Spatial Aggregation and the Value of Natural Capital

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ABSTRACT

The appropriate spatial scale at which to measure the value of natural capital has received scant attention despite rapidly growing interest in valuing natural capital. Perhaps this is because valuing natural capital is associated with wealth accounting, and that wealth accounting has been strongly associated with national accounts. Yet, appropriate valuation methods reflect the scale of the relevant economic jurisdiction, or geographic extent of the population of individuals who value a resource. Important differences in value can arise depending on the aggregation scale and method chosen when natural capital asset values and prices are aggregated across areas with high variability in economic values, preferences, or other characteristics that pertain to local resource use and scarcity. Theory provides two results relevant to the choice of spatial scale. First, spatial heterogeneity of resource characteristics can impact approximations of the value function and accounting price for a resource because spatial aggregation generally implies greater arbitrage opportunities and reduced scarcity. Second, aggregation of observed values across variation in resource and institutional characteristics leads to a selection bias. These results apply to abiotic and biotic natural capital assets. We explore the value of groundwater in the Kansas High Plains Aquifer across five groundwater management districts (GMDs) to test this theory. We demonstrate a less elastic accounting price for groundwater aggregated by GMD than by aggregation across the entire state. Choosing the appropriate scale across which to aggregate natural capital has implications for the calculation of national aggregates of natural capital and some reproducible capital assets.

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INTRODUCTION

Manufactured, reproducible, or financial capital assets can often be aggregated independent of their spatial distribution. Spatial arbitrage for these forms of capital carries low transaction and transportation costs. Summing, for example, the value of all sewing machines in the United States at the census tract, county, or state level would yield identical results with respect to the wealth stored in sewing machines. The value of some forms of reproducible capital, like roads or bridges, however, can potentially vary by aggregation scale or method. Roads and bridges are not so easily reallocated. The value of the marginal bridge in New York may be different than the value of a similar bridge in Wichita.

Location matters for natural capital valuation. Like bridges, many forms of natural capital can be extremely costly or impossible to arbitrage across space. Methods of aggregation for natural capital need to reflect the weak arbitrage opportunities for these assets since the value of natural capital is often spatially fixed. Aggregation method and scale are important determinants of the value and accounting price of natural capital assets. Spatial heterogeneity of resource stocks, in combination with weak arbitrage opportunities, creates variation in relative scarcity across space. This variation means that aggregation method and scale impact the asset accounting (shadow) price elasticity with respect to the available resource stock.

Valuing natural capital is closely associated with wealth accounting (World Bank 2011; UNU-IHDP and UNEP 2014; Hanley, Dupuy, and McLaughlin 2015; Hamilton and Ruta 2009; Arrow et al. 2012). This literature focuses on national accounts with a few important exceptions that focus on regional applications (Dovern, Quaas, and Rickels 2014; Pearson et al. 2013; Yun et al. in press). Yet, the correct spatial scale to measure the components of such accounts has yet to be addressed. More generally, the spatial aggregation of natural capital values is a crucial but rarely addressed issue in practice (Whittington and MacRae 1986). The literature mostly focuses on determining per-unit values under various accounting and institutional frameworks for wealth accounting and natural capital valuation, with the hope that well-estimated local values can be applied across locations with similar characteristics through benefits transfer, much like environmental values used in benefit-cost analysis (Boyle et al. 2010). This technique may be justified by the high-cost of obtaining location specific data and the similarities between locations across which a particular value is applied (Costanza et al. 1997; Plummer 2009). However, benefit transfer, or even benefits function transfer may not be appropriate where location characteristics vary across space for benefit-cost analysis (Loomis 1992), and similar principles likely apply in natural capital valuation for wealth accounting. The spread of values in the literature for similar resources is often attributed to a lack of consensus methodology for the valuation of natural capital stocks (Guerry et al. 2015), but the spread of marginal values could just as easily be attributable to assumptions about spatial aggregation. The treatment of relative scarcity may be as important in natural capital valuation as refinements to methodology.

Nonmarket valuation of natural capital should reflect the scale of the relevant economic jurisdiction, or geographic extent of the population of individuals who value a resource (Loomis 2000; Smith 1993). The economic jurisdiction is an abstract area that can be estimated empirically by finding the distance at which individuals are unwilling to pay for a resource, though in reality need not be a contiguous shape (Bateman et al. 2006). Smith (1993) articulates this point: "Definitions of the extent of the market are probably more important to the values attributed to the environmental resources as assets than any changes that might arise from refining estimates of per-unit values."

Some frameworks for natural capital valuation use political or regulatory jurisdictions as guiding principles for aggregation, however, political designations seldom coincide with their economic counterparts (Bateman et al. 2006). Often, political boundaries straddle or bisect ecological boundaries and natural areas across which aggregation is incommensurate (van den Bergh and Verbruggen 1999).

The choice of economic jurisdiction must be carefully considered where there is a high degree of spatial variation of resource stocks and characteristics as the value of natural capital is operationalized for policymaking. Variation in resource availability and flows of benefits from resource use across space can lead to differences in estimated resource values and accounting prices under the assumptions embedded in different aggregation decisions. Relative scarcity within regions, the availability of substitutes, and the costs of, or opportunities for, arbitrage are a few characteristics that could drive a wedge between the sum of the parts and the value of the whole for spatially dependent natural capital. Summing the values of regional resource stocks captures spatial variation differently than constructing a representative value function to determine the value of the aggregate stock level across economic jurisdictions.

FRAMEWORK

Fenichel and Abbott (2014) provide a link between the inclusive wealth theoretical framework established by Arrow et al. (2004); (2013) and the available empirical tools for measuring the changes in the quantities of natural capital stocks and the flows of benefits from these stocks (ecosystem services). The Fenichel and Abbott treatment is consistent with Jorgenson's (1963) capital theoretic framework. This natural capital pricing approach provides accounting prices that are reflective of the implied scarcity of the resource stock and are applicable even under imperfect management by non-optimizing institutions and is applicable to biotic and abiotic stocks of natural capital.

The crux of the approach is an implicit relationship between the accounting price, p, the change in resource stock growth rate, $MG(s) - MHI\big(s, x(s)\big)$, the marginal growth rate and the marginal human impact, and the flow of marginal net benefits or marginal dividends from that resource, $MD\big(s, x(s)\big)$.

$$p(s) = \frac{MD\big(s,x(s)\big)+\dot{p}(s)}{\delta-\big[MG(s)-MHI\big(s,x(s)\big)\big]} \tag{1}$$

The accounting price can be approximated using a Chebyshev polynomial over a given resource stock range using functional approximation techniques. Yun, Fenichel, and Abbott (2016) developed a software package to implement this approximation.

Following the wealth accounting (Dasgupta and Mäler 2000; Arrow et al. 2013; Mäler 1991) and natural capital asset pricing (Fenichel and Abbott 2014; Fenichel et al. 2016b) literatures, given the stock of a resource in a given year, $s(t)$, we can describe the flow of net benefits derived from a resource given some societal characteristics Ω, as $W(s(t), x(s(t); \eta); \Omega)$ where $x(s(t); \eta)$ provides the economic program of resource use as a function of its availability, given characteristics of the economic program η. The value of a quantity of natural capital at time t is the present value of future benefits from the resource given by:

$$V(s(t);\phi) = \int_t^{\infty} W(s(\tau), x(s(\tau);\eta);\Omega)e^{-\delta(\tau-t)}\,d\tau \tag{2}$$

where $\phi = \{\eta, \Omega\}$, the collection of characteristics that dictate the dividends function and economic program of resource use, including resource characteristics and societal constraints.

The marginal change in this intertemporal welfare function, $V(s(t),\phi)$, for a change in stock is defined as the asset price:

$$\frac{\partial V(s(t),\phi)}{\partial s(t)} \equiv p(s(t),\phi) \tag{3}$$

To build intuition for how spatial heterogeneity in characteristics can alter functional approximations, consider an arbitrary function, for example, the intertemporal welfare function $V(s,\phi_i)$ for a fixed level of s, which gives the value of a specific resource stock level with a location specific characteristic ϕ_i (Eq. 2). Jensen's inequality states that if a function, V, is strictly concave in a parameter ϕ, then $\frac{V(\phi_1)+V(\phi_2)}{2} < V(\frac{\phi_1+\phi_2}{2})$ for $\phi_1 \neq \phi_2$. Whether or not $V(\frac{\phi_1+\phi_2}{2})$ is bounded between $V(\phi_1)$ and $V(\phi_2)$ depends on assumptions about the shape of V.

Suppose ϕ represents local availability of substitutes for a resource. Greater substitutability drives the value function and accounting price to be more elastic across stock levels. Furthermore, heterogeneity of resource characteristics can lead to selection bias in estimating values and accounting prices for natural capital.

CASE STUDY: GROUNDWATER IN KANSAS

Fenichel et al. (2016b) use the natural capital asset pricing framework embodied in Eq (2) in an application by estimating changes in the value of groundwater in the Kansas High Plains Aquifer (KHPA) from 1996-2005. They implicitly assume that the relationship between the stocks of groundwater at each well and the characteristics of the field irrigated by the well to the water withdrawal and crop choice decisions do not vary across the state. The statewide applications illustrated a mechanism for credible valuation of groundwater as a natural capital asset. However, there is substantial spatial variation across Kansas in the quantity of groundwater available and the benefits derived from its use. The KHPA system provides an empirical illustration of the importance of assumptions about spatial aggregation for determining the value and accounting price of natural capital. One can observe the impact of aggregation assumptions by comparing the shadow price of groundwater as determined by a statewide analysis to the average shadow price of groundwater as determined within each of five groundwater management districts about the KHPA. Analysis of the role of heterogeneity in recovering accounting prices suggests that unique value and accounting price functions approximated for each GMD better reflects local relative scarcity of the resource. Restricting measurement to groundwater management districts reduces the implicit arbitrage opportunities for capital made by aggregating at the state-wide level.

Groundwater is an important natural resource and, in the case of Kansas, is useful as a case study because the rich data lets us investigate issues of spatial aggregation. Groundwater resources are also of interest in their own right. Groundwater is the single most extracted resource on the planet (Todd Jarvis 2012). The United States extracts over 378.5 million cubic meters of water per day for irrigation and agriculture, accounting for 10% of global groundwater use (Maupin et al. 2014). The High Plains Aquifer is vital to agricultural production in the heartland of the United States and underlays eight states including 30,500 square miles of the state of Kansas (Dugan, McGrath, and Zelt 1994). The KHPA supports the congressional district with the highest market value for agriculture in the nation (Steward et al. 2013) and 99% of groundwater extracted from the KHPA is used for agriculture (Pfeiffer and Lin 2010). Nevertheless, insights from this illustrative example apply broadly to valuing abiotic and biotic natural capital.

THEORETICAL RESULTS

Fenichel et al. (2016a) assume that $\phi_i = \phi_{state}$ for $i = 1,2,3,\dots 5$. This implies that $V(s(t),\phi_1) = V(s(t),\phi_2) = V(s(t),\phi_{state})$. Proposition 1 is an illustration of this assumption.

Proposition 1: Homogeneous characteristics generate the same value functions

Let $V(S_i,\phi_i)$ represent the intertemporal welfare function over a set of stocks S distributed across region i with characteristics ϕ. Where $s \in S$, is a resource stock level in set S.

Two identical regions (i.e. $\phi_1 = \phi_2$) with identically distributed stocks, $S_1 = S_2$, will have identical intertemporal wealth functions, $V(S_1,\phi_1) = V(S_2,\phi_2)$.

The proof here is trivial. Under this assumption, observing the value of stock level s in region 1, $V(s,\phi_1)$ provides information about (identifies) the value of that same level of stock in region 2, $V(s,\phi_2)$ without observing s in region 2. ■

Proposition 2: Greater substitutability makes the value function and price function more elastic to stock levels

Proof: Regions differ in their characteristic set described by a parameter ψ within the vector of characteristics ϕ. Changes in ψ affect the elasticity of V with respect to s for any parameter change other than affine transformations.

Therefore, ψ measures of the elasticity of substitution for the capital stock s. Greater values of ψ imply greater opportunities for substitution and smaller values of ψ imply fewer opportunities for substitution of s.

The local curvature of the intertemporal welfare function $V(s,\psi)$ can be defined by that function's elasticity, $\frac{d\ln V(s,\psi)}{ds} = \frac{V_s s}{V(s,\psi)} = \frac{ps}{V(s,\psi)}$. The interesting case is when $V_s > 0$ and $V_{ss} < 0$ so that s is scarce.

For the intertemporal welfare function, $V(s,\psi)$, assume there exists a point $s = s_0$, such that $V_s(s_0,\psi) = V_s(s_0,\psi')$, implying the price curves are not parallel, and that $V_s(s_0+\epsilon,\psi) > V_s(s_0+\epsilon,\psi')$ for $\epsilon \in R^+$ and $V_s(s_0-\epsilon,\psi') > V_s(s_0-\epsilon,\psi)$. Assuming V is globally concave and that $V(s,\psi)$ and $V(s,\psi')$ have the same functional form $\forall s$, then there can be at most one point s_0, if $V(s,\psi) \neq V(s,\psi')$. This implies $\frac{dln\left(V_s(s,\psi)\right)}{ds} > \frac{dln\left(V_s(s,\psi')\right)}{ds}$ $\forall s$, or equivalently, $\frac{V_s(s,\psi)}{V(s,\psi)} > \frac{V_s(s,\psi')}{V(s,\psi')}$. ■

As an example consider

$$V(s,\psi) = \frac{s^{1+\psi}}{1+\psi}. \tag{4}$$

This implies that $V_s(s,\psi) = s^\psi$ and $\frac{d\ln(s^\psi)}{ds} = \psi s^{-1}$ (Fig 1& 2). Therefore, $\frac{d(\psi s^{-1})}{d\psi} = \frac{1}{s}$, which satisfies the above conditions.

Corollary 2.1 Wealth equals welfare if and only if V is linear in s.

Notice that if the elasticity of the intertemporal welfare function equals one, then the marginal value of the capital stock equals the average value of capital stock and wealth, ps, is exactly equal to welfare, V. In this case, V must be linear in s, have no curvature, and price, V_s, is constant irrespective of s. For this to be true there must be a perfect substitute for s irrespective of the stock size of s. This leads to the price taking notation in traditional measures of wealth.

Proposition 2 exemplifies that heterogeneity in resource characteristics can give rise to heterogeneity in value and price functions. Under these assumptions observing $V_1(s_0)$ does not inform $V_2(s_0)$. Measurements of $\dot{s}$, the change in stock level over time, and the flow of benefits from having s units of natural capital, given by $W(s(\tau), x(s(\tau); \eta(t)); \Omega(\mathrm{t}))$, are samples. The approximation for the natural capital pricing approach using Chebyshev polynomials requires N observations of $\dot{s}$ and flows of benefits to identify an $N-1$ degree approximating polynomial for V (Fenichel and Abbott 2014). If there are two distinct value functions across which the estimation occurs corresponding to two regions with differing characteristic sets ϕ, then each value function will be less precisely estimated than a similar case with identical characteristic sets $\phi = \bar{\phi}$, where $\bar{\phi}$ represents the representative characteristics across both regions. This is because each of the two value functions with characteristics $\phi_1 \neq \phi_2$ will be estimated with a strict subset of the data that was used to estimate a single value function over a homogeneous region with characteristics $\phi = \bar{\phi}$.

Proposition 3: The assumptions $\phi_1 = \phi_2$ and $S_1 \neq S_2$ are mutually exclusive given arbitrage.

Proof: Consider the setup explored in Proposition 1 where two identical regions (i.e. $\phi_1 = \phi_2$) with identically distributed stocks, $S_1 = S_2$, have identical intertemporal wealth functions, $V(S_1, \phi_1) = V(S_2, \phi_2)$. Retain that $\phi_1 = \phi_2$, but assume the distribution of capital within each region differs so that $S_1 \neq S_2$. Assuming that $\phi_1 = \phi_2$, implies that observing the value of an arbitrary stock level s in region 1, $V(s, \phi_1)$ provides information about (identifies) the value of that same level of stock in region 2, $V(s, \phi_2)$ without observing s in region 2.

With different distributions of stocks S_1 and S_2, in the extreme case they are non-overlapping. The image of S_1 provides information about a portion of the domain of V, and the image of S_2 provides new information about a different portion of the domain of the same intertemporal welfare function V.

With arbitrage opportunities between regions, it cannot be true that $\phi_1 = \phi_2$ that $S_1 \neq S_2$ implies $V_1 = V_2 \; \forall \, s$. If Region 1 has more capital than Region 2, Region 2, by definition, has greater substitution opportunities, $\psi_1 > \psi_2$ as s_2 is a substitute for s_1 and therefore $\phi_1 \neq \phi_2$, which is a contradiction. ■

Corollary 3.1 and 3.2: Approximations of Value Functions and Price Functions across Heterogeneous Characteristics are Subject to Selection Bias

Under the strong assumptions of Proposition 3, each region is differentiated only by distribution of resource stocks. Regional characteristics are heterogeneous with differently distributed resource stocks, aggregate approximations of the value function (and price function) based on pooled observations from $S_1,\ S_2$ suffer from selection bias compared to approximations of regionally specific value functions V_1 and V_2.

To demonstrate the corollary to Proposition 3, consider two regions with price functions, $p_1(s) = p_a$ and $p_2(s) = p_b$. If one perfect observation in each region is collected, $p_1(s_a) = p_a$ and $p_2(s_b) = p_b$, assuming a single price function will yield an aggregate approximation $\hat{p}_{agg}(s) = \frac{p_a+p_b}{2}$. This is equivalent to approximating the regions separately, estimating $\widehat{p_1}(s) = p_a$, $\widehat{p_2}(s) = p_b$ and deriving $\hat{p}_{regional}(s) = \frac{\widehat{p_1}(s)+\widehat{p_2}(s)}{2} = \frac{p_a+p_b}{2}$

Suppose one additional observation is added in region 2 at stock level s_c where $p_2(s_c) = p_2(s_b) = p_b$. We obtain $\hat{p}_{agg}(s) = \frac{p_a+2p_b}{3}$, whereas by region we approximate $\widehat{p_1}(s) = p_a$, $\widehat{p_2}(s) = \frac{p_b+p_b}{2} = p_b$ and find $\hat{p}_{regional}(s) = \frac{\widehat{p_1}(s)+\widehat{p_2}(s)}{2} = \frac{p_a+p_b}{2}$. The divergence between $\hat{p}_{regional}(s)$ and $\hat{p}_{agg}(s)$ after the addition of an additional observation illustrates the sensitivity of the aggregate approximation to data selection. The approximation that fails to account for regional heterogeneity here suffers from selection bias. Note that if $p_a > p_b$ then $p_2 < \hat{p}_{agg} < \hat{p}_{regional} < p_1$ in this case. Given $p_b > p_a$, the relationship inverts to $p_2 > \hat{p}_{agg} > \hat{p}_{regional} > p_1$. Provided the additional observation was from region 1, the relationship between $\hat{p}_{agg}$ and $\hat{p}_{regional}$ inverts.

Replacing the above example with observations on the price curve $V(s)$, by induction demonstrates that the value function approximation can also be sensitive to selection bias (Corollary 3.2).

Graphically, consider two value functions $V(s,\phi_1)$ (solid blue curve), $V(s,\phi_2)$ (solid red curve) (Fig 3), and their associated price functions $p(s,\phi_1), p(s,\phi_2)$ (Fig 4). Take $V(s,\bar{\phi})$ as the average of the value functions and price functions (dotted black curve). Suppose we observe a subset of potential observations for $V(s,\phi_1)$, $p(s,\phi_1)$ and a different subset of observations for $V(s,\phi_2)$, $p(s,\phi_2)$. Let filled in circles represent observed data and the unfilled circles represent data unobserved. The dashed lines represent the linear approximations of the value and price functions. The dot-dashed lines represent the average of the linear approximations for $V(s,\phi_1)$ and $V(s,\phi_2)$ (Fig 3) and $p(s,\phi_1)$ and $p(s,\phi_2)$ (Fig 4). Compared to the true averages, the average of the approximations of the value and price functions (dot-dashed lines) differs from the approximations of the true value and price function observations (dashed black lines).

A simple average of prices in two different regions is only appropriate if the regions contain the same quantity of resource stock when moving from regionally aggregated price curves and value functions to ones for the state. A more appropriate statewide price function is a weighted average of the regional price curves given the relative quantity of stock in each region as the weights.

AGGREGATION OF VALUES ACROSS THE KANSAS HIGH PLAINS AQUIFER

Fenichel et al. (2016) determined the capital asset value of groundwater in the Kansas High Plains Aquifer (KHPA), though they implicitly assumed that resource characteristics were heterogeneous across the state and by Proposition 1, assumed and approximated a single value function for all of Kansas. To explore the impact of varying the spatial aggregation of the value of natural capital, we use Fenichel et al.'s (2016) groundwater dataset for the KHPA using a ten year data series from 1995-2006 including well-head and agricultural data from the Kansas Water Information Management and Analysis System (WIMAS), the United States Department of

Agriculture Economic Research Service, and the Kansas State University Agricultural Extension (Pfeiffer and Lin 2014; Pfeiffer and Lin 2012).

The KHPA groundwater system is well suited to explore the impact of aggregation method on the value of a natural capital asset stock given that the state contains five distinct groundwater management districts. Groundwater management districts (GMDs) were established through the authority of the 1972 Kansas Groundwater Act in response to groundwater depletion in the KHPA (Sophocleous 2000). Since its passage, five GMDs were formed, with the three western districts (GMD 1,3,4) over the Ogallala proper, which contains 70% of wells in our dataset and a majority of the high capacity wells in the state. These western districts also have the lowest recharge rates in the state (Hansen 1991) and in combination with the number of wells, suffer the most groundwater depletion. For these districts, restricting withdrawals to recharge rates was deemed to be too harmful to the local economy and instituted a policy of planned-depletion, allowing 40% of the remaining aquifer to be depleted over the next 20-25 years (Sophocleous 2000). GMD 4, however, seeking to increase the economic life of the aquifer implemented a policy in 1991 limiting new wells to pumping at average recharge rates. In addition to this policy, the western GMDs have generally closed new appropriation of groundwater by restricting new wells to the less depleted and high saturated thickness locales (Sophocleous 2000). This illustrates that there is substantial institutional variation across Kansas in addition to variation in the physical quantity of the resource. Both types of variation are important for valuing natural capital assets.

CASE STUDY METHODS

We follow Fenichel et al.'s (2016) approach to determine the value of a marginal increase in the per acre stock of water in the KHPA by mapping the groundwater system to the natural capital pricing theory developed by Fenichel and Abbott (2014) and using Equation (1) to approximate the accounting price of an acre-foot of groundwater in the KHPA.

Following Pfeiffer and Lin (2014) and Fenichel et al. (2016), the components of the accounting price are approximated as drawdown of groundwater, which lead to the marginal human impact (MHI) and marginal net benefits or marginal dividends (MD) from the extracted groundwater in terms of profits from crops in each region. MHI, and MD are assumed to be conditional on the quantity of groundwater, s, and the economic program of groundwater extraction at a given stock level, $x(s)$.

To recover the economic program, a vector, $\boldsymbol{APF}(s)$, representing the expected acres of a representative field planted in wheat, corn, soy, sorghum, alfalfa, or unirrigated, given the stock of groundwater at a well-head is estimated using a multinomial logit model for the various crop mix types encoded in the agricultural data, and a matrix of the acreage allocations for each crop mix designation (Fenichel et al. 2016b).

We follow Pfeiffer and Lin (2014) and estimate water withdrawal for a representative acre at a given stock level, $x(s)$, using Lee's generalization (Lee 1990) of Amemdiya's two-stage estimator. Following Fenichel et al (2016) we work in logs rather than levels:

$$x(s) = \frac{e^{\alpha+\beta s+\boldsymbol{APF}(s)\boldsymbol{\gamma}_{\mathbf{1}}+\boldsymbol{APF}(\boldsymbol{s})^{2}\boldsymbol{\gamma}_{\mathbf{2}}}}{\sum_j APF_j} \tag{4}$$

β is the estimated coefficient for water in the aquifer, $\boldsymbol{\gamma_1}$ and $\boldsymbol{\gamma_2}$ are vectors of coefficients for acres planted in each of the crops modeled, and α is a constant including all other explanatory variables evaluated at their means and adjusted for the log transformed estimation.

We use crop-choice and water withdrawal estimation results along with the R package, capN (Yun, Fenichel, and Abbott 2016), to recover realized shadow prices for groundwater.[1] The capN package implements the Chebyshev polynomial approximation method in Fenichel et al. (2016). We assume the discount rate is 3%, following the recommendation of The US Office of Management and Budget (OMB 2003).

Groundwater stock is defined as the thickness of the saturated zone multiplied by a local estimate of specific yield of the aquifer at each well head (Haacker 2016), and the groundwater stock varies widely across the state with mean 22.2 acre-feet (AF) and standard deviation 16.5. The five groundwater management districts are distributed over the KHPA and cover the areas of highest groundwater well density, about 93% of the observations in the WIMAS dataset are within water management districts. Each district manages the groundwater resources in their local area under separate management plans (McGuire et al. 2003).

Our district-level examination involves the characterization of regional water withdrawal curves, $x_i(s)$ and regional crop-choice models for management district $i = 1,2,3,4,5$. The sixth region in this analysis represents the outgroup of wells that lie within Kansas, but outside of a management district. The water withdrawal estimation and accounting price curves for the outgroup are evaluated using the statewide parameters.

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[1] http://environment.yale.edu/profile/eli-fenichel/software

The value of the water at the well-head by this approach reflects regional crop-choice decisions and water withdrawal rates, a more granular scale than the statewide crop-choice and water withdrawal model estimated in previous work. For a fixed amount of available groundwater different GMDs face different local water scarcities. These different levels of scarcity result from different water availability, reflecting heterogeneity in environmental conditions, and varying crop choice and water withdrawal profiles, reflecting heterogeneity in institutions and preferences. This relative scarcity is reflected in the accounting price and the ability to find substitutes is reflected in the elasticity of the accounting price for an acre foot of water (as explored in Proposition 2). For this example, if the characteristics that influence crop choice and water withdrawal are not spatially heterogeneous, the approximations of groundwater accounting price is expected to converge to the original statewide approximation. The regionally aggregated price and value functions are averaged, unweighted and weighted by the number of observations in each region, to depict statewide value and price functions that reflect aggregation that is sensitive to regional characteristics.

We expect that there is directionality associated with the selection bias in water wealth approximations. This contrasts with the theory presented above that shows the impact of selection bias on price could occur in either direction (Proposition 3). One would expect a region with greater resource availability to have a lower accounting price value at its average resource stock level than the accounting price of the same quantity of a resource realized in a region with less resource availability on average. Thus, aggregation across the larger area would result in a less elastic price curve than aggregating within each region.

RESULTS

The five groundwater management districts illustrate spatial heterogeneity in water availability, well-level characteristics and crop choice profiles across the state of Kansas (Table 1). The mean groundwater availability for a representative acre in groundwater management district 1 (low) is 8.3 (AF) with a standard deviation of 6.4 AF, while in district 3 (high), the mean is 30.0 AF with standard deviation 18.9 AF.

Moving groundwater is expensive. For municipalities, the energy costs alone of pumping water can account for over a third of total energy expenditures. A district level approach to groundwater valuation recognizes that water transfers across districts may involve nontrivial transaction costs (Rosegrant and Binswanger 1994). The spatial heterogeneity of groundwater and costs of arbitrage across the KHPA suggest, by Proposition 3, that groundwater shadow prices differ across the state. The statewide crop choice model, dictating $\boldsymbol{APF}(\boldsymbol{s})$, coupled with regional water withdrawal parameters α and β, estimates regional variation in water withdrawal across the KHPA. In addition to the regional differences in groundwater availability and management institutions, there exists spatial heterogeneity in crop choice across GMDs. These crop choices are consistent with water availability and other local conditions. The most water scarce district has the lowest mean alfalfa acreage planted and the smallest fraction of each field planted in alfalfa (<1%).

Figure 5 shows the variation in the water withdrawal function across the management districts with a single crop choice model applied across districts. The dotted red curve represents the simple average water withdrawal function across the six management districts. The dotted black line represents the average water withdrawal function weighted by the relative number of observed wells in each region. Regional mean water availability for each district is marked on each curve, with values corresponding to Table 1. The weighted average and state water withdrawal functions given the same economic program of crop choice across districts are nearly identical, however, the simple average of the GMD water withdrawal functions corresponds to 13% less water withdrawn at the statewide mean water availability level, a difference of 0.3 AF/acre. GMD water withdrawal using the statewide crop choice parameters varies from the state aggregated water withdrawal approximation by up to an acre-foot of water per acre.

Estimating crop choice parameters for each groundwater management district allows the economic program within each management district to vary. This accounts for local institutions and cultural norms as well as market access and biophysical conditions. Fields in different districts with the same stock of groundwater plant different crop mixes (Fig 6). Using GMD crop choice parameters results in a different rank ordering of water withdrawal functions (Fig 7). The weighted average and state water withdrawal functions given regional crop choice parameters diverge and the simple average of the GMD water withdrawal functions is closely aligned with the state water withdrawal function. The weighted average water withdrawal function now estimates more water withdrawal relative to the statewide estimated model. GMD water withdrawal using the GMD crop choice parameters varies from the state aggregated water withdrawal approximation by up to two acre-feet of water per acre.

Including regional crop choice models changes the rank ordering of the water demand functions (Fig 7) as crop choice is a substitute for groundwater in net revenue generation. Hoyt and Pfeiffer (1985) concluded that irrigation systems and crop choices may change as a result of groundwater withdrawal over time (Sloggett and Dickason

1986). This tradeoff is captured in regional water withdrawal and crop choice models for GMD 2 and GMD 5. GMD 2, GMD 5 and the state share similar mean groundwater stocks, about 21 AF/acre. Using a state crop choice model, water withdrawal is approximated to be 1.85 AF/acre for GMD2, 2.30 AF/acre for GMD5, and 2.83 AF/acre for the state. When analyzed using management district crop choice parameters GMD 2 extracts 0.05 less AF/acre, GMD 5 extracts 1.71 more AF/acre, and the state estimation is unchanged. Figure 8 shows the differences between the water withdrawal functions estimated using the state crop choice and GMD crop choice parameters, illustrating the change in the elasticity of water withdrawal with respect to groundwater stock that is expected from the theory developed earlier due to spatial variation in local availability of groundwater and institutions.

Different water withdrawal functions based on regional crop choice decisions imply different profit functions for each GMD. The profits, change in stock, and water withdrawal by (1) allow accounting price curves to be approximated for each region following Fenichel and Abbott (2014); Fenichel et al. (2016b). The accounting prices at the regional mean groundwater levels with a statewide crop choice model range from \$9.64/AF (GMD 2) to \$11.28/AF (GMD 1). However, the accounting price range for the mean water availability spans \$4.29/AF in GMD 4 to \$20.41/AF in GMD 1 with regional crop choices included (Table 2, Fig 9, Fig 10).

Different GMDs withdraw different amounts of water with a single statewide crop choice model, but have very similar accounting price curves (Fig 9). Introducing GMD specific crop choice parameters leads to a divergence in the GMD accounting price curves (Fig 10). We can conclude from this institutional heterogeneity leading to crop choice parameters that are spatially heterogeneous characteristics in this system, ϕ_i, that drive variation in groundwater value and accounting prices across space.

Figure 11 depicts the difference between GMD accounting prices with statewide crop choice parameters and prices with regional crop choice parameters. Positive curves in this figure represent price curves for regions that have a lower accounting price with regional crop choice parameters than with statewide parameters.

GMD 3, which has the highest mean water availability and contains the most wells in the dataset, has very elastic accounting price curve with respect to groundwater stock. The simple average of the price curves with regional crop choice parameters (dotted red curve, Fig 10) illustrates the theoretical finding that accounting for spatial heterogeneity with respect to substitutability of resource stocks can impact the elasticity of the regionally aggregated price function. Here, the average of the GMD price curves is more inelastic relative to the statewide price curve (solid red curve). The weighted average GMD price curve reflects impact of unbalanced samples across management districts. Weighting by the number of well-observations in each region lowers the average price curve and increases its elasticity relative to the simple average as GMD 3, the district with the most elastic and second lowest price curve, contains nearly half of the total observations across the state of Kansas (Table 1).

Policy decision making in Kansas occurs at the GMD and State levels. Therefore, it is important to determine the appropriate scale for aggregating natural capital. All else equal, the resolution at which characteristics that determine the value of groundwater are uniform would be a first-best aggregation scale. It is not guaranteed, however, that data at this scale are available or rich enough to identify crop-choice and water withdrawal parameters. The management district scale is certainly one political jurisdiction at which it may be appropriate to estimate the value of groundwater. Ideally the management district value should be used within each management district, to provide the best approximation of the marginal value of groundwater *in situ*. In the case of Kansas, it appears local institutional variation is more important than physical variation in the aquifer. For statewide policies, however, the weighted average of the management district values by the number of observations in each district is a better approximation than the statewide estimated value due to spatial heterogeneity in resource characteristics like substitutability. Even with a statewide crop choice model and almost identical accounting price curves across the regions using a GMD-aggregated pricing approach to value changes in the KHPA over the period 1996-2005 results in approximately 80% more water value lost than aggregating value changes using statewide water withdrawal parameters. Wells in GMD 3 with regional water withdrawal characteristics and statewide crop choice parameters withdraw more water than the representative well for the entire state (Fig 5). Aggregating at a higher resolution accounts for the higher withdrawals in GMD 3 and more water withdrawn, with similar accounting price schedules reflects a greater loss in water value over the period.

DISCUSSION

Natural capital is often difficult to arbitrage spatially. Therefore, accounting prices need to be recovered locally and aggregated. The Kansas High Plains Aquifer exhibits spatial variation in resource stock distribution (Table 1) and economic program characteristics (Figs 8 and 11) that lead to a divergence in groundwater value and accounting price approximations when aggregated at the regional level. Reflecting local economic values and preferences in Kansas is important for determining accounting prices and value changes across the state. Local economic values and preferences for agriculture across the KHPA, however, are comparatively homogeneous in the context of statewide agricultural production, or more broadly in the context of natural capital stock distribution and use. Water use in Kansas doesn't vary as widely (Fig 6) as in California, for example, where top agricultural commodities span nuts, grapes, berries, citrus, and livestock (National Agricultural Statistics Service 2012) and residential, commercial, and industrial water users all exert nontrivial water demand. Yet, the Kansas example shows that even small differences in regional preferences, characteristics, or values can lead to a divergence in values estimated via aggregation at different scales.

Gehlke and Biehl (1934) noted a related problem in spatial aggregation, the Modifiable Areal Unit problem (MAUP). They explored the tendency for correlation coefficients to increase in size as the units of census tract areas increased in size and found that various methods of spatial aggregation had considerable influence on the magnitude of the correlation coefficient between male juvenile delinquency and home rental values. Gehlke and Biehl ask whether a geographical area is an entity possessing traits, or merely one characteristic of a trait itself.

The MAUP suggests that aggregation using jurisdictions of different sizes can influence the estimation of results across heterogeneous landscapes. Briant, Combes, and Lafourcade (2010) confirm that in the context of economics, the MAUP matters especially when dependent and independent variables are aggregated on different scales. Where arbitrage of natural capital is costly, aggregation of values at large scales commutes values freely across space that resource stocks would otherwise seldom be exchanged. This is effectively what Briant et al. caution against: aggregation of inputs and outputs, dependent and independent variables, at different scales.

The importance of properly considering methods of aggregation across spatial heterogeneity in resource characteristics is agnostic to measurement error and selection bias. Selection bias in natural capital value approximations taken at large scales may persist across broader applications of capital asset pricing. Choosing the appropriate scale across which to aggregate natural capital could impact national aggregates of natural and potentially fixed capital. National aggregates of production and consumption provide measures of the economic activity of a country, however, they do not include many components of well-being. Over the past 30 years, various frameworks have been devised to operationalize natural capital for wealth accounting and policy decision-making. To address the gap between measures of economic activity and well-being, a suite of more inclusive metrics has been devised including Systems of National Accounts (SNA) and the Inclusive Wealth Index. As these are rarely applied at the sub-national level, considerations of economic jurisdiction should be included when aggregating values or performing benefits transfer across the heterogeneous landscapes encompassed within many national borders.

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Seong Do Yun, Eli Fenichel and Joshua Abbott contributed towards creating the R package, Capn, that readily implements the capital asset pricing approach.

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FIGURES

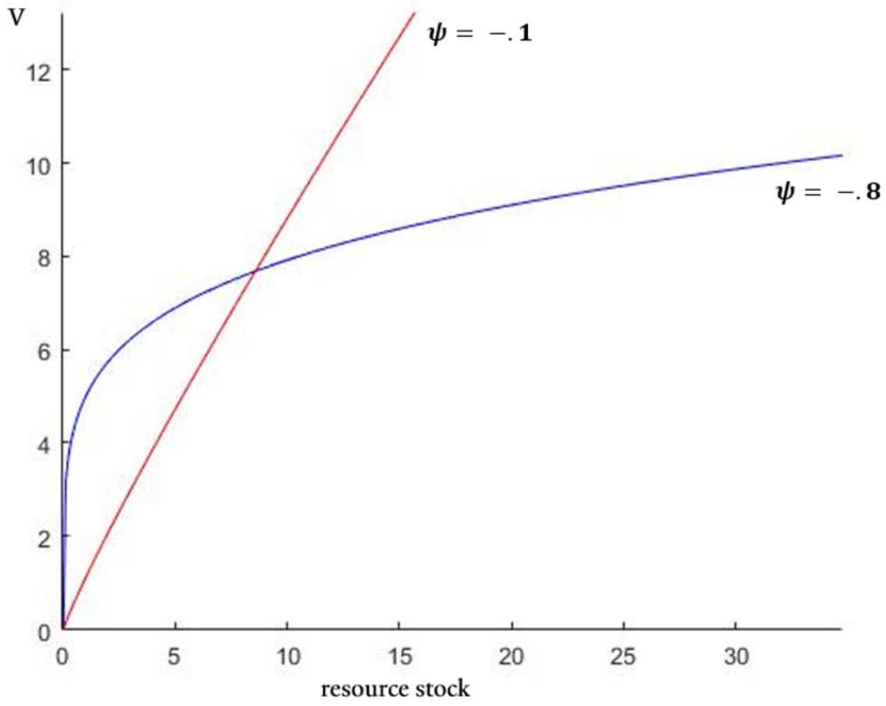

Figure 1: Heterogeneity in Resource Characteristics Can Influence Resource Value

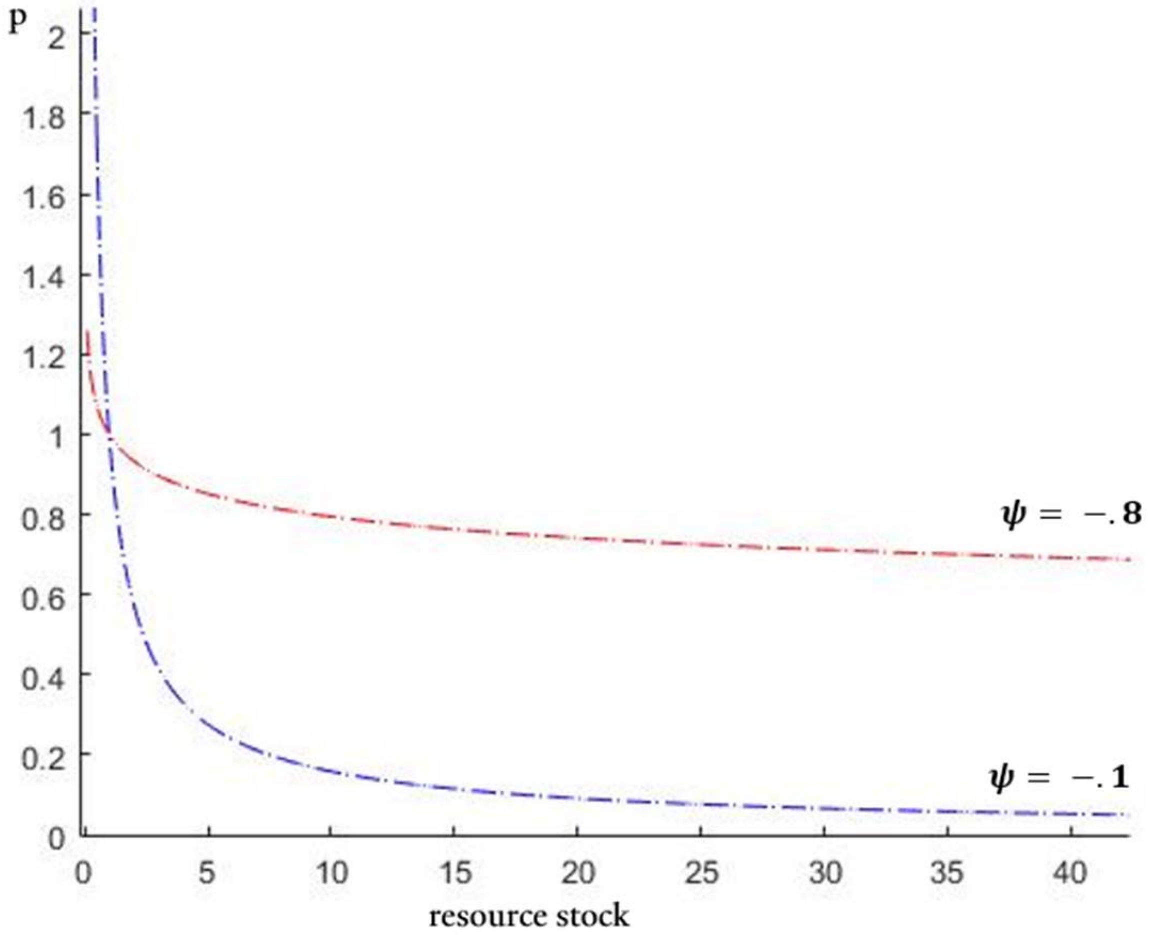

Figure 2: Heterogeneity in Resource Characteristics Can Influence The Accounting Price of a Resource

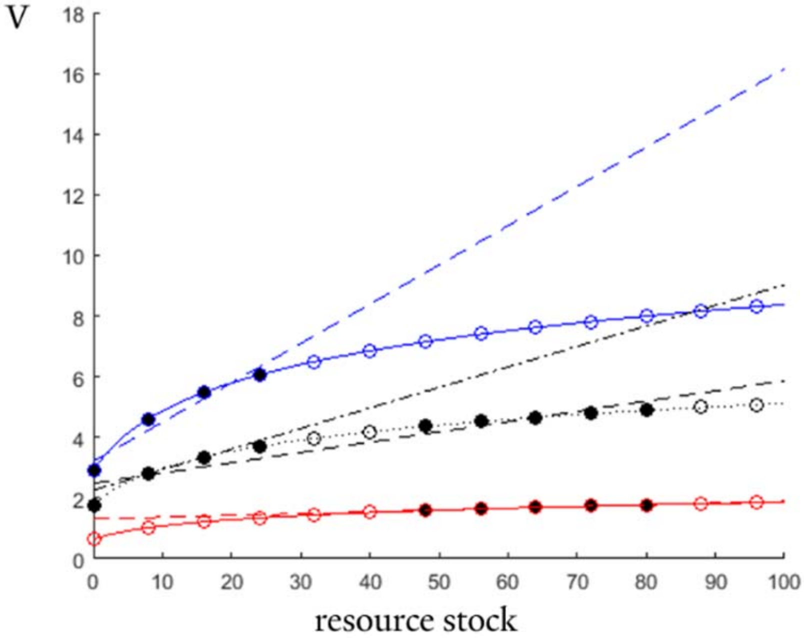

Figure 3: Selection Bias in Resource Value Approximation

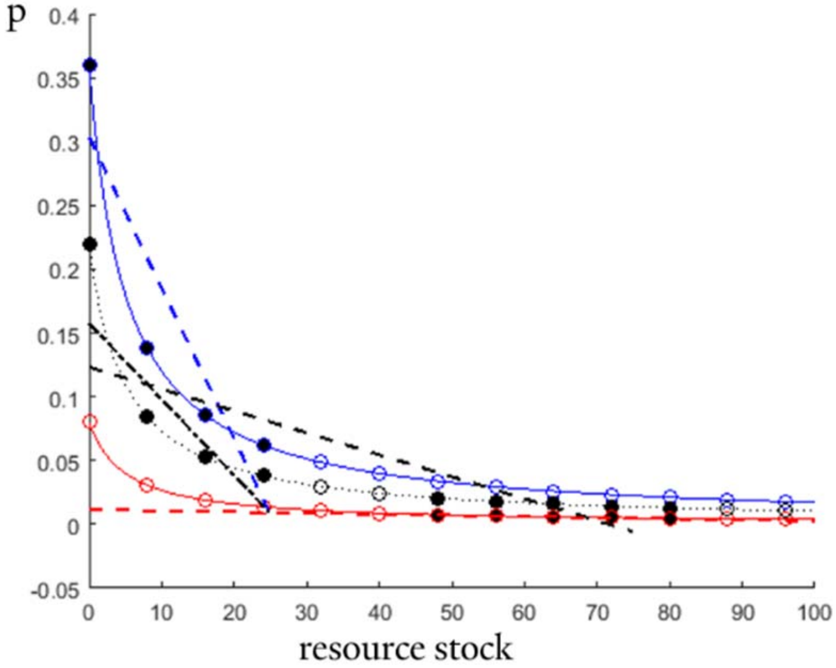

Figure 4: Selection Bias in Resource Price Approximation

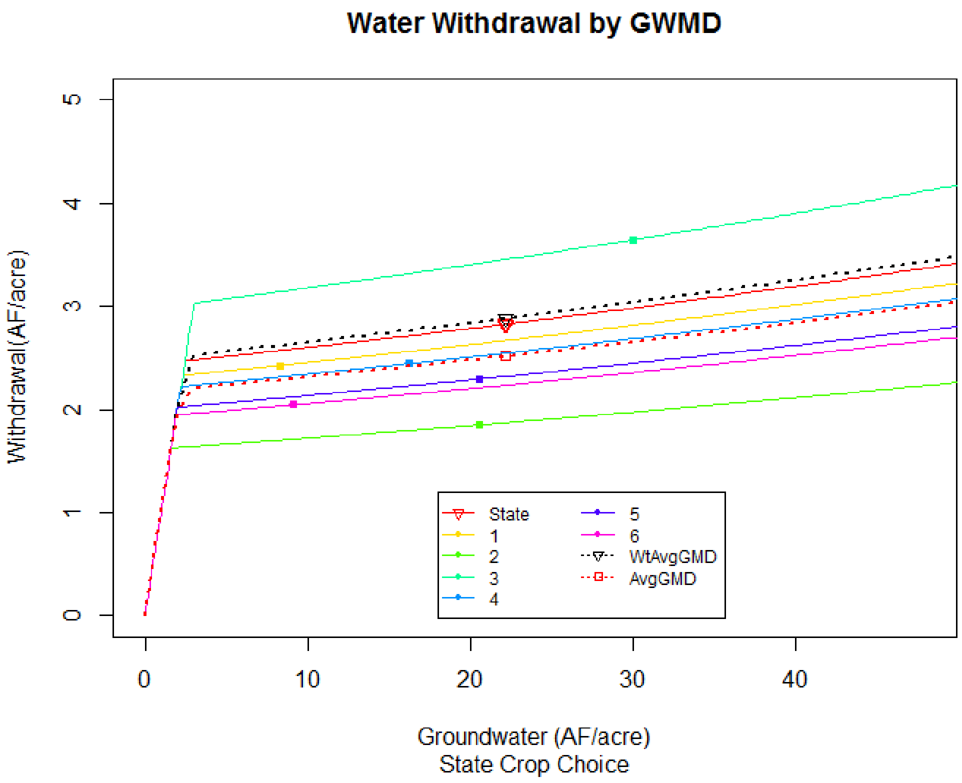

Figure 5: Water Withdrawal Functions by GMD with Regional Water Withdrawal Parameters and Statewide Crop Choice Parameters

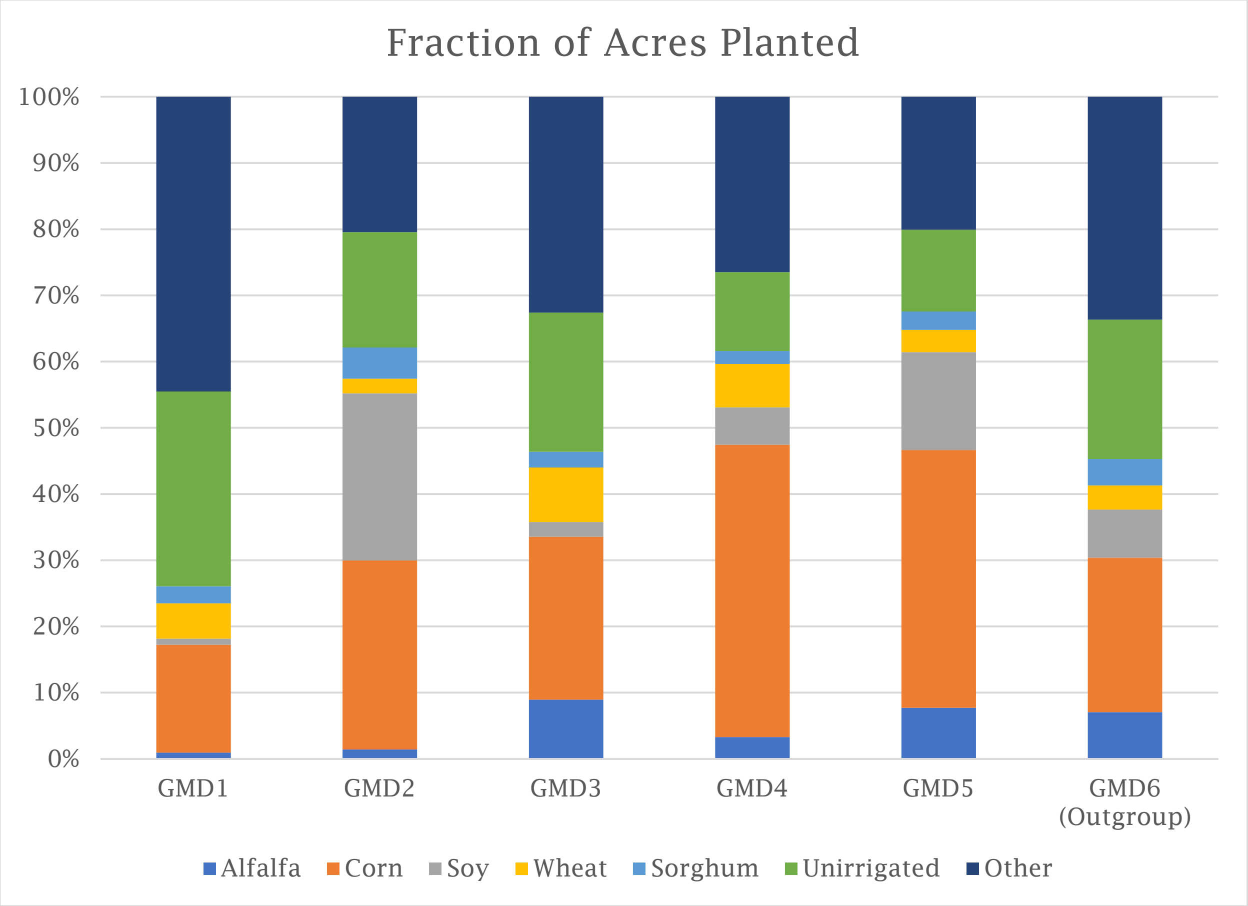

Figure 6: Representative Fields in Each GMD Reflect Differences in Crop Choices

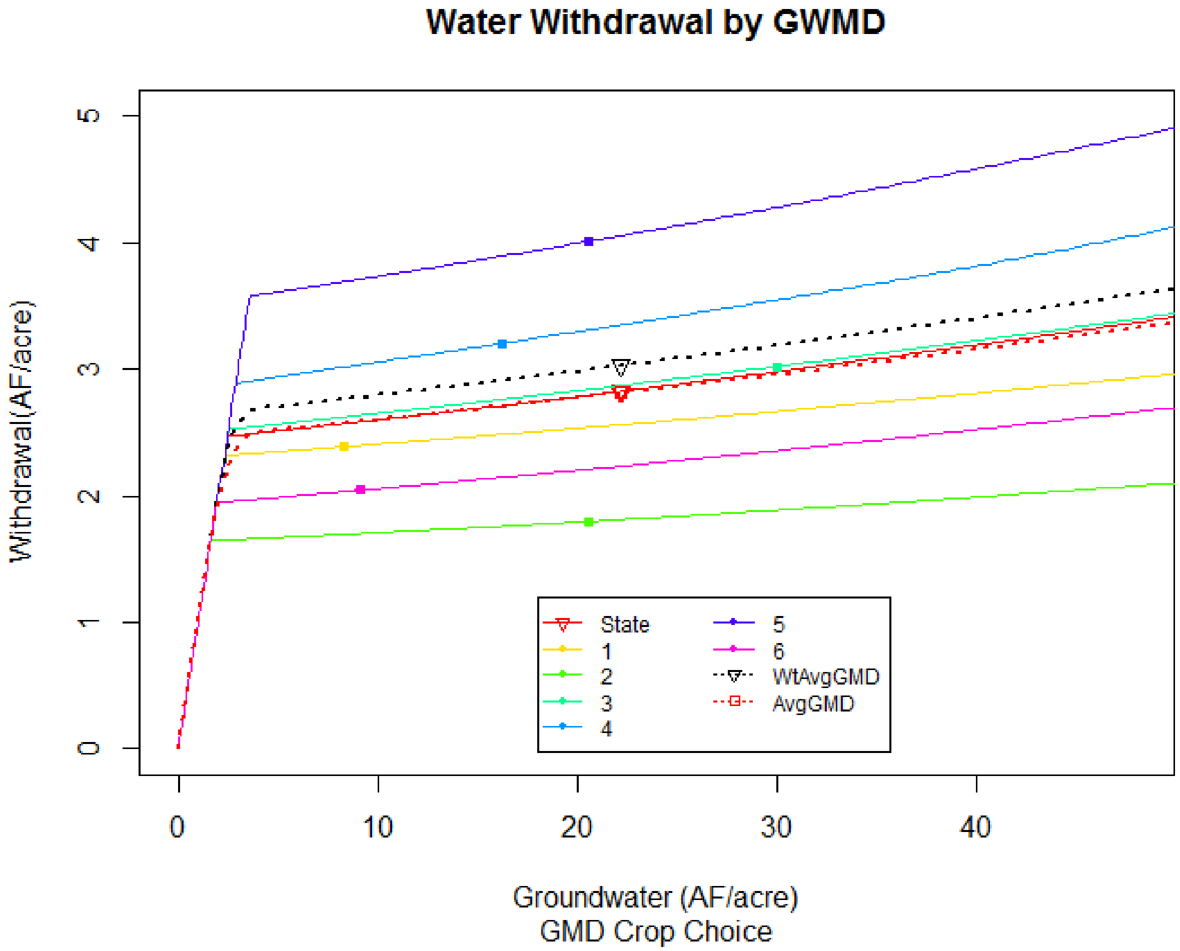

Figure 7: Water Withdrawal Functions with Regional Water Withdrawal Parameters and Regional Crop Choice Parameters

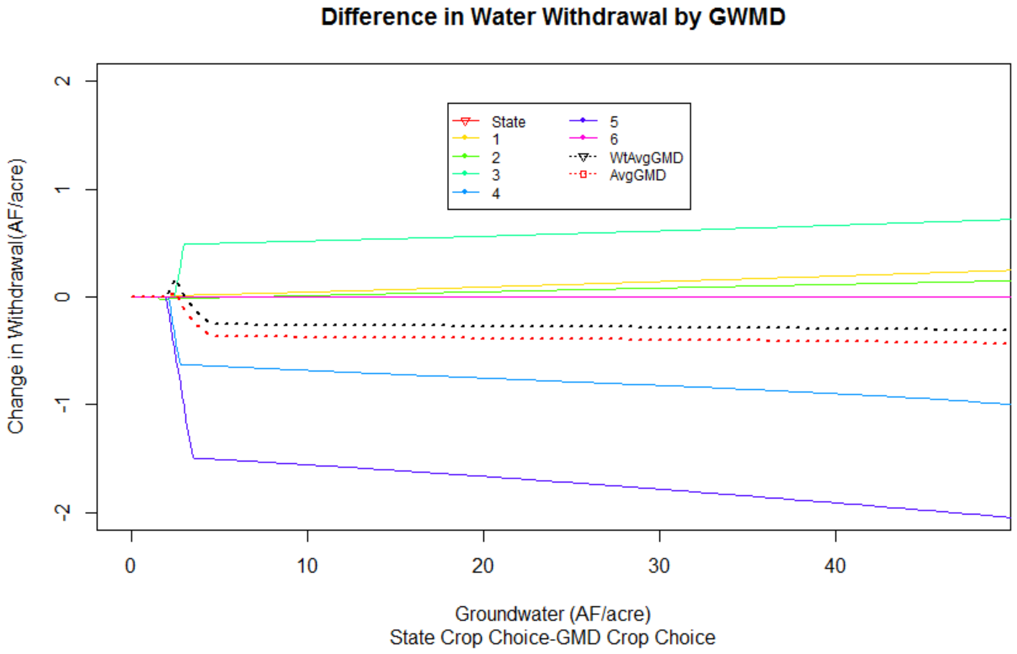

Figure 8: Differences Between Water Withdrawal Functions with Statewide Crop Choice Parameters and Regional Crop Choice Parameters

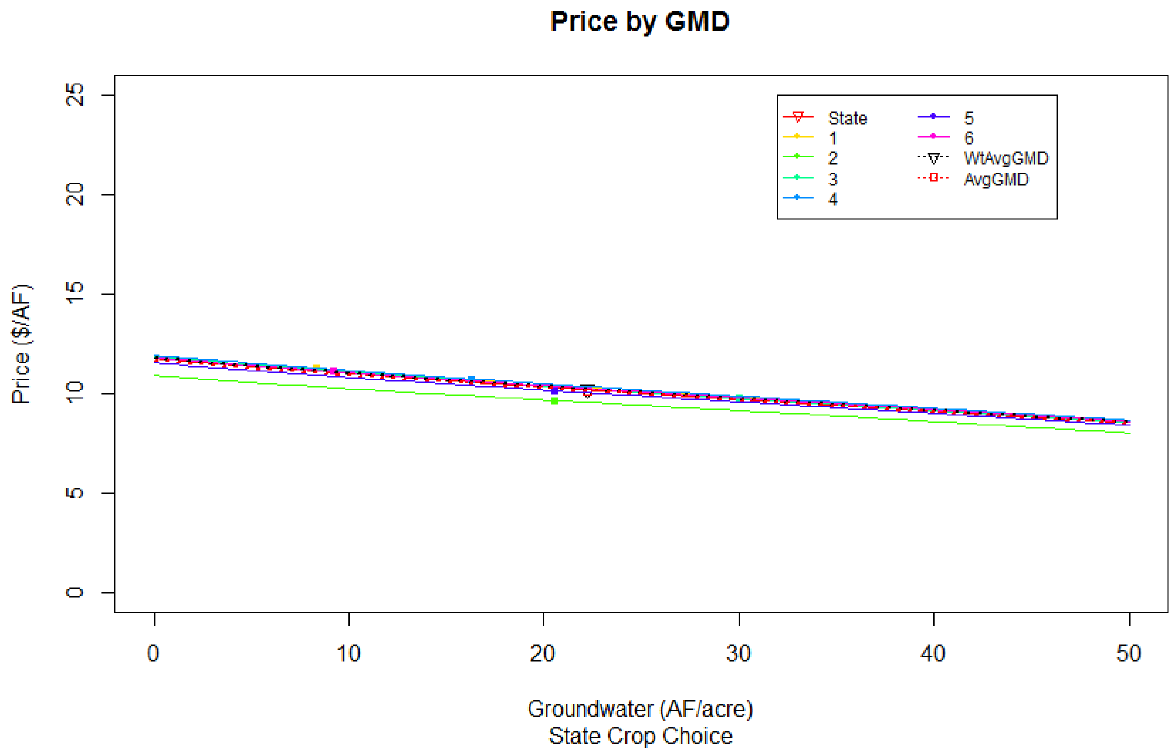

Figure 9: Accounting Price Functions with Regional Water Withdrawal Parameters and Statewide Crop Choice Parameters

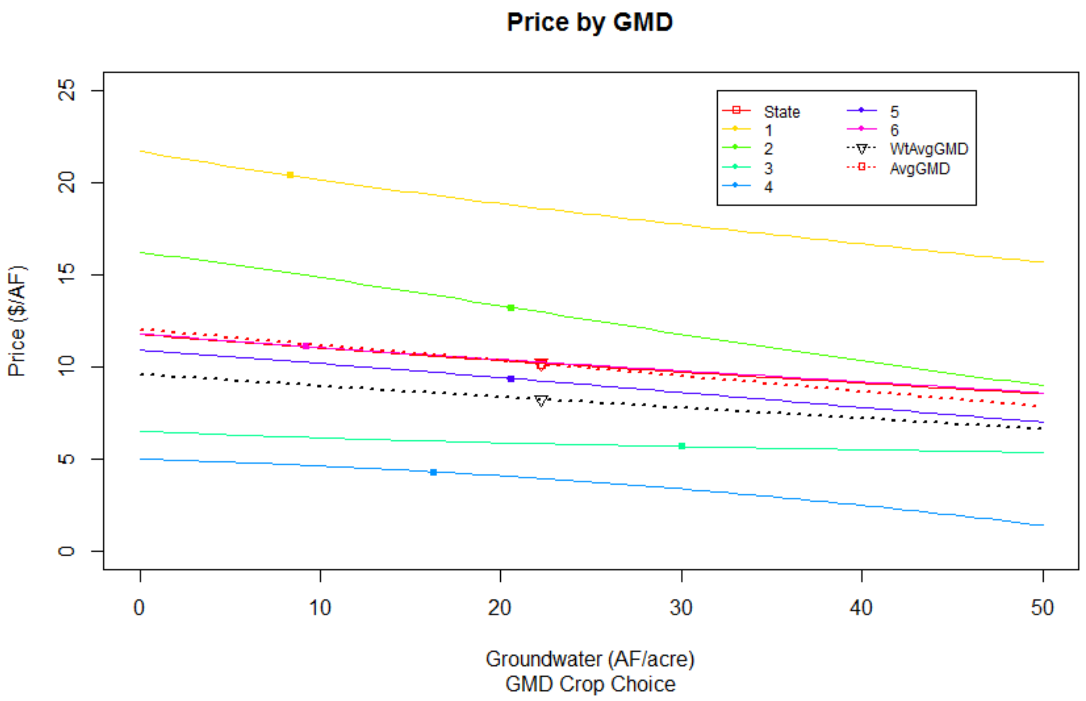

Figure 10: Accounting Price Functions with Regional Water Withdrawal Parameters and Regional Crop Choice Parameters

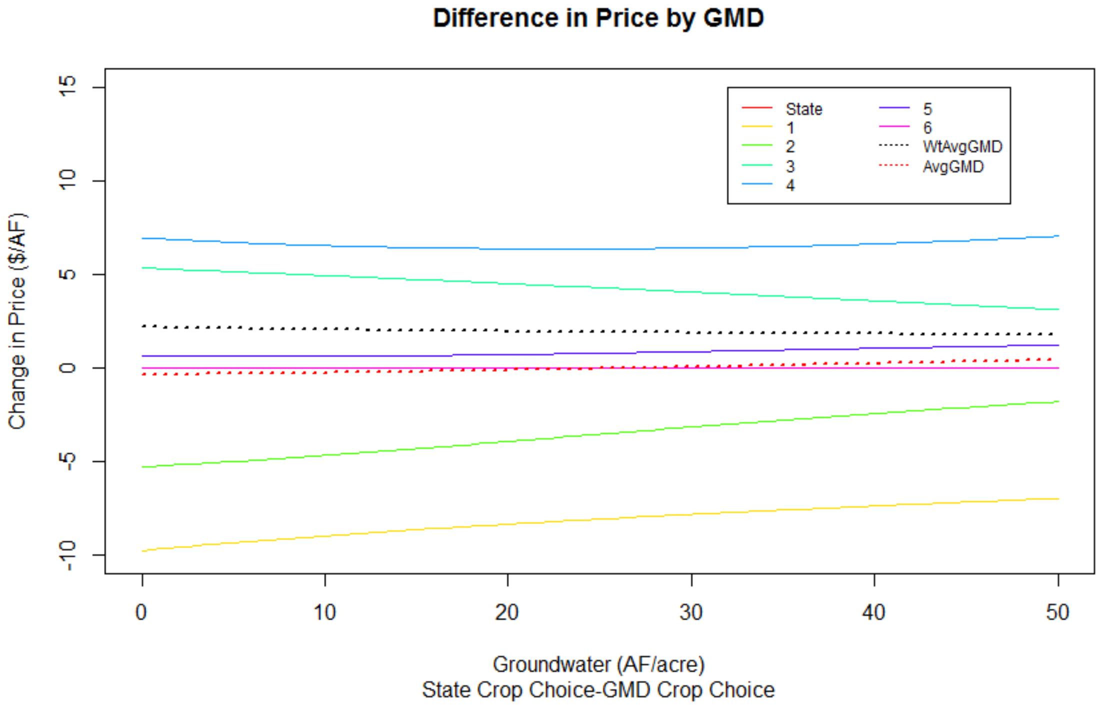

Figure 11: Differences Between Accounting Price Functions with Statewide Crop Choice Parameters and Regional Crop Choice Parameters

TABLES

Table 1: Summary Statistics for Wells

Water Availability By Region	Number of Wells	Mean	Std. Dev.	Min	Max
GMD 1	24,870	8.304	6.460	0	56.063
GMD 2	11,076	20.543	12.142	0	71.457
GMD 3	100,192	29.992	18.902	0	115.713
GMD 4	31,714	16.235	7.351	0	48.100
GMD 5	39,527	20.554	10.781	0	62.496
(Outgroup) GMD 6	12,393	9.158	7.569	0	39.016
State	219,772	22.204	16.488	0	115.713

Table 2: Water Withdrawal and Price Approximations Using State and Regional Crop Choice Parameters at Mean Water Availability by GMD

		State Crop Choice		***GMD Crop Choice***	
Region	**Mean Water Availability**	**Water Withdrawal (AF/acre)**	**Price ($/AF)**	**Water Withdrawal (AF/acre)**	**Price ($/AF)**
GMD 1	8.304	2.427	11.281	2.389	20.405
GMD 2	20.543	1.851	9.643	1.799	13.228
GMD 3	29.992	3.643	9.757	3.023	5.661
GMD 4	16.235	2.445	10.732	3.207	4.290
GMD 5	20.554	2.295	10.134	4.011	9.366
(Outgroup) GMD 6	9.158	2.045	11.110	2.045	11.110
State	22.204	2.827	10.193	2.827	10.193

APPENDIX

A1: Representative Field Characteristics Across GMDs

	GMD1	*GMD2*	*GMD3*	*GMD4*	*GMD5*	*(Outgroup) GMD 6*	*ALL*
Field size (ac)	172.71	122.69	224.93	152.82	132.62	125.74	181.27
Energy price $/mmBtu	9.79	10.30	7.79	9.82	7.65	9.33	8.50
Energy Price squared	103.42	113.37	67.67	104.30	64.89	95.53	80.38
Depth to Water	143.31	29.28	177.31	148.71	33.94	154.97	134.83
*Energy price $/mmBtu*Depth to groundwater*	1401.07	300.96	1354.38	1446.16	254.44	1372.62	1123.02
Yearly precipitation (in)	19.27	31.72	19.53	20.14	26.10	23.95	21.63
Average evapotranspiration (in)	55.27	53.67	55.24	56.52	54.06	55.02	55.12
Slope (% of distance)	0.69	1.05	0.98	1.45	0.93	1.78	1.05
Irrigated Capability Class	1.22	1.88	2.05	1.59	2.18	1.80	1.89
Water Depth	8.30	20.54	29.99	16.24	20.55	9.16	22.20
Dummy for Sat Thick < 29.5	0.27	0.02	0.05	0.05	0.03	0.29	0.08
Quantity authorized for extraction (AF)	300.89	131.72	338.81	256.71	167.21	141.79	269.00
10 year forecast of the real acreage-weighted price of commodities $/bu	2.72	2.69	2.71	2.70	2.70	2.70	2.71
Dummy Irrigation	0.46	0.32	0.26	0.14	0.12	0.35	0.24
Dummy Center pivot sprinkler	0.10	0.23	0.22	0.19	0.35	0.23	0.23
Dummy Center pivot with drop nozzles	0.45	0.45	0.51	0.67	0.54	0.42	0.53
Recharge (in)	0.50	5.38	0.86	0.50	2.25	1.04	1.26

A2: Water Withdrawal Regression Coefficients

	(1)		(2)	
	Coefficient	SE	Coefficient	SE
Acres planted to alfalfa	0.00524	(0.00017)	0.00543	(0.00017)
ac_alf2	-0.00000826	(0.00000)	-0.00000867	(0.00000)
Acres planted to corn	0.00504	(0.00009)	0.00504	(0.00009)
ac_corn2	-0.00000751	(0.00000)	-0.00000758	(0.00000)
Acres planted to sorghum	0.000283	(0.00024)	0.000373	(0.00024)
ac_sorg2	0.00000245	(0.00000)	0.00000218	(0.00000)
Acres planted to soybeans	0.00401	(0.00022)	0.00382	(0.00021)
ac_soy2	-0.00000584	(0.00000)	-0.00000518	(0.00000)
Acres planted to wheat	0.000739	(0.00016)	0.000896	(0.00016)
ac_wheat2	-0.00000345	(0.00000)	-0.00000401	(0.00000)
fallow	-17.22	(0.01190)	-17.21	(0.01190)
Field size (ac)	0.00146	(0.00004)	0.00154	(0.00004)
Energy price $/mmBtu	-0.0362	(0.00593)	-0.0479	(0.00568)
energy_price1sq	0.000763	(0.00026)	0.00114	(0.00025)
dtw_	0.000344	(0.00006)	0.000386	(0.00006)
Energy price $/mmBtu*Depth to groundwater	-0.0000268	(0.00001)	-0.0000283	(0.00001)
Yearly precipitation (in)	-0.0201	(0.00097)	-0.0215	(0.00085)
Average evapotranspiration (in)	-0.0385	(0.00640)	-0.0317	(0.00453)
Slope (% of distance)	0.00666	(0.00396)	0.00783	(0.00387)
Irrigated Capability Class	-0.0473	(0.00732)	-0.0534	(0.00725)
wdep_	0.0057	(0.00023)	0.00665	(0.00022)
no_st_	-0.12	(0.01270)	-0.125	(0.01240)
Quantity authorized for extraction (AF)	0.000363	(0.00002)	0.000383	(0.00002)
10 year forecast of the real acreage-weighted price of commodities $/bu	-0.175	(0.01980)	-0.204	(0.01820)
flood	0		0	
center pivot sprinkler	-0.0157	(0.00951)	-0.0124	(0.00939)
center pivot with drop nozzles	0.018	(0.00820)	0.0174	(0.00809)

gmd=1	-0.0388	(0.01810)		
gmd=2	-0.0543	(0.02350)		
gmd=3	0.0842	(0.01610)		
gmd=4	0.00375	(0.01890)		
gmd=5	-0.00907	(0.01800)		
gmd=6	0			
Constant	7.334	(0.35700)	7.116	(0.24000)
Observations	172717		172717	
R-squared	0.938		0.938	
Root Mean Squared Error	1.244		1.245	

A3: Multinomial Logit Crop Coefficients

GMD 1 (Crop Codes)	*1*	*2*	*3*	*4*	*5*	*10*	*15*	*16*	*17*	*23*	*24*	*25*	*26*	*28*	*44*	*46*	*48*
Water Depth	0.0078	0.0606	0.0281	0.0331	0.0285	0.0338	0.0065	-0.0080	0.0551	-0.0324	0.0068	0.0220	0.0402	-0.0719	-0.0282	-0.0126	0.0071
Field size (ac)	-0.0046	-0.0013	-0.0027	-0.0060	-0.0020	0.0006	0.0048	0.0055	0.0032	0.0019	0.0008	0.0053	0.0029	0.0050	0.0066	0.0056	0.0059
Depth to Water	-0.0360	-0.0031	-0.0212	0.0040	0.0017	0.0646	0.0013	-0.0190	0.0118	-0.0136	-0.0021	-0.0043	0.0388	0.0031	0.0069	0.0164	0.0130
Energy price $/mmBtu	-0.8890	-0.6060	-0.4850	-0.1730	0.4430	2.6290	0.4260	-0.5660	0.8780	-1.1700	-0.3280	0.2250	1.2270	0.4800	0.8790	0.8910	0.5550
Energy price squared	0.0276	0.0246	0.0135	0.0071	-0.0171	-0.0879	-0.0020	0.0212	-0.0340	0.0443	0.0148	-0.0052	-0.0250	-0.0198	-0.0413	-0.0395	-0.0080
*Energy price $/mmBtu*Depth to groundwater*	0.0036	0.0010	0.0026	0.0000	0.0000	-0.0065	-0.0007	0.0022	-0.0007	0.0024	0.0010	0.0006	-0.0030	-0.0002	0.0001	-0.0005	-0.0002
Yearly precipitation (in)	-0.0323	0.3030	0.4900	0.7550	-0.2000	-0.5050	-0.1690	0.3010	0.4120	0.7810	1.1650	0.1250	0.0717	0.1110	0.8660	0.5270	-0.5100
Average evapotranspiration (in)	-0.0512	-0.0362	-0.2240	0.8270	0.1220	0.5630	0.8660	0.0613	-0.2520	0.0010	-0.0599	-0.3020	-0.1600	0.2200	-0.1850	0.7050	0.1360
Slope (% of distance)	0.0096	-0.0041	-0.2130	0.0802	0.0424	-0.3240	-0.4050	-0.1390	-0.5900	0.0967	0.1060	0.0162	0.1290	-0.4200	0.0853	0.2930	0.3080
Irrigated Capability Class	0.4470	0.1190	-0.4210	-0.2380	-0.0714	1.0270	0.6110	-0.0703	0.4960	-0.1320	-0.9840	-0.3290	-0.0618	-0.1190	0.2410	-0.8540	0.4830
Dummy for Sat Thick < 29.5	-0.9880	-0.4230	-0.1520	0.2880	-0.4490	-0.5270	-0.0486	-0.2710	0.2270	0.0697	-0.5360	-0.2840	-0.4440	-0.4600	-0.6400	-1.1220	-0.3950
Quantity authorized for extraction (AF)	0.0006	0.0007	0.0006	0.0003	0.0004	-0.0004	-0.0005	0.0007	0.0019	0.0011	0.0022	0.0008	0.0007	0.0004	0.0004	0.0012	0.0015
Futures Price of Alfalfa ($/bu)	-0.0155	-0.0123	0.0083	-0.0084	-0.0028	-0.0119	0.0564	-0.0097	0.0165	0.0167	-0.0083	0.0002	-0.0258	0.0140	-0.0136	-0.0373	-0.0310
Futures Price of Corn ($/bu)	-0.0026	-0.0090	-0.0305	0.0384	-0.0261	0.0271	0.0165	-0.0104	0.0009	-0.0179	-0.0047	0.0001	-0.0310	-0.0333	-0.0710	-0.0127	-0.0197
Futures Price of Sorghum ($/bu)	-0.4500	0.3310	0.6080	-0.6380	0.4630	-0.0629	0.9000	0.4110	0.8370	0.4220	0.1740	0.1780	2.2100	0.9350	0.5060	-0.9600	1.8320
Futures Price of Soybeans ($/bu)	0.0000	0.0029	0.0053	-0.0009	0.0058	-0.0139	-0.0013	0.0022	0.0027	0.0051	0.0089	0.0010	0.0048	0.0016	0.0067	-0.0014	0.0053
Futures Price of Wheat ($/bu)	0.0120	-0.0040	0.0053	-0.0120	-0.0059	-0.0019	-0.0242	-0.0036	-0.0115	0.0006	-0.0230	-0.0066	-0.0339	0.0046	0.0233	0.0277	-0.0318
Recharge Rate	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
10 year forecast of the real acreage-weighted price of commodities $/bu	1.0870	0.7980	-0.1110	-0.4390	1.7650	3.4430	4.0910	0.4310	0.5210	0.0386	0.2590	2.2500	3.8150	1.1390	2.0490	0.2550	1.3940
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Dummy Center pivot sprinkler	0.2200	0.4400	-0.7190	-0.1370	1.6990	1.0940	0.4910	-0.3700	0.6090	-1.5070	-0.6420	0.9540	-0.0712	-0.8500	-1.2300	0.3330	0.5320
Dummy Center pivot with drop nozzles	0.7970	1.3750	-0.5900	1.9500	2.0670	1.0340	0.7290	0.5070	2.0960	-0.8570	0.8810	1.2650	0.9890	0.0591	-0.0501	0.6310	0.8250
Constant	4.1110	-1.8690	5.8640	-64.1900	-9.0580	-50.5400	-67.4000	-5.0390	-9.5920	-13.3000	-17.8000	5.8810	-7.4520	-20.9200	-14.8200	-57.9900	-4.5040

GMD 2 (Crop Codes)	*1*	*2*	*3*	*4*	*5*	*15*	*16*	*24*	*27*	*30*
Water Depth	-0.024	0.0134	0.017	0.0137	-0.0173	0.0666	-0.0079	0.0182	0.0137	0.0073
Field size (ac)	-0.00838	-0.00325	-0.00185	-0.0031	-0.00877	-0.002	0.00169	0.0047	0.00579	-0.00511
Depth to Water	-0.061	-0.00699	-0.00876	-0.0219	-0.0625	-0.1	-0.0265	-0.0148	-0.0105	-0.0459
Energy price $/mmBtu	-1.798	-0.603	-0.97	-0.278	-0.448	-0.754	-0.202	-0.557	0.00211	-0.425
Energy price squared	0.0721	0.027	0.0446	0.0118	0.0219	0.03	0.0112	0.0255	-0.00195	0.0151
*Energy price $/mmBtu*Depth to groundwater*	0.00792	0.00267	0.00295	0.0041	0.00811	0.0129	0.00428	0.00345	0.00303	0.00636
Yearly precipitation (in)	-0.842	0.0825	-0.324	0.189	-0.258	1.255	0.23	1.631	0.976	-0.13
Average evapotranspiration (in)	0.709	0.675	0.416	0.468	0.322	1.441	0.474	0.649	0.591	0.497
Slope (% of distance)	0.285	-0.199	0.146	0.0157	-0.0516	-0.178	-0.412	-0.0412	0.175	0.16
Irrigated Capability Class	0.466	0.186	0.265	0.203	0.292	-0.382	0.726	0.407	0.536	0.316
Dummy for Sat Thick < 29.5	-1.019	0.0583	-1.259	-0.271	0.69	-13.24	-0.859	0.0427	-0.537	0.415
Quantity authorized for extraction (AF)	0.00434	0.00952	0.00366	0.00819	0.00538	0.00315	0.0091	0.00915	0.00509	0.00958
Futures Price of Alfalfa ($/bu)	0.0162	-0.000219	-0.0000599	-0.000528	0.0198	-0.0122	0.00411	0.00209	-0.00805	0.00358
Futures Price of Corn ($/bu)	-0.0267	-0.026	-0.0258	-0.0103	-0.0285	-0.0515	-0.0263	-0.011	-0.0102	-0.0256
Futures Price of Sorghum ($/bu)	0.821	0.644	1.25	0.103	0.577	0.655	0.533	0.492	0.372	-0.514
Futures Price of Soybeans ($/bu)	0.00521	0.00374	0.00282	0.002	0.00269	0.00539	0.00255	0.00245	0.00323	0.000671
Futures Price of Wheat ($/bu)	-0.00521	-0.0000604	-0.00943	0.00121	-0.00141	0.0106	0.00369	-0.00462	-0.00278	0.0268
Recharge Rate	-0.249	0.0504	0.285	0.0762	0.0373	5.232	0.498	-0.0498	0.142	0.284
10 year forecast of the real acreage-weighted price of commodities $/bu	-1.411	-1.013	-0.0302	-0.766	1.84	-1.591	0.0538	-0.0668	-0.711	-0.617
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Dummy Center pivot sprinkler	1.583	0.987	0.425	1.029	1.219	2.622	0.0729	-0.522	0.102	2.062
Dummy Center pivot with drop nozzles	0.809	0.844	-0.187	0.858	0.038	2.356	-0.21	-0.275	-0.388	1.906
Constant	1.949	-31.72	-7.355	-28.1	-12.08	-140.2	-35.39	-84.35	-64.7	-25.55

GMD 3 (Crop Codes)	1	2	3	4	5	8	10	11	15	16	17	18	19	21	23	24	25
Water Depth	0.00632	0.0174	-0.0117	0.012	0.00406	0.023	0.0203	-0.0219	-0.0001	-0.0027	-0.00241	-0.00865	-0.0138	-0.00495	-0.0103	0.0143	0.00191
Field size (ac)	-0.0037	-0.00385	-0.0037	-0.00833	-0.00425	-0.00567	0.00000222	-0.00424	-0.00366	0.00387	0.00125	0.00367	0.00236	0.00221	0.00295	0.000323	0.00359
Depth to Water	0.00648	-0.00139	-0.00193	0.000621	-0.00459	0.0218	-0.000559	-0.00897	-0.00249	-0.00181	0.00745	-0.0149	-0.00586	-0.00599	-0.0039	-0.00418	0.00195
Energy price $/mmBtu	0.22	-0.173	-0.105	-0.0842	-0.294	0.407	-0.116	-0.104	-0.513	-0.346	0.103	-1.025	-0.507	-0.615	-0.403	-0.313	-0.0576
Energy price squared	-0.00969	0.00351	0.00272	0.000235	0.0122	-0.0152	0.00491	0.0114	0.019	0.00976	-0.00275	0.0237	0.0114	0.0174	0.0153	0.003	0.00405
Energy price $/mmBtu*Depth to groundwater	-0.00123	0.000569	0.000248	0.000228	0.000693	-0.00414	-0.0000531	0.00166	-0.000278	0.000299	-0.0013	0.0019	0.000213	0.000184	0.000734	0.00103	0.0000221
Yearly precipitation (in)	0.263	0.118	0.22	0.361	0.174	-0.0924	-0.173	0.156	-0.378	0.0626	0.049	0.333	0.294	0.139	0.253	0.453	0.0505
Average evapotranspiration (in)	0.223	0.0782	0.04	0.0859	0.0376	-0.368	0.0436	-0.25	-0.257	-0.0629	-0.105	0.109	-0.00844	-0.0241	-0.0819	0.144	-0.0116
Slope (% of distance)	-0.119	-0.184	0.0364	-0.57	-0.0493	-0.0344	0.119	-0.452	-0.409	-0.283	-0.221	-0.142	-0.197	-0.211	-0.0691	-0.498	-0.247
Irrigated Capability Class	0.733	0.0806	-0.158	0.297	0.189	0.406	-0.178	-4.096	0.533	0.0446	0.49	0.143	0.229	0.304	-0.457	-0.407	-0.26
Dummy for Sat Thick < 29.5	-0.795	-0.43	0.0678	-0.783	-0.0285	-0.432	0.166	-14.45	-0.308	-0.278	-0.0775	-0.991	-0.487	-0.44	-0.342	-1.44	-0.291
Quantity authorized for extraction (AF)	0.000138	0.000724	0.000827	0.000782	0.000468	-0.000878	0.000095	-0.00483	0.00018	0.000908	0.000769	0.00104	0.000642	0.00108	0.000269	0.00101	0.000718
Futures Price of Alfalfa ($/bu)	0.0158	-0.00894	0.00993	-0.00877	0.00285	-0.00052	-0.0103	-0.00563	0.0158	0.000401	0.00756	-0.0168	0.00881	0.0159	-0.00549	-0.0195	-0.00392
Futures Price of Corn ($/bu)	0.008	-0.0144	-0.0374	0.0112	-0.00943	-0.00289	0.00198	-0.0344	0.00521	-0.0121	0.0265	-0.0154	-0.023	0.00438	-0.0247	0.000962	-0.0114
Futures Price of Sorghum ($/bu)	-0.269	-0.0772	0.64	-0.377	0.0559	-0.801	-0.877	0.349	-0.178	-0.0676	-0.593	-0.573	0.0676	-0.501	0.541	-0.683	0.136
Futures Price of Soybeans ($/bu)	-0.000992	0.00289	0.005	0.000434	0.00254	0.000209	-0.00374	0.00362	0.0000793	0.00262	-0.00416	0.00577	0.00386	0.00122	0.0037	0.000206	0.00216
Futures Price of Wheat ($/bu)	-0.000638	0.00555	0.00353	-0.00101	0.00141	0.000699	0.0166	0.00785	-0.00216	0.00545	0.00144	0.0127	0.00678	0.00749	0.000103	0.0141	0.000387
Recharge Rate	-0.605	1.868	0.213	2.517	-0.937	3.202	-0.169	1.23	3.83	0.705	0.635	0.555	1.344	0.0907	2.792	2.917	0.112
10 year forecast of the real acreage-weighted price of commodities $/bu	0.843	0.446	0.583	-1.82	0.216	3.053	-0.488	2.438	-0.736	-0.282	0.0786	-1.364	-0.0273	-0.438	0.424	-1.528	1.653
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Dummy Center pivot sprinkler	1.637	1.198	0.32	1.195	0.993	1.398	1.701	-2.034	0.717	-0.39	0.503	0.53	-0.375	0.168	-0.318	-0.333	0.284
Dummy Center pivot with drop nozzles	1.916	1.661	0.526	1.96	1.42	1.477	1.824	-2.555	1.018	0.342	1.236	0.889	-0.164	0.645	0.133	0.641	0.602
Constant	-24.25	-7.355	-6.468	-11.61	-5.26	7.037	-2.48	7.438	19.48	4.136	-3.81	-6.966	-6.684	-3.658	-1.443	-16.6	-4.18

GMD 3 cont'd (Crop Codes)	*26*	*27*	*28*	*30*	*32*	*35*	*38*	*44*	*46*	*48*	*49*	*63*
Water Depth	-0.0147	-0.00835	-0.0172	-0.0072	0.00201	0.00668	0.000793	-0.00199	-0.00392	0.0136	-0.00494	-0.00817
Field size (ac)	0.00258	0.00063	0.00217	0.00197	0.00127	0.00471	0.00308	0.00596	0.00517	0.0056	0.00765	0.00633
Depth to Water	-0.000142	-0.00557	-0.00413	-0.00213	0.0044	-0.0113	-0.0119	0.00236	-0.0053	0.00362	-0.00494	0.00353
Energy price $/mmBtu	0.328	-0.357	-0.279	-0.302	0.468	-0.889	-0.797	-0.208	-0.776	0.474	-0.543	-0.278
Energy price squared	-0.0156	0.0132	0.0151	0.0107	-0.0177	0.0247	0.016	0.00925	0.0253	-0.0301	0.0237	-0.00689
*Energy price $/mmBtu*Depth to groundwater*	0.000304	0.000607	0.000279	0.000619	-0.000545	0.00159	0.000939	-0.000046	0.000972	-0.000498	0.000276	-0.0000976
Yearly precipitation (in)	-0.173	0.49	-0.103	0.477	-0.137	0.353	0.599	-0.134	0.29	-0.234	0.582	0.306
Average evapotranspiration (in)	-0.22	0.0948	-0.101	-0.104	0.0103	0.254	0.409	-0.209	-0.0648	0.237	-0.188	-0.241
Slope (% of distance)	-0.319	-0.715	0.279	-0.44	-0.1	-0.219	0.231	0.0435	-1.261	-0.451	-0.534	-0.944
Irrigated Capability Class	0.134	-0.325	-0.461	0.0274	-0.0096	0.188	-0.239	-0.597	-0.248	-0.131	-0.848	-0.0329
Dummy for Sat Thick < 29.5	-0.957	0.401	0.00314	-0.222	-0.74	-1.064	-0.914	0.306	-2.206	0.366	-0.494	-0.3
Quantity authorized for extraction (AF)	0.00149	0.00036	0.000927	0.0006	0.00076	0.00125	0.00133	0.00141	0.000901	0.000883	0.000855	0.00147
Futures Price of Alfalfa ($/bu)	-0.0362	-0.00347	0.019	-0.0173	-0.022	-0.011	-0.0119	-0.00252	-0.00745	-0.0083	-0.00718	0.00963
Futures Price of Corn ($/bu)	-0.0684	0.025	-0.017	0.0205	-0.00194	-0.0315	0.00253	-0.0143	0.00753	-0.0418	0.00203	-0.012
Futures Price of Sorghum ($/bu)	0.377	-0.554	0.454	-0.366	0.0134	-0.298	-0.583	0.378	-0.234	-0.351	0.0998	-1.204
Futures Price of Soybeans ($/bu)	0.00796	-0.00447	0.0024	0.00113	-0.00982	0.00412	0.00119	0.00273	0.000521	0.00415	0.00117	0.00196
Futures Price of Wheat ($/bu)	0.0163	0.00808	-0.000839	-0.00484	0.0217	0.0207	0.0148	-0.000041	0.00164	0.0243	0.000875	0.0371
Recharge Rate	3.545	1.747	1.158	1.026	0.183	-2.704	-2.409	3.24	3.261	3.885	3.448	7.236
10 year forecast of the real acreage-weighted price of commodities $/bu	2.1	-2.463	1.442	-2.241	-0.799	-0.491	-1.599	1.053	-1.711	1.819	-0.966	-1.779
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Dummy Center pivot sprinkler	0.737	0.336	-0.136	0.508	1.156	-1.256	-1.586	-0.327	-0.887	0.00688	-0.585	-1.224
Dummy Center pivot with drop nozzles	0.786	0.71	-0.00262	1.189	1.274	0.0459	-1.08	0.0102	0.0985	0.772	-0.398	-0.732
Constant	8.92	-15.78	2.475	-2.273	-3.343	-15.55	-29.76	7.364	0.0452	-21.82	-4.807	-4.08

GMD 4 (Crop Codes)	*1*	*2*	*3*	*4*	*5*	*9*	*10*	*15*	*16*	*17*
Water Depth	0.0548	0.0449	0.00625	0.0575	0.0695	0.114	0.0769	0.0155	0.0503	0.04
Field size (ac)	-0.0119	-0.00751	-0.0045	-0.0125	-0.00527	-0.00895	-0.00596	-0.00914	0.000286	-0.00729
Depth to Water	-0.000278	-0.00151	-0.0059	-0.00259	-0.00138	0.00143	-0.0013	0.00163	-0.00435	-0.0114
Energy price $/mmBtu	-0.0453	-0.0528	0.399	-0.163	0.0779	-0.139	-0.0915	0.301	-0.374	-0.926
Energy price squared	0.00256	0.00474	-0.0161	0.0031	-0.000802	-0.000316	0.00469	-0.00574	0.0162	0.0334
*Energy price $/mmBtu*Depth to groundwater*	0.0000557	0.000164	0.000594	0.000317	0.0000733	-0.000232	0.000198	-0.000516	0.000448	0.00122
Yearly precipitation (in)	0.142	0.377	0.595	0.563	-0.0972	-0.198	-0.15	-0.102	0.201	0.381
Average evapotranspiration (in)	-0.396	0.124	-0.0663	0.0808	-0.0646	0.358	0.152	-0.017	0.389	0.354
Slope (% of distance)	0.284	-0.335	-0.189	-0.367	-0.101	-0.637	-0.159	-0.0346	-0.137	-0.129
Irrigated Capability Class	0.266	0.645	0.163	0.223	0.336	0.886	0.272	0.217	0.325	0.359
Dummy for Sat Thick < 29.5	0.965	0.0392	0.448	0.384	0.944	-1.487	0.12	0.804	0.386	0.319
Quantity authorized for extraction (AF)	0.00299	0.00352	0.00137	0.00259	0.000859	0.00285	0.00271	0.00295	0.00289	0.00345
Futures Price of Alfalfa ($/bu)	0.00485	0.00603	0.0177	0.0122	-0.00056	0.0142	-0.0162	0.0233	0.0078	0.012
Futures Price of Corn ($/bu)	-0.00672	-0.000786	-0.0302	0.0245	-0.0193	-0.00424	-0.0477	0.014	-0.0155	0.0365
Futures Price of Sorghum ($/bu)	0.0709	-0.145	0.506	-0.579	0.383	-0.83	-0.047	-0.219	0.366	-0.316
Futures Price of Soybeans ($/bu)	0.00159	0.000211	0.00336	0.00151	0.00426	-0.0039	0.00446	-0.00206	0.00426	-0.00388
Futures Price of Wheat ($/bu)	0.000276	0.00221	0.00481	-0.00651	-0.00053	0.0265	0.0158	0.000798	-0.00284	-0.0049
Recharge Rate	.	.	.	.	.	.	.	.	.	.
10 year forecast of the real acreage-weighted price of commodities $/bu	0.594	1.41	1.039	-2.259	0.225	1.127	0.637	0.33	-0.921	-2.641
	.	.	.	.	.	.	.	.	.	.
Dummy Center pivot sprinkler	0.805	1.113	-0.28	2.014	0.915	0.788	0.226	-0.415	0.324	0.906
Dummy Center pivot with drop nozzles	1.406	1.493	0.0276	2.502	1.173	1.455	0.792	0.327	0.607	1.689
Constant	15.35	-18.97	-13.67	-14.45	3.305	-26.34	-4.329	-5.824	-23.36	-23.76

GMD 4 cont'd (Crop Codes)	18	21	23	24	25	26	30	32	46	48
Water Depth	0.014	0.00561	0.0154	0.0223	0.0286	0.052	0.0502	0.0765	-0.0286	0.0282
Field size (ac)	-0.00245	-0.00182	0.0000769	-0.00154	0.0036	0.000499	0.000558	0.00188	0.00719	0.00336
Depth to Water	-0.00244	-0.0129	0.00545	0.00124	-0.00306	-0.00162	0.00356	-0.00148	-0.000518	0.00284
Energy price $/mmBtu	-0.448	-0.127	1.345	0.373	-0.113	-0.412	-0.227	-0.406	-0.167	0.125
Energy price squared	0.0173	0.00357	-0.0577	-0.00967	0.0086	0.0233	0.0146	0.0184	0.00637	0.000239
Energy price $/mmBtu*Depth to groundwater	0.000343	0.000127	-0.00113	-0.000242	0.00033	0.000212	-0.000688	0.000241	0.000052	-0.000501
Yearly precipitation (in)	0.112	-0.15	0.497	0.723	0.152	-0.13	0.516	-0.19	0.766	-0.362
Average evapotranspiration (in)	0.394	-0.0528	0.717	0.3	0.302	0.221	0.563	0.327	-0.0438	0.514
Slope (% of distance)	0.246	0.243	-0.317	-0.531	-0.211	-0.402	-0.469	-0.22	-0.589	0.0393
Irrigated Capability Class	0.144	0.00944	0.664	0.417	0.368	0.362	0.15	0.699	0.607	0.281
Dummy for Sat Thick < 29.5	0.752	0.227	-1.402	-0.0813	-0.147	-0.0675	-0.938	0.645	-0.443	-1.186
Quantity authorized for extraction (AF)	0.00298	0.00436	0.00183	0.00276	0.00251	0.00295	0.00082	0.00238	0.00111	0.00376
Futures Price of Alfalfa ($/bu)	0.00196	0.0111	0.0115	0.0101	0.00703	-0.00812	0.0149	0.0000579	0.00587	-0.00789
Futures Price of Corn ($/bu)	0.00151	0.0436	-0.036	0.0126	-0.0129	-0.0137	0.0756	-0.0452	0.0105	-0.019
Futures Price of Sorghum ($/bu)	-0.0191	-0.848	-0.546	-0.17	0.505	0.0351	-0.244	0.718	0.412	0.164
Futures Price of Soybeans ($/bu)	0.000251	-0.00365	0.000954	-0.000409	0.0035	-0.000651	-0.00309	0.0051	0.00402	0.00161
Futures Price of Wheat ($/bu)	0.0019	-0.00403	0.0316	-0.00373	-0.00449	0.0114	-0.026	0.0121	-0.0186	0.00898
Recharge Rate	.	.	.	.	.	.	.	.	.	.
10 year forecast of the real acreage-weighted price of commodities $/bu	0.314	0.75	2.667	0.102	0.9	1.62	-3.179	0.0697	-1.914	2.222
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Dummy Center pivot sprinkler	-0.668	0.0284	-1.328	0.828	0.229	-0.19	0.892	0.535	-0.0739	-0.897
Dummy Center pivot with drop nozzles	0.219	0.448	-0.491	1.396	0.97	0.523	1.908	1.772	0.763	0.157
Constant	-27.1	-4.113	-68.29	-38.42	-24.82	-15.22	-45.95	-17.48	-12	-32.9

GMD 5 (Crop Codes)	*1*	*2*	*3*	*4*	*5*	*8*	*15*	*16*	*17*	*18*
Water Depth	0.0173	0.0436	0.00446	0.0325	0.0198	0.0539	0.0379	-0.00707	0.0213	-0.00745
Field size (ac)	-0.00505	-0.00282	0.00233	-0.0046	-0.00442	0.011	-0.00235	0.00689	0.000977	0.00756
Depth to Water	0.00607	-0.00722	0.0147	-0.00461	0.0123	0.05	0.00585	0.000244	0.0137	-0.0312
Energy price $/mmBtu	0.08	-0.0452	0.481	-0.0163	-0.00798	-0.0857	-0.187	0.018	0.256	-0.252
Energy price squared	-0.00419	-0.000247	-0.0145	0.000189	-0.0024	0.00396	0.0108	-0.00516	-0.00824	0.000866
*Energy price $/mmBtu*Depth to groundwater*	-0.000576	0.00192	-0.00203	0.00177	-0.00018	-0.0065	0.000937	0.00147	-0.000526	0.00244
Yearly precipitation (in)	-0.113	0.0797	-0.1	0.0372	-0.0157	0.121	0.222	-0.0661	0.109	0.00858
Average evapotranspiration (in)	0.34	-0.123	-0.0243	-0.0258	0.00821	0.364	0.117	0.00831	-0.084	-0.167
Slope (% of distance)	0.321	-0.179	-0.297	-0.189	0.0113	0.19	0.372	-0.171	-0.265	-0.922
Irrigated Capability Class	0.308	0.0698	0.117	0.0879	0.0513	0.457	0.0858	0.227	0.263	0.575
Dummy for Sat Thick < 29.5	-0.494	-0.419	-0.0445	-0.15	-0.532	0.419	-0.151	0.107	-0.416	-0.259
Quantity authorized for extraction (AF)	0.00632	0.00838	0.00402	0.00767	0.00381	0.00651	0.00545	0.00717	0.00802	0.00894
Futures Price of Alfalfa ($/bu)	0.00474	-0.000838	0.00389	-0.000613	-0.006	0.0268	0.0194	0.000849	-0.00601	0.00828
Futures Price of Corn ($/bu)	-0.00908	-0.00606	-0.0204	0.00612	-0.0183	-0.0154	-0.0011	-0.00734	-0.00507	-0.00304
Futures Price of Sorghum ($/bu)	0.158	0.00749	0.92	-0.187	0.21	0.175	0.642	-0.0807	0.28	-0.376
Futures Price of Soybeans ($/bu)	0.00103	0.000622	0.00162	0.00175	0.00213	0.000763	0.00173	0.00115	-0.000827	-0.000787
Futures Price of Wheat ($/bu)	0.00324	0.00565	-0.0052	-0.00209	0.00582	0.00725	-0.0124	0.00792	0.00412	0.0145
Recharge Rate	.	.	.	.	.	.	.	.	.	.
10 year forecast of the real acreage-weighted price of commodities $/bu	-0.158	-0.369	1.3	-0.949	-1.645	-1.134	-1.777	-1.325	-0.629	-0.716
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Dummy Center pivot sprinkler	0.444	0.414	-0.636	0.465	0.0206	2.392	0.188	-0.786	1.376	-0.722
Dummy Center pivot with drop nozzles	0.786	0.73	-0.664	0.718	0.0844	2.405	0.516	-0.769	1.792	-0.646
Constant	-17.48	4.952	-1.538	1.049	4.121	-30.72	-11.15	2.414	-2.453	5.951

GMD 5 contd (Crop Codes)	*20*	*21*	*23*	*24*	*25*	*26*	*27*	*28*	*30*	*46*
Water Depth	-0.0167	-0.009	-0.00982	0.0219	0.00226	-0.0112	-0.0351	-0.0192	0.0163	0.0118
Field size (ac)	0.00432	0.00755	0.00464	0.00564	0.00921	0.000446	0.00487	0.00812	0.00605	0.0135
Depth to Water	-0.0146	0.0363	-0.0405	0.00432	0.000646	-0.041	0.0147	-0.00232	0.00375	-0.0154
Energy price $/mmBtu	-0.0338	0.531	-0.104	0.0891	-0.252	-0.269	0.611	0.211	-0.0198	-0.452
Energy price squared	-0.00385	-0.0244	0.00375	-0.00183	0.0087	0.0149	-0.0188	-0.0155	-0.00257	0.0156
*Energy price $/mmBtu*Depth to groundwater*	0.00165	-0.00689	0.00482	0.000995	0.00142	0.00471	-0.00207	0.000903	0.00113	0.00336
Yearly precipitation (in)	0.04	-0.168	-0.093	0.149	-0.0385	-0.0913	-0.171	-0.0357	0.2	0.185
Average evapotranspiration (in)	0.0276	0.489	-0.224	0.00672	-0.144	-0.363	-0.137	-0.164	-0.0157	-0.266
Slope (% of distance)	-0.864	-0.299	-0.318	-0.374	-0.519	-0.573	-0.35	-0.397	-0.082	-0.334
Irrigated Capability Class	0.221	0.209	0.178	-0.0485	0.241	0.652	0.0612	0.181	0.144	0.324
Dummy for Sat Thick < 29.5	0.709	-0.191	0.219	0.927	-0.48	-0.978	0.642	-0.253	-0.115	0.309
Quantity authorized for extraction (AF)	0.00726	0.00709	0.00796	0.00685	0.007	0.0125	0.00825	0.00691	0.0083	0.00974
Futures Price of Alfalfa ($/bu)	-0.0148	0.0274	0.00545	0.00338	-0.00693	-0.0375	0.014	0.00128	-0.0145	0.0103
Futures Price of Corn ($/bu)	0.000204	-0.00944	-0.016	0.00215	-0.00237	0.0238	0.0307	-0.0247	-0.0115	-0.0243
Futures Price of Sorghum ($/bu)	-0.509	-0.33	-0.0000736	-0.206	-0.0251	-0.772	0.0288	0.593	-0.0954	0.189
Futures Price of Soybeans ($/bu)	0.00183	0.0025	0.00175	-0.000436	0.0000778	-0.00396	-0.000194	0.0061	0.00343	0.00434
Futures Price of Wheat ($/bu)	0.0117	0.00106	0.0118	0.00404	0.00683	0.00502	-0.0135	0.000613	0.00709	0.00515
Recharge Rate	.	.	.	.	.	.	.	.	.	.
10 year forecast of the real acreage-weighted price of commodities $/bu	-0.0479	1.733	0.653	0.674	-1.217	0.717	0.591	-0.386	-1.677	-0.973
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Dummy Center pivot sprinkler	-0.067	-0.0391	-1.57	-0.894	-0.12	0.616	-1.424	-0.204	0.223	0.115
Dummy Center pivot with drop nozzles	-0.199	0.46	-1.351	-0.759	-0.0333	1.327	-1.279	-0.318	0.366	0.0529
Constant	-7.536	-34.71	9.15	-9.429	8.361	15.66	-0.429	6.38	-3.899	8.517

GMD 6 Outgroup (Crop Codes)	*1*	*2*	*3*	*4*	*5*	*15*	*16*	*17*	*18*	*19*	*23*	*24*	*25*	*27*	*28*	*30*
Water Depth	-0.0184	0.0349	-0.0144	0.0269	0.0582	0.0731	0.0505	0.084	0.0106	0.00315	-0.0246	-0.0873	0.0602	-0.104	-0.00599	0.0199
Field size (ac)	-0.00407	-0.0023	-0.00265	-0.00439	-0.000283	-0.0151	0.00279	0.00129	0.00201	0.00509	0.00269	0.00165	0.00559	0.00271	0.00655	0.00271
Depth to Water	0.000417	0.000225	-0.00199	0.000911	0.000224	-0.000101	0.000291	0.00185	0.00453	0.000874	0.00107	0.000128	-0.000227	0.00224	0.000235	0.00225
Energy price $/mmBtu	-0.541	0.355	-0.242	-0.0923	-0.144	-0.3	-0.187	-0.345	-0.564	-0.491	0.136	0.263	0.131	-0.224	-0.193	-0.0736
Energy price squared	0.0216	-0.007	0.0119	0.0125	0.00654	0.00896	0.0106	0.0182	0.03	0.0322	-0.0042	-0.000888	-0.00411	0.0187	0.0153	0.000722
*Energy price $/mmBtu*Depth to groundwater*	-0.0000133	-0.0000505	0.000206	-0.000116	-0.000109	-0.00000909	-0.0000352	-0.000228	-0.000788	-0.000133	-0.000142	-0.00000943	-0.0000277	-0.000387	-0.0000437	-0.000391
Yearly precipitation (in)	-0.0153	-0.0646	0.0526	0.0548	0.0375	0.184	0.164	0.149	-0.246	0.528	0.499	0.0808	0.0778	0.564	0.27	0.305
Average evapotranspiration (in)	0.013	-0.123	-0.23	-0.128	-0.203	-0.466	-0.217	-0.345	0.162	0.0225	-0.351	-0.0404	-0.301	-0.247	-0.184	0.126
Slope (% of distance)	0.0411	0.00997	-0.0315	-0.00135	0.142	0.199	-0.0115	0.308	0.383	0.289	0.242	-0.015	-0.042	-0.701	-0.0248	-0.0448
Irrigated Capability Class	0.175	0.0684	-0.0469	-0.125	0.129	-0.0552	0.0547	-0.0508	-0.255	-0.12	-0.403	-0.264	0.0579	0.362	0.358	-0.125
Dummy for Sat Thick < 29.5	-0.0814	-0.457	-0.646	-0.889	0.0905	0.59	-0.449	-0.0279	-0.634	-1.133	-0.929	-1.296	0.00747	-1.346	-0.402	-0.146
Quantity authorized for extraction (AF)	0.00256	0.00393	0.00413	0.00269	0.00231	0.00438	0.00452	0.00195	0.00259	0.00113	0.00692	0.00466	0.00427	0.0039	0.00331	0.0048
Futures Price of Alfalfa ($/bu)	0.00359	0.00725	0.0179	0.0172	-0.00783	-0.00363	0.0118	0.00631	0.0119	0.000363	0.00847	0.00605	0.00318	0.0013	-0.0137	-0.0184
Futures Price of Corn ($/bu)	-0.00913	-0.0049	-0.0229	0.0307	-0.021	0.00124	0.000494	0.0375	0.0107	-0.0225	0.00364	0.0279	-0.000872	0.0137	-0.015	-0.0168
Futures Price of Sorghum ($/bu)	0.182	0.0579	0.598	-0.112	0.163	-0.0691	0.156	-0.316	0.348	1.127	0.267	-0.163	-0.374	0.86	1.082	0.156
Futures Price of Soybeans ($/bu)	0.00277	0.000224	0.00455	0.000465	0.00167	0.000332	0.0016	-0.000444	0.00227	-0.0036	0.00236	-0.00242	0.000341	0.00532	0.000419	0.00385
Futures Price of Wheat ($/bu)	0.000506	0.0000303	-0.00192	-0.0164	0.00975	-0.000277	-0.00347	-0.0128	-0.0127	-0.000764	-0.006	-0.0111	0.00745	-0.0321	-0.0079	0.00123
Recharge Rate	-0.343	0.919	-0.34	0.905	-0.869	-2.302	-2.524	-1.144	0.755	-3.41	-3.765	0.74	-1.769	-3.32	-1.445	-0.341
10 year forecast of the real acreage-weighted price of commodities $/bu	-0.807	2.509	0.764	-0.11	-0.507	-1.913	-0.483	-1.624	0.163	2.286	0.488	0.44	0.69	0.548	0.498	-0.691
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Dummy Center pivot sprinkler	-0.245	-0.234	-0.844	-0.109	0.353	1.446	-1.629	1.578	-0.511	-1.718	-1.61	-0.758	-0.801	-1.751	-0.956	0.184
Dummy Center pivot with drop nozzles	0.539	0.371	-0.172	0.657	0.628	1.44	-0.536	1.916	0.104	-0.271	-0.167	-0.188	0.162	-1.266	-0.19	1.104
Constant	3.943	-1.278	10.35	0.759	11.48	27.81	10.37	13.31	-6.583	-14.86	4.363	-6.273	9.445	1.261	3.826	-12.7

State (Crop Codes)	1	2	3	4	5	8	9	10	11	15	16	17	18	19
Water Depth	0.0126	0.0268	-0.00819	0.0193	0.0101	0.0308	0.0209	0.0196	0.00037	0.0231	-0.000158	0.00563	-0.000453	-0.00385
Field size (ac)	-0.00426	-0.00421	-0.00298	-0.00808	-0.00408	-0.00192	-0.00807	-0.00319	-0.00205	-0.00397	0.00372	-0.000481	0.00238	0.00272
Depth to Water	0.000104	0.0000964	-0.00249	-0.00472	-0.000866	0.0108	-0.000259	0.000854	-0.0014	0.000352	-0.000542	0.00155	0.00156	-0.000285
Energy price $/mmBtu	-0.0212	0.0915	0.159	-0.105	0.0304	-0.386	0.338	0.368	0.276	-0.214	-0.0595	-0.0404	-0.243	-0.0301
Energy price squared	-0.000452	-0.00209	-0.00508	0.00336	0.000967	0.0124	-0.0121	-0.00864	-0.00649	0.00939	0.00487	-0.000239	0.00609	0.00208
Energy price $/mmBtu*Depth to groundwater	-0.00000398	0.0000296	0.000238	0.000493	0.0000516	-0.00228	0.0000465	-0.0001	0.000177	-0.000254	-0.0000135	-0.000233	-0.000206	-0.000544
Yearly precipitation (in)	0.159	0.235	0.171	0.389	-0.00303	0.308	-0.3	-0.199	-0.396	0.0607	0.0242	0.31	0.278	0.333
Average evapotranspiration (in)	0.133	0.147	0.0242	0.195	-0.00775	-0.0487	1.238	0.965	0.0444	0.00393	-0.077	-0.032	0.458	0.119
Slope (% of distance)	-0.0368	-0.0932	-0.102	-0.201	-0.017	0.0768	-0.394	0.0718	-1.474	-0.0642	-0.267	-0.0839	0.155	0.0121
Irrigated Capability Class	0.761	0.0766	0.027	0.101	0.176	0.456	0.374	-0.228	-2.789	0.426	0.0844	0.318	0.194	0.234
Dummy for Sat Thick < 29.5	-0.344	-0.612	-0.146	-0.587	-0.33	-0.35	-1.928	-0.752	-0.247	-0.0649	-0.163	-0.399	-0.363	-0.903
Quantity authorized for extraction (AF)	0.000257	0.00127	0.000856	0.000871	0.000622	-0.000849	0.000659	0.000709	-0.00364	0.000397	0.00121	0.00128	0.00111	0.000959
Futures Price of Alfalfa ($/bu)	0.00484	0.00079	0.0103	0.00348	0.00379	0.0118	-0.00138	-0.0119	0.00974	0.0131	0.00553	-0.00117	-0.00148	0.0112
Futures Price of Corn ($/bu)	-0.00741	-0.00239	-0.026	0.0158	-0.00926	-0.0202	-0.00245	-0.023	0.00713	-0.00294	-0.00203	0.00749	-0.00301	-0.0109
Futures Price of Sorghum ($/bu)	0.0316	-0.104	0.627	-0.421	0.167	-0.203	-0.408	-0.129	-0.108	0.174	0.102	-0.208	-0.241	0.282
Futures Price of Soybeans ($/bu)	0.00122	0.000137	0.00304	0.000507	0.00196	0.00168	-0.00444	-0.000607	0.000632	0.000632	0.000836	-0.00182	0.00121	0.00122
Futures Price of Wheat ($/bu)	0.00171	0.00261	0.000458	-0.00335	-0.000362	0.0102	0.0123	0.0104	-0.0015	-0.00314	-0.00151	0.00538	0.00642	0.00136
Recharge Rate	-0.407	-0.476	-0.247	-0.351	-0.269	-0.606	-0.196	-0.0608	1.437	-0.132	-0.197	-0.485	-0.433	-0.739
10 year forecast of the real acreage-weighted price of commodities $/bu	0.375	1.517	1.255	-0.365	0.688	0.273	3.587	2.141	0.778	-0.449	0.514	-0.458	0.344	1.298
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Dummy Center pivot sprinkler	1.059	0.949	-0.17	1.105	1.02	1.881	1.208	0.563	-4.052	0.608	-0.532	1.187	-0.133	-0.857
Dummy Center pivot with drop nozzles	1.413	1.484	0.0114	1.657	1.361	2.146	1.667	1.074	-2.4	0.903	0.0923	1.843	0.423	-0.333
Constant	-13.4	-17.04	-8.411	-20.19	-2.709	-7.811	-77.91	-57.06	-2.462	-2.53	2.216	-8.394	-34.8	-20.82

State contd (Crop Codes)	*21*	*23*	*24*	*25*	*26*	*27*	*28*	*30*	*32*	*35*	*43*	*44*	*46*	*48*	*49*
Water Depth	0.00212	0.00555	0.0168	0.00963	0.00248	-0.00828	-0.0114	0.00405	0.00467	0.00519	0.0124	0.0119	0.0105	0.0224	-0.00613
Field size (ac)	0.00237	0.00285	0.000531	0.00406	0.000833	0.00239	0.00318	0.00192	0.00207	0.00536	0.00495	0.00646	0.00576	0.00471	0.0069
Depth to Water	-0.0093	0.000163	-0.0014	0.00153	-0.00612	-0.00598	-0.00216	-0.0012	0.000251	-0.00739	0.00246	0.00246	0.000173	0.000875	-0.00696
Energy price $/mmBtu	-0.428	0.198	0.0272	-0.0345	0.0151	0.174	-0.241	-0.0505	0.402	-0.536	0.405	0.0583	-0.321	0.611	-0.245
Energy price squared	0.0127	-0.0056	0.00354	0.00618	0.0058	-0.00444	0.011	0.00245	-0.0113	0.014	-0.0112	0.000865	0.0135	-0.0155	0.0105
*Energy price $/mmBtu*Depth to groundwater*	0.000715	-0.0000204	0.000169	-0.000181	0.000669	0.000345	0.000177	0.000106	-0.0000539	0.00067	-0.000193	-0.000293	0.00005	-0.000101	0.000468
Yearly precipitation (in)	-0.00983	0.292	0.552	-0.0345	0.136	0.414	-0.0558	0.401	-0.0658	0.039	0.579	0.0162	0.367	-0.126	0.357
Average evapotranspiration (in)	0.181	0.123	0.68	-0.132	0.564	0.385	-0.17	0.284	0.648	0.132	0.426	-0.195	0.198	0.177	0.0704
Slope (% of distance)	-0.0604	-0.0269	-0.25	-0.17	-0.25	-0.443	0.142	-0.197	-0.0326	-0.101	-0.269	0.0605	-0.459	0.0746	-0.0402
Irrigated Capability Class	0.303	-0.123	-0.0609	-0.162	0.0936	-0.0093	-0.207	0.0307	-0.013	0.256	-0.513	-0.386	-0.0234	-0.143	-0.207
Dummy for Sat Thick < 29.5	-0.262	-0.289	-0.445	-0.427	-1.01	-0.0154	-0.0509	-0.523	-0.631	-0.88	-1.171	0.0422	-1.102	-0.329	-0.607
Quantity authorized for extraction (AF)	0.00135	0.000839	0.00169	0.00114	0.00156	0.000111	0.00123	0.000941	0.000765	0.00154	0.0015	0.0017	0.00142	0.00153	0.00108
Futures Price of Alfalfa ($/bu)	0.00943	0.00803	0.00506	0.00465	-0.0221	0.0103	0.0143	-0.00639	-0.00746	-0.00308	-0.0141	0.00434	0.00343	-0.0138	-0.000158
Futures Price of Corn ($/bu)	0.00256	-0.0155	0.0134	-0.000293	-0.021	0.0155	-0.0233	0.0185	-0.026	-0.0179	-0.00354	-0.0131	0.0108	-0.0212	-0.00786
Futures Price of Sorghum ($/bu)	-0.342	0.318	-0.155	0.153	0.0456	-0.0937	0.691	-0.357	0.553	-0.146	0.0935	0.424	0.0169	0.376	0.255
Futures Price of Soybeans ($/bu)	0.000802	0.00166	-0.000563	0.000734	-0.000318	0.000719	0.00324	0.000467	0.0000977	0.00199	-0.00113	0.00137	0.000332	0.00146	0.00105
Futures Price of Wheat ($/bu)	0.00535	0.00229	-0.00494	-0.0039	0.0115	-0.00645	-0.000658	-0.0027	0.00789	0.0121	0.00167	-0.000175	-0.00619	0.00174	0.00189
Recharge Rate	-0.0936	-0.656	-0.473	-0.54	-0.43	-0.29	0.144	-0.506	-0.17	-0.647	-0.543	-0.174	-0.665	-0.702	-0.208
10 year forecast of the real acreage-weighted price of commodities $/bu	0.258	1.717	1.129	1.67	3.005	0.572	0.514	-0.88	1.397	0.224	2.277	1.824	-0.449	3.547	0.0721
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Dummy Center pivot sprinkler	0.0394	-0.841	-0.33	0.227	0.255	-0.611	-0.163	1.111	1.104	-1.301	-1.537	-0.629	-0.475	-0.189	-0.304
Dummy Center pivot with drop nozzles	0.581	-0.276	0.392	0.58	0.99	-0.31	-0.0154	1.615	1.739	-0.25	-1.025	-0.304	0.167	0.661	0.0988
Constant	-14.13	-20.35	-55.71	2.467	-42.57	-38.3	8.185	-27.27	-43.58	-9.055	-46.83	2.151	-20.17	-21.84	-15.49