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Shadow price of water for irrigation—A case of the High Plains

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ABSTRACT

The 2011 and 2012 droughts considerably affected the Ogallala Aquifer supplying irrigation water for agricultural production in the US High Plains (HP). Shrinking water resources and growing demand for water create a challenging tradeoff situation. This also poses a question about the value of water and efficient water allocation. Currently, water rates for irrigating crops paid by farmers do not reflect the actual value of water that can be expressed solely as a shadow price. Also studies are missing that would comprehensively compare different states and different crops in one methodological framework. This paper helps to fill this gap. Farm-budget residual valuation is applied to estimate the shadow price of water for irrigation in three High Plains states: Texas, Kansas and Nebraska, for five prevailing crops: corn, cotton, sorghum, soybean, and wheat.

Among the analyzed High Plains states the highest shadow price of water was found for wheat production in the Texas Northern High Plains ($865.99/af = $0.70/m^3), while the lowest shadow price was found for corn in the Texas Southern High Plains ($5.13/af = $0.004/m^3). The study can be helpful to stakeholders and policy makers to evaluate scenarios and tradeoffs between profitable crop production and conservation of water resources.

1. Introduction

According to the most recent (2005) survey by USGS (2013a), in the last 60 years, the total water withdrawals for irrigation in the US showed an increasing trend between 1950 and 1980, and reached the peak in 1980 at the level of 150 billion gallons per day (Bgal/d) (567.8 million m^3). Since then, water withdrawals for irrigation in the US have been decreasing and dropped to 128 Bgal/d (484.5 million m^3) in 2005. Water withdrawals for the entire agricultural sector in the US amounted to 139 Bgal/d (50,826.7 Bgal/year) (192.4 billion m^3/year) in 2005, which accounts for 40.2% of the total water withdrawals in the country (author's calculations based on UN Water (2013)). Irrigation accounts for more than 90% of the agricultural water use and represents the largest single consumptive water use in the US (US Environmental Protection Agency (EPA), 2012).

The above mentioned developments pose a question about economics of water resources in the agricultural sector. This paper addresses this question based on the example of the US High Plains (HP). The research question is relevant as the agricultural sector plays an important role in the High Plains with 28% of the agricultural land being irrigated (USGS, 2013b; US EPA, 2007). The research presented in this paper is also timely as the High Plains region has been plagued by extreme drought for the past several years, which resulted in an increasing pressure on water resources.

Currently, knowledge about the actual value of water as a resource is very limited. While the water rates represent the costs of extracting water from aquifers and delivering it to the final consumer, they do not reflect the real value of the resource. Thus, water for irrigating crops is underpriced. This can lead to an irreversible depletion of the Ogallala Aquifer in the mid-term and can inevitably stymie agricultural production in the High Plains region. In order to avoid such scenarios from happening in the near future, it is crucial to estimate the actual value of water for irrigation in the High Plains and assess the water rates that would allow farmers to still breakeven, while also protecting water resources at the same time. This paper seeks to answer this question for three selected states in the High Plains: Texas, Kansas and Nebraska.

The contribution presented in this paper is novel in that the value of water for irrigation has not been previously analyzed with a comparative and comprehensive analysis for different states and different crops in the High Plains region. Previous studies in this field were focused on single regions in the High Plains, and in addition they applied various methodologies (e.g., farm budget analysis, change in net income (CINI) method or programming methods). Thus, a direct comparison of the value of water for irrigation among different states in the High Plains was not possible. By using one methodological approach for each of the

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analyzed states, this paper provides a comparative-static analysis that can be used for further regional and large-scale program planning analyses.

The actual value of water for irrigation has been expressed in this paper as the shadow price of water. The shadow price has many definitions in the literature. Here, the shadow price of water for irrigation was methodologically defined and calculated as the ratio between the production net returns and the total amount of water used for irrigating the respective crops. Conceptually, the shadow price of water can also be viewed as the difference between the given water rate for irrigation and the actual economic value of water as a natural resource. In other words, the shadow price estimated here reflects the price that would need to be paid by farmers to veritably account for the actual value of water. Due to the applied methodology (residual valuation), the shadow price of water can also be referred to as residual value of water. In order to maintain the separation between the theoretical concept and the methodology applied in this paper, the term 'shadow price of water' will be used throughout the paper.

This paper applies farm-budget residual valuation due to its simplicity and robustness. An extensive review of the residual valuation methodology has been provided by Young (2005a,b). Despite the relevance of evaluating the shadow price of water, the number of studies applying the residual valuation method is rather limited (Hellegers and Davidson, 2010). Berbel et al. (2011) applied the method to determine an aggregate value for agricultural water use across regions in Spain. Also Hellegers and Davidson (2010) used residual valuation to determine the disaggregated economic value of irrigation water used in agriculture across crops, zones and seasons in the Musi sub-basin in India. Otherwise, recent studies applying this methodology are missing.

This paper has two goals: (1) it presents a practical application of the residual valuation method for the High Plains region, and (2) it extends the standard methodological proceeding by considering differences occurring between regions and different crops.

The results of the study can be used by policy makers and stakeholders to evaluate scenarios and tradeoffs between profitable agricultural production in the region and a sustainable level of water protection and conservation.

The paper is structured as follows. Section 2 depicts the concept of economic value of water and economic approaches to measure it. Section 3 presents the case study region—the US High Plains in the context of crop production conditions. In Section 4, methodology and data are presented with state specific assumptions. Section 5 presents results and a discussion on the shadow price in the analyzed regions as well as a comparison analysis for the Texas High Plains in 2010 and 2011. Section 6 discusses limitations and challenges of the residual valuation methodology. Finally, conclusions and outlook are presented in Section 7.

2. Economic value of water for irrigation—Concept and evaluation approaches

The concept of value of water has been adopted as one of the principles at the 1992 International Conference on Water and the Environment in Dublin that indicated that '*water has an economic value in all its competing uses and should be recognized as an economic good*' (Hanemann, 2006). Some authors define the economic value of water as the amount that a rational user is willing to pay for a publicly or privately supplied water resource (Ward and Michelsen, 2002).

The economic value of water used specifically for irrigation results from the fact that it produces revenue to farmers through their crop production and sales (Nikouei and Ward, 2013). The World Bank has been advocating neoliberalist policies to reform the management of water, particularly in less-developed countries by establishing rational market-based institutions to solve problems of water availability, quality, and access (Euzen and Morehouse, 2011). Also, US EPA (2013) underlined that water is not a one-dimensional commodity and the user's willingness to pay for water from a particular source may depend on water quantity, quality, time, space, and access reliability.

According to US EPA (2013), the future economic value of water will rise, driven by the competition in water allocation between different sectors. This will create even a greater need for decision-makers in the private and public sectors for additional information that can help them maximize the benefits derived from water use. Existing estimates of the economic value of water are relatively few and vary significantly within and across sectors. In 2012, the economic value of water was estimated to amount to \$12–\$4500/acre-foot (af) (\$0.01–3.65/m^3) in the agricultural sector, \$14–\$1600/af (\$0.01–1.30/m^3) in manufacturing, \$12–\$87/af (\$0.01–0.07/m^3) for cooling water at thermoelectric power plants, \$1–\$157/af (0.00–0.13/m^3) for hydropower generation, \$40–\$2700/af (\$0.03–2.19/m^3) for mining and energy resource extraction, and up to \$4500/af (\$3.65/m^3) for public supply and domestic self-supply (US Environmental Protection Agency (EPA), 2012). Several studies evaluated the economic value of irrigation water in the European Union as well as water policies for irrigated agriculture (Gomez-Limon et al., 2002; Gomez-Limon and Riesgo, 2004; Gomez-Limon, 2004). A study by Rigby et al. (2010) for Spain found marginal water values to be typically above those paid by farmers.

Several previous studies analyzed various aspects of optimal irrigation strategies and the economic value of water in the High Plains. For example, according to Schloss et al. (2000) and the Kansas Geological Survey, reductions in authorized water use of at least 75% are needed in many areas of Western Kansas for water use to meet criteria of a sustainable yield. Lilienfeld and Asmild (2007) applied Data Envelopment Analysis to identify farms with the highest irrigation efficiency in Kansas, based on the reduction potential or excess of irrigation water. This paper builds up on the past research in the field and extends the analysis by evaluating the economic value of water in different states of the High Plains and for different crops.

In recent years, most studies have focused on estimating the economic value of irrigation by comparing irrigated versus non-irrigated agricultural production. Only a few recent studies focus directly on the shadow price of water for irrigation (Mesa-Jurado et al., 2012; Hellegers and Davidson, 2010). This paper seeks to fill this theoretical and methodological gap and extend the literature in this field.

3. Case study area—High Plains

The US High Plains are a sub-region of the Great Plains and encompass Wyoming, southwestern South Dakota, western Nebraska, eastern Colorado, western Kansas, eastern New Mexico, western Oklahoma and northwestern Texas (Fig. 1).

Among the High Plains states, Texas, Kansas and Nebraska cover the largest percentage of the area and provide the largest supply of agricultural production in the region. For this reason and also due to data paucity in the other HP states, Texas, Kansas and Nebraska have been selected for the analysis presented in this paper.

In 2007, almost 50% of the area in the HP was used for crop cultivation. The main crops grown in the High Plains are corn, wheat, hay, alfalfa, soybeans, cotton, and sorghum; with corn grown primarily in the Northern High Plains (NHP), wheat in the Central High Plains (CHP), and cotton in the Southern High Plains (SHP) (U.S. Department of Agriculture, 2008).