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Does crop insurance impact water use?

By Tatyana Deryugina, Don Fullerton, Megan Konar and Julian Reif

Crop insurance has become an important part of the national agricultural system in the United States. It was instituted to protect farmer incomes in times of volatile production, for example because of droughts or floods. Although crop insurance was not designed to impact water resources, it may have unintended consequences for water use, because agriculture and water resources are tightly linked. In particular, crop production relies on water as an input, and irrigation for crop production is the largest user of water resources. Thus, if crop insurance changes farmer behavior, it may affect water use as well. Crop insurance is expected to become more important to farmers in the future, as the frequency of production losses increase under a changing climate, such as from droughts, floods, or pest outbreaks. At the same time, a changing climate will affect the availability of water resources. For these reasons, it is important to understand the relationship between crop insurance, agriculture, and water use.

This policy brief provides an overview of recent research on the relationship between crop insurance, agriculture, and water use. First, we describe the setting in Illinois. Next, we explain why crop insurance may impact water use, and we discuss estimates of the effects of crop insurance on water use. Finally, we detail the reasons why crop insurance impacts water use. We conclude by discussing implications for policy.

Crop insurance, water use and agriculture in Illinois

Water use falls into two main categories. "Withdrawal uses" refer to water that is taken out of a lake or stream to be used but then may be returned to the same body of water to be available for other water uses. This category of use is distinct from "non-withdrawal uses" of water, such as boating on a reservoir or fishing in a river. This policy brief focuses only on withdrawal uses of water, primarily because the U.S. Geological Survey provides this water withdrawal information for each county and economic sector. In Illinois, water withdrawals for cooling power plants represent the majority of water withdrawals. Water for irrigation is another major withdrawal use of water. Irrigation water withdrawals are important to consider because they are a "consumptive use of water," which means that water withdrawn for irrigation is no longer available for use in the immediate area. The reason is that most irrigation water applied to farm fields evaporates and does not return to the water body from which it was withdrawn.

In most states, irrigation is the dominant withdrawal use of water. In Illinois, however, plentiful and regular supplies of rainfall mean that only a small fraction of water is withdrawn to irrigate crops. In 2010, 226 million gallons per day of water were withdrawn to irrigate crops in Illinois, accounting for approximately 2 percent of water withdrawals in the state (Maupin et al 2014). Rainfall patterns are projected to change in Illinois as the climate becomes more variable, so demand for irrigation will likely increase (Baylis et al 2015).

Illinois has more than 26 million acres under agricultural operation and ranks 7th in the nation in value of agricultural production (USDA, 2017). Illinois agricul-

About the Authors:

Tatyana Deryugina is an assistant professor in the Department of Finance at the University of Illinois at Urbana-Champaign and a visiting scholar at IGPA. Contact: deryugin@illinois.edu.

Don Fullerton is the Gutsgell Professor in the Department of Finance at the University of Illinois at Urbana-Champaign and a member of the IGPA faculty. Contact: dfullert@illinois.edu.

Megan Konar is an assistant professor in the Department of Civil and Environmental Engineering at the University of Illinois at Urbana-Champaign. Contact: mkonar@illinois.edu.

Julian Reif is an assistant professor in the Department of Finance at the University of Illinois at Urbana-Champaign. Contact: jreif@illinois.edu.

ture is part of the corn and soy belt of the United States, a vital rain-fed agricultural production region (Franzluebbers, 2011). Crop insurance has become an important part of the agricultural production system in Illinois. In 2016, 10.1 million acres of corn were insured in Illinois, corresponding to 87 percent of planted acreage (Schnitkey, 2016).

Impact of crop insurance on water use

Why might crop insurance impact water use? First, crop insurance may change farmers' irrigation decisions. In a dry year, for example, crop insurance may make farmers less likely to water their crops, because watering is costly and they understand they will receive insurance payouts ("indemnities") in the event of crop failure. This behavior is commonly called "moral hazard." Insurance companies know that crop insurance may cause farmers to water less than is optimal, so their policies typically require that farmers demonstrate they have irrigated a "normal" quantity of water before receiving insurance payouts in the event of a drought. This policy clause, in turn, may in some cases lead farmers to use more water on their crops than they otherwise would.

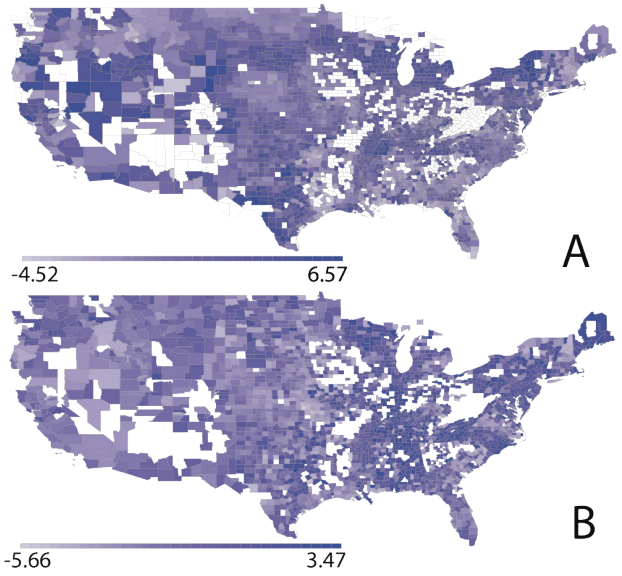
The second channel through which crop insurance may affect water use is crop choice. Since crop insurance reduces the cost of failure, it can lead farmers to plant crops that have highly variable payouts: if the crop yield is high, then the farmer reaps the benefit, but if the yield is low then the farmer does not bear all of the costs. If these types of crops are more water-intensive than the original crop mix, then water use will increase. Finally, another complication is that changed water use by one farmer in response to crop insurance may have no effect on total water use in an area if water rights are scarce. In such cases, a decrease in use by one farmer may simply allow another farmer to increase her use. Thus, the impact of crop insurance on water use is an empirical question.

Point One: Evidence that crop insurance leads to more water use in agriculture

Here, we investigate the impact of crop insurance on water use. Figure 1 presents maps of crop insurance coverage and irrigation in the United States.[1] The change in crop insurance from 1985 to 2001 is shown in map A. The change in irrigation withdrawals from 1985 to 2001 is shown in map B. Figure 1 shows no clear visual trends. To gain a better understanding of the relationship between crop insurance and water use in agriculture, we turn to a formal statistical analysis.

First, we report an ordinary least squares (OLS) regression analysis across U.S. counties, using the change between 1985 and 2001 for each county.[2] This analysis reveals that a 1 percent increase in crop insurance is associated with a 0.05% increase in irrigation (column 1 of Table 1). However, this OLS analysis does not prove that the increase in crop insurance *causes* the increase in irrigation. Farmers choose for themselves whether to purchase crop insurance, and farmers who purchase insurance may differ from farmers who do not purchase insurance in ways that are related to their use of water resources. For example, farmers who are risk-averse may be both more likely to buy crop insurance *and* more likely to irrigate their crops. Additionally, it is possible that it is anticipation of scarce water resources that causes increased insurance demand among farmers and not the other way around. For these reasons, we will also employ more sophisticated econometric methods to establish whether additional crop insurance causes more water use.

Figure 1: Maps of the percentage change from 1985 to 2001 in acres insured (Panel A) and in water withdrawals for irrigation (Panel B)



Notes: In Figure 2, the percent change in insured acres from 1985 to 2001 ranges from -4.52% to +6.57% (Panel A). The percent change in water withdrawals for irrigation from 1985 to 2001 ranges from -5.66% to +3.47% (Panel B). White shading indicates that data are not available for that county.

Specifically, the analysis uses an instrumental variables (IV) regression to assess the impact of crop insurance on water use. This methodology takes advantage of a factor that affects the propensity to purchase crop insurance, but otherwise has no direct effect on water use. For this purpose, the 1994 Federal Crop Insurance Reform Act is used as the instrument. Insured acreage increased dramatically in response to this policy mandate. Thus, the 1994 policy impacted crop insurance (i.e. number of acres insured). Because it likely had no direct effect on water use, however, it meets the necessary conditions of the IV approach. The time series of insured acreage is provided in Figure 2, in which 1995 has been highlighted to indicate when the 1994 policy mandate took effect. A dramatic increase in insured acreage between 1994 and 1995 is clear in the figure.

[1] Deryugina, T. and M. Konar (2017). "Impacts of crop insurance on water withdrawals for irrigation" *Advances in Water Resources,* doi: 10.1016/j.advwatres.2017.03.013

[2] The *change* from 1985 to 2001 is reported for each of the 2,007 counties in the analysis. Excluded from the analysis were 1,000 counties without data on water use or on crop insurance, either in 1985 or in 2001.

Table 1: Percentage change in water withdrawals (first two columns) and percentage change in acres insured, for a 1 percent change in crop insurance.

	Change in log water withdrawals		Change in log acres insured
	OLS	IV	First stage
5-year change in log acres insured	0.051** (0.024)	0.223*** (0.069)	
Log acres insured in 1994			-0.145*** (0.012)
Observations First stage F-statistic	2007	2007 149	2007 149

[1] Robust standard errors in parentheses
[2] *** denotes significance at the 1% level. ** denotes significance at the 5% level
[3] Dependent variable indicated at the top of the columns
[4] All regressions include each of the year-to-year changes in insured acres (in logs) over 1989-1994 as controls.

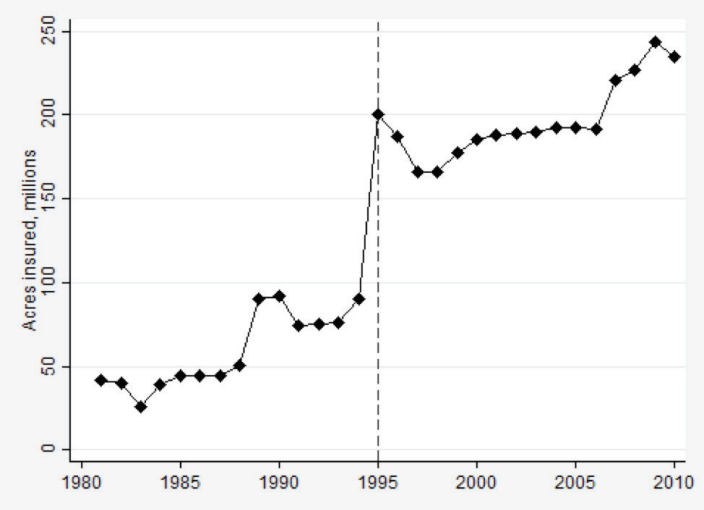
To exploit this policy change in our analysis, the "first stage" of the IV method uses the fact that counties that already had high insurance coverage were less affected than counties where coverage was low. Intuitively, coverage rates (i.e., the percent of farm acres that are insured) cannot exceed 100 percent, and counties that are closer to having 100 percent uptake have less scope to increase their insurance coverage. For example, a county where only a third of the acres are insured is impacted by the insurance mandate much more than a county where three quarters of the acres are insured. Thus, insurance coverage in 1994 can be used to help predict future changes in coverage, since higher 1994 insurance coverage implies smaller increases in coverage between 1990 and 1995. Specifically, this first stage predicts the change of insurance take-up that is driven by the 1994 policy change. Results are provided in column 3 of Table 1. As we would expect, the negative estimate (–0.15) means that counties that already had high insurance penetration rates in 1994 saw smaller increases in insurance uptake between 1990 and 1995. Specifically, for every additional percentage point of insurance coverage that a county had in 1994, it experienced 0.15 percent less insurance increase in 1995.

Next, we report the second stage of the IV estimates, namely, the effect of this change in crop insurance on the resulting change in water use. The coefficient in column 2 of Table 1 is positive (0.22) and statistically significant. These results indicate that a 1 percent increase in insured acreage causes a 0.22 percent increase in water withdrawals for irrigation. It is also about four times larger than the corresponding OLS estimate, suggesting that the OLS estimate was subject to considerable bias.

Point Two: Crop insurance has more effect on groundwater than on surface water

Next, we estimate how much of the total effect of crop insurance on water withdrawals is from surface water or groundwater. Understanding this breakdown is important for public policy. Surface water is subject to water laws; the 'riparian doctrine' is followed in the eastern portion of the United States, while the 'prior appropriation doctrine' is observed in the western part of the country.[3] In contrast, groundwater resources are typically not subject to any water law or policy, and are often overused. Also, surface water bodies are also more variable than groundwater resources, since they change with weather. Access to groundwater resources typically requires private investment by a farmer to drill a well, which often requires substantial upfront cost. By contrast, surface water infrastructure like dams and aqueducts are often built by government agencies, making surface water extremely cheap for farmers.

Figure 2: U.S. insured crop acreage from 1980 to 2010 (the 1994 Federal Crop Insurance Reform Act took effect in 1995)



The IV analysis shows that a 1 percent increase in insured acres leads to a 0.15 percent increase in surface water use (Table 2). However, the same 1 percent increase in insured acres leads to a 0.28 percent increase in groundwater use. Thus, our results suggest that the crop insurance mandate leads to the depletion of national groundwater resources, which are likely to be of increased importance under a changing climate, when surface water supplies become more variable.

Table 2: Percentage change in water withdrawals by source, for a one percent change in crop insurance

	Total	Surface	Groundwater
Log acres insured	0.223*** (0.069)	0.148* (0.081)	0.275*** (0.076)
Growth Controls	Y	Y	Y
F-Stat Observations	148.71 2,007	146.81 1,649	136.01 1,580

1 Robust standard errors in parentheses
2 *** denotes significance at the 1% level. * denotes significance at the 10% level.
3 Dependent variable is 5-year change in log water withdrawal by type. Water type indicated at the top of the columns.
4 Growth controls include each fo the year-to-year change in insured acres (in logs) over 1989-1994 as controls.

[3] The riparian doctrine is a system of water law in which the owner of land bordering a water body is able to use that water. The prior appropriate doctrine provides the legal right to use water based on who was first to put that water to 'beneficial use'.

Point Three: Crop insurance leads farmers to switch crops

Crop insurance may also lead farmers to change their crop mix. For example, it may cause them to switch to more water-intensive crops. Table 3 presents results for the change in the harvested area by crop. The harvested areas of corn and soy fall when farmers increase their use of insurance, while results for rice are not statistically significant. The harvested area of cotton and wheat increased: a 1percent increase in crop insurance leads to a 0.10 percent increase in wheat acreage, corresponding to almost 58,000 acres, and to a 0.62 percent increase in cotton acreage, or almost 96,000 acres. So, crop insurance leads to a greater impact—in both relative and absolute terms—on cotton acreage than it does on wheat acreage. Additionally, cotton is a water-intensive crop, while wheat is typically rain-fed. For this reason, the increases in cotton acreage likely contribute to increased irrigation.

Table 3: Percentage change in harvested area by crop, for a 1 percent change in crop insurance

	Corn	Cotton	Rice	Soy	Wheat
Long Acres Insured	-0.162*** (0.030)	0.624*** (0.185)	-0.061 (0.096)	-0.301*** (0.043)	0.100** (0.045)
Growth Controls	Y	Y	Y	Y	Y
Observations	1,705	452	106	1,368	1,629
F-Stat	420.72	66.02	7.12	337.83	201.47

[1] Robust standard errors in parentheses.
[2] *** denotes significance at the 1 percent level. ** denotes significance at the 5 percent level.
[3] Dependent variable is 5-year chane in acres harvested of different crops, as indicated at the top of the columns.
[4] Growth controls includes each of the year-to-year changes in insured acres (in logs) over 198901994 as controls.

Point Four: Farmers use more water per unit area

Crop insurance may also lead farmers to apply more water per acre of land, reducing their efficiency of water use. Farmers may use water less efficiently if insurance reduces their total farm expenditures, inducing them to spend more on irrigation (or on electricity for groundwater pumping). Moreover, the 'normal' irrigation clause that is present in many crop insurance contracts requires farmers to perform a minimal amount of watering in order to be eligible for insurance payments. If farmers are unsure whether they are in compliance with this clause, then they may make a conservative decision to water their crops—even after the crop has failed—in order to guarantee the receipt of their insurance payment. Our results reveal that farmers apply more irrigation water per unit of irrigated area following the policy change. Unfortunately, the data in this analysis are not sufficient to understand *why* farmers apply more water per acre of land. They could be either responding to the costs of farming or to the crop insurance policy requirements, or both.

Summary

Crop insurance leads to more water use for irrigation in agriculture. Specifically, each 1 percent increase in insured crop acreage causes a 0.22 percent increase in irrigation withdrawals. The impact is more pronounced for groundwater withdrawals: a 1 percent increase in insured acreage leads to a 0.28 percent increase in groundwater withdrawals. Thus, an unintended consequence of the 1994 Federal Crop Insurance Reform Program could be the further depletion of national groundwater resources. Under a changing climate, surface water supplies are likely to become more variable. For this reason, groundwater resources are likely to be of increased importance in the future for stabilizing our food supply.

Crop switching is one important reason that crop insurance increases irrigation withdrawals. For example, insurance uptake leads farmers to grow more cotton, which is a water-intensive crop. Specifically, a 1 percent increase in insured acreage leads to a 0.62 percent increase in cotton acreage, or almost 96,000 acres. Crop insurance also increases the volume of irrigation water applied per acre of land. This study highlights the importance of existing national data collection efforts related to water resources and crop insurance. Going forward, the scientific and policy communities would benefit from enhancements to the quality, quantity, and detail of national water use information.

Crop insurance is an important component of the agricultural production system in Illinois. As the climate becomes increasingly variable in Illinois (Baylis et al 2015), it will be important to identify opportunities to maintain farmer incomes while also conserving water resources. Since crop insurance has been shown to lead to more water use nationwide, policy makers may want to explore options for insurance policy design that could help mitigate water use. Currently, Illinois does not heavily rely on irrigation supplies for agriculture, but may do so as precipitation patterns shift in the future. Now is a good time to start the conversation on potential interactions of crop insurance, agriculture, and water use in Illinois.

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