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Ensuring Our Future or Sowing the Seeds of Our Own Destruction? Crop Insurance and Water Use in Texas

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Introduction

Many policy analyses or news stories often deal with the unintended consequences of policies that are well intentioned, but do not consider the full range of possible outcomes and effects. This is one of those stories. Crop insurance has become an important part of farm policy in the United States over the last two decades. This paper is concerned specifically with the unforeseen effects that crop insurance provided to farmers may have on other decisions they may make. Specifically, I am concerned with the impact that the insurance program has on water use. The effect that a taxpayer funded policy has on the sustainable use of a vital resource should be of concern to all.

One of the most fundamental questions any society has to determine is how to feed its population. This has been particularly important since the global baby boom around the middle of the last century. Food production has changed rapidly over the past century in the United States, as it has become more industrialized, allowing greater yields to feed a growing population (Vandermeer 2011). Various congresses have passed and various presidents have enacted many policies and tools that to maintain an adequate food supply while also dealing with some of the variability that is inherent in agriculture. Because agriculture accounts for about 45% of the total land area in the United States (World Bank 2014), actions that are taken by farmers have important consequences for our environment as a whole. Furthermore, as producers of the food we eat and the fibers we wear, and as users of the land we love and the water we need, agriculture has vitally important and complex interactions with the environment that are important to understand.

Sustainable production of our food and cotton, as well as the policies that govern this level of production should be of great concern for all. Crop insurance is one of these key tools that we use in the United States to help support farmers, and one that has increased dramatically in recent decades as a program thanks to generous subsidies (Environmental Working Group 2012). Any effect that it has on water use, positive or negative, has important implications for sustainability, not only of the freshwater resource, but also of the ability to grow food and fiber.

Freshwater is one of the most fundamental resources on our planet. It is sometimes tempting to think of water as a renewable resource because of its well-known cycle through the environment. Simplified diagrams show water evaporating from the ocean, precipitating on land, and then flowing back to the ocean to complete the cycle. Even more complex diagrams ultimately show a closed loop. However, it is also well understood that only a small fraction of this water is usable as a potable source. Freshwater accounts for less than 3% of all water on the planet (NOAA 2014). When we disregard the water that is contained in polar ice caps (because it is unlikely that we will use that water for drinking or farming, despite some farfetched plans to transport icebergs (Madrigal 2011)), only 30% of that 3%, or about 0.9%, is available in the form of groundwater or surface water (NOAA 2014). Often these sources, especially groundwater, are not replenished as fast as they are being diminished through water withdrawals. Estimates are that over three quarters of the world's groundwater supplies are nonrenewable (Jackson et al. 2003). In this context, nonrenewable means that the time it would take to replenish if we stopped extracting water would be over one century.

This problem of freshwater scarcity is made more complex because the fundamental importance of water makes it so often seen as a right. Farmers in the Central Valley of California were recently upset by a law that set up groundwater pumping restrictions, with representatives claiming that it removed the rights to the water that once belonged solely to the farmer (Nielson 2014). Farmers are reluctant to have restrictions placed on them or pay fees for the use of what they see as their water, making it harder for a market to do what it does best, and efficiently allocate this scarce resource. How we use this resource now will affect how much will be available in the future.

Agriculture currently accounts for more than 80 percent of all water consumed in the United States and 31 percent of all water withdrawals (water used for cooling in thermoelectric power plants primarily account for this difference) (Schaible and Aillery 2012). As the largest consumer of water, any policy that may impact water use in this sector has the potential to have a large overall impact water use overall. Almost half of all crop revenue in the United States is generated from the roughly 16 percent of cropland that is irrigated (Aillery 2004). Water is a common access resource, meaning that the use of it by one farmer affects the ability for other farmers to use it now and in the future. From an agronomic perspective, we would like to get the most value per unit of water that is used, while conserving for future use. Unfortunately, if a farmer makes more money because of higher overall production by growing a crop that uses more water per dollar value, then he or she will not be incentivized to switch production, all else equal. In California in 2005, for example, revenues from rice were valued at $31 per acre-foot of water

used, whereas other field crops generated $375 per acre-foot of water (Hanak 2011). Farmers are not seeking to maximize profit per unit of water, only profit. By not paying for the full true cost of water (which includes the potential future use) farmers are imposing a negative externality on future and concurrent users of that water, who might have other more efficient uses of the water. This example demonstrates the effect that policy, or lack thereof, can have on water use. The effect that crop insurance has on the use of water is likely to be more subtle, though as we will see, may have some influence on cropping decisions (i.e. how much and what to grow).

Crop insurance is inherently linked to water in that many of the risks that it insures against are water related, either through drought or flood. Crop insurance has been provided in the United States since the New Deal. It was first promoted as an experiment to help farmers after the Dust Bowl and the Great Depression for major crops in major producing areas (RMA 2014a). However, it was not until the Crop Insurance Reform Act of 1994 that a large number of farmers started to enroll as a result of generous subsidies and an expansion of the area and crops covered. Before this law was passed, many farmers were supported by ad hoc disaster relief (Williams et al. 1993), which shifted the cost of insurance onto everyone else, and created uncertainty as to when aid would be given. According to a 2013 congressional report, even up until 2008, disaster payments were still somewhat routine, so that Congress tried to further expand access to insurance programs to uncovered farmers in the 2008 Farm Bill (Shields 2013). Since then, insurance levels have increased, and disaster payments have decreased. In 2012, around 86% of

insurable cropland was insured, equivalent to 282 million acres (O'Donoghue 2013). That is an increase from just 82 million acres 20 years earlier. The study of any unintended consequences, big or small, of such a large and fast growing program, is an important task.

Just as other insurance markets face the issue of moral hazard, the concern of this paper is whether there is evidence of moral hazard in the crop insurance market, specifically in terms of water use. Moral hazard occurs when an insured party engages in riskier behavior that he or she would not have engaged before he or she was insured. This may be especially pronounced because insurance is subsidized. Moral hazard in crop insurance, if it exists, has potential environmental impacts through chemical use, resource use, or land use. Some work has already been done to look for the effect of insurance on farmers' decisions about levels chemical inputs.

The oft-cited paper in this area by Horowitz and Lichtenberg (1993) finds that chemical input use of all kinds, pesticides and fertilizers, increases with levels of insurance. This, of course, is undesirable from an environmental perspective because of the impacts that these chemicals often have downstream. They contend that chemical inputs increase yield while also increasing the variability of yields. This is the context in which moral hazard occurs: the reduction of risk because of the insurance incentivizes farmers to engage in an activity that involves more risk, but also has the potential for greater benefits.

The impact that crop insurance has on input use, however, is not a settled debate. Smith and Goodwin (1996) counter the theory and empirics behind the

argument laid out by Horowitz and Lichtenberg. To Smith and Goodwin, the likelihood of increasing inputs after being insured is counterintuitive because fertilizers and pesticides would decrease the probability that yields would fall below the threshold that would result in indemnities. Using empirical evidence from Kansas, they show that chemical inputs on winter wheat crops decreased with insurance. This is still an example of moral hazard because behavior changes in response to the participation in the insurance program, but it is in a direction that is far more agreeable to environmentalists because a decrease in fertilizer and pesticide use leads to less nutrient loading and water pollution (Tilman et al. 2002). Using a slightly different model and a different set of data, Zhong, Ning, and Xing (2006) find a similar relationship. They assume that input use affects the decision to enroll in crop insurance (note that their data comes from China, which has different policies about crop insurance, though are still suggestive of possible effects in the US). Use of pesticides decreased the likelihood that a farmer enrolled in crop insurance, while use of fertilizers increase this likelihood. Different inputs interacted with the insurance program in different ways. This is an example of moral hazard decisions due to crop insurance with a different decision timeframe.

Wu (1999) takes a different approach to this moral hazard question by looking at land use changes before and after enrollment in crop insurance programs. He finds that insurance tends to encourage farmers to change their planting patterns in a way that shifts away from less intensive pastoral land to more intensive cropland, with clear environmental implications. Intensive agriculture increases the nutrient and toxin levels in surrounding bodies of water due to

increased fertilizer and pesticide use, increased water use, and soil degradation (Tilman et al. 2002). Very few studies have looked specifically into the effect that crop insurance may have on the use of water resources, despite the vital importance of this resource (O'Connor 2013; Hook et al. 1999; Dalton et al. 2004).

A hypothetical farmer who uses crop insurance may will feel that he or she is faced with less risk overall, and therefore may be willing to engage in more risk at the margin. This means that they may be willing to use less of the inputs, including water, that they may otherwise use in order to reduce their risk (Smith and Goodwin 2006; Zhong, Ning, and Xing 2006). As water becomes scarcer in some regions due to climate change, any policy that inadvertently changes the way that farmers use water—positively or negatively—will be of great importance for our future ability to use stores of water.

To measure the effect of the United States crop insurance program on water use, this paper will use county-level data from Texas. The reason for this focus is threefold. First is a matter of convenience: the Texas Water Development Board provides county level data on irrigation water use by crop for the period of time between 1985 through 2012. This is especially helpful because it spans the period in which insurance rates rose dramatically. Texas is additionally a good source of data in that it is comprised of 254 counties, so data is relatively granulated as compared to other states like California with only 58 counties. Finally, Texas is an important agricultural state, accounting for about 7% of total land area and water use of the United States, and producing over $20 billion in agricultural products in 2011 (Gleaton and Robinson 2013). Water is also not a trivial issue in Texas, which has

faced several droughts during the roughly three recent decades that are analyzed in this study. This concern is particularly relevant in the future era of possibly increasing drought frequency and intensity due to climate change.

Before looking into the data, it is important to a have background on crop insurance policies and their history as well as the structure of the crop insurance and agricultural industry. I will then review in greater depth the relevant literature on the subject of moral hazard as it relates to crop insurance. Following this will be an overview of the data, model specifications, and empirical results, followed by a conclusion.

Background

Crop insurance is a financial tool that is very similar to other forms of insurance. People who are risk averse (which describes most people; all people if one assumes diminishing marginal utility of income) are willing to engage in an actuarially unfair insurance agreement. That is, a risk averse individual is willing to pay a premium to avoid risk and increase certainty. Insurance companies, as risk neutral entities, are usually willing to provide this service. There are two complicating factors: adverse selection and moral hazard. Adverse selection occurs when the individual knows more than the insurance agency. This can cause problems because the insurance company may be providing coverage that is riskier than it is prepared cover. To deal with this problem, insurance agents try to get as much information as they can on the person or entity to be insured. Another way of managing this unknown risk is to cover a wide variety of individuals with uncorrelated risks. By doing this, the insurer can slightly diminish the problem of

adverse selection. This helps to explain some of the difficulty in establishing a private crop insurance market without government help.

Moral hazard is one of the other major concerns when it comes to almost any insurance market. Moral hazard occurs when the insured party engages in riskier behavior because he or she is insured. This is the issue of concern in this paper, especially as it relates to agriculture, not only because of the increase in risk to the farmer and the insurer, but also because of the potential environmental externalities that relate to farmers' decisions.

Because the problems that are present in other insurance markets are perhaps more pronounced in the crop insurance market—most notably the high correlation of catastrophic risk across areas due to natural disasters—a private market was very hard to establish. If a wide scale drought affected many farmers in a given year, an insurance company would have to make many payouts at one time, potentially ruining the company financially. In 1938, in response to the Dust Bowl and Depression effects on agriculture, the United States Congress passed the Agricultural Adjustment Act, establishing the Federal Crop Insurance Corporation (FCIC) (National Crop Insurance Services 2014; RMA 2014a). During the early years of the program, the FCIC offered pilot plans that remained very limited in scope. It was not until the passage of the Federal Crop Insurance Act of 1980 that crop insurance spread in a significant way. That law was designed to encourage more farmers to enroll in crop insurance by removing the assistance that had been provided in cases of natural disaster. If farmers knew they were essentially insured for risk of natural disaster by the disaster payments from the federal government,

there was far less of an incentive for them to enroll in additional crop insurance programs (Shields 2013).

In addition to removing the funding for disaster coverage from the farm bills (though Congress continued to pass ad hoc disaster relief), the Federal Crop Insurance Act of 1980 offered 30 percent premium subsidy for coverage up to 65 percent (National Crop Insurance Services 2014). The crop insurance system was revised once again in 1994 to increase subsidies with the idea of increasing insurance participation to a level at which disaster relief would not need to be provided. The issue that many policymakers were concerned with regarding disaster relief administered at the federal level was that all taxpayers felt the burden. By increasing enrollment in crop insurance programs, more of that burden was also shouldered by the farmers themselves. This was also politically popular in that it provided a service to farmers at a discounted rate. The other significant change in crop insurance policy that brought about this rapid expansion came in 2000, when the Agricultural Risk Protection Act again significantly increased the subsidies of insurance premiums. It is important to note the dramatic rise in coverage in a relatively short period of time, as well as the related government policies that promoted this change. Such rapid growth of such a large program in a vital industry warrants interest in possible side effects. Before we look into some of these possible side effects, positive or negative, especially as it relates to agricultural water use, we must first understand the actual structure of some of the insurance policies.

Multiple peril crop insurance is the most common type of policy, which insures for all types of natural disasters: from frost and hail to disease and drought. Farmers are able to choose what level of insurance he or she wants between 50 and 85 percent yield loss (RMA 2014b). Losses are calculated based on average historical yields. The more he or she insures, the more it will cost. The fact that the farmer is not allowed to insure 100 percent of his or her crops makes sure that the farmer is still bearing some of the risk, and protects insurers against slight variations in yields. The farmer can also choose the predicted price at which to insure his or her crops. If he or she insures at a 100 percent of the predicted price, the cost will be greater than being insured at a smaller percentage of the predicted price. The clearest way to understand how these policies work is through an example. If your farm had a production history of 150 bushels per acre, and you chose a coverage level of 70 percent, then if your yields fell below 105 bushels per acre (150*0.70), then you would be paid the difference, times whatever price you had agreed to. If yield fell to 90 bushels per acre, and you agreed to a price of $2 per bushel, then you would be paid (105-90)*2 = $30 per acre (adapted from Edwards 2013).

Farmers can also enroll in catastrophic coverage at 50 percent yields and 55 percent of the predicted price for a small administrative fee ($100) with the premium paid for by the federal government (RMA 2014b). Mechanistically, private companies that are approved by the Risk Management Agency's (a branch of the USDA) Federal Crop Insurance Corporation provide insurance (the federal government technically acts as a reinsurance agent, backing up these private

insurers). These companies then base premiums on the Actual Production History (APH) or the Actual Revenue History (ARH), determined from between four and ten years of historical data, adjusted for trends and dropping bad years. It should also be noted that for farmers who are transitioning from growing one crop to growing another, or that have less than four years of production history, the RMA uses what are called transitional yields, which are equal to the average historical yield of the county in which the farm resides. Production history is then calculated based on 75% of the transition yield for years in which no actual production history exists (RMA 2014b).

The other major crop insurance program is the Group Risk Plan (GRP), which uses county level data to insure widespread losses due to natural disasters. A farmer can choose the level at which an indemnity (payout) is paid should area yields, as opposed to personal yields, fall below that level. There are many other types of plans, and individual plans vary based on the farmer's choice and what crop they are growing (over 100 are coverable). Many of the small details of the plans are designed to try to get as much information as possible so that insurers can do their best to avoid adverse selection, as noted above.

The issue of moral hazard is harder to grapple with. Moral hazard deals with how behavior changes after insurance is provided, so it is much harder from a technical perspective to monitor and enforce possible limits on this behavior, as well as to know exactly how behavior may change. There are rules that prevent the most blatant examples of moral hazard. For instance, there is a specific enrollment period that ends before crops are planted, after which farmers cannot buy

insurance. That way, if something happens in the middle of the growing season, they cannot quickly decide to enroll in the insurance program just to reap the payout without paying the full premium.

Other possible moral hazard effects, such as the possibility of increased water use that is analyzed in this paper, cannot be so easily controlled for. The use of irrigation water varies widely by state. In some states, such as Iowa, which is not very dry, most crops are rain fed, and therefore do not use much irrigation. Because water is less scarce, they can reasonably count on rainfall to feed their thirsty crops, and can benefit from insurance when those crops fail because of either too much or too little water. Texas, a state that relies mostly on groundwater for irrigation (about 75%), accounts for about 6% of total freshwater withdrawals in the US (Kenny et al. 2009). Given its size and relative importance in terms of agriculture, as well as its recent drought and reliance on irrigation, Texas provides a good test case to analyze factors that may affect the demand for water.

Because this paper's primary concern relates to water use in Texas, it is important to also understand rules governing water allocation in Texas. Texas has what is called "absolute ownership," in that property owners have the right to the groundwater beneath their property. They are permitted to pump the water and for "reasonable use," with very few limits provided that they do not intentionally try to harm their neighbors (Kaiser 2014). Because water is not priced in Texas, the only cost of water is the cost of transporting it from a source to the crops. For groundwater, this amounts to mostly pumping costs, amounting to roughly 20 to 45 dollars per 1000 acre-feet (Kanazawa 1992).

With such limited restrictions on how much water farmers may use, the question what policies may encourage or discourage sustainable use are more pressing. Only a few counties, such as those in the North Plains Groundwater Conservation District that overlies the Ogallala Aquifer and those that overlie the Edwards Aquifer, have any limit to groundwater pumping been instituted in the state of Texas.

Literature Review

Factors affecting water use.

Because groundwater is a valuable and limited resource, a lot of research has gone into trying to define what constitutes an efficient use of water for crops. Water productivity, usually defined as the yield per unit of water, is usually the way agronomists conceptualize water use efficiency (Cai and Rosegrant 2003). Because we generally assume a diminishing marginal product of water, much like other inputs, there comes a point at which the addition of another unit of water is wasteful compared to its potential for future use. If water were an infinitely available resource, we would not care much about the productivity of water, and farmers could continue to apply water until the marginal product of that water was equal to zero. This measure of efficiency also depends on the use of other inputs. If a farmer adds more nitrogen as fertilizer, then the addition of water might be more productive than if there were no applied fertilizer (Sadras et al., 2009).

Other important factors affect the productivity of water. An important underlying factor that affects water demand is the choice of crop that is planted, because some need more water than others (Martin et al. 1993). For example, rice

and cotton are far more water intensive than corn and wheat (Sadras et al., 2009). The key difference between crops is the variation in rates of evapotranspiration. Evapotranspiration combines the concepts of evaporation and transpiration (water that is released to the air directly from the plants). Because it is often hard to distinguish between the two when measuring the amount of water that is moved from the ground to the air, especially over the course of a lifetime of a crop, these concepts must be combined to help measure the overall water use of different crops.

Besides the crop that is planted, a number of other factors affect the amount of evapotranspiration. Of these are climate and irrigation type (Martin et al. 1993). There are known irrigation methods to limit the water delivered to given crop in order to get similar yields (Seo et al. 2008). More precise irrigation techniques are more focused getting water to the plant, deliver water in lower quantities at one time, and can even be used to deliver water only at precise times when water is most needed. In other words, precision irrigation tries to limit the evaporation component of evapotranspiration, while focusing on using water where it is most productive. While precise irrigation techniques use less water to get similar yields, they often have higher initial fixed costs.

Another potential strategy for reducing water demand is called deficit irrigation (Fereres and Soriano, 2006). Deficit irrigation is the use of water below what is fully required by the crop in order to get the most value per unit of water. It is argued (but certainly not settled) that there is some potential for crops to adapt to the water deficit, and thus would not harm yield or profits. Farmers may choose to

engage in this risky behavior if have a desire to use water more sustainably and they are insured for losses.

Finally, on a larger scale, much has been written on the socially efficient use of groundwater (Rauscher, 2007; Rubio and Casino, 2001; Saak and Peterson, 2007; Hellegers et al. 2001). All of these note the common resource nature of groundwater, and suggest the need for different management systems.

Effects of crop insurance.

The literature on the possible unforeseen consequences of crop insurance abound, though are largely inconclusive. The chief concerns of researchers and policymakers are related to adverse selection and moral hazard. Adverse selection is the result of an asymmetry of information that results in insured individuals being characteristically different from those who choose to be uninsured. In other words, because the insured individual knows more about the many unobservable factors about his or her farm than the insurer, he or she may have systematically different characteristics than those who are uninsured. Sherrick et al. (2004) found this to be the case in a large sample of Midwestern farmers. Insured farmers tended to be less wealthy, larger, and more highly leveraged than uninsured farmer. This corroborates the findings of other studies examining the possibility of adverse selection in the crop insurance market (Makki and Somwaru 2001; Luo, Skees, and Marchant 1994). Apparent differences in behavior between insured and uninsured farmers may be the result of either adverse selection or moral hazard, which are often difficult to distinguish.

The moral hazard effect of crop insurance has been studied for its possible implications on the amount of fertilizer and other chemical inputs have been used (Zhong, Ning, and Li, 2007). Pesticides and fertilizer have different effects on the amount of insurance demanded (they assume an alternate direction of causality, with input use affecting the decision to purchase insurance). They contend, but do not provide a specific mechanism to explain, that fertilizers are risk increasing (offering higher yields with greater variability) and pesticides are risk reducing. It is plausible, then that a similar effect could show up in water use. This is, however, less likely because of the lower relative cost of water compared to fertilizers.

Original moral hazard implications were thought to be through the intensive margin of agrochemical use, or how much chemical inputs are used. Horowitz and Lichtenberg (1993) found that insured farmers used more chemical inputs on their farms than uninsured farmers. This would have clear negative environmental effects through increased runoff pollution and all the associated damage therein (Tilman et al. 2002). However, Smith and Goodwin (1996), found evidence to the contrary using data from wheat production in Kansas. The authors argued that this finding was more in line with conventional wisdom that insurance would cause farmers to use fewer chemical inputs on the margin. The model that they use suggests that chemical inputs are, in part, a risk management tool, which can be traded for insurance. A similar argument could be made for water. It could be the case that the (over)use of irrigation water is in some instances a risk management technique, and that when provided the opportunity to avoid risk through insurance, less water is used.

Another possible moral hazard effect of crop insurance is through the extensive margin. That is, the behavior change that was witnessed as a result of insurance appeared through the vehicle of crop mix or how much land to plant. Claassen et al. (2011) show how crop insurance induced some farmers to convert pastureland to cropland. It is possible that a similar effect, crop insurance affecting what crops a farmer decides to plant, to occur, thus affecting overall water use. Furthermore, if crop insurance requires a history to become insured, then insurance may make it more difficult for farmers to switch crops. This may prevent a farmer from switching from a highly water intensive crop to a less water intensive crop, thus preventing a decline in overall water use. Wu (1999) found that in Nebraska, the availability of crop insurance, which was far more limited then in terms of crops that were covered, induced farmers to switch to increase corn production, resulting in greater agrochemical input use (because of the nature of corn production as compared to hay or pasture). This may be less of a concern now that insurance programs cover more crops.

Additionally, Chen (2005) found that acreage abandonment (measured by the percentage of acres harvested to acres planted) was greater among insured farmers in Texas (looking at three different counties). This change in land management suggests that less water would be used (but more wasted) than otherwise because there would be no effort to revive crops on abandoned land, resulting in less water requirements.

Small yield effects of crop insurance have been observed in limited areas (Roberts, O'Donoghue, and Key 2007). If a decision is made to plant less, or plant

less intensively, then that could affect water use. For example, in the Corn Belt, Lobell et al. (2014) found that the use of new genetically modified crops allows for greater planting density, but that this also increases water use and sensitivity to drought. Sowing crops closer together allows for greater yields on average, but densely planted crops suffer more when the air is drier than crops planted with lower density. This intuitively makes sense. If we think of each plant as a small pump that moves water from the ground to the air through transpiration, having more plants will lead to less water immediately available for other plants. When plants are not planted so densely, there is less transpiration, and the shade they create between plants limits evaporation, and therefore more water for each plant. In times when there is water stress, on warm dry days, farmers must replenish the densely planted crops with more than they would for the more sparsely planted crops. The higher yield with higher risk that is associated with this trend in cropping density is exactly the behavior that we would expect insured individuals to engage in more of due to moral hazard.

Finally, Walters et al. (2012) looked specifically for the four different environmental consequences due to changes in crop mixes because of crop insurance. They looked at four different environmental effects: wind and soil erosion and nitrogen loss and carbon loss, as well as acreage decisions, in four different regions: North Dakota, Iowa, Eastern Colorado, and Eastern Washington. The results they found were often limited, and were of different signs, suggesting weak and seemingly contradictory effects of crop insurance depending on region and environmental impacts. The benefit of this study is that they used farm level

data, and therefore were able to have more granularity enabling them to detect more nuanced changes that were not detectable at the county level. We should therefore be aware that the effect of crop insurance may depend on a lot of different factors that are undetectable at larger levels of aggregation. Additionally, because the effect of crop insurance varies, it is important to analyze different specific effects in different regions, depending on what is a particular concern in different regions, such as water use in Texas.

As described above, crop insurance can affect the use of water through a number of different mechanisms. If farmers use water as a risk abatement tool, then crop insurance may be seen as a substitute for water use, resulting in lower water use. Alternatively, crop insurance may affect what to plant, how intensely to plant, or rates of abandonment, which may either increase or decrease water use. Finally, farmers may choose to engage in a number of different water reducing methods such as deficit irrigation in order to conserve water while risking lower yields. These must all be kept in mind as possibilities when analyzing the data.

Theory To Equations

Because the literature suggests that the effect of crop insurance on water demand could reasonably be expected to be positive or negative, the only way to get at an answer is to look at the data. The first equation that will be run to look into the effect of insurance on irrigation water use is a simple regression of the irrigation water use on overall level of insurance, with controls. Mathematically the equation is as follows:

$$WaterUse_{c,i,t} = \beta_0 + \beta_1 Acres_{c,i,t} + \beta_2 CropIn_{c,i,t} + \beta_3 controls + \mu$$

Where *WaterUse* is measured in acre-feet by crop by county and by year. *Acres* is the number of acres planted of each crop by county and by year. It stands to reason that if more acres of a crop are planted, water use will likely increase. *CropIn* is measured by acres enrolled in crop insurance by crop by county and by year. One of the controls that must be accounted for is a dummy variable for those counties that have pumping restrictions such as those in the North Plains Groundwater Conservation District in Texas from the years 2005-2012. In 2005, the aforementioned district became the only groundwater conservation district in Texas to implement a limit on groundwater pumping to 24 inches per acre per year. This limit was increased in 2012, which is outside our data range, and therefore does not need to be adjusted for twice.

The other controls that we will use include rainfall and temperature. If it rains more in a given year, then we expect irrigated water use to be less because farmers do not need to add as much water to their crops in order to sate their thirst. Similarly, if it is warmer, we expect more water to be needed. According to Schlenker and Roberts (2009) there is a severe decrease in yields after temperature rises above 29, 30, and 32 degrees Celsius for Corn, Soybeans and Cotton respectively. It is likely that until this threshold temperature is reached, a farmer may decide to wait and see if temperature falls or rain comes rather than watering. Once the temperature reaches this threshold level, it is increasingly likely that a farmer will either start using more water or risk the crop's failure. Therefore, the more days in a year that cross this threshold temperature, and the higher above this threshold they are, the more water will likely be needed. To measure this, I use what

are called degree-days, which is equal to the sum of the difference between the temperature and our baseline temperature of 29 degrees Celsius across all days with a temperature above 29 degrees.

I also add a timetrend to control for any other variations in demand that may have occurred throughout Texas such as changes in irrigation technology, other climatic factors, or pumping costs, that are not included explicitly in the model, but trend with time. We also may want to include county level fixed effects to control for regional variation of these extraneous factors. One concern is that if we include both year and county fixed effects, we may have an over-determined equation, with both of those factors capturing all of other effects not included separately in our water demand equation. This will limit our overall understanding of the total effect of the crop insurance on its own. Finally, we have to include crop fixed effects because, as noted earlier, different crops may require different quantities of water. Thus our equation becomes:

$$\begin{aligned} WaterUse_{c,i,t} = {} & \beta_0 + \beta_1 Acres_{c,i,t} + \beta_2 CropIn_{c,i,t} + \beta_3 Limits \\ & + \beta_4 Rainfall_{i,t} + \beta_5 DegreeDays_{i,t} + \beta_6 Year_t + \beta_7 County_i \\ & + \beta_8 Crop_c + \beta_9 timetrend + \mu \end{aligned}$$

With all of these controls in our equation, we must be wary of over-controlling. If we include factors through which crop insurance affects water use, then we are limiting the overall effect of the crop insurance as estimated by our equation. For example, if crop insurance does influence crop mix, then controlling for the type of crop will reduce the value of our coefficient on *CropIn* to just the direct effect on water use, and not its overall effect both through the intensity

through which farmers use water as well as through the extensive margin of how much and what to grow.

Data

The data on levels of crop insurance comes from the Risk Management Agency. They provide county level data on "net reported acres" which is equal to total acres insured times the level insured (i.e. if 100 acres were insured at the 75 percent level, then "net reported acres" would be 75) for the years 1981-2014. It also provides data on category of insurance (whether it was catastrophic coverage or greater), what crop was covered, type of plan (whether yield protection or revenue protection), and many other variables. The most important for this study is the value of net reported acres for each crop for each county. Data on irrigation water use comes from the Texas Water Development Board for each county and crop between the years 1985-2012. It should be noted that because these statistics are estimated, there are some data points for which the total acreage insured was listed as greater than the total acreage planted. For these points, I adjusted the acres insured to reflect the number of acres planted. Estimates of total acreage planted and harvested of various crops in the various counties come from the US Department of Agriculture's National Agricultural Statistics Service. The crops that overlap in these three databases are the ones that are included in this study, and are as follows: corn, cotton, sorghum, peanuts, rice, soybeans, and wheat. Finally, data on average precipitation and temperature for each county and year is provided by the Center for Disease Control's WONDER (Wide-ranging Online Data for Epidemiologic Research) database.

Figure 1 shows a general picture of how overall levels of insurance coverage have changed over the years. It shows the average "net reported acres" insured across all Texas counties for the years 1981 to 2014. One can see the dramatic increase in insured acres following the 1994 reform act. Water use, in contrast, is far more variable (Figure 2), owing in large part due to changes in weather. Only through regression analysis, controlling for various factors described above, can we learn the specific effect crop insurance had on water use.

<u>Results</u>

Table 1a shows the results of the ordinary least squares (OLS) regressions based on equations above. Columns 1 only includes crop fixed effects, column 2 adds a timetrend to control for any other variables that trend with time that are not included explicitly in the model, such as technological progress, and column 3 includes both a timetrend and county fixed effects. Some results are in line with our expectations, while others are more surprising. We find a positive relationship between acres planted (or harvested) and water use of about 0.3. In other words, and increase in one acre of land should result in an increased use of 0.3 acre-feet of water. Rainfall is only statistically significant when county fixed effects are not included. However, when statistically significant, it has a negative effect as expected, signifying that increased rainfall reduces the demand for water. We can also see in Table 1b, that an increase in degree-days increases overall water use as expected. It makes sense that the higher more frequently the temperature is above 29°C should increase the demand for water if farmers are trying to keep their crops from being

severely damaged. In column 1 of table 1a, we see a negative coefficient for degree-days. However, this goes away after we control for county fixed effects.

Most interestingly, the correlation between crop insurance and the level of water use, the relationship of interest, is contrary to we might expect from the balance of the literature. I found that, holding other factors constant, an increase of one insured acre is associated with roughly a 0.2 acre-foot increase in water use. Results were statistically significant in all specifications of our model at the one percent level (i.e. the probability of the value being zero, meaning no effect of crop insurance, is less than one percent). This is a large result. 0.2 acre-feet is equal to about 65,000 gallons of water. When considering that there are over 8.3 million acres insured in Texas in 2012, this translates into an increase in water consumption by 1.6 million acre-feet, or enough for roughly 3 million households in a given year, solely due to the effect of crop insurance. Results of the panel model confirm this number. Results also vary widely by crop, with corn and rice using relatively more water, and the other crops using less (wheat least of all).

To find the mechanism through which crop insurance affects water use, I simulated Chen's (2005) study on the effect of insurance on abandonment rates using this data set and similar equation. This data confirms Chen's results, in that a one acre increase in insured area led to a .02 acre increase in area abandoned. This makes sense in terms of how we would expect moral hazard to operate through crop insurance. With more land insured, there is less pressure to put in the effort to try to guarantee the harvest of marginal lands. This is likely to decrease the demand

for water, but further studies may be interested to know other possible environmental impacts of unharvested acres.

I also tested the hypothesis that increased water use was due to increased planting intensity, following the work of Lobell et al. (2014). This was true of corn, sorghum, peanuts, and soybeans, and had almost no effect on cotton, rice, or wheat. This may be because cultivars have been developed for farmers to increase the planting intensity of some crops but not others. Table 1b shows the results when controlling for abandonment, increased intensity, and both. On the aggregate level shown in the table, there appears to be little effect of the changes in intensity. However, when limited to just those crops that are most affected by intensive planting, the inclusion of production intensity explains roughly half of the increase in water use due to crop insurance.

To see if there are regional differences in this effect, I divided the data according to the 10 climate regions in Texas as determined by the National Weather Service (Figure 3). Tables 2a and 2b show the results of these regressions (I included both county fixed effects and a timetrend). Results were strongest in the High Plains and Trans-Pecos, which overlie the Ogallala and Edwards aquifers, respectively. Interestingly, the results were a lot closer to 0, and in some cases negative, showing that insurance may in fact lead to lower uses of water in areas such as South Texas, which have a different relationship with water.

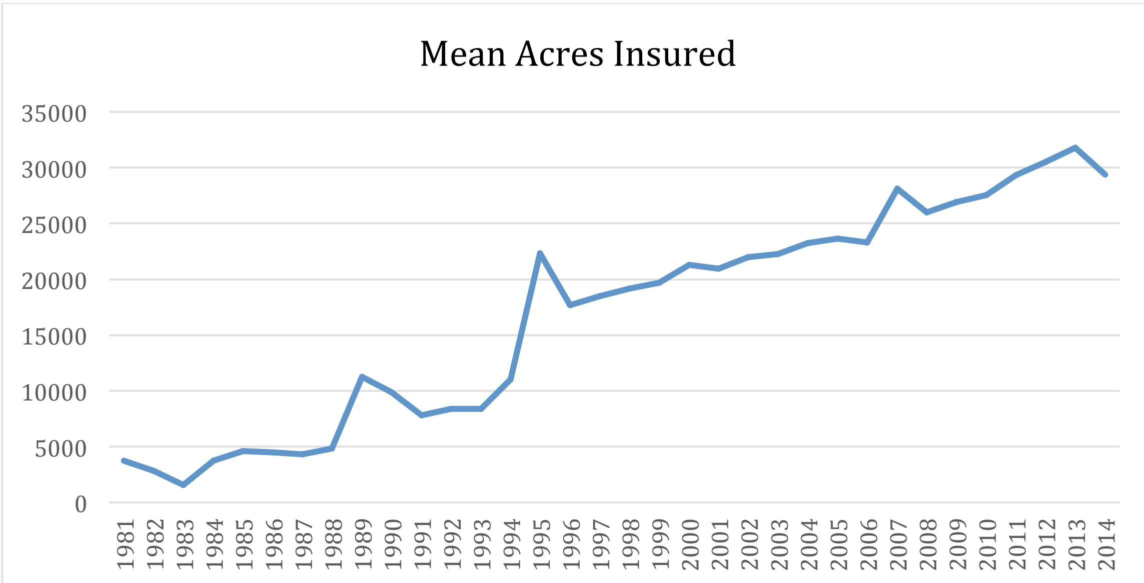
Conclusion

Unlike many previous studies on the potential impacts that crop insurance has on various decisions relating to the environment or sustainability, this study

found significant and strong results on the effect of insurance on water use in Texas. I was also able to confirm the results of previous studies done by Chen (2005) and Lobell et al. (2014). While I was not able to explain the entire increase in water use, much could be explained by increased planting intensity for certain crops in certain regions.

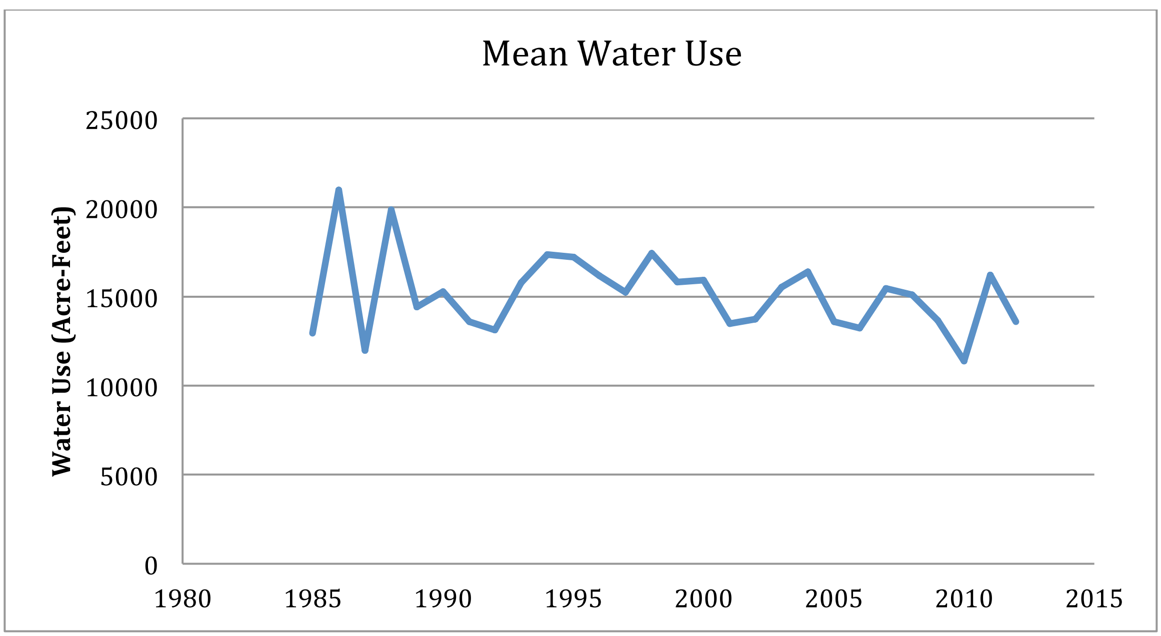
Freshwater is a vitally important resource that we need to conserve if we are going to sustain growing populations in the future. Yet without access to water, we cannot grow the crops we need to feed ourselves. While other policies, such as pumping restrictions or water pricing mechanisms, are more directly related to the limiting of groundwater to sustainable levels, it is important to know that other policies that govern such a heavy water user affect water use in a large way. This is especially important in Texas where laws that limit the use of groundwater are either in a very nascent phase or nonexistent. Knowing that crop insurance has this effect on water use, policy makers at the Risk Management Agency should pilot efforts to govern how much water insured farmers use, so that there will be enough water for both current and future generations to enjoy.

Figure 1



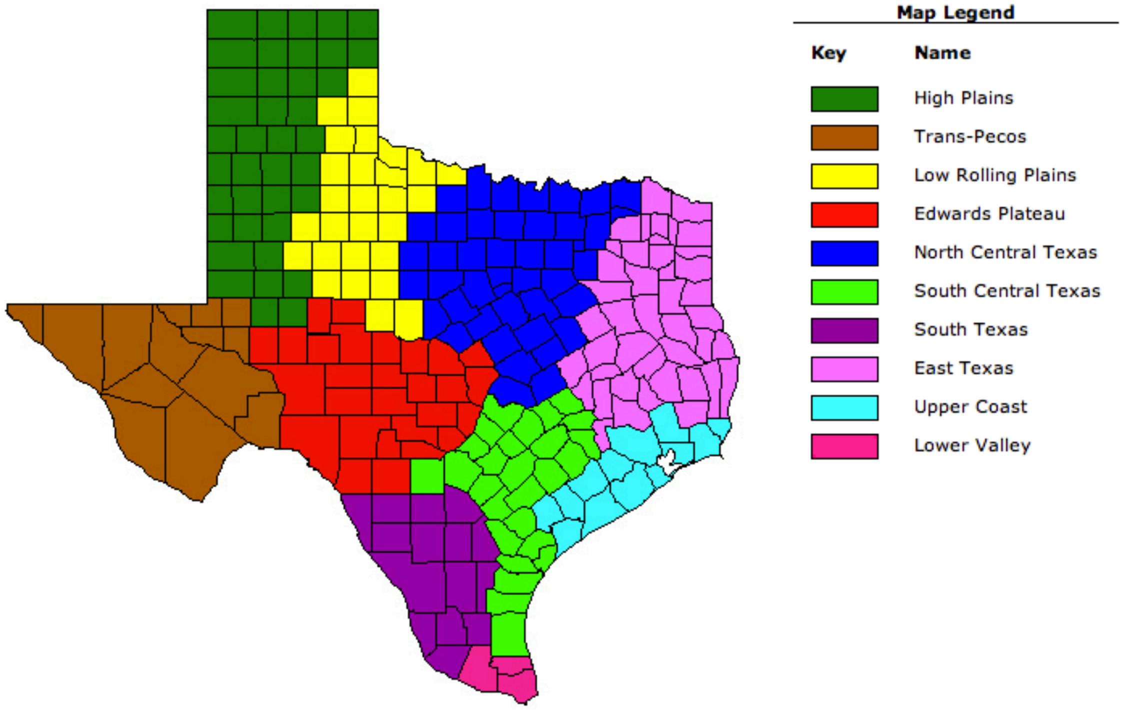
Source: Risk Management Agency

Figure 2



Source: Texas Water Development Board

Figure 3: Texas Climate Divisions



Source: National Agricultural Statistics Service

Table 1a

	(1)	(2)	(3)
VARIABLES	Acre-Feet	Acre-Feet	Acre-Feet
Constant	57,287.15***	17,344.13***	17,113.39***
	(26.149)	(3.240)	(3.148)
Acres Insured	0.15***	0.22***	0.23***
	(5.220)	(9.503)	(9.216)
Acres Planted	0.34***	0.26***	0.25***
	(14.646)	(13.909)	(12.334)
Limits	-8,735.36***	1,484.56	1,757.49
	(-3.391)	(0.491)	(0.578)
Avg Daily Precipitation	-11,009.42***	-1,099.20	-871.06
(mm)	(-23.208)	(-1.540)	(-1.200)
Degree-days	-20.44***	0.11	1.53
	(-16.513)	(0.058)	(0.766)
Crop Fixed Effects	Y	Y	Y
Timetrend			Y
County Fixed Effects		Y	Y
Observations	8,953	8,953	8,953
R-squared	0.486	0.668	0.668

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 1b

	(1)	(2)	(3)
VARIABLES	Acre-Feet	Acre-Feet	Acre-Feet
Constant	14,336.66***	19,746.70***	21,000.30***
	(2.712)	(3.889)	(4.105)
Acres Insured	0.24***	0.25***	0.25***
	(9.608)	(10.208)	(10.161)
Acres Planted	0.02	-0.01	0.05*
	(0.606)	(-0.369)	(1.935)
Limits	2,632.31	2,385.95	2,138.98
	(0.875)	(0.732)	(0.650)
Avg Daily Precipitation	-971.55	-1,036.42	-1,017.63
(mm)	(-1.345)	(-1.553)	(-1.534)
Degree-days	5.55***	9.62***	8.89***
	(2.799)	(5.205)	(4.800)
Control for Abandonment	Y		Y
Control for Intensity		Y	Y
Observations	8,953	8,952	8,952
R-squared	0.680	0.723	0.724

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2a

	High Plains	Trans-Pecos	Low Rolling Plains	Edwards Plateau	North Central Texas
VARIABLES	Acre-Feet	Acre-Feet	Acre-Feet	Acre-Feet	Acre-Feet
Constant	47,960.27***	-15,260.70*	-4,476.90***	16,001.05***	1,932.96**
	(9.576)	(-1.881)	(-3.551)	(4.177)	(2.287)
Acres Insured	0.28***	0.81**	0.02***	0.01	0.04***
	(8.879)	(2.093)	(3.472)	(0.174)	(4.212)
Acres Planted	0.32***	2.33***	0.02***	0.26***	-0.02***
	(12.039)	(7.373)	(4.160)	(6.345)	(-2.812)
Avg Daily Precipitation	-3,283.89*	-4,233.04	-295.68	-772.71	-297.57*
(mm)	(-1.780)	(-1.199)	(-1.131)	(-0.997)	(-1.673)
Degree-days	0.47	8.28	2.30**	-0.30	-0.41
	(0.096)	(0.690)	(2.293)	(-0.107)	(-0.783)
Observations	3,511	203	1,533	608	642
R-squared	0.711	0.811	0.518	0.621	0.040

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2b

	South Central Texas	South Texas	East Texas	Upper Coast	Lower Valley
VARIABLES	Acre-Feet	Acre-Feet	Acre-Feet	Acre-Feet	Acre-Feet
Constant	-75,003.82***	-98.51	-3,973.14*	-25,629.98*	18,117.90
	(-5.558)	(-0.033)	(-1.879)	(-1.798)	(0.836)
Acres Insured	-0.11**	-0.23***	0.35**	-0.31	0.05
	(-2.121)	(-2.799)	(2.379)	(-1.059)	(0.338)
Acres Planted	0.23***	0.39***	0.47***	1.22***	0.45***
	(3.991)	(4.653)	(3.690)	(4.777)	(3.033)
Avg Daily Precipitation	73.03	202.51	-50.90	-1,240.06	526.03
(mm)	(0.088)	(0.340)	(-0.116)	(-0.480)	(0.090)
Degree-days	5.24*	2.79	0.29	8.52	30.27
	(1.810)	(1.598)	(0.216)	(0.651)	(1.307)
Observations	819	489	310	590	248
R-squared	0.799	0.633	0.735	0.659	0.496

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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