Ecological Economics 91 (2013) 57–68

Contents lists available at SciVerse ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

The value of agricultural water rights in agricultural properties in the path of development

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ARTICLE INFO

Article history:
Received 10 September 2012
Received in revised form 26 March 2013
Accepted 31 March 2013
Available online 11 May 2013

JEL classification:
Q1
Q15
Q19
R3

Keywords:
Water rights
Hedonic price method
Urbanization
Farmland prices
Elasticity
Marginal-willingness-to pay

ABSTRACT

This paper estimates the value of water rights in a rapidly urbanizing semi-arid area: Phoenix, Arizona. To do this we use hedonic pricing to explore the impact of water rights on property values in 151 agricultural land transactions that occurred between 2001 and 2005. We test two main hypotheses: (1) that the marginal willingness to pay for water rights is higher in more developed urbanizing areas than in less developed rural areas, and (2) that the marginal willingness to pay for water rights in urban areas is increasing in the value of developed land. We find that the marginal willingness to pay for water rights is highest among properties in urbanized or urbanizing areas where a significant proportion of the land has already been developed. Additionally, we find that the marginal willingness to pay for agricultural water rights is greatest in cities where developed land is most valuable.

1. Introduction

Among all the 'ecosystem services' supplied by arid or semi-arid landscapes, water supply is perhaps the most critical. Water is a basic ingredient of life. It is also an essential input in every sector of the economy. In the U.S. Southwest, water demand has changed in response to two sets of drivers. High rates of economic and demographic growth have let to rapidly increasing demand for water for residential, industrial and commercial uses. At the same time, a reduction in production has reduced water demand in the agricultural sector. Between 2000 and 2010, Arizona experienced the second highest rate of population growth in the U.S. after Nevada—24.6% (Bureau of Census, 2010). Average annual rates of employment and output growth in the state, at 10.6% and 20.5% respectively, were not far behind. Most of this growth was concentrated in the area of metropolitan Phoenix. In the same period, a considerable amount of land was withdrawn from agricultural production, and converted to a range of urban uses. We investigate the implications of this phenomenon for the value of water rights held by landowners in the agricultural sector.

Agriculture in the area has historically depended on two sources of water: surface water from the Colorado, Salt and Verde watersheds, and groundwater from the Phoenix aquifer. These two sources of water are separately managed and regulated by the Arizona Department of Water Resources (ADWR, 2010). Each is subject to a different set of property rights. Property rights to extract groundwater include grandfathered irrigation rights (GFRs), Type I non-irrigation rights, and Type II non-irrigation rights (described below). Property rights to extract surface water allow the diversion of in-stream flows or the construction of dams and reservoirs. Many surface water-bodies are subject to open access rights for recreation—the general public is free to boat or canoe in lakes or rivers. However, the right to extract water is generally more well-defined. All rights are assigned by the Arizona Department of Water Resources (ADWR, 2010), or by more local bodies such as irrigation districts.

The nature of water rights in Arizona differs from that in neighboring states. In Colorado, for example, groundwater rights can be bought or sold separately from land (Jenkins et al., 2007). In such systems, the value of a water right will reflect the market equilibrium between local water demand and supply and, if there are no significant

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http://dx.doi.org/10.1016/j.ecolecon.2013.03.024

externalities, will lead to an efficient allocation (Petrie and Taylor, 2007). In Arizona, however, water rights for agricultural uses are appurtenant to the land (they are transferred with the land when it is bought or sold). The result is that a distinct market for groundwater rights has not yet established in the state. The lack of a well-functioning water rights market creates two related problems. One is the difficulty of reallocating water rights based through the market. The other is the absence of price signals of the scarcity of water-rights (Faux and Perry, 1999).

The lack of a price signal for water rights makes it difficult to compare the value of water in areas with different levels of development (e.g. urban versus rural uses) (Brookshire et al., 2004). Yet understanding the marginal value of groundwater water rights in Arizona is critical to the efficiency of water allocation. In this paper we estimate the marginal willingness to pay (MWTP), and the elasticity of marginal willingness to pay, for grandfathered irrigation rights (including Type I water rights[1]) in agricultural areas affected by urban expansion. Most existing studies (Brookshire et al., 2004; Butsic and Netusil, 2007; Crouter, 1987; Faux and Perry, 1999; Jenkins et al., 2007; Petrie and Taylor, 2007) explore the value of irrigation rights in general, but not the difference in the value of rights in urban and rural areas experiencing different levels of development.

We test two hypotheses:

1) that the marginal willingness to pay for water rights should be higher in more developed urban (and urbanizing) areas than in less developed rural areas; and
2) that the marginal willingness to pay for water rights in urbanizing areas should be increasing in the potential for future development.

Implicit in these hypotheses is the assumption that marginal willingness to pay for water rights depends on the spatial location of agricultural properties with respect to urban growth nodes. Also implicit is the assumption that the value of irrigation rights appurtenant to land is derived from their value to land developers. The latter assumption directly reflects the legal water regime.

In 1980, Arizona established five active management areas (AMAs)[2] to protect and conserve groundwater supply. Within these AMAs, residential/commercial developers are required to demonstrate an “assured water supply”. If developers acquire property with groundwater rights they are entitled to extinguish the groundwater right, and convert it to meet water demand for municipal or commercial purpose. Under the assured water supply (AWS) rules, developers of new subdivisions must either obtain a Certificate of Assured Water from ADWR or be served by a water provider with an ADWR-issued AWS designation (Eden and Megdal, 2010). In order to acquire a certificate, developers are required to demonstrate that they have access to a water supply that is expected to be physically, legally, and continuously available for the next 100 years. One way that developers are able to obtain a Certificate of AWS is by extinguishing a grandfathered or Type I water right. Once they extinguish a grandfathered right, water providers or developers are then able to utilize that amount of groundwater for their own purposes.

The groundwater credit obtained through this process allows water to be separated from land, and to be traded in the water permits market. The credit holder can then pump water anywhere within the AMAs for industrial, commercial or residential use (Eden et al., 2008). For this reason groundwater rights (including Type I water rights) can be very valuable to both farmers and residential/commercial developers.[3] Since the value of groundwater for residential/commercial use is typically higher than for agricultural use (Brookshire et al., 2004), the value of groundwater rights on agricultural property located in urbanizing areas is expected to be higher than on agricultural property located in rural areas.

It follows from this that the implicit price of water rights may vary both because of variation in the highest valued use of water (captured in the market), and because of the location of the appurtenant land. In other words, the bundled nature of land and water rights is likely to create significant spatial heterogeneity in the implicit prices of water rights that would not exist if water rights were freely transferable within the connected aquifer. To measure this we estimate a single hedonic price function in which the percentage of developed/undeveloped land, city dummy variables, and water rights are allowed to interact.

2. Agricultural Water Rights Within the Phoenix AMA

2.1. Active Management Areas (AMAs)

The four active management areas authorized under the 1980 Groundwater Code in Arizona are the Phoenix, Pinal, Prescott, and Tucson AMAs (ADWR, 2012). In 1994, the Santa Cruz AMA, which was previously the southeast portion of the Tucson AMA, became a 5th AMA.

Fig. 1 shows the location of AMAs within the state of Arizona. These 5 AMAs include the main urban areas in the state, in all of which groundwater has at various times been pumped at rates greater than the natural recharge rate. When groundwater pumping rates exceed the natural recharge rate, an aquifer is said to experience “overdraft”. Effects of this include changes in the quantity and quality of water in the aquifer, land subsidence above the aquifer, and resulting damage to infrastructures, including oil or water pipelines, roads, railways and canals, and buildings.

For these reasons, groundwater use within the AMAs is subject to more strict and detailed regulation than groundwater outside the AMAs. Within the AMAs, the expansion of irrigated lands is prohibited, and a management plan sets the maximum annual groundwater allotment for irrigation rights (ADWR, 2012). This is calculated by multiplying the irrigation water duty by the farm area. The irrigation water duty is the annual amount of water, in acre-feet, required to produce the crops historically grown during the period 1975 to 1980, divided by an assigned irrigation efficiency. Irrigation efficiency is a measure of the overall effectiveness of water application during a crop season. It is a function of evaporation loss, soil intake rate, water application rate, crop type, and irrigation water management practices (ADWR, 2012). To comply with the AMA management plans, irrigation efficiencies are required to improve over time. In other words, the volume of agricultural water demand is required to decrease over time, even if there is no change in land use. While farmers are entitled to switch from less water-intensive to more water-intensive crops such as alfalfa, vegetables, and rice, they are legally bound by the amount of groundwater extraction specified in the groundwater right, which is regulated by AMA's management plan. The net effect has been a decrease in agricultural demand for water over time.

2.2. Water Uses and Agriculture in AMAs

Rapid urbanization within the AMAs has resulted in a decrease in land committed to agriculture. Nevertheless, the agricultural sector is still the largest single source of water demand within the AMAs—approximately 2.2 million acre-feet of water or 58% of average annual water consumption in the state of Arizona between 2001 and 2005.[4] Among AMAs, the Phoenix AMA is the most populous—accounting for around 75% of all residents in the state. Fig. 2 shows land use in Arizona, the Phoenix AMA being represented by black boundary. It indicates that the Phoenix AMA is also the most heavily developed (shown in dark gray).

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[1] Type I water rights comprise non-irrigation groundwater rights (see more detail in Section 2.3).

[2] Details on AMAs are discussed in Section 2.

[3] There is also another type of groundwater right: the Type II water right. Type II water rights can only be used for non-irrigation purpose such as industry, livestock watering, and golf courses. Type II rights are the most flexible water rights because they are sold separately from the land with ADWR approval. These were not, however, included in our analysis.

[4] All water demand statistics presented here are based on the period of 2001 to 2005 reported in the Arizona Water Atlas Vol. 8 (ADWR, 2012).

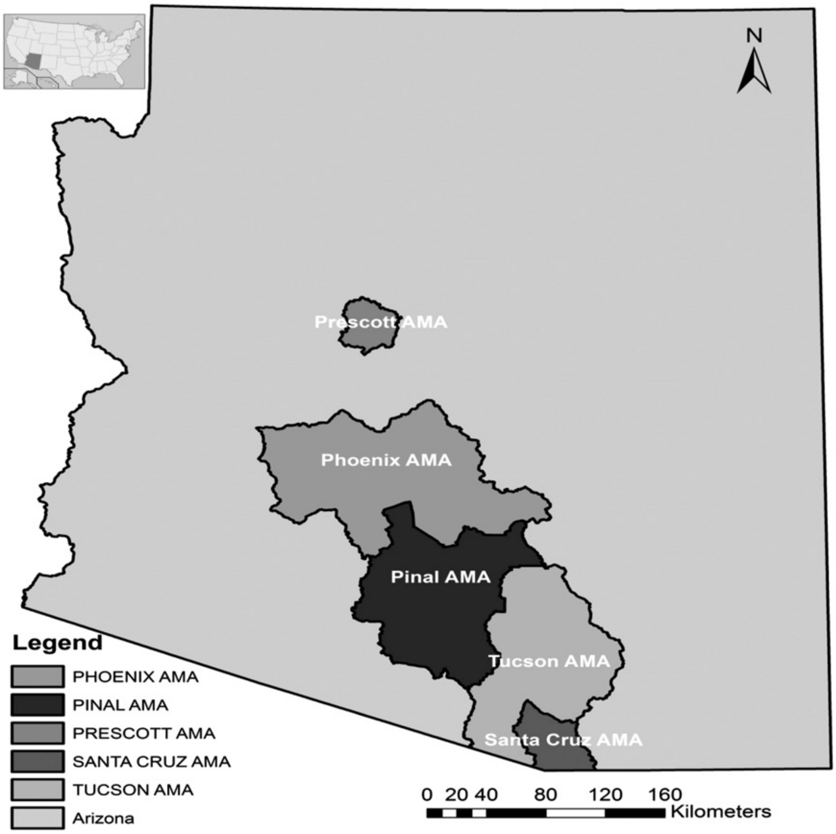

Fig. 1. Spatial location of AMAs in Arizona (created by the authors in GIS).

Paradoxically, the Phoenix AMA also had the largest annual average agricultural demand for water at 1.1 million acre-feet (47% of the total Phoenix AMA demand). Agricultural water demand in the Phoenix AMA is met mostly from groundwater sources (41%). Surface water from the Salt, Verde and Colorado is the second most important source (28%), followed by CAP (Central Arizona Project) (28%), and effluent (3%). To get a sense of the source of agricultural water demand, note that in 2007, 55% of farms in Maricopa County (the location of the Phoenix AMA) were devoted to crop production, and 31% were devoted to livestock. Major crops included forage (90,063 acres), cotton (26,234 acres), vegetables (17,472 acres), wheat (16,386 acres), and barley (14,374 acres). The dominant livestock species were cattle and calves (167,262 acres), followed by bees (17,552 acres), horses and ponies (11,769 acres) (Census of Agriculture, 2007).

2.3. Water Rights in AMAs

We have already noted that the two main sources of agricultural water — ground and surface water[5] — are regulated separately. Surface water refers to waters from all sources, flowing in streams, canyons, ravines or other natural channels, or in definite underground channels, whether perennial or intermittent, floodwaters, wastewaters, or surplus water, and lakes, ponds and springs on the surface (Arizona Revised Statues 45-101). The use of surface water is governed by the doctrine of prior appropriation: “first in time, first in right.” This means that the person who first puts the water to a beneficial use[6] obtains a right that has priority over later appropriators of the water. Prior to 1919 surface water rights could be acquired simply by putting water to beneficial use, and then posting a notice of appropriation. In June, 1919, the public water code, also known as the Arizona surface water code, was enacted. This law required a person to apply for and acquire a permit in order to appropriate surface water. In general, surface water rights — like groundwater right — are appurtenant to the land. However, there are cases where a water right has been severed and transferred to a different location. In such cases, a person must obtain the approval of an irrigation district or water user's association if water is used within their boundary.

Groundwater rights are governed by the groundwater code within the AMAs, and by ‘reasonable use’ outside the AMAs, and are conferred based on irrigation history. As with surface water rights, most groundwater rights are appurtenant to the land. Of the three main types of groundwater rights within the AMAs (GFRs, Type I and Type II), a

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[5] There are three different types of surface water rights: (a) in-stream flow surface water rights, (b) stock-pond surface water rights, and (c) reservoir surface water rights. An in-stream flow right is a surface water right that remains in-situ or “instream”. This water is not physically diverted for consumptive uses. The right aims to maintain the flow of water in-stream in order to preserve wild habitat for fisheries or recreation. Water rights for stock-ponds are required of people who own stock-ponds constructed between June 12, 1919 and August 27, 1977. Landowners with stockponds constructed before June 12, 1919 are entitled to divert water from the pond without a stockpond right. The reservoir permit allows a person to construct a reservoir and divert public surface water in the state unless one of the following applies: (a) the water is from the main stem of the Colorado river, (b) the person or the person's ancestor lawfully appropriated the surface water before June 12, 1919, or (c) the water is stored in a stockpond constructed between June 12, 1919 and August 27, 1977.

[6] Beneficial use includes domestic use, stock-watering, mining, hydropower, municipal use, recreation, fish and wildlife (instream flow), irrigation, etc. All the beneficial uses mentioned here except instream flow are associated with water consumption or diversion of water out of stream. Instream flow that is not physically diverted or consumptively used includes flows necessary to protect and preserve recreation and wildlife habitat. In Arizona, it was recognized in 1983 when the Arizona Department of Water Resources (ADWR) approved instream flow permits and defined an instream flow right as a surface water right that remains “in-situ” or “instream”. Later in February of 1991, the governor of Arizona, Rose Mofford, enacted Executive Order No. 91-6 stating “The state of Arizona shall encourage the preservation, maintenance, and restoration of instream flows throughout the state”.

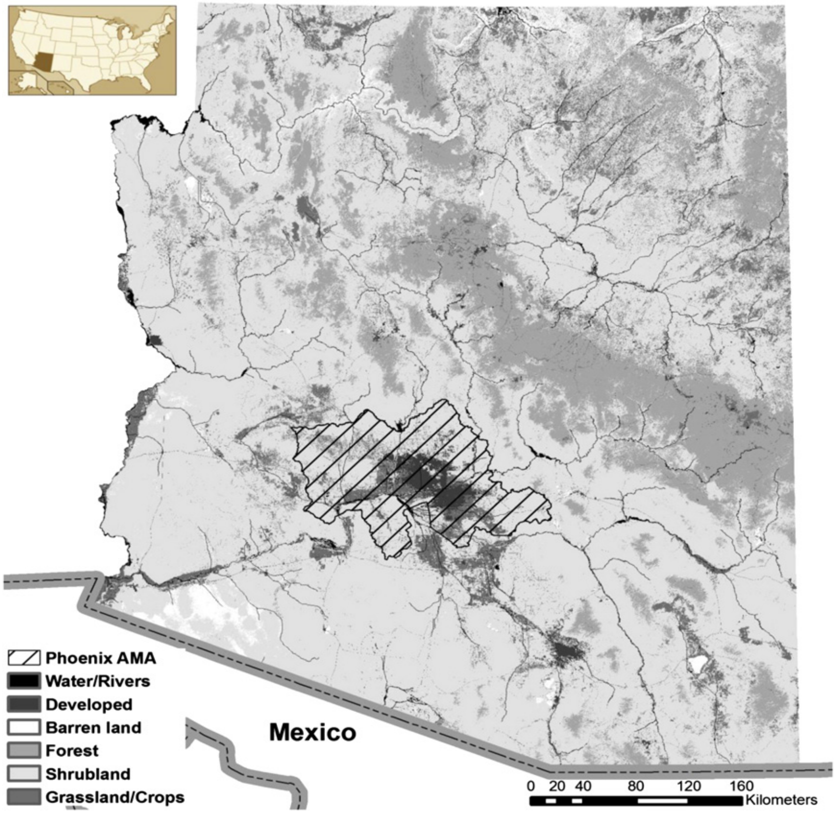

Fig. 2. Land use in Arizona.
Source: 2006 NLCD Land Cover Map.

landowner may acquire a grandfathered right when he or she buys a property that was irrigated[7] with groundwater between 1975 and 1980. This right is permanent, but is extinguished on change of land use (development). It specifies how much groundwater may be withdrawn for irrigation within a property in terms of volume (maximum annual acre-feet of water). Farmers with GFRs can only extract groundwater for irrigation purpose. Type I rights, by contrast, are associated with land permanently retired from farming and converted to a non-irrigation use such as building a new industrial plant, livestock feeding, and dairy. Like GFRs, Type I water rights are, in general, conveyed only with the property. Type II water rights, like Type I water rights, can only serve non-irrigation purpose such as industry, livestock watering, and golf courses. The main difference between Type I and Type II is that Type II water rights are more flexible because they are sold separately from the land with ADWR approval. Type II water rights are not included in this study because they are not attached to the land, and are therefore never bundled with the sale of land.

3. Previous Research on the Value of Appurtenant Water Rights

Hedonic pricing methods have been used to estimate the value of non-marketed environmental attributes in many circumstances. Attributes valued in this way include: open space (Abbott and Klaiber, 2011; Goeghegan, 2002; Goeghegan et al., 2003; Irwin, 2002; Irwin and Bockstael, 2001; Ready and Abdalla, 2005; Sander and Polasky, 2009; Shultz and King, 2001; Weicher and Zerbst, 1973), air quality (Kim et al., 2003, 2010; Zabel and Kiel, 2000), landfill (Hite et al., 2001; Lim and Missios, 2003; Ready, 2010) and noise pollution (Dekkers and Van der Straaten, 2009; Nelson, 2004). The characteristic of all such studies is the use of property transactions in well functioning real estate markets to infer the value of some environmental attribute. A limited number of studies have applied hedonic methods to investigate the value of water or water rights in agricultural land transactions (Butsic and Netusil, 2007; Crouter, 1987; Faux and Perry, 1999; Jenkins et al., 2007; Petrie and Taylor, 2007).

Most of these studies have found that water rights do affect land prices. Table 1 presents an overview of studies that estimate the value of water rights using this method. One study by Crouter (1987) examined the relationship between irrigation water and farmland prices using 57 farm sales in Colorado and found no significant effect of irrigation water. All other studies, however, have found a significant positive correlation between water rights and land prices. Faux and Perry (1999), using 225 farmland sales in Malheur County, Oregon, for example, found values of irrigation water ranging from \$9 to \$44 per acre-foot per annum, depending on land class. Torell et al. (1990) estimated separate hedonic functions for dry land and for irrigated land. While they found that the price differential between those two types of land had diminished over time, they also found that the water value component of irrigated farms accounted for 30%–60% of farmland sale prices. Butsic and Netusil (2007) estimated the value per acre-foot of irrigation water, using 113 farmland transactions for 2000 and 2001 in Douglas County, Oregon. They found that a property with an irrigation water right sold for 26% to 30% more than a property without a water right. They also estimated the value of leasing water using a range of discount rates and leasing periods and found that a farmer would be willing to accept \$5.22 to \$26.1 for a 1-year lease of an acre-foot of water depending on the discount rate used.

Findings elsewhere have been similar. For example, Petrie and Taylor (2007) investigated the value of water rights in the eastern United States, focusing on the impact of a policy change called the "agricultural irrigation permits moratorium". Using 324 farmland sales in the state of Georgia, they found the value of water rights

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[7] Under the Groundwater code, "irrigate" means to apply water to 2 or more acres of land to produce crops for sale or human consumption or as feed for livestock.

Table 1
Overview of previous studies on the valuation of water rights.

	Dependent variable	Main explanatory variables	Study area (study year)	Number of observation (adjusted R square)	Functional form	Main findings
Crouter (1987)	Farmland price/acre	W: Average acre-feet of water delivered to the parcel O: Dummy for the presence of irrigation well	Weld County, Colorado (1970)	53 (0.71)	Box–Cox transformation	There is no significant effect of irrigation water on farmland price. Land and water variables are not separable.
Torell et al (1990)	Dryland farmland price/acre Irrigated farmland price/acre	Yield: Amount of water that would flow by gravity from a cubic foot of bedrock Water: Depth of water available for pumping	Five US states: New Mexico, Oklahoma, Colorado, Kansas, Nebraska (1979–1986)	Dryland model: 6311 (0.61) Irrigated model: 985 (0.74)	Linear	The water value component of irrigated farms comprises approximately 30%–60% of farmland sale prices.
Faux and Perry (1999)	Farmland price/acre	Land class (irrigated or non-irrigated) Soil quality	Malheur County, Oregon (1991–1995)	225 (0.92)	Box–Cox transformation	Values of irrigation water ranging from $9 to $44 per acre-foot per annum, depending on land class
Butsic and Netusil (2007)	Log of farmland price/acre	Water (1 if property has a water right, otherwise, 0)	Douglas County, Oregon (2000–2001)	113 (0.88)	Semi-log	A property with an irrigation water right sold for 26% to 30% more than a property without a water right
Petrie and Taylor (2007)	Log of farmland price	Permit$_{pre}$: 1 if property has an irrigation right before moratorium Permit$_{post}$: 1 if property has an irrigation right after moratorium	Dooly County, Georgia (1993–2003)	324 (not reported)	Semi-log	Irrigation water permits increase in agricultural land value by approximately 30% once access to permits is restricted (permit moratorium).

to be capitalized into farmland prices post-moratorium. However, none of these studies explored the relationship between the value of agricultural water and potential urban development. Our study fills this gap by estimating the value of water rights in areas with different development potentials.

4. Methodology

4.1. Hedonic Price Model

We used the hedonic price method, a revealed preference method for non-market valuation originally introduced by Rosen (1974), to explore the impact of water rights on property values. Agricultural land is considered to have a set of n characteristics, z_1, z_2, … z_n, each of which potentially influences property prices (Palmquist, 1989). Hedonic price functions for agricultural properties are typically estimated by regressing the natural log of farmland prices on farmland characteristics, neighborhood land use characteristics, and locational characteristics. Formally, the specification of this semi-log hedonic model is expressed as follows:

$$\ln P = b_0 + \sum b_k L_k + \sum b_l D_l + \varepsilon \tag{1}$$

where P is a vector of farmland prices per acre; L_k is a matrix of land characteristics including land size, slope, neighborhood land use characteristics, and appurtenant water rights; D_l is matrix of location characteristics such as the distance to the nearest highway or employment center; b_0, b_k, and b_l are estimated parameters associated with the constant in the model, land use and location characteristics; and ε represents unobserved errors.

4.2. Data

The database was constructed from multiple sources. First, information on property prices, the size of farms (acres), and the year of sale, and property use code were collected from the Maricopa County[8] Assessor. In order to match the period of the third groundwater management plan (2000 to 2010), and to avoid the most dramatic part of the housing boom and recession years, we restricted our attention to sales between 2001 and 2005. This also makes the situation simpler since the annual groundwater allotment for each groundwater right is constant within a management plan phase, but increases between management plans. The property use code (PUC) of Maricopa County Assessor allowed us to classify parcels by type of land management. Originally, the database had 8 types of land management: crop field, mature crop field, mature citrus field, high density agriculture, jojoba, ranches, pasture, and fallow land. Of these, crop and livestock production accounted for more than 95% of farms. During preliminary analysis, we found that grandfathered irrigation rights (including Type I rights) were important in crop farms but not in ranches. This is for three reasons. First, ranch properties do not require irrigation water to serve their needs beyond Type I non-irrigation rights.[9] Second, there are few ranches with irrigation and Type I water rights for the period, which makes it hard to tease out the impact of such water rights. Third, crop farms are the dominant type of agriculture in Maricopa County (Census of Agriculture, 2007). Hence, we restricted our attention only to arable properties. The distribution of agricultural property[10] transactions is shown in Fig. 3.

To simplify land classification, we combined crop fields, mature citrus, high-density agriculture, and jojoba, into the category of crop farms. This yielded 1665 observations. We found, however, that in a large number of cases buyers bought a bundle of properties at the same price in the same year,[11] that those properties were contiguous to each other, and that they had very similar characteristics. Treating bundled properties of this kind as many single transactions would pose a serious problem, because it would break the link between parcel's characteristics and its transacted prices in the hedonic model. As a result, all bundled transactions were aggregated. After further excluding other non-arm's length and erroneous transactions, we ended up with 151 cropland sales for analysis. Table 2 shows the

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[8] The Phoenix AMA planning area includes two counties: Maricopa and Pinal County, but Pinal County geographically comprises only 15% of the Phoenix AMA. Maricopa County is representative of the Phoenix AMA since it accounts for 85% of the Phoenix AMA in terms of geographical coverage. Hence, the geographical boundary of the dataset we collected is accordingly confined to Maricopa County.

[9] In the case where ranchers have a mixed crop–livestock farming, access to groundwater for irrigation might play an important role; however, the information on mixed land management was not available.

[10] Parcels included in this study are large farms that do not contain residence.

[11] 159 buyers (mostly agricultural companies) purchased multiple properties, of those 13 buyers purchased more than 10 properties at the same prices in the same year.

steps involved in arriving at the 151 observations used for analysis. The sale price was deflated to 2001 constant prices using the Case–Shiller home price index for the Phoenix market.

The USGS Digital Elevation Model for Maricopa County was used to calculate mean slope, in degrees, for each property. This variable was included to capture the impact of land characteristics that might potentially influence the price of agricultural lands. Location was represented by the log of the Euclidean distance of each property to the nearest major highway. Initially we had calculated travel time over the road network but this proved to be insignificant.

Water rights[12] information was acquired from the ADWR GIS data center. The original shape file contains information both on Type I and grandfathered rights, with the acreage of property attached to each water right. Information on the amount of water involved was manually collected from imaged records managed by ADWR. Finally, year dummy variables for 4 years (2002–2005) were included to capture temporal variation in property prices beyond the appreciation in land values already captured by the Case–Shiller deflation.

Whether neighboring land was developed, in crops, or in natural vegetation indicates whether transacted farmlands were subject to a development pressure. In order to capture the impact of surrounding land cover, the percentage of developed land (DEV3000) and shrubland (SHRUB3000) within a 3000 m buffer of the boundary of each parcel was calculated using the 2001 and 2006 NLCD land cover maps. Changes in land use that occur over time are recorded in five yearly revisions of the land cover maps. In order to reduce the inaccuracy caused by the lack of availability of individual annual maps, properties that were sold in 2001, 2002, and 2003 were matched with 2001 land cover maps, and those that were sold in 2004 and 2005 were matched with the 2006 land cover map. Sensitivity analysis was conducted with different size buffers and revealed that the coefficients on these variables were robust in terms of magnitude and sign up to 3000 m. We initially included a variety of other neighborhood land use characteristics such as the percentage of surrounding land occupied by crop field, open space, pasture and wetland. However, these variables were dropped from the final models because they were consistently insignificant regardless of variations in buffer size. The percentage of developed land was selected to explore the difference in the value of water rights between developed and undeveloped areas. The percentage of land covered by shrub vegetation was chosen as a proxy variable for the soil quality of agricultural land.[13]

Finally, a GIS layer showing the boundary of cities within Maricopa County was obtained from the Institute for Social Science Research at ASU. The file includes more than 20 cities within Maricopa County. However, excluding cities with no observations left us with only 4 major cities: Phoenix, Mesa, Goodyear, and Buckeye. Table 3 displays the statistics of population, average farmland price per acre, the amount of water attached to each farm, average farm size, city surface, and population density (ha) by city.

It shows that population density is higher in Phoenix and Mesa than in other cities. In addition, it shows that urban areas have substantially less water associated with each water right than rural areas. Rural areas engage in more water-intensive activities than urban areas. Finally, it shows that there is a noticeable difference in farmland price/acre across cities. Goodyear had the highest farmland price ($375,561), followed by Mesa ($286,626), Phoenix ($127,912), and Buckeye ($45,096). The average farmland price/acre in rural areas was also significantly lower than farmland prices in all cities except Buckeye.

Higher farmland prices in cities reflect at least two factors. First, agricultural properties in urban areas have a higher probability of being converted to residential or commercial uses than agricultural properties in rural areas. Second, even if the likelihood of conversion was similar between urban and rural areas, land in the urban area would be expected to have a higher value in development due to the existence of cultural amenities and transportation infrastructure, and the availability of public goods like schools and parks. It is not altogether clear why the average farmland price/acre was so much lower in Buckeye than in other cities, although it does correlate with the much lower population density/ha in that city (Table 3). We do not have data on population densities in rural areas within city limits, but it is likely to be similar to that in rural areas.

Table 4 reports summary statistics for the selected variables. The price/acre varies between $3809 and $3,763,111, indicating significant heterogeneity in property prices. In our dataset, 88.1% (133 sales) of croplands had a groundwater or Type I water right at the time of sale. The annual amount of water attached to each water right varied widely across properties, ranging from 11.53 to 131,010 acre-feet.

5. Model Estimation

The selection of the functional form for hedonic price function has been a controversial issue for some time. Table 5 presents an overview of functional forms used in previous studies. Economic theory does not provide much guidance for specifying the appropriate functional form for the hedonic price functions (Faux and Perry, 1999; Palmquist, 1991). Empirically, however, more flexible specifications such as Box–Cox outperform the simpler semi-log model if they include appropriate use of spatial fixed effects (Kuminoff et al., 2010). Given our relatively small and spatially dispersed sample we were unable to utilize extensive spatial fixed effects. We therefore stayed with the semi-log functional form given its ability to outperform more complex specifications in recovering the marginal implicit price in the presence of model misspecification, and the interpretability of its marginal effects (Abbott and Klaiber, 2010; Cropper et al., 1988).

Taking care of the omitted variable bias embedded in hedonic price model has also been a controversial issue between spatial econometricians and experimentalists (Gibbons and Overman, 2012). Spatial econometricians assume that functional forms are known and estimate parameters by using model comparison techniques to select the best performing spatial model. Experimentalists are interested in the causal relationship between outcome and independent variables. However, the small number of observations did not provide us with the flexibility needed to take an experimental approach to deal with the potential for omitted neighborhood variable bias issue. In order to alleviate potential bias associated with omitted spatial variables, we therefore included city dummy variables in our specification. We also investigated whether there was any spatial auto-correlation in prices and unobserved error terms. Moran's I test (Moran, 1950) and LM tests for spatial autocorrelation in neighboring house prices and residuals were performed using a range[14] of distance-based row standardized spatial weights matrix and k-nearest spatial weights matrices. The null hypothesis of no spatial autocorrelation in prices could not be rejected consistently with a p-value greater than 0.16 and the null hypothesis of no spatial autocorrelation in unobserved errors could not be rejected consistently with a p-value greater than 0.4, suggesting that the use of spatial econometric techniques may not be necessary. In addition, as shown in Fig. 3,

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[12] Data for surface water rights were collected from the same source. The geographical boundary for surface water rights was not defined in the shape files, but a point of diversion/use from reservoir or stockpond was provided. We used the existence of points of diversion/use to define dummy variables for surface water rights. However, dummy variable for surface water rights was dropped out of the final model since it was insignificant.

[13] We estimated the preliminary model with more detailed soil quality variables such as % of silt, sands, and organic matters, but they were dropped out of the final model since they were insignificant in all models.

[14] 5–50 nearest neighbors were used as cut-off neighbors for constructing k-nearest spatial weights matrix, and 3000 m–20,000 m was used as cut-off distances for constructing the row-standardized spatial weights matrix.

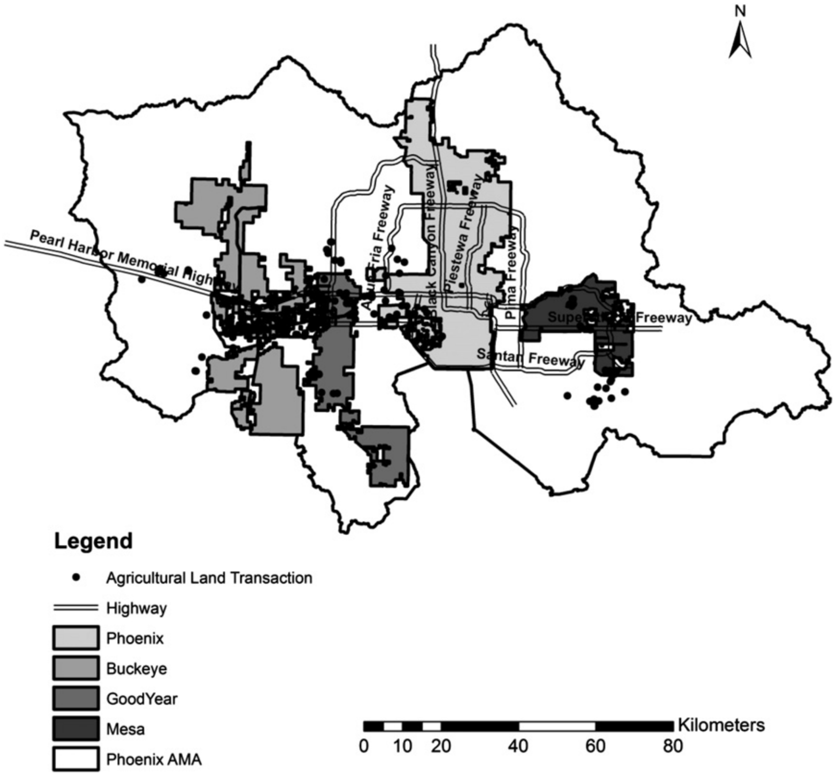

Fig. 3. Spatial location of agricultural farms within the Phoenix AMA. Source: Created in GIS by the authors.

agricultural parcels for our study area were very sparsely distributed across space, which also makes it hard to justify the use of spatial econometric methods.[15]

Three different models were specified as the final hedonic models: a simple baseline model without any interaction terms (MODEL1), a model with interactions between DEV3000 and water rights quantity (MODEL2), and a model with interactions between city dummies and water rights quantity (MODEL3). MODEL2 was estimated to test our first hypothesis that the value of water rights varies between developed and undeveloped areas, and MODEL3 was estimated to test our second hypothesis that the value of water rights varies across cities.[16] In MODEL2, we defined farmland to be 'undeveloped' if there was no developed[17] land within a 3000 m buffer of the boundary of the property; otherwise, we call it 'developed'. Based on this criterion, 139 farmlands (92.1%) were classified as developed and 12 farmlands (7.9%) were classified as 'undeveloped.' This way, we were able to recover MWTP for both developed and undeveloped samples. The range of prices and land sizes was large, indicating the possibility of non-constant errors across observations. To avoid potential heteroscedasticity, robust standard errors were calculated for all models.[18]

6. Results and Discussion

Table 6 reports the estimated coefficients and robust standard errors for the three models. The magnitudes and signs of coefficients are robust across all three and the signs and magnitudes of most variables conform to our expectations. The coefficient on the log of land size was negative and less than unity indicating that the price per acre decreases as total land size increases, ceteris paribus. The negative coefficient on slope is intuitive since steeper properties are less desirable for growing crops—also consistent with previous studies (Grimes and Aitken, 2008). Being nearer to major highways was found to increase the value of land. The coefficient on our proxy for unexploited land (the proportion of land in native vegetation surrounding agricultural properties: SHRUB3000) was negative, but insignificant. Three out of the four year-dummy variables (baseline year: 2001) were found to be significant. In addition, the coefficients on year dummies increased up to 2005, reflecting the fact that the local economy was expanding rapidly up to 2005.

The baseline coefficients on variables involving water rights, the variables of greatest interest for this paper, were found to be positive and significant across all three models. This shows that the presence of legal access to irrigation or non-irrigation water is an important factor in the price of agricultural lands. The coefficients on interaction between land size and water rights (Int_WR_LAND) were negative across all models, indicating that irrigation becomes less valuable on a per-acre basis as land size increases (Butsic and Netusil, 2007). This may also imply that water may be more efficiently allocated on smaller properties. The coefficients on the interaction between water rights and the percentage of developed area turned out to be positive and significant in MODEL2, indicating that an increase in

Table 2
The steps from 1665 to 151 observations.

Original observation	Removing non-arms' length and erroneous transactions	Aggregating bundled transactions	Removing transactions for housing boom and recession years
1665 observations	1607 observations	391 observations	151 observations

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[15] We thank Luc Anselin for this observation.

[16] In early versions of the model a dummy variable for surface water rights was found to be insignificant. Thus, a dummy variable for surface water rights was excluded from the final model.

[17] The developed areas are calculated based on the sum of developed land cover (NLCD classification 22, 23, and 24) within a specified buffer size.

[18] A Breusch–Pagan test (Breusch and Pagan, 1979) was performed to identify the presence of heteroscedastic errors. We found that the null hypothesis of constant error variance was rejected (p-value < 0.001).

Table 3
Population, average farmland price, land size, water amount, average water amount, city surface, and population density by city.

City	Population (2010)	Farmland price/acre ($)	Average water amount per water right (AF/year)	Average farmland size (acre)	City surface (ha)	Urban density (pop/ha)
Phoenix	1,445,632	127,912	1065	46	134,205	10.77
Mesa	439,041	286,626	1156	40	34,285	12.81
Goodyear	65,275	375,561	4216	139	49,522	1.32
Buckeye	50,876	45,096	3155	111	97,660	0.52
Rural	–	115,608	4395	84	–	–
Developed	–	168,068	3152	77	–	–
Undeveloped	–	133,545	7704	213	–	–

Source: 2010 Census of Bureau and author's calculation.
–: not available.

the proportion of developed land within a 3000 m buffer increases the impact of water rights on farmland prices. The coefficients on the interaction between water rights and city dummy variables were significant for Phoenix and Mesa. These effects were generally weak, but the most strongly positive coefficient was associated with Phoenix, followed by Mesa, and Goodyear. The coefficient associated with Buckeye, by contrast, was negative. Positive coefficients imply that the effect of water rights on agricultural land prices is increasing in the cities concerned, and the absolute value of those coefficients indicates that agricultural water rights have the strongest effect in the most developed cities, Phoenix and Mesa. The negative coefficient on Buckeye reflects the fact that the value of land committed for development in that area was less than the value of agricultural land across the whole area.

The partial F-test was conducted to test the null hypothesis of all interaction terms in MODEL2 and MODEL3 being statistically equal to zero against MODEL1. The F-Test1 in Table 6 compares MODEL2 and MODEL3 against MODEL1. The result shows that the null hypothesis is rejected with p-value less than 0.01 for MODEL2 and p-value less than 0.01 for MODEL3, supporting MODEL2 and MODEL3 over MODEL1. The F-test2, showing the comparison between MODEL2 and MODEL3, reveals that there is marginal significant improvement (p-value < 0.1) when moving from MODEL2 to MODEL3. Hence, the parameters from MODEL2 were used to derive the MWTP and price elasticity of water rights between developed and undeveloped areas. The parameters from MODEL3 were used to derive the marginal willingness to pay and price elasticity of water rights across cities.

Given the estimated baseline parameters for water rights, and interaction parameters between water rights and (a) development within a 3000 m buffer or (b) cities, mean willingness to pay for an additional acre-foot of water in rural, developed, undeveloped, and city lands was calculated using the following equations:

$$MWTP_{no\_Dev} = P_{no\_Dev} * \left(\overline{Land_{no\_Dev}} * \beta_{Land2} + \beta_{BaseWR2}\right) \tag{2}$$

$$MWPT_{Dev} = P_{Dev} * \left(\overline{Land_{Dev}} * \beta_{Land2} + \beta_{BaseWR2} + \beta_{\mathrm{int}\_WR\_Dev2} * \overline{DEV3000}\right) \tag{3}$$

where

P_{no_Dev}	mean farmland price/acre for undeveloped area
P_{Dev}	mean farmland price/acre for developed area
$\overline{Land_{no\_Dev}}$	mean farmland size for undeveloped area
$\overline{Land_{Dev}}$	mean farmland size for developed area
β_{Land2}	coefficient on interaction between land size and water right quantity (MODEL2)
$\beta_{BaseWR2}$	baseline coefficient on water right quantity (MODEL2)
$\beta_{int\_WR\_Dev2}$	coefficient on interaction between water right quantity and DEV3000 (MODEL2)
$\overline{DEV3000}$	mean value of DEV3000 for developed area

Table 4
Summary statistics of data.

Variable	Description	151 observations		
		Mean	Min	Max
Sale price/acre	Deflated property price in acre (2001)	$165,325	$3809	$3,763,111
Land size	The size of land in acres	87.70	0.44	1294
Slope	Average slope in degrees	0.396	0	4.708
Ln_Free	Natural log distance to nearest freeway	7.954	4.850	10.178
SHRUB3000	The % of shrub cover within a 3000 m buffer of a boundary of farmland	0.256	0.019	0.910
DEV3000	The % of developed cover within a 3000 m buffer of a boundary of farmland	0.061	0	0.405
WR	Total acre-feet of water in water right (grandfathered right or Type I water right)	3514AF	0	131,010AF
Int_WR_LAND	Interaction between WR and land size	1958,059AF	0	1.70×10^{8}AF
Int_WR_DEV3000	Interaction between WR and DEV3000	77.662AF	0	2552.64AF
Year dummy (base year: 2001)				
YR2001	1 if farm transacted in 2001, else 0	0.113 (17 obs)	0	1
YR2002	1 if farm transacted in 2002, else 0	0.086 (13 obs)	0	1
YR2003	1 if farm transacted in 2003, else 0	0.106 (16 obs)	0	1
YR2004	1 if farm transacted in 2004, else 0	0.205 (31 obs)	0	1
YR2005	1 if farm transacted in 2005, else 0	0.490 (74 obs)	0	1
City dummy (reference: rural)				
Urban	1 if farm transacted in urban areas, else 0	0.503 (76 obs)	0	1
Rural	1 if farm transacted in rural areas, else 0	0.497 (75 obs)	0	1
Phoenix	1 if farm transacted in Phoenix, else 0	0.093 (14 obs)	0	1
Mesa	1 if farm transacted in Mesa else 0	0.113 (17 obs)	0	1
Good Year	1 if farm transacted in Good Year, else 0	0.152 (23 obs)	0	1
Buckeye	1 if farm transacted in Buckeye, else 0	0.146 (22 obs)	0	1

Table 5
Functional form used in previous hedonic studies.

Functional form	Study
Box–Cox transformation	Halvorsen and Pollakowski (1981), Crouter (1987), Faux and Perry (1999), and Nivens et al. (2002)
Linear model	Torell et al. (1990) and Mansfield et al. (2005)
Log–Log model	Conway et al. (2010)
Semi-log model	Butsic and Netusil (2007), Petrie and Taylor (2007), Goeghegan (2002), Sander and Polasky (2009), Poudyal et al. (2009), Ready and Abdalla (2005), and Abbott and Klaiber (2010)
Nonparametric model	Meese and Wallace (1991), McMillen (1996), Parmeter et al. (2007), Kuminoff et al. (2010), and McMillen and Redfearn (2010)

and

$$MWTP_R = P_R * \left(\overline{Land_R} * \beta_{Land3} + \overline{DEV3000_R} * \beta_{\text{int}\_WR\_Dev3} + \beta_{BaseWR3}\right) \quad (4)$$

$$MWTP_C = P_C * \left(\overline{Land_C} * \beta_{Land3} + \overline{DEV3000_C} * \beta_{\text{int}\_WR\_Dev3} + \beta_{BaseWR3} + \beta_{\text{int}\_WR\_City}\right) \quad (5)$$

where

P_R	mean farmland price/acre for rural area
$\underline{P_C}$	mean farmland price/acre for each of city
$\overline{Land_R}$	mean farmland size for rural area
$Land_C$	mean farmland size for each of city
β_{Land3}	coefficient on interaction between land size and water rights quantity (MODEL3)
$\beta_{BaseWR3}$	baseline coefficient on water rights quantity (MODEL3)
$\beta_{int\_WR\_City}$	coefficient on interaction between water rights quantity and city dummies (MODEL3)
$\beta_{int\_WR\_Dev3}$	coefficient on interaction between water rights quantity and DEV3000 (MODEL3)
$\overline{DEV3000_R}$	mean value of DEV3000 for rural sample
$\overline{DEV3000_C}$	mean value of DEV3000 for each of city sample.

In the same way, the price elasticity of the marginal willingness to pay (the percentage change in property price/acre with respect to a 1% increase in acre-feet of water right) was calculated as follows:

$$\varepsilon_{No\_Dev} = WR_{No_{Dev}} * \left(\overline{Land_{No\_Dev}} * \beta_{Land2} + \beta_{BaseWR2}\right) \quad (6)$$

$$\varepsilon_{Dev} = WR_{Dev} * \left(\overline{Land_{Dev}} * \beta_{Land2} + \beta_{BaseWR2} + \beta_{\text{int}\_WR\_Dev2} * \overline{DEV3000}\right) \quad (7)$$

$$\varepsilon_R = WR_R * \left(\overline{Land_R} * \beta_{Land3} + \overline{DEV3000_R} * \beta_{\text{int}\_WR\_Dev3} + \beta_{BaseWR3}\right) \quad (8)$$

$$\varepsilon_C = WR_C * \left(\overline{Land_C} * \beta_{Land3} + \overline{DEV3000_C} * \beta_{\text{int}\_WR\_Dev3} + \beta_{BaseWR3} + \beta_{\text{int}\_WR\_City}\right) \quad (9)$$

where

WR_{No_Dev}	mean value of water rights (WR) for undeveloped areas
WR_{Dev}	mean value of water rights (WR) for developed areas
WR_R	mean value of water rights (WR) for rural areas
WR_C	mean value of water rights (WR) for each city
$\beta_{\text{int}\_WR\_City}$	coefficient on interaction between water rights quantity and city dummies(MODEL3).

The 95% confidence intervals for both marginal willingness to pay and elasticity estimates were then generated using the Monte-Carlo simulation method proposed by Krinsky and Robb (1986). The procedure generates 10,000 random variables from the distribution of the estimated parameters and calculates 10,000 marginal willingness to

Table 6
OLS, OLS + interaction hedonic models (dependent variable: log price/acre).

Variable	MODEL1: OLS	MODEL2: OLS with interactions (WR and DEV3000)	MODEL3: OLS with interactions (WR and city dummy)
Constant	13.230 (0.856)[b],***	13.685 (0.838)***	13.245 (0.835)***
Ln(Land Size)	−0.282 (0.078)***	−0.355 (0.082)***	−0.384 (0.093)***
Slope	−0.674 (0.177)***	−0.635 (0.176)***	−0.608 (0.174)***
Ln_Free	−0.237 (0.091)***	−0.275 (0.087)***	−0.237 (0.087)***
DEV3000	1.869 (1.366)	1.004 (1.279)	0.954 (1.358)
SHRUB3000	−0.192 (0.495)	−0.308 (0.496)	−0.147 (0.586)
WR(Water Right)	$\mathbf{2.8 \times 10^{-5}}$ $\mathbf{(9.2 \times 10^{-6})}$***	$\mathbf{9.6 \times 10^{-5}}$ $\mathbf{(2.0 \times 10^{-5})}$***	$\mathbf{8.9 \times 10^{-5}}$ $\mathbf{(1.9 \times 10^{-5})}$***
Int_WR_LAND	–	$\mathbf{-6.7 \times 10^{-8}}$ $\mathbf{(1.6 \times 10^{-8})}$***	$\mathbf{-5.1 \times 10^{-8}}$ $\mathbf{(1.4 \times 10^{-8})}$***
Int_WR_DEV3000	–	$\mathbf{7.1 \times 10^{-4}}$ $\mathbf{(3.1 \times 10^{-4})}$**	$\mathbf{1.4 \times 10^{-4}}$ $\mathbf{(3.2 \times 10^{-4})}$
Phoenix	–	–	−0.132 (0.387)
Mesa	–	–	0.426 (0.356)
Good Year	–	–	0.549 (0.362)
Buckeye	–	–	0.189 (0.322)
Phoenix_WR	–	–	$\mathbf{4.9 \times 10^{-4}}$ $\mathbf{(1.3 \times 10^{-4})}$***
Mesa_WR	–	–	$\mathbf{2.0 \times 10^{-4}}$ $\mathbf{(9.9 \times 10^{-5})}$**
Good_Year_WR	–	–	$\mathbf{9.0 \times 10^{-6}}$ $\mathbf{(2.2 \times 10^{-5})}$
Buckeye_WR	–	–	$\mathbf{-8.2 \times 10^{-7}}$ $\mathbf{(4.3 \times 10^{-5})}$
YR2002	−0.334 (0.351)	0.374 (0.355)	0.486 (0.389)
YR2003	0.628 (0.336)*	0.602 (0.341)*	0.567 (0.380)
YR2004	0.854 (0.274)***	0.771 (0.285)***	0.781 (0.292)***
YR2005	0.725 (0.234)***	0.732 (0.245)***	0.715 (0.262)***
R^2	0.3734	0.4213	0.4819
SSE	162.528	150.122	134.391
DF	10	12	20
Partial F-test1	–	5.6608[a],***	2.7008***
Partial F-test2	–	–	1.8875*

Reference year dummy variable: 2001.
Reference city dummy variable in MODEL3: rural.

[a] The number represents the F-statistics derived from Partial F-test.

[b] The number inside the bracket represents the robust standard errors.

* Significance at 10% level.

** Significance at 5% level.

*** Significance at 1% level.

pay estimates and elasticities for both samples. Then the 95% confidence interval bounds were obtained from the 2.5 and 97.5% empirical percentiles of the resampled estimates. The estimated means and sampling errors of elasticity and marginal willingness to pay for developed and undeveloped samples were summarized in Table 7. From it, the null hypothesis of equality of marginal willingness to pay and elasticities between developed and undeveloped samples were tested via 2-sample T-statistics. These showed that marginal willingness to pay was significantly higher for developed land (\$23.09, p-value < 0.0001) than for undeveloped land (\$10.91, p-value < 0.0001). In the same way, Table 8 reports the estimated means and sampling distributions of elasticities and marginal willingness to pay across cities. Those values were calculated based on parameters obtained from MODEL3. The null hypothesis of the equality of elasticities and marginal willingness to pay across cities was also tested. We found marginal willingness to pay to be significantly higher for land in Phoenix and Mesa than for rural properties. The estimated mean marginal willingness to pay was highest for Mesa (\$89.52), followed by Phoenix (\$76.60). The opposite is true for the price elasticity of marginal willingness to pay. Elasticities were found to be higher for undeveloped land (0.63%) than for developed land (0.43%), and elasticities in rural areas (0.41%) were found to be higher than Mesa (0.36%). Two factors might explain this. First, Table 3 shows that farmland prices/acre were higher for developed than for undeveloped land, and were higher for all cities except Buckeye than for land in rural areas. At the same time, the amount of water attached to each water right was highest in undeveloped and rural areas. It follows that agricultural water rights would be expected to explain a larger portion of farmland prices in rural/undeveloped area relative to urban/developed area. At the same time the potential for future development contributes more to farmland prices/acre in developed/urban areas.

Using the estimated coefficients from MODEL2 and MODEL3, we calculated the predicted farmland price between agricultural properties with and without water rights at the mean values of all dependent variables. Table 9 presents the comparison of predicted farmland price/acre for land in developed, undeveloped and rural areas, and for land in two major cities.

We found that the average farmland with water rights in developed areas sold for \$7631 more than the average farmland without water rights, while the average farmland with water rights in undeveloped areas was worth \$6760 more than average farmland without water rights. We also found that average farmland with water rights in Phoenix and Mesa was worth \$30,072 and \$24,387 more than the same farmland without water rights, while average farmland with water rights in rural areas was worth \$5036 more than the same agricultural farmland without water rights.

To see how this compares to previous findings, note that Butsic and Netusil (2007), in their study of the valuation of water rights, found that the presence of water rights increased farmland price/acre from 26 to 30%. Petrie and Taylor (2007) found that the presence of a water right increased property values by approximately 30% when access to water permits was restricted. Finally, Torell et al. (1990) discovered that the water value component of irrigated farmland transactions ranged from 30 to 60% of total farm sale price. In our study, agricultural properties with water rights were priced between 28 and 87% above those without water rights. Of course, the results from abovementioned studies should be interpreted and compared with those from ours with caution because situation, geographic location and other characteristics of the area vary across studies. However, our results are still comparable to others, the water right component of farmland price in other studies falling within the range observed in our study.

Table 7
The comparison of elasticity and MWTP between developed and undeveloped areas.

	Elasticity (% increase in price/acre with respect to 1% increase in water right)	MWTP (\$)/additional 1 acre foot of annual water attached to a water right
Developed	0.43 (0.26–0.61)	23.09 (\$13.82–\$32.57)
Undeveloped	0.63 (0.32–0.93)	10.91 (\$5.61–\$16.11)

Number inside the bracket represents 95% confidence interval generated from Monte-Carlo simulation.

Table 8
Comparison of elasticity MWTP across cities.

City	Elasticity (% increase in price/acre with respect to 1% increase in water right)	MWTP (\$)/additional 1 acre foot of annual water attached to a water right
Phoenix	0.64 (0.34–0.93)	76.60 (41.17–111.62)
Mesa	0.36 (0.09–0.63)	89.52 (22.41–155.63)
Rural	0.41 (0.21–0.60)	10.67 (5.65–15.72)

Number inside the bracket represents 95% confidence interval generated from Monte-Carlo simulation.

7. Summary and Policy Implications

To summarize, we investigated the impact of groundwater rights on farmland prices using the hedonic price method, and focusing on the difference in the value of water rights between urban and rural areas, and developed vs undeveloped areas. First, we used city dummy variables and their interaction with water right quantity to explore the difference in the value of water rights between more developed urbanizing areas and undeveloped rural areas. We found that the value of water rights is significantly higher in major cities such as Phoenix and Mesa than in rural areas. Second, we investigated the value of water rights in areas with different degrees of development using the proportion of developed land cover in the neighborhood of property as a proxy. We found that the value of water rights is highest for parcels that are surrounded by more developed land.

Water rights are capitalized into the value of both urban and rural lands. We found that water rights in urbanizing areas are worth 3–8 times as much as water rights in rural areas, a significantly greater range than has been observed in other studies (see for example, Brewer et al., 2007). Since other studies have not investigated the effect of water rights on property values in rapidly urbanizing/urbanized areas, however, this is not surprising.

The critical factor in central Arizona is the obligation on developers within the active management areas (AMAs) to demonstrate sufficient water to support a growing population for the next 100 years. This is what drives the growth in the value of water rights in urbanizing areas. Our results on the effect this has on property

Table 9
Difference in predicted farmland price/acre at the mean values of all independent variables.

	Predicted price with water right (\$)	Predicted price without water right (\$)	Difference in predicted price (\$)	Difference in percentage (%)
MODEL2				
Developed	34,908	27,277	7631	28
Undeveloped	18,326	11,566	6760	58.5
MODEL3				
Phoenix	64,762	34,690	30,072	86.7
Mesa	82,945	58,558	24,387	41.7
Rural	23,326	18,290	5036	27.5

values have implications for a number of bodies concerned with the management of water resources: urban/city managers and residential/commercial developers, and the Arizona Department of Water Resources (ADWR).

For urban/city managers, for example, an understanding of the capitalized value of water rights in urban–rural fringe areas, as well as across different cities, should help in setting property taxes more efficiently. Property taxes in Maricopa County are calculated by multiplying the assessed value of properties by the tax rate in that year. The assessed value of agricultural lands reflects the existence of water rights in addition to land area, land use and so on. However, water rights are not taxed separately. Given their critical importance to the development of the region it would be desirable to tax water rights at a different rate from land.

For residential/commercial developers an understanding of the land price elasticity of water rights in any given location is a guide to the expected value of converted land/water right bundles in that location. For ADWR there are two potential benefits. First, the amount of irrigation water available through permits is historically determined by ADWR with the aim of conserving future groundwater supplies and promoting the economic development of Arizona. We show that while the absolute value of the premium per acre-foot of water rights was lower in rural than in urban areas, land price elasticity of water rights was higher in rural areas. Understanding the difference in land price responses and the value of the premium per acre-foot of water rights between urban and rural areas could help ADWR set the quantity of water rights so as to better approximate an efficient allocation. Specifically, if land prices change with conversion to urban use and with the allocation of appurtenant water rights, then the optimal change in appurtenant water rights should reflect both the reallocation of land to urban use and the ratio of the marginal impact of conversion and water rights on land prices.

More generally, information on the marginal willingness to pay for water rights should also help the development of an efficient water rights market in Arizona. Since groundwater rights may be converted into groundwater credits at the time of land development, and since these could potentially be separately traded in a water rights market, information on the marginal willingness to pay for water rights could provide a useful guideline for setting the base price of groundwater credits. We would expect the efficient market price of groundwater credits to reflect degree of development in a location. While we are not able to say exactly how much the market price of groundwater credits would be expected to increase with future development, our estimates indicate a reasonable baseline for the cities included in our study.

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