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Analysis

Long-term impacts of major water storage facilities on agriculture and the natural environment: Evidence from Idaho (U.S.)

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ABSTRACT

This paper investigates the long-term impacts of water storage infrastructure (dams) on agriculture and the natural environment in the semi-arid U.S. West. We conduct an empirical analysis of the agricultural impacts associated with major dams in Idaho, focusing on their crop mixes, crop productivities, and overall agricultural land values using an integrated county-level repeated cross section dataset. Our results suggest that the presence of a dam resulted in significant increases in total crop acreage, particularly in those counties in which farmers have predominantly junior water rights. Dams led to an increase in the acreage of the higher-valued, more water-intensive crops and positively impacted some crop productivities, particularly during periods of severe droughts. In contrast to the traditional literature, we find that the presence of a dam had a small, positive, but non-significant effect on farmland values. Finally, we evaluate long-term patterns in stream flow change and examine the impacts of dams on the natural environment. We find that the presence of dams enabled the spatiotemporal transfer of water resources from cold (non-agricultural) to warm (agriculturally-intensive) seasons, reduced the potential availability of water resources for ecosystem use, and increased the seasonal volatility in water supplies.

1. Introduction

Land in the western United States is North America's driest and has its most variable climate (Lettenmaier et al., 2008). Agriculture in this region is particularly vulnerable to variability in water supply, and relies heavily on irrigation (Olmstead and Rhode, 2008).[3] Recent literature on climate change has highlighted the impact that climate change may exert on irrigated agriculture across arid and semi-arid regions in the western U.S., as well as in Australia, the Middle East, and along the Mediterranean Coast, as temperatures and variations in precipitation are predicted to increase (Ragab and Prudhomme, 2002). Consequently, many studies address the impact of climate change on agriculture as well as potential agricultural adaptation responses (including, among others, Adams, 1989; Adams et al., 1990, 1995, 1999; Mendelsohn et al., 1994; Schlenker and Roberts, 2009; Schlenker et al., 2005, 2006, 2007). A number of other studies examine the specific concerns of irrigated agriculture in arid and semi-arid regions, including reduced and more variable water supply, impact of increased salinity due to lower flows, and many other water management issues (for example, Azad and Ancev, 2010; Fleischer et al., 2008; Gómez and Pérez-Blanco, 2012).

Concerns over the variability of water supplies are not new. As population increased and agricultural development expanded in the western U.S., major water infrastructure projects (large dams, reservoirs and canals) were initiated throughout the 20th century. These infrastructure projects helped reduce the variability associated with seasonal water supplies and enabled water managers to meet the historical demand for agricultural irrigation, and provided hydroelectric power, flood protection, and drinking water supplies. However, in addition to their enormous up-front construction costs, the major water storage facilities also brought about a number of environmental concerns, including the problems associated with low flow rates, increased salinity and impacts on native fish populations.

This paper addresses the long-term agro-ecological impacts of water storage infrastructure development in the western U.S. using Idaho as a case study. We examine the agricultural land use and crop productivity benefits of water storage infrastructure during 1920–2002, and address some of the potential ecosystem impacts, such as low levels of stream flow and water supply variability that may have been artificially exacerbated by the water supply infrastructure.

We construct and utilize an integrated, historical, county-level repeated cross section dataset of major water storage infrastructure projects in Idaho, which spans most of the twentieth century. We use this information to investigate the extent to which dams helped to stabilize agricultural production, especially during major droughts and under the

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[3] U.S. Department of Agriculture (USDA) reports that in 2007, of the ~23 million hectares of irrigated cropland and pastureland in the U.S., nearly three-quarters was in the 17 western-most contiguous states and according to USDA's Farm & Ranch Irrigation Survey (FRIS) irrigated agriculture applied 112.5 billion cubic meters of water, with over four-fifths being used in the arid and semi-arid West in 2008 (USDA-ERS, 2007).

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influence of different water rights priorities. Water rights data are consolidated at the county level in order to better address the priority and sources of water resources that are available to agricultural irrigators. By spatially linking the topographic characteristics, historical climate data, historical agricultural data and water rights data, and focusing on historical episodes of severe droughts, we are able to provide a historical case of adaptation, specifically focusing on the impact of water infrastructure. For the agricultural sector, we utilize a difference-in-difference estimation method and empirically analyze the impact of the presence of a dam on changes to crop mixes, productivity, total cropland acreage, and farmland values. In addition, we take advantage of long-term stream flow data and investigate the spatio-temporal transfers of water resources from cold (non-agricultural) to warm (agriculturally-intensive) seasons due to the presence of major water infrastructure.

Our results indicate that the construction of a dam resulted in positive and statistically significant impacts on crop water-use intensity, productivity, and total cropland acreage over time. We observe that both new and existing farms increased their share of higher valued and more water intensive crops when faced with increased water availability. We also observe that the presence of a dam had a generally large, positive productivity effect, and that this effect was particularly strong during those periods with severe droughts, for some, but not all crops in Idaho. In contrast to the traditional literature which posits that infrastructure improvements were important in increasing the value of farmland in the arid and semi-arid West, our results indicate that the presence of a dam has a positive, but non-significant effect on farmland values. In addition to these financial benefits, we find that the construction of major dams in Idaho spatiotemporally transferred water resources between cold and warm seasons, reduced the portion of water resources available to in-stream uses, and increased the seasonal variability in water supplies, thus negatively affecting the natural environment.

2. Impact of Dams on Irrigated Agriculture and the Natural Environment

Historically, major water infrastructure has played a critical role in influencing agricultural production and productivity in the western states. Without storage and distribution infrastructure, agriculture is limited by the capacity that nearby rivers and streams can carry, and by the often uncertain seasonal weather conditions. Prior to the development of dams, agriculture was generally found in those lands in close proximity to riparian areas, or along ditches that were constructed off of the major rivers. The long-distance delivery of water was difficult, and the construction of major water storage facilities was both costly and risky for private farmers. Because of this, land that was located farther away from the riparian areas, although often of a similar or higher quality as the riparian lands, was largely uncultivated (French, 1914; Hibbard, 1924). Limited irrigation resources not only inhibited agricultural production, but also reclamation and settlement on public land across the West. Federal legislation, including the Carey Act (1894) and Reclamation Act (1902), promoted major water storage and distribution infrastructure projects in the western states through federally funded projects that enabled the delivery of water to users at a great distance from the major watercourses.

The increased access to irrigation water, based on the establishment of new water rights, which varied greatly across states and regions in the western U.S., resulted in a number of different outcomes. Existing farms could, on average, receive more water per acre in the form of storage water, which would enable them to grow more water-intensive crops (crop shifts), to use more water for crops that were already in rotation (thus potentially increasing the yield per acre) and to expand their existing cropland acreage. Moreover, access to storage water may have generated distinct short- and long-run impacts as farmers adjusted their crop choices (Hornbeck and Keskin, 2011).

In the long run, farmers would be better able to respond to drought risks with increased access to irrigation water sources. Specifically, access to irrigation decreases the negative impact of the drought, particularly for the farmers that grow more water-intensive crops. This adjustment process may be gradual as the stored water can only be distributed slowly and based on available technology, but the overall value of access to surface water is capitalized quickly into the land values in anticipation of the increases in agricultural rent (Hornbeck and Keskin, 2011). The new farms that benefit from the additional surface water rights that are created as new dams are constructed, are established on lands otherwise not used for farming. This farmland expansion would certainly increase the total acreage in production, but could have an indeterminate effect on the productivity (yield per acre) of the crops that are grown and on the variety of crops that are grown. It is also important to note that the potential impacts of increased access to irrigation water could be strongly moderated by the distribution of the storage water rights. The additional water that is made available through the increased storage capacity will not be equally allocated to every water user, and thus, there will be potentially divergent responses in regions with differing water rights priorities and water supply conditions.

Increased water storage and distribution channels extend agricultural land use and cause many negative environmental impacts in these arid and semi-arid regions. Agricultural production is associated with soil erosion, chemical use and contamination, pollution of ground and surface water, loss of genetic diversity, and pesticide resistance (Soule et al., 1990). Agricultural practices impact a wide range of ecosystem services, including water quantity and quality (lower flow rates and lower water quality due to increased run off of nutrients, sediments and dissolved salts from agricultural lands), soil quality and even air pollution from pesticides, dust, and allergenic pollens (Dale and Polasky, 2007). The Millennium Ecosystem Assessment (2005) found that increases in agricultural production between 1960 and 2000 negatively affected ecosystem services, and led to major declines in wild fish stocks and decreases in the quantity and quality of fresh water.

Irrigation practices and large dams result in a number of additional ecological problems stemming from the diversion and depletion of streams and rivers. These hydrologic alterations may in turn affect fish and other wildlife habitats, and introduce saturation and salinity problems that reduce farmland quality and degrade water quality (Soule et al., 1990). In addition, the stabilization of natural flows can result in the elimination of native fish that need high levels of variation in natural flow rates and in the establishment of invasive fish species (Holling and Meffe, 1996). Thus, as river flows are increasingly regulated in order to support growing populations and their agricultural needs, these benefits "come at unforeseen and unevaluated cumulative ecological costs" (Trush et al., 2000).

In this study, our main objective is to empirically examine the long-run impacts of surface irrigation, focusing specifically on the financial impacts of the large dams on agricultural land use and crop productivity. Since our analysis covers most of the 20th century and it is impossible to quantify all of the negative ecological impacts of the major dams, we use an alternative strategy to better understand the negative impacts that result from reduced stream flows in Idaho. Instead of incorporating ecological costs into our empirical models, we survey these negative impacts and describe the extent of the specific problems that they introduce in Idaho and other arid and semi-arid regions.

3. Historical Background

3.1. Agriculture

Like many western states, access to irrigation water was vital to the success of agriculture, and thus human settlement, in Idaho. Idaho is distinct in that it presents a very broad area of agricultural land, with climatic, hydrologic, topographic and other agriculture-related characteristics that vary considerably from region to region (Brosnan, 1918). Agricultural operations in Idaho are extensively distributed along the Snake River Basin and its major tributaries, where conditions are more