The Effects of Policy Uncertainty on Irrigation and Groundwater Extraction

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Abstract

Irrigated agriculture on the Southern High Plains of Texas relies heavily on water extracted from the Ogallala Aquifer, which is functionally non-renewable. Concerns about depletion of the aquifer have led to the implementation of policies designed to slow water extraction and increase the usable life of the resource. Policies have not been uniform across the aquifer, however, leaving some farmers in regions where no effective groundwater extraction policy exists yet, but are only a short distance away from regions where farmers do face regulatory limits on extraction. This paper investigates the effects of policy uncertainty on the extraction of groundwater in those areas where farmers must make irrigation decisions without knowing whether they will be restricted in their irrigation decisions in the future. We build a production model of the major crops in 6 counties in Texas, and use the quantity of corn (an irrigation-intensive crop) produced as a proxy for irrigation use. We find that corn acreage has increased significantly in years in which a policy was in place, but was officially unenforced in 5 of the 6 counties. After controlling for price and climate effects, we conclude that there is strong evidence that policy uncertainty increases groundwater extraction.

Keywords: Policy uncertainty; Resource extraction; Irrigation

Introduction

The purpose of this paper is to examine how farmers respond to uncertainty policies of water use on the Southern High Plains of Texas. Understanding how policy affect farmers' decision is important because they indirectly affect the usage of Ogallala Aquifer. On the other hand, conservation of the Ogallala Aquifer is a hot topic on the researching area of this study. The result of this study intends to make contributions on the Ogallala Aquifer Conservation District and assist policy maker to establish appropriate policy in the future.

Grain corn, upland cotton, grain sorghum, and winter wheat are mainly crops produced on the Texas High Plains for the past decades. Farmers make their decisions on choose what to produce in the future depend on if they can receive the maximum profit. Prices of the four crops and how much water need to use for irrigation are the important factors that affect farmers' decisions. Moreover, the availability of groundwater in the Southern Ogallala Aquifer directly impact the agricultural of the Texas High Plains. In order to slow the water extraction and increase the usable life of the Ogallala Aquifer, relative policies have been designed. However, policies have not been uniform across the aquifer, and in some counties the district's rules even did not really enforced. Concerning on this point, this study tend to analyze if uncertain or impending policy regarding irrigation water restrictions may actually cause farmers to withdraw more water than in the absence of those regulations. Specific objectives are to:

(1) Construct econometric models and determine the relationship of selected factors. Analyze how dependent variables affect independent variables.

(2) Test if and how existing policy of groundwater of Ogallala Aquifer will affect irrigation and ground water extraction.

Literature Review

The semi-arid Texas High Plains consists of a part of southern region of the Great Plains area in the U.S., which is a main supplier of irrigated and dry land crops. The main crops comprise upland cotton, winter wheat, grain corn, and grain sorghum. Soybeans, silage and peanuts are secondary crops. In the long term, increasing irrigation area of silage will be a trend in order to meet the rapid growth of dairy market. In general, irrigation can bring doubled to quadrupled crop production when we compare it with dry land yield levels which makes agricultural irrigation become a significant element of the regional economy (Howell 2001). From 1930s to 1940s the turbine pumps, rotary well drilling, internal combustion engines and right-angle gear drives started to be useable for pumping groundwater, it was massive irrigation first became practical (Simpson et al. 2005).

When surface water resources became insufficient to irrigate crops, the Ogallala (High Plains) Aquifer plays an extremely significant role in supplying almost all irrigation of the Texas High Plains. As one of the largest freshwater aquifers in the world, the Ogallala Aquifer underlies parts of eight states of the USA, which includes New Mexico, Colorado, Nebraska, Oklahoma, South Dakota, Kansas, Wyoming and Texas. Nevertheless, the Ogallala recharge was far less than withdrawals. Thus, groundwater levels declined rapidly since the development of irrigation (Marek et al. 2005). A data shows that more than 90 percent of the Ogallala withdrawals are used for irrigation. Additionally, over 50 percent of the predevelopment saturated thickness has been pumped in many regions that lead to groundwater levels have declined more than 50m (McGuire 2003). After 1974, the pumping rates of the Ogallala groundwater reduced a lot compared to earlier, based on some strategies like maintain comparatively stable commodity prices, demand for more requirements, increase cost of irrigation, raising unit energy costs and decreasing well production (Musick et al. 1990). Fortunately, in many areas, the rate of decline of Ogallala groundwater levels has slow down. Upper limits in withdrawal rates of aquifer will appear, which depend on increases in pumping energy costs and declining well yields (Almas LK et al. 2006). Thus, crop productivity will be affected as well. In addition, on September 1, 2005, the 79th Texas Legislature passed House Bill 1763, which requires, among other items, that groundwater management areas establish upper limits for groundwater production (Mace et al. 2006). In the long-term, these factors will play important role in affecting economic viability of agricultural irrigation in the Texas High Plains (Taylor et al. 2007).

In the 1940s until the late 1970s, agricultural producers took legal Texas groundwater law, which generally known as the “right of capture” (Terell 1998). It granted full rights to landowners and their properties, and the right of all of the groundwater beneath the land reserve to landowners (Kaiser and Skillern 2001). Falling groundwater levels, increasing pump lifts, as well as high energy prices in the late 1970s, gradually reduce groundwater pumping and irrigation area. In the year of 2002, there were 3.5 million Texas High Plains crop acres were irrigated, and it was about 55% less than acres irrigated in the late 1960s (Texas Senate Bill 2, Austin, TX, 2002).

In Texas legislation has explicitly recognized the increasingly scarce groundwater supplies, particularly Senate Bills 1 (Texas Senate Bill 1, Austin, TX, 1997) and 2 (Texas Senate Bill 2, Austin, TX, 2002), explicitly recognized the growing scarcity of groundwater supplies. Senate Bill 1 (SB 1) modified several parts of Texas water law and changed the structure of the state water management. It required the Texas Water Development Board (TWDB) to develop a comprehensive statewide water use plan that incorporated locally developed regional water plans (Article 1, Section 1.01). Senate Bill 2 (SB 2) established Texas Water Advisory Committee, as well as a guide to improve surface water and groundwater management planning at the local, regional and state levels (Texas Joint Committee on Water Resources, 2002). SB 2 also increased the power specification groundwater area within its jurisdiction, allowing them to carry out the production charges to limit groundwater exploitation. These costs cannot be more than one US dollars per acre - feet of water extraction. Both bills are collectively designed to transition from Texas to capture a groundwater management rules to a ‘‘statutory-based groundwater management system administered by local districts that are tailored to meet the needs of specific aquifers’’ (House Research Organization, 2000, p. 8).

High Plains Water District Rules (HPWDR) (2013) indicated “50/50 Management Goal” which means that 50 percent of the saturated thickness of the Ogallala Aquifer will need to be in the Ogallala Aquifer 50 years later. The first planning interval of the 50/50 Management Goal started on January 1, 2010 and will end on January 1, 2060. Moreover, since January 1, 2012 all persons who own or operate a well or well system that withdraws groundwater from the Ogallala Aquifer are required to limit the total amount of production from the well or well system. However, High Plains Water Conservation District (HPWD) extends moratoriums through 2014. During their Nov. 12 regular meeting, the HPWCD Board of Directors voted 5-0 to extend current moratoriums in the district’s rules through calendar year 2014.

Data and Methods

We collected data from 20 counties that are located within both the High Plains and Northern High Plains Underground Water Conservation Districts, and are mainly above the Ogallala aquifer in the Texas High Plains area. The data was found from the National Agricultural Statistics Service (NASS). However, data availability required us to restrict our focus to 6 countries of within the High Plains Water District. The 6 countries are Deaf Smith, Parmer, Castro, Swisher, Hale and Floyd (shown in Figure 1 and Figure 2). Through observation of the data, these 6 countries mainly produce corn, cotton and sorghum in agricultural production while corn is grown on the most acreage of the three crops.

Figure 1

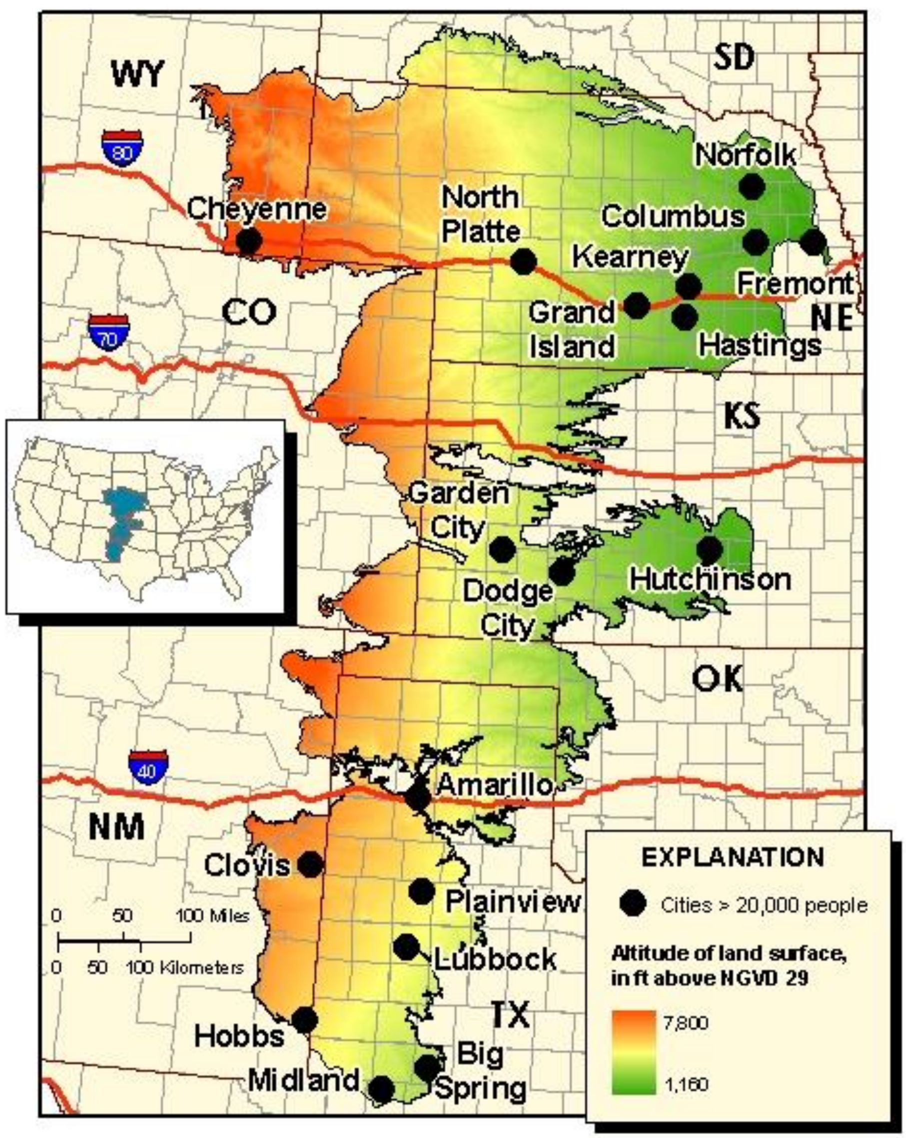
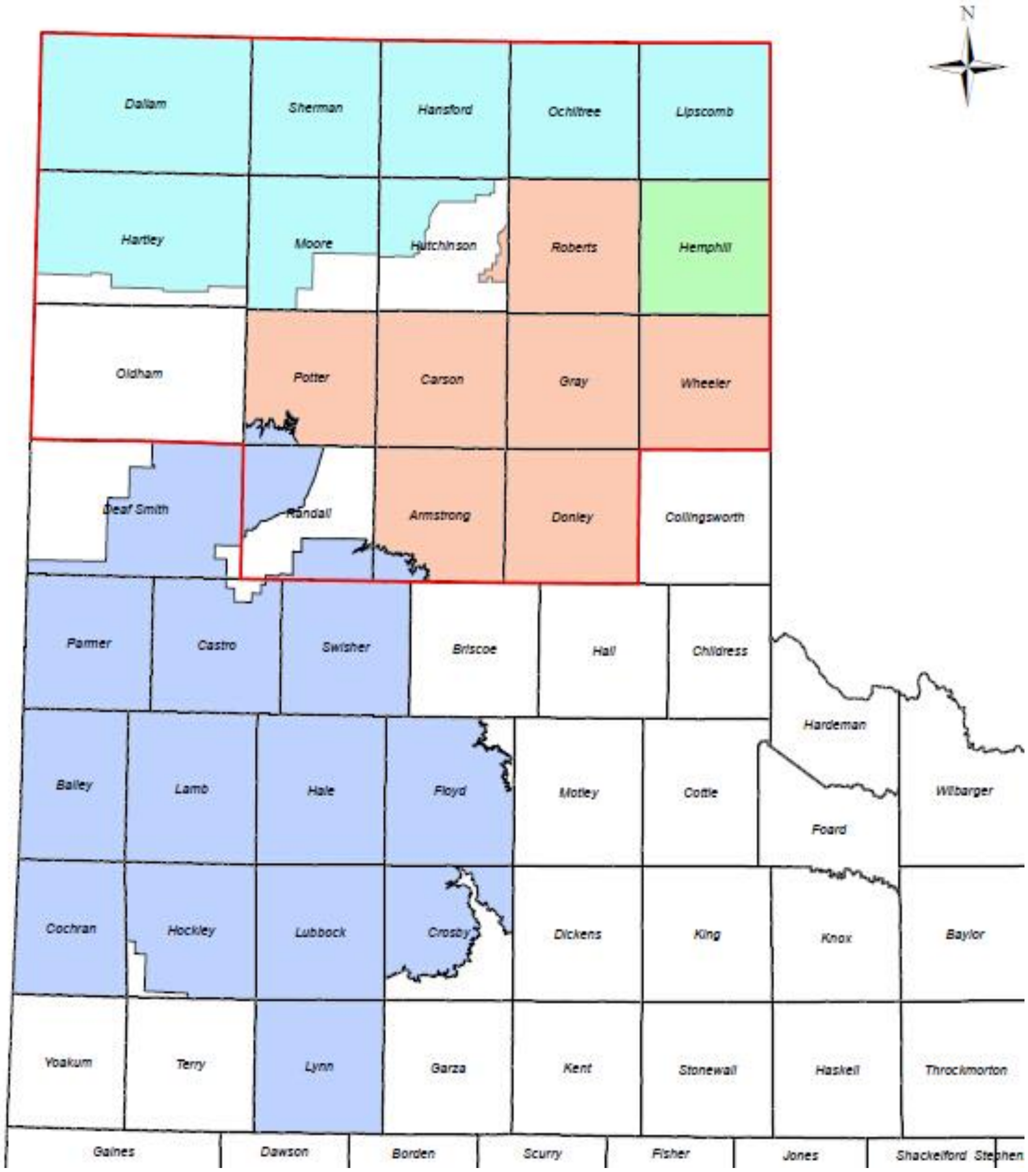


Figure 2



The purpose of this study is use an econometric model to analyze how uncertain polices effect farmers' agricultural production decisions. Specifically, we wish to know if uncertain or impending policy regarding irrigation water restrictions may actually cause farmers to withdraw more water than in the absence of those restrictions. We assume that farmers want to maximize their profit over time, so they need to make their decision for the present and the future about what to produce and how much input they need to use to achieve their goals. If follows that, if farmers anticipate a restriction in input use some time in the future, they may intensive their use of that input in the current period. Input use directly affects output, so farmers' input use decisions are revealed by the production of the crops. In other words, the output of crops reflects what decisions farmers made.

In order to protect groundwater, policies have been crafted to limit groundwater use in the past several years. However, in some places, such as within the High Plains Water District, these policies have never been enforced, but irrigators are left with the expectation that enforcement is a possibility in the future. We hypothesize that producers who expect to face future production losses and lower revenues because of resource-limiting policies will use as much water as they can now to increase their current production in order to gain more profit while possible. In order to test our hypothesis, we use a crop production model for each of our 6 counties (modeling each county as a profit-maximizing producer), and estimate them using Seemingly Unrelated Regression (SUR) to analyze how policy, crop prices and climate affects crop production. Corn, cotton and sorghum are the three main crops producing in the 6 countries, so we set acres harvested for each crop as our output variable which reflects the crop production. We estimate three linear supply equations (which represent the first derivatives of an unspecified normalized quadratic profit function) for each crop, which are functions of a time trend, irrigation policy, rainfall, corn price, cotton price and sorghum price. Functions are showing as follow:

$$Corn\ Acre\ Harvested = f(year, rainfall, ploicy, corn\ adjusted\ price,$$
$$cotton\ adjusted\ price, sorghum\ adjusted\ price)$$

$$Cotton\ Acre\ Harvested = f(year, rainfall, ploicy, corn\ adjusted\ price,$$

$$cotton\ adjusted\ price, sorghum\ adjusted\ price)$$

$$Sorghum\ Acre\ Harvested = f(year, rainfall, ploicy, corn\ adjusted\ price,$$

$$cotton\ adjusted\ price, sorghum\ adjusted\ price)$$

Irrigation policy is specified as dummy variable: 0 reflects no policy for groundwater use, 1 reflects there exists a stated, but unenforced, policy for groundwater use. The estimated model will support our hypothesis if the estimated parameter on the policy variable in the corn supply equation is positive and significant; where a positive and significant policy variable indicates that corn acreage increased due to the introduction of the unenforced policy. This supports our hypothesis because corn is the most water-intensive of the three main crops, and an increase in corn acreage is directly related to an increase in water use.

Results and conclusion

Following are the results for each county.

Castro

	constant	year	rainfall	policy	adjusted corn price received	adjusted cotton price received	adjusted sorghum price received
corn acre harvested	1768394	-890.0615	1196.341	15666.39	70946.43	-38721.85	-20235.16
	(1.39)	(-1.4)	(2.06)	(1.48)	(3.12)	(-1.77)	(-1.59)
cotton acre harvested	-2774749	1450.522	-1380.08	-15505.47	-38721.85	138928.1	-4933.392
	(-1.54)	(1.61)	(-2)	(-1.22)	(-1.77)	(3.43)	(-0.39)
sorghum acre harvested	-756921.2	382.6358	-144.696	-18364.54	-20235.16	-4933.392	17808.61
	(-0.97)	(0.98)	(-0.4)	(-2.76)	(-1.59)	(-0.39)	(2.28)

Deaf Smith

	constant	year	Rainfall	policy	adjusted corn price received	adjusted cotton price received	adjusted sorghum price received
corn acre harvested	2912021	-1459.66	1208.579	14063.13	33887.02	-27699.53	-13699.87
	(3.6)	(-3.62)	(1.98)	(2.39)	(2.26)	(-2.44)	(-1.65)
cotton acre harvested	-2552878	1305.372	198.963	-4972.322	-27699.53	46648.27	229.5909
	(-3.37)	(3.46)	(0.38)	(1.02)	(2.44)	(2.89)	(0.04)
sorghum acre harvested	1896877	944.226	1556.632	-17836.27	-13699.87	229.5909	15838.11
	(2.03)	(-2.04)	(2.04)	(-2.41)	(-1.65)	(0.04)	(2.79)

Parmer

	constant	year	rainfall	policy	adjusted corn price received	adjusted cotton price received	adjusted sorghum price received
corn acre harvested	7263851	-3644.195	1074.695	21460.2	102630.4	-32068.98	-43626.76
	(4.94)	(-4.96)	(1.6)	(1.82)	(3.63)	(-1.28)	(-2.69)
cotton acre harvested	-2752937	-726.2631	-7625.02	-7625.02	-32068.98	164035.5	-13288.62
	(-1.34)	(1.4)	(-0.9)	(-0.54)	(-1.28	(3.73)	(-0.88)
sorghum acre harvested	-40385.6	22.14387	170.3538	-24836.3	-43626.76	-13288.62	37812.59
	(-0.04)	(0.05)	(0.37)	(-3.03)	(-2.69)	(-0.88)	(3.74)

Hale

	constant	year	rainfall	policy	adjusted corn price received	adjusted cotton price received	adjusted sorghum price received
corn acre harvested	7805467	-3922.35	1130.463	20416.43	89596.54	-70429.6	-31864.54
	(5.69)	(-5.74)	(1.95)	(2.1)	(3.54)	(-2.29)	(-2.09)
cotton acre harvested	-8691431	4529.097	1047.127	-31483.9	-70429.6	230319	-30935.44
	(-2.16)	(2.26)	(0.56)	(-0.97)	(-2.29)	(2.96)	(-1.29)
sorghum acre harvested	378279.7	-185.446	-1072.69	-10601.6	-31864.54	-30935.44	38558.92
	(0.18)	(-0.18)	(-0.97)	(-0.53)	(-2.09)	(-1.29)	(2.96)

Floyd

	constant	year	rainfall	policy	adjusted corn price received	adjusted cotton price received	adjusted sorghum price received
corn acre harvested	1508725	-761.241	246.7875	7736.948	26067.81	-6380.397	-10481.4
	(2.83)	(-2.87)	(1.39)	(2.16)	(3.64)	(-0.53)	(-2.27)
cotton acre harvested	-485538	317.9905	2210.568	6161.101	-6380.397	67864.33	-17343.92
	(-0.15)	(0.2)	(1.77)	(0.25)	(-0.53)	(1.14)	(-1.12)
sorghum acre harvested	588803.3	-287.293	-97.6458	-30674.4	-10481.4	-17343.92	16636.23
	(0.31)	(-0.3)	(-0.11)	(-1.69)	(-2.27)	(-1.12)	(1.82)

Swisher

	constant	year	rainfall	policy	adjusted corn price received	adjusted cotton price received	adjusted sorghum price received
corn acre harvested	1021134	-519.3822	308.1142	-3797.191	23716.47	-8451.112	-6015.282
	(1.69)	(-1.73)	(1.22)	(-0.89)	(2.28)	(-0.6)	(-0.96)
cotton acre harvested	-2945110	1521.934	-436.8686	6668.183	-8451.112	120007.3	-17287.31
	(-1.58)	(1.64)	(-0.58)	(0.52)	(-0.6)	(2.64)	(-1.65)
sorghum acre harvested	78587.84	-43.1811	279.4173	-16803.42	-6015.282	-17287.31	15625.73
	(0.11)	(-0.13)	(0.79)	(-2.58)	(-0.96)	(-1.65)	(3.24)

Restriction:

(1) [corn acre harvested] adjusted sorghum price received - [sorghum acre harvested] adjusted corn price received = 0

(2) [corn acre harvested] adjusted cotton price received - [cotton acre harvested] adjusted corn price received = 0

(3) [cotton acre harvested] adjusted sorghum price received - [sorghum acre harvested] adjusted cotton price received = 0

The parameter on the policy variable in the corn supply equation is positive and significant in each county except Swisher. The results imply that when policy in place, farmers will consider producing more corn. Since corn is the plant that needs most water when growing in three crops, it implies that farmers tend to use more water since the policy was created.

The results shown and supported our hypothesis that uncertain polices effect farmers' agricultural production decisions is true. Specifically, uncertain or impending policy regarding irrigation water restrictions may actually cause farmers to withdraw more water than in the absence of those restrictions. Farmers want to maximize their profit in the future, so they need to make their decisions on what to produce and how much input they need to use to achieve their goals. Input use directly affects output, so farmers' input use decisions are revealed by the production of the crops. In other words, the output of crops reflects what decisions farmers made. In addition, producers who expect to face future production losses and lower revenues because of resource-limiting policies will use as much water as they can now to increase their current production in order to gain more profit while possible.

Based on the estimation results, sometimes it may result in the expectation which is not the policy makers anticipate when the policy is pending and farmers have already known the relative information about it. As a result, the policy maker need to be cautious about making policies. Furthermore, due to the limitation of data and knowledge, there are still some future work to do. I hope this research would shed light on the study of environmental protection and water conservation on Ogallala Aquifer Area in some policy implications.

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