Technological Change and Climatic Resiliency: Evidence from Irrigation in the United States

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Abstract

Does technological innovation reduce the effect of climatic shocks on economic activity? If so, through what channels? We explore these questions by examining the relationship between irrigation and drought in the historical development of agriculture in the western United States. A lack of adequate water for agricultural production is one of the defining characteristics of the American West, in particular during its irregular drought cycles. Early in the development of its agricultural economy, the western US saw two severe, prolonged droughts that led to significant political and social change. Drought from 1890-1896 led to a dramatic reversal of westward immigration trends and economic depression across the Great Plains. The drought was the primary impetus for the beginning of federal involvement in irrigation, leading directly to the Reclamation Act of 1902, although with limited impact initially. The Dust Bowl, a period of drought and wind erosion that occurred in portions of the Great Plains from 1930-1936 is perhaps the most important human-natural disaster in American history (Hansen and Libecap 2004; Hornbeck 2012). Compared to these early droughts, which transformed the social and economic lives of residents of western states and altered migration patterns, later droughts, similar in magnitude, appear to have been much less impactful. As Hansen and Libecap (2004) point out, droughts in the 1950s and 1970s did not result in the same levels of wind erosion, nor similar levels of economic or social upheaval.

One potential explanation is adaptation through technological innovation. Beginning with the completion of the Hoover Dam in 1936, federal reclamation projects began to deliver water across the west and increased irrigation rates in many areas (Edwards and Smith 2018). Starting in the 1940s, technological innovation allowed for widespread adoption of groundwater irrigation on the Great Plains (Hornbeck and Keskin 2014; Hornbeck and Keskin 2015) and across the west (Edwards and Smith 2018). This paper seeks to test whether agriculture has grown more resilient to drought, and what role irrigation played in this change. We examine the response of agricultural production to drought before and after the adoption of large government reclamation projects and widespread groundwater irrigation. Using US Agricultural Census data from 1910 onward digitized by Haines (2010), we construct long-term measures of crop yields, value, and failures. For land without access to large reclamation projects or groundwater irrigation, drought was and remains damaging to crop production, reducing crop yields 23-36%, depending on how drought is defined. The effect of drought on these unirrigated lands remains similar over time, even during the droughts of the 1950s and 1970s.

This result is not surprising. Extreme weather shocks like heatwaves and droughts have previously been linked to reduced economic output, especially in the context of developing economies (Dell et al. 2012; Dell et al. 2014). The effect of these types of shocks on US agricultural production has been more ambiguous (e.g. Deschenes and Greenstone 2007; Mendelsohn et al. 1994), but this is in part due to a lack of

consideration of the role of irrigation in the estimates of these effects (Schlenker et al 2005).

Turning to irrigated lands, we find that counties with access to large rivers that could contain reclamation projects, or overlying aquifers for groundwater irrigation, become more susceptible to drought over time, in the sense that the percentage loss in crop yields during drought years is in the neighborhood of 40%. These results suggest that rather than solving the drought problem, irrigation actually intensified it, at least in terms of crop production. Why then does the economic and social impact of drought appear lessened over time even as the impact on crop production is increasing? To answer this question, we develop a dataset stretching back to 1850 to examine the relationship between water access, agricultural activity and investment, and crop choice. We explore five possible explanations:

1. Increased agricultural production in non-drought years as a result of irrigated water applications increases overall wealth and spurs economic growth. Crop production and land value data are used to measure the extent to which production in non-drought years makes up for the large losses in drought years.
2. The labor force is leaving agriculture, so impacts in agricultural production are less important to drought-hit regions, economically and socially. Here we examine incomes from agricultural and non-agricultural workers to understand the extent to which non-agricultural sectors are insulated from the effects of drought.
3. Institutional innovations such as crop insurance make drought something that is easy to smooth using financial instruments, rather than water. We use data on crop insurance payments to farmers and the timing of implementation of federal insurance programs to understand how these financial instruments interact with drought and agricultural production decisions.
4. Water during drought is flowing away from agriculture to higher marginal value uses, leaving a larger impact on agriculture but a lower overall impact in terms of the county economy. Using measures of irrigated acres, we explore to what extent water moves out of agriculture during drought years, and the marginal effect this has on agricultural incomes, i.e. we expect the least productive land will be pulled from production first if the amount of irrigation water is reduced.
5. The users of irrigation water, whether held in dams or underground, see little incentive to conserve year-to-year due to common pool issues, and therefore fail to smooth water consumption in drought years. We examine failed crops and crop choices to understand the extent to which farmers plan for drought over time.

The historical experience of the United States offers key lessons for understanding our ongoing response to a climatic shock. Technological innovation changed the relationship between agriculture and the environment, but instead of utilizing the additional water to decrease productive variability, farmers increased production of water intensive crops, amplifying the effect of drought. Alternative financial instruments such as crop insurance and economic diversification served instead to maintain income. Thus, irrigation technology was not used as a buffer but rather as a means of increasing production, although due to common pool problems this increase may not have been fully efficient.

Sources

Dell, M., Jones, B.F. and Olken, B.A., 2012. Temperature shocks and economic growth: Evidence from the last half century. American Economic Journal: Macroeconomics, 4(3), pp.66-95.

Dell, M., Jones, B.F. and Olken, B.A., 2014. What do we learn from the weather? The new climate-economy literature. Journal of Economic Literature, 52(3), pp.740-98.

Deschenes, O. and Greenstone, M., 2007. The economic impacts of climate change: evidence from agricultural output and random fluctuations in weather. American Economic Review, 97(1), pp.354-385.

Haines, Michael R. “Historical, Demographic, Economic, and Social Data: The United States, 1790–2002.” Ann Arbor, MI: Inter-University Consortium for Political and Social Research, 2010. http://doi.org/10.3886/ICPSR02896.v3.

Hornbeck, R., 2012. The enduring impact of the American Dust Bowl: Short-and long-run adjustments to environmental catastrophe. American Economic Review, 102(4), pp.1477-1507.

Hornbeck, R. and Keskin, P., 2014. The historically evolving impact of the ogallala aquifer: Agricultural adaptation to groundwater and drought. American Economic Journal: Applied Economics, 6(1), pp.190-219.

Hornbeck, R. and Keskin, P., 2015. Does agriculture generate local economic spillovers? Short-run and long-run evidence from the Ogallala Aquifer. American Economic Journal: Economic Policy, 7(2), pp.192-213.

Hansen, Z.K. and Libecap, G.D., 2004. Small farms, externalities, and the Dust Bowl of the 1930s. Journal of Political Economy, 112(3), pp.665-694.

Mendelsohn, R., Nordhaus, W.D. and Shaw, D., 1994. The impact of global warming on agriculture: a Ricardian analysis. The American economic review, pp.753-771.

Schlenker, W., Hanemann, W.M. and Fisher, A.C., 2005. Will US agriculture really benefit from global warming? Accounting for irrigation in the hedonic approach. American Economic Review, 95(1), pp.395-406.