The Economic Impacts of Agricultural Groundwater Markets

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Groundwater markets offer a cost-effective means of meeting management goals under the 2014 Sustainable Groundwater Management Act. Using data from the Coachella Valley groundwater basin, we quantify the economic impacts of trade in one of California's most important agricultural regions. Facilitating groundwater trade under a mandatory basin-wide "cap" on pumping will reduce disruptions to the local economy and keep land in production, relative to a scenario where trade is prohibited.

The 2014 Sustainable Groundwater Management Act (SGMA) is revolutionizing the way that Californians use and manage groundwater. Previously unmanaged and unregulated by the state, many California groundwater basins have suffered significant declines in storage levels because groundwater is pumped faster than the replenishment rate. SGMA imposes timelines for newly formed, local regulatory agencies to reach long-term sustainable groundwater levels. In order to end unsustainable practices, many agencies are currently working to find ways to reduce overall groundwater withdrawals from their basins. Groundwater markets have entered the discussion as a potential management tool, and in some cases, are already being implemented.

Groundwater markets are an appealing management tool. They represent the cheapest way for society as a whole to achieve a sustainability goal by incentivizing reduction in pumping by those that can cut back at the least cost. Furthermore, relative to some other management tools, markets can eliminate some uncertainty in reaching a sustainability goal; an explicit "cap" is set on the amount of water available for pumping prior to trade. However, the potential spatial redistribution of extraction resulting from trading can have impacts on the hydrologic system. Extraction from Point A vs. Point B can affect hydrologic connectivity and spatial variability in the depth to the groundwater, ultimately affecting extraction costs and groundwater-dependent ecosystems.

When considering these external impacts, it is important to consider what would happen under alternative management approaches, i.e., groundwater restrictions but no trade, as opposed to the status quo. Under SGMA, the status quo (no groundwater management at all) is no longer an option; agencies must make their basins sustainable whether they implement markets or not. Given the necessity of a "cap," the relevant comparison becomes "cap-and-trade" vs. "cap-but-no-trade." In this article, we explore the responses of agriculture to both scenarios, estimate the economic impacts of allowing trade, and discuss ways of preparing for the spatial redistribution of pumping that may occur due to trade.

Responses to Groundwater Restrictions

To prevent continued groundwater basin overdraft, a farmer's allocation of groundwater pumping rights will likely be reduced from past practices. Let us first consider a farmer's response to groundwater reductions when trade of pumping rights is prohibited. We can think of a restriction on groundwater use as an increase in the price or cost of using water as an input to production. Farmers can respond to changes in the price of water by adjusting water use along several dimensions. These dimensions might include acreage, crop choice, and other inputs and technologies that affect water use. These responses are important to consider when comparing different policies, and will change if water is available to buy or sell.

Since a constraint on groundwater use effectively increases the cost of applying water as an input, groundwater restrictions will incentivize farmers to switch to crops that are less water-intensive. An increase in the price of water effectively decreases the value of a water-intensive crop, and thus we expect substitution towards crops that require less applied water per acre.

If we consider water and land to be complementary inputs to production, then an increase in the price of water will decrease irrigated acreage, meaning groundwater restrictions may induce land being taken out of production. Similarly, if we think water and labor are complementary inputs to production, then we can expect an increase in the price of water to decrease the use of labor as well. As a result, we expect groundwater regulations to affect land use and labor decisions, regardless of whether trading is allowed.

The Role of Markets

In a groundwater market, or a cap-and-trade scenario, those who hold rights to pump groundwater would be allowed to sell or lease their rights, and others would be able to buy the right to pump additional groundwater. Those willing to pay the most for an additional acre-foot of groundwater would buy from those who are willing to be compensated in exchange for that groundwater. Selling or supplying groundwater in this context simply means being paid not to pump up to one's full allocation of groundwater pumping rights. Unless permits were auctioned off, farmers would not have to pay for

Table 1. Top 10 Coachella Valley Crops, Revenue, and Average Applied Water

Crop	Acreage	Revenue	Revenue Per Acre	Applied Water (AF/Acre/Year)	Revenue Per Acre-Foot
Dates	7,964	$40,110,000	$5,036	8.0	$630
Grapes	7,379	$143,222,000	$19,409	3.0	$6,470
Bell Peppers	5,288	$77,700,000	$14,693	2.0	$7,347
Lemons	5,200	$110,605,000	$21,270	2.9	$7,334
Carrots	4,777	$28,700,000	$6,007	2.5	$2,403
Broccoli	2,475	$14,561,000	$5,883	1.7	$3,461
Sweet Corn	1,883	$11,174,000	$5,934	5.0	$1,187
Lettuce	1,600	$12,480,000	$7,800	1.2	$6,500
Watermelon	1,525	$14,860,000	$9,744	3.0	$3,248
Mandarins	1,475	$19,721,000	$13,370	2.5	$5,348
Total	**39,566**	**$473,133,000**			

their initial allocation of groundwater permits. Once permits were allocated, an individual could choose to opt out of trading (that is, hold on to their pumping rights), and in that sense, can be made no worse off in the presence of a trading regime than under a scenario where trade is not allowed.

Allowing trade of groundwater pumping rights is a way to reduce the increased water costs associated with a required reduction in groundwater use, meaning land and labor adjustments would happen to a lesser extent. Water markets provide another avenue through which to adapt, so less land would be fallowed, and less acreage would be switched to different crops relative to a cap-but-no-trade scenario.

Well-functioning groundwater markets would, in theory, minimize the disruption to the local farm economy that would come from a mandated reduction in groundwater use. Markets represent an economically efficient or cost-effective way to reach a conservation goal; the outcome after trade represents the most efficient way for society to reach a given basin-wide curtailment of groundwater pumping.

Economic Benefits from Trade

Quantifying the relative benefits from market-based instruments is important for understanding which groundwater management tools are best. To estimate the magnitude of the benefits from trade, I combined a theoretical and statistical model of agricultural groundwater use to evaluate the impacts of groundwater markets. The model is applied to the Coachella Valley, a groundwater-dependent agricultural region in Southern California located just north of the Salton Sea and southeast of the San Bernardino Mountains.

A novel feature of this model is that all parameters were either constructed or estimated with observational data from the Coachella Valley. Importantly, the price responsiveness of groundwater users was estimated with rich, micro-level data on groundwater extraction and groundwater prices. The Coachella Valley Water District is one of very few water districts that charge volumetric prices for agricultural groundwater pumping, enabling the estimation of the price responsiveness.

Agriculture in the Coachella Valley depends heavily on groundwater and Colorado River water for irrigation, and has roughly 65,000 acres in crop production with a total production value of over half a billion dollars a year. The area produces 95% of the nation's dates, as well as table grapes, citrus fruits, bell peppers, and other vegetables.

Because the Coachella Valley groundwater basin has suffered at times from groundwater overdraft, three of the Valley's four groundwater sub-basins are subject to a timeline and set of goals mandated by SGMA for reaching groundwater sustainability. Multiple water agencies in the Coachella Valley have been approved by the California Department of Water Resources to jointly manage the Coachella Valley groundwater basin over the coming years. They are required to work together to reach sustainability targets for the entire basin, e.g., by trading groundwater pumping rights. In this analysis, we consider the impacts of a 20% reduction in basin-wide groundwater reduction, which is the reduction required to eliminate the roughly 70,000 acre-feet (AF) of average overdraft reported by the Coachella Valley Water District.

Table 1 lists the 10 leading crops grown in the Coachella Valley, along with information on revenues and average applied water. Revenue and acreage data come from the Coachella Valley 2016 Acreage and Agricultural Crop Report and applied water by crop comes from University of California Cooperative Extension Cost and Return Studies. Revenue per acre-foot of water is calculated by dividing per-acre revenues by the average acre-feet of water applied (note 1 AF=325,853 gallons).

The economic model characterizes the short-run gains from groundwater trade in equilibrium as a function of four features of the market setting: the heterogeneity in demand for groundwater across users, the price responsiveness of groundwater pumpers, the total allowable pumping in the basin, and the initial allocation of groundwater rights among users. Assuming a required reduction in basin-wide use of 20% and an initial allocation of permits based on land holding, model results for the Coachella Valley show that the economic surplus with trade is 47% larger than under a cap-but-no-trade scenario, if trade is perfectly competitive.

We can alternatively consider the impacts of markets in terms of the reduction in the cost of compliance with SGMA. Model results show that the cost of compliance from a 20% reduction in basin-wide groundwater extraction can be reduced by 59% with voluntary groundwater trade.

The value of the gains from trade for the Coachella Valley were calculated with estimates of average annual groundwater extraction of about 230,000 AF and a pumping price of $126 per AF. Assuming the water district imposed pumping restrictions of a reasonable magnitude and distributed permits for pumping based on current acreage, the possible gains to Coachella Valley groundwater users from water trading relative to cap-but-no-trade are estimated at $40.6 million annually. Allowing groundwater trade could significantly improve welfare.

Given the model assumptions and parameter estimates calculated for the Coachella Valley, the gains from trade are large, meaning markets have potential to cause significant cost-savings when it comes to implementing SGMA. Furthermore, a simulation analysis shows that the gains from trade remain large over a reasonable range of parameter values. Therefore, results are likely to generalize to other basins where trading might occur. Allowing and enabling trade on groundwater basins facing pumping reductions due to SGMA will mean fewer disruptions to the local economy and less land being taken out of production, relative to the alternative where trade is prohibited.

Protections for Third Parties

Groundwater markets will have impacts on parties that are not directly involved in trading. These external parties may include rural communities that rely on groundwater for drinking supply, groundwater-dependent ecosystems, surface water supplies, and farm labor. Relative to a cap-but-no-trade scenario, markets result in economic benefits for the farm labor economy and rural communities through their substantial cost-savings. However, due to some of the unique features of groundwater as a commodity, the spatial redistribution of extraction due to trade may have physical consequences that will affect surface water, small-system drinking supplies, habitat, and ecosystems.

Trading rules and restrictions can be imposed to protect these third parties. Nylen et al. (2017) suggest a number of rules to address concentration, hydrologic connectivity, and other spatial impacts. Instead of allowing groundwater to be traded on an AF-for-AF basis, it has been suggested that trades be adjusted according to where the trades are occurring and the impacts associated with the locations. For example, groundwater trades near streams could be subject to a different trading ratio than sales far from surface water supplies. To further avoid ``hot spots" or cones of depression in the groundwater table near rural residential areas, limitations or boundaries can be set. Trading restrictions can be set to limit transactions from certain areas entirely.

Conclusion

Many groundwater management agencies are considering, or already implementing, market-based instruments for managing groundwater under SGMA. This research contributes to our understanding of the potential for groundwater markets by estimating the efficiency gains from groundwater trade for the water district serving the Coachella Valley. In this simulated scenario, Coachella Valley irrigators had to reduce aggregate groundwater use by 20%. With this cut-back, allowing trade improves economic outcomes by almost 50% relative to the same restriction without trade.

The substantial cost-savings that come from allowing groundwater trade in the face of basin-wide groundwater restrictions can have large positive impacts on agricultural producers, consumers, disadvantaged communities, and local farm labor. Of course, these results are conditional on assumptions about the nature of trading and they must be considered in light of the impacts from the spatial redistribution of pumping, but they speak to the potential benefits of allowing trade given a water restriction of this magnitude.

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For additional information, the author recommends:

Bruno, E.M. and K.K. Jessoe. 2018. ``Water Markets and Climate Change Adaptation: Micro-level Evidence on Agricultural Water Demand." Working Paper, Department of Agricultural and Resource Economics, UC Berkeley.

Bruno, Ellen. "California's New Groundwater Law and the Implications for Groundwater Markets." *ARE Update* 20(4) (2017):1–4. University of California Giannini Foundation of Agricultural Economics.

Nylen, N.G., M. Kiparsky, K. Archer, K. Schnier, and H. Doremus. 2017. ``Trading Sustainably: Critical Considerations for Local Groundwater Markets under the Sustainable Groundwater Management Act." Working Paper, Wheeler Water Institute and Center for Law, Energy & the Environment, UC Berkeley School of Law.