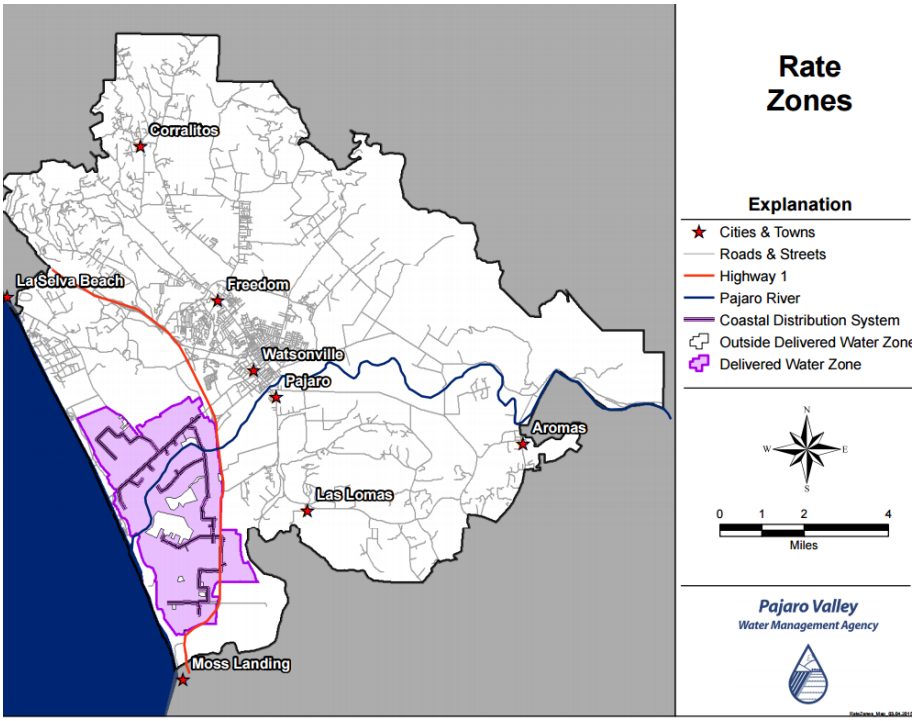
In the second (and main) part of this project, we take advantage of unique and recently acquired micro-level agricultural water use and crop data to empirically corroborate the relationship

between water prices and technology choice. To do this, we will begin by exploring the empirical linkages among groundwater extraction, water prices, and land use. We will utilize monthly well-level groundwater extraction data in an area that charges volumetric rates for agricultural water use to estimate the effect of water prices on farmers' irrigation water pumping and crop choices. The nature of the data allows us to control for confounding factors such as crop prices, surface water availability, region-month shocks, and fixed well-level unobservable characteristics that may be systematically correlated with water prices and affect water use and crop choice. With an estimate of how decisions are affected by water prices, we can then evaluate the economic impacts of changes in water prices on the incentives to adopt more efficient technologies. This portion of the project brings empirical rigor to the existing literature on technology adoption for agriculture.

The primary challenge to estimating the impact of water prices on technology choice is the absence of micro-level evidence on the marginal value agricultural users attach to water. A first obstacle is a paucity of data on agricultural water use at a temporal and cross-sectional scale necessary for credible estimation. Where these data do exist, a second obstacle arises due to the absence of prices for water. For these reasons, existing estimates on the marginal value of agricultural water rely on aggregate measures of water, one cross-section of well-level data, or proxies for water prices. This project overcomes both of these empirical hurdles by taking advantage of quarterly well-level data on irrigation water spanning several years in a jurisdiction that charges prices for agricultural water.

The data for this project come primarily from The Pajaro Valley Water Management Agency, a water district located on California's central coast. The Pajaro Valley is a small agricultural region that depends on groundwater exclusively for its agricultural water supply. Through a partnership with this agency, we have recently obtained a confidential, spatial dataset of groundwater extraction, groundwater prices, and irrigated acreage by crop at the farm-level. Agency staff inspect over 800 wells in the groundwater basin, collect quarterly meter readings, and charge volumetric fees that vary depending on the location within the service area. Coupled with irrigation technology data and additional hydrologic and geologic data for the basin, we will investigate the interaction between water prices and farm-level decision-making. This rich micro-level dataset provides a unique opportunity to evaluate farm-level decision making.

The Pajaro Valley Water Management Agency deploys a water pricing scheme that lends itself to a fuzzy regression discontinuity design with which to evaluate the impact of water prices on crop and technology choice. The water district is characterized by two distinct regions - metered users inside the Delivered Water Zone (coastal) and metered users outside the Delivered Water Zone (inland) - that face different water prices. As shown in Figure 1, the boundary separating the two regions is loosely defined by Highway 1, which runs down the middle of the basin. In each district, agricultural customers face a per acre-foot pumping fee, where the rate depends on the farm's location in the basin.



In a third portion of this project, we will use Pajaro Valley data to parameterize the theoretical model, estimate optimal farm-level investment, and simulate how optimal investment (with and without water trading) changes as the model parameters vary. Estimates of the impacts of changing water prices on agricultural technology choice will support sustainable agriculture in a changing climate.

To meet the food demands of a rapidly growing population in an increasingly water scarce world, global agriculture requires innovation. An essential first step in agricultural innovation is an understanding of what drives technology adoption. This project seeks to make empirical and theoretical headway into the factors that encourage technology adoption by dissecting how water prices and water markets impact incentives to invest in agricultural technology. In doing so, this research will help inform the design of incentives for irrigation efficiency in the coming decade.

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Conflict of Interest Statement

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest in the materials and content of this manuscript.