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The Roles of Cost Sharing Rules and Well Sharing in Irrigation Inefficiency: A Case Study in Groundwater Pumping in Mexico

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Market Report	Year Ago	4 Wks Ago	
Livestock and Products, Weekly Average			
Nebraska Slaughter Steers, 35-65% Choice, Live Weight.	149.15	160.00	148.23
Nebraska Feeder Steers, Med. & Large Frame, 550-600 lb.	254.00	289.49	305.08
Nebraska Feeder Steers, Med. & Large Frame 750-800 lb.	207.17	227.24	241.78
Choice Boxed Beef, 600-750 lb. Carcass.	238.39	263.19	254.31
Western Corn Belt Base Hog Price Carcass, Negotiated.	120.03	78.16	74.05
Pork Carcass Cutout, 185 lb. Carcass 51-52% Lean.	124.66	84.86	82.16
Slaughter Lambs, wooled and shorn, 135-165 lb. National.	154.75	146.30	158.67
National Carcass Lamb Cutout FOB.	359.20	356.28	257.10
Crops, Daily Spot Prices			
Wheat, No. 1, H.W. Imperial, bu.	6.56	4.93	5.09
Corn, No. 2, Yellow Nebraska City, bu.	4.43	3.45	3.71
Soybeans, No. 1, Yellow Nebraska City, bu.	14.05	8.99	9.86
Grain Sorghum, No.2, Yellow Dorchester, cwt.	7.73	6.88	7.46
Oats, No. 2, Heavy Minneapolis, Mn, bu.	3.80	2.77	2.94
Feed			
Alfalfa, Large Square Bales, Good to Premium, RFV 160-185 Northeast Nebraska, ton.	193.75	190.00	*
Alfalfa, Large Rounds, Good Platte Valley, ton.	*	*	*
Grass Hay, Large Rounds, Good Nebraska, ton.	100.00	120.00	90.00
Dried Distillers Grains, 10% Moisture Nebraska Average.	145.00	170.50	121.50
Wet Distillers Grains, 65-70% Moisture Nebraska Average.	52.00	52.00	41.00
* No Market			

Concerns about groundwater depletion in the High Plains Aquifer and other aquifers throughout the world have been well documented in the media and the scientific literature. A recent study found that groundwater use exceeds recharge in about one-third of the world's largest aquifers (Barringer, 2015). Thus, developing appropriate groundwater management policies that encourage conservation and preserve the long-run viability of aquifers is of paramount importance in many regions. However, policies and institutional arrangements in many areas may exacerbate aquifer depletion by encouraging groundwater consumption. Policies that subsidize the cost of energy inputs may increase groundwater extraction. Subsidized electricity or diesel rates for irrigators are pervasive in many countries including India, Mexico, and Tunisia (among many others). Concerns about neighbors using groundwater and depleting a shared aquifer may lead to all irrigators using more water than if the aquifer was not shared. Using inefficiently large amounts of groundwater is a concern as it can lead to the depletion of existing aquifers and an increase in future costs as groundwater tables are drawn down.

In a recent study we use data from Mexico to examine the effect of three characteristics of groundwater use. Specifically, we examine the effect of well sharing, cost sharing, and energy subsidies on the efficiency of groundwater use. The data was collected during the 2003 – 2004 winter season by the Instituto Nacional de Ecología y Cambio Climático (National Institute of Ecology and Climate Change). Two surveys were used to collect data for each well. The first survey includes questions about the irrigation unit (e.g., number of farmers sharing the well, crops grown by producers).

The second crop-specific survey was completed for each of the main crops grown using water from the well. The crop-specific survey includes questions about inputs (including irrigation), yields, and prices for each crop. All of the wells in the sample use only groundwater for irrigation and natural precipitation without any supplemental surface water diversions

Irrigation well characteristics:

Well sharing: In contrast to the independently owned and operated groundwater wells of the High Plains, it is very common in many countries for multiple producers to share a single groundwater well. This is the situation in much of Mexico, as many producers own or use small plots of land, and individually owned irrigation wells are technically inefficient and prohibitively costly. We use a randomly chosen sample of 197 irrigation wells in our study. Of the 197 wells, 77 (39.1 percent) are owned by a single user while the rest are shared by multiple farmers. The 120 shared wells have a median of 6 users and an average of 12 users.

Cost sharing: When multiple farmers share an irrigation well they need to choose how to divide the costs associated with paying for the electricity necessary to pump groundwater. There are three methods used to share those costs: equal cost sharing, land based cost sharing, and irrigation time based cost sharing. With the first method farmers split the electricity costs equally (e.g., if 5 farmers share the well, each one pays 20 percent of the electricity bill). With the second method farmers split the electricity costs based on the amount of land irrigated. For example, if two farmers share a well and the first plants 10 acres while the second plants 20 acres, the first will pay one-third of the bill and the second will pay two-thirds of the bill. With the last method farmers split the electricity costs based on the number of hours each one irrigates. For example, if two farmers share a well and the first irrigates for 10 hours per week while the second irrigates for 20 hours per week, the first will pay one -third of the bill and the second will pay two-thirds of the bill. Of the 120 shared wells 30 divide the costs equally for all users (method one), 45 share costs on the amount of land farmed (method two), and 45 share costs on total hours of irrigation use (method three).

Electricity subsidies: Electricity is the primary cost of pumping groundwater in all of the wells included in the study. While subsidies in Mexico have been reduced since the study period, they have not been eliminated. Removing electricity subsidies is frequently advocated as a policy change to encourage conservation of water resources. Our study results allow us to estimate how much water use would be reduced if electricity subsidies were eliminated.

Methods: Our goal in this study is to measure the impact of these three characteristics on the efficiency of groundwater groundwater use. It is important to note that simply using a large amount of groundwater is not necessarily undesirable if that water use is associated with a high level of production. We account for this in our analysis by examining water use relative to total yield. We develop three hypotheses based on studies from other locations and economic modeling.

First, we hypothesize that eliminating electricity subsidies will not make a large difference in groundwater use. While we will test this with the data from our sample, studies in other places have generally found a small price response in irrigation water use (Hendricks and Peterson, 2012). *Second*, we hypothesize that a greater number of farmers sharing a well will increase the inefficiency of irrigation application. This is based on previous work that has found a strategic relationship in farmer pumping decisions (Pfeiffer and Lin, 2012). *Third*, we hypothesize that farmers with equal cost sharing or land-based cost sharing will use groundwater more inefficiently than those who pay the full cost of their water consumption (i.e., those with cost sharing based on the duration of irrigation).

To test these hypotheses we estimate the quantity of groundwater irrigation used by all farmers who share the well based on the three characteristics of interest. We also include other control variables to account for other things that affect water use. For example, we also include information on climate conditions, average education level, total output, soil type, and crop type. However, we focus our discussion of results on the characteristics of interest[1].

Results: Our first hypothesis is that eliminating electricity subsidies will not have a large effect on groundwater use. We find evidence this is true in our sample. Our estimates show that a 100 percent increase or doubling of water prices (i.e., electricity prices) will only reduce groundwater use by 6 percent. So, while eliminating subsidies will have some effect on groundwater use and aquifer depletion, that effect is extremely small. Policymakers who are concerned about aquifer sustainability may find that other policy tools are more effective than subsidy elimination at encouraging conservation.

Our second hypothesis is that irrigation inefficiency is greater when more farmers share a well. However, our results fail to support this hypothesis. We investigate this in several different ways such as including a subset of the wells and including multiple indicators of the

[1]More details on the estimation results and other variables are available from the corresponding author.

number of users. But, we find no empirical evidence from our sample that irrigation wells shared by a greater number of farmers are less efficient. While surprising, this result may show that farmers who share a well are organized in other decisions such as crops, acreage, and timing of irrigation use. It's important to note that this result may not hold worldwide. Other countries with shared wells may not show the same result. But, this provides evidence that well sharing is unlikely to be a major source of irrigation inefficiency in Mexican irrigated agriculture.

Our last hypothesis is related to cost sharing rules. Past policy recommendations on improving the efficiency and sustainability of groundwater have failed to recognize this as an important issue for policymakers to address. However, our results support our hypothesis and show that cost sharing rules are a major source of inefficiency in irrigation application. We use the case where farmers pay the full cost of their water use (i.e., volumetric pricing) as the base case with an irrigation efficiency of 100 percent. Relative to the base case, an equal cost share rule and a land based cost share rule reduce irrigation efficiency to 58 and 73 percent, respectively. Therefore, moving to volumetric pricing provides a substantially larger improvement in irrigation efficiency than eliminating or reducing electricity subsidies. However, we caution that a thorough analysis of these benefits needs to incorporate the costs of implementing volumetric pricing, something we were unable to do in our study.

<ins>Summary and conclusion:</ins> We investigate the effect of multiple characteristics of shared wells on groundwater use efficiency. While some of the characteristics (price, number of users) have been studied in other areas, we do not know of other work that has included cost sharing as a potentially important source of irrigation inefficiency. We find evidence that wells that use a cost sharing rule instead of volumetric pricing have greater irrigation inefficiency, and that the difference is both statistically and economically significant. This provides evidence that policymakers should encourage users of shared wells to move away from arbitrary cost sharing rules and toward rules that incorporate volumetric pricing.

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