MARKETS FOR WATER: ALL-IN-AUCTIONS

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ABSTRACT. Although water markets hardly exist in many parts of the world, those that do exist suffer from illiquidity to the extent that potential sellers do not participate in markets (a *participation effect*) and those who do participate tend to ask too much for their water (an *endowment effect*). This paper describes an auction mechanism that will minimize these effects, maximizing water allocation efficiency and social welfare. In the final section, we briefly discuss our future plans to test the mechanism in the lab and field.

1. Background

Economists support market-based allocation of natural resources over command and control allocations in which a regulator estimates "appropriate" quantities and/or prices based on a-priori guesses of agent preferences and/or behavior (Hayek, 1945). The natural resource subject to more command and control than many others is water, and economists have argued for years that markets for water would increase both efficiency-in-use and social welfare (Milliman, 1956; Vaux Jr. and Howitt, 1984; Rosegrant and Binswanger, 1994; Zilberman et al., 2007).

Auctions are superior to other trading institutions (e.g., bargaining) because they move goods from sellers who value them least to buyers who value them most (maximizing surplus) with reasonably low transactions costs (McAfee and McMillan, 1987; Milgrom, 1987) and evolutionary stability (Lu and McAfee, 1996).

Auctions have been widely used to effectively allocate and privatize natural resources such as oil and gas, timber and even pollution. The practical use of auctions has, in turn, led to substantial developments in the theoretical and empirical analysis of auctions.

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1.1. **Multi-unit Auctions.** In a single-unit auction, potential buyers compete for the good under any one of several pricing rules (English, Dutch, Vickrey, etc.). When multiple, homogenous units need to be exchanged, these rules are no longer efficient.[1]

In single-sided, multi-unit auctions, potential buyers' bids are compared to determine winners. Because bids are interdependent (one bid can affect the price paid for another, successful bid), the bidding mechanism matters. A uniform-price (highest rejected bid), multiple-unit auction, e.g., suffers from bid-shading. Ausubel (2004) solved this problem with a discriminatory price design where bidders "clinch" units—in ascending order—at prices just below their bids. Ausubel's design achieves efficiency for multiple units in the same way that the Vickrey auction did for single units (Vickrey, 1961).

When more than one seller exists, a two-sided, multiple-unit auction is appropriate. They are most efficient, theoretically, when sellers and buyers submit, respectively, their supply and demand schedules.[2] Two-sided auctions can suffer from two problems, however. The first is when too few sellers participate (the participation effect), and the second is when sellers ask for prices that are too high (the endowment effect). Jointly or severally, these effects can result in a suboptimal allocation of goods.

1.2. **Participation Effects.** The participation effect appears in the literature on the extent or existence of markets, i.e., when markets *do not exist* for goods that could be reallocated in markets, social surplus is smaller. For example, it is "immoral" to allow a market in human organs; businesses may produce internal goods that could be outsourced; water, as a human right, should be free; land should not be owned by individuals, etc. (Polanyi, 1944; Cyert and March, 1963; Buchanan, 1978; Easter et al., 1998; Blank and McGurn, 2004). If these markets do exist but participation is too low (e.g., too few sellers increases the market power of participating sellers or the collapse of the market), then social surplus is. likewise, lower.

[1]Consecutive or aggregated single-unit auctions suffer from the lumpy bid problem (Tenorio, 1993).

[2]Unfortunately, the multiplicity of possible equilibria in multi-unit auctions makes analytical comparison of bidding strategies intractable. (The generalized Vickrey is the only format for which equilibrium bidding strategies can be analytically calculated (Ausubel, 2004).) Researchers instead explore optimal bidding behavior using experiments and simulations (Alsemgeest et al., 1998; Kagel and Levin, 2001; Hailu and Thoyer, 2006).

1.3. **Endowment Effects.** Kahneman and Tversky (1979) developed prospect theory to explain how people see gains and losses differently. The endowment effect arises when people attach higher values to the objects they already own than to objects they want to buy, i.e., their willingness to accept exceeds their willingness to pay.[3] Although the literature supporting the existence of the endowment effect (reviewed in Plott and Zeiler (2007)) is vast, some argue that endowment effects are the residual of carelessly-designed experiments (Plott and Zeiler, 2004, 2007). In Engelmann and Hollard (2008), for example, the endowment effect disappears when participants are forced to trade arbitrarily-assigned lab endowments.

1.4. **Application to Water.** These effects are particularly strong in the water sector, i.e., those who own water rights often do not participate in water markets, and those who do participate often ask to be paid more for their water than they could ever make by using it.[4]

From a strategic perspective, water rights owners may be averse to participating in a market because they fear that such participation would signal that they have "water to spare," which might lead policy makers to reallocate water elsewhere. In the absence of suitable substitute to fresh water, farmers are alert to keep their (historical) rights to water use.

From a cultural and psychological perspective, the strength of endowment effects is plain: Water rights tend to be held for years (if not generations); water is essential for life and community existence; water distribution is often carried out by organizations with deep cultural and social roots in a community; and water costs are often in proportion to system costs, not water consumption. All of these factors weaken the commodity aspect and strengthen the integral aspect of water to water users, many of whom have never considered the possibility selling *their* water to the highest bidder. If asked to name a price, water users are more likely to over-estimate than under-estimate what they would be willing to accept.

Notwithstanding these factors, the case for water markets (and particularly the All-in Auction) is strong. In most countries water is owned by the People. (Water users have

[3]For empirical evidence in support of the endowment effect, see Kahneman et al. (1990).

[4]Because water use creates positive and negative externalities, the decision to participate in a market has both private and social consequences. We ignore these effects in our analysis but assume that they will be integrated into the AiA.

usufruct rights, i.e., the right to *use* a certain flow of water.) Because water rights are divided among owners (the People) and users, it is not obvious that users can or should participate in markets, but it is obvious that the allocation of water to highest and best use is in the interests of the People, which not only justifies forcing users to participate in the AiA but also justifies State support for the AiA's existence and operation.

2. Existing Markets for Water

Trade in water takes place in both formal and informal water markets. Informal markets tend to work better when water rights are not well defined or recorded, e.g., in India and Pakistan. Formal markets work when water rights are well defined, and conveyance infrastructure facilitates trading, e.g., in the US (California, Colorado and Georgia), Chile and Australia (Easter et al., 1998).

Tisdell and Ward (2001) ran field experiments with Australian farmers to see how they would perform with auctions. Years later, Taylor (2008) reports that water trades—amidst record drought—are worth over $A 1 billion per year. These trades, representing about 30 percent of total water, tend to be complicated by many rules and regulations, and participants from all sides are interested in greater efficiency. Cummings et al. (2004) describe a *reverse* auction mechanism in which farmers competed to offer water at the lowest price to the state of Georgia. This mechanism was only used once (in 2001-2002), but ongoing drought may force Georgia to use it again.

2.1. **Israel.**

Israel exemplifies a country struggling to reconcile the demand and supply for water. Winter precipitation averages 400–800mm per year in the north and west and drops almost to zero in the south-east of the country. Annual precipitation varies considerably from one year to the next. In the 60 percent of the country classified as arid, agriculture requires year-round irrigation; in the relatively wet north-western region, crops require irrigation between April and October. Annual sustainable water yield averages roughly 2,000 gigaliters (1.62 MAF).

Israel's water resources are regarded as national asset and are protected by law. Subject to availability, Israel's Water Authority allocates about 90 percent of fresh water resources among agricultural, domestic and industrial sectors based on their historical use. (Agriculture accounts for about 70 percent of total water consumption.) The Authority sets water prices independently of market signals.[5]

Israel's climate, hydrology and development would lead us to expect a formal and stable market for water, but only an informal market exists. Farmers are allowed to transfer water rights after receiving special authorization from the Water Authority. Recent experts' reports (Kislev, 2001; Feinerman et al., 2003) have supported a transition to a market-based allocation of water, particularly within the agricultural sector. However, to our knowledge, no concrete proposal for a water reallocation mechanism has been made.

2.2. **California.** California has a population of nearly thirty-eight million people, the largest economy in the US, and the largest agricultural sector (by value) in the US. The trouble is that agriculture, the source of less than one percent of the State's economy, controls over 80 percent of its water. In an era of increasing population, a stronger environmental ethos and realignments *within* the agricultural sector, historical patterns of water allocation do not reflect contemporary priorities. Water reallocation is going to happen; the only question is how. While the traditional means of reallocation are political and legal (e.g., Judge Wanger's recent decisions to shut down pumps exporting water from northern California's Sacramento River Delta to southern California to protect endangered fish that live in the Delta), economic reallocation via markets promises—as usual—to put water in the right place at the right time at the right price, with lower transactions costs and higher overall social welfare.

Although some water trading does occur in California, markets are mostly voluntary, informal and/or severely regulated (Hanak, 2002). In the face of the current drought, the California's Department of Water Resources is establishing a Water Bank to allow trades, but prices will be set by fiat, participation is limited, and transactions costs are high. Further,

[5]For a review on economic aspects underling the water management is Israel see (Kislev, 2001). See Bar-Shira et al. (2006) on the efficiency of Israel's increasing block rate system.

the Bank is unlikely to trade more than 600 TAF (740 GL); statewide water use is about 43 MAF (53,021 GL), divided about 80/20 between agriculture and urban users.

3. Comprehensive Description of the Methodology

The AiA auction has two main features:

(1) *All* water rights are available for purchase—nullifying the participation effect.
(2) All rights are redistributed to those who make the highest *bids*—minimizing the endowment effect.

This mechanism uses soft paternalism (your rights are for sale, but you can always buy back those rights) to reframe the cost of rights from "free" to the final price in the AiA. Such reframing forces those who have held rights for years to reconsider whether the benefit of exercising those rights is high enough. In other words, the AiA makes opportunity costs explicit.

Because the AiA increases liquidity and decreases endowment effects, we expect that AiA efficiency (reallocation from lower to higher-value uses) will be greater than efficiency under the status quo or other market designs. Although the AiA has two additional costs—property rights are weakened because owners cannot opt out, and transactions costs are higher because the AiA has more participants and more units—we believe that the net benefits of the AiA are positive. We intend to test this belief (hypothesis) in the lab and in the field.

Besides economic efficiency, the AiA also addresses a political reality: Those who hold water rights (real or imagined) cannot be forced to give them back without court fights and generous compensation. Because the AiA allows rights holders to *buy from themselves*—by bidding for as many units as they own—it does not threaten their rights. (We expect, of course, that many rights holders will be net buyers or sellers.)

There are a few reasons why the value of the AiA may not be obvious to experimental economists and outsiders. First, non-participants are ignored in real markets and hardly exist in lab markets.[6] Second, we know little about endowment effects in real markets

[6]Outside the lab, ownership over many years (even generations) creates a tradition of ignoring markets, which weakens participation.

because endowment effects only matter when trades *do not* happen; in lab markets, missing trades are more obvious, but it's harder to claim that lab results apply (external validity) in situations where endowments are possessed over many years and/or are non-discrete (e.g., multiple units of water). Finally, it's hard for most people to understand the purpose of a market in which participants might buy back some/all of their endowments.

As mentioned in Section 1.4, economics has little to say about the participation effect. In one example, the US Environmental Protection Agency auctioned sulphur dioxide permits. Under 1990 Clean Air legislation, the EPA was charged with capping SO_2 emissions and facilitating trade in SO_2 permits. To alleviate fears of insufficient trade in permits, the EPA ran auctions for about three percent of all permits. These permits were taken from permit holders and sold to the highest bidders (Joskow et al., 1998). Although such a structure resembles the AiA, it differs in two ways: First, buyers paid their bid (discriminatory pricing) in the EPA auction; they pay a uniform price in the AiA. Second—and more important—the EPA only auctioned three percent of permits, while the AiA has all rights on sale. While one might argue that the EPA was efficient because it reallocated marginal units (many more units were exchanged in bilateral trades outside the auctions), the AiA may increase efficiency by requiring water owners to assess their inframarginal demand for water before they bid to buy back some or all of "their" supply.

So how novel is the AiA? It is the first auction design where all units are for sale ("all in").[7] It is also the first design where sellers (rights owners) have a strong ability to affect the price they receive by bidding as buyers.[8] The typical problem with multi-unit, uniform price auctions is that bidders have an incentive to bid high on the first unit and then shade down their bids on subsequent units because, theoretically, one's subsequent bid may determine the price paid for *all* units (Kagel and Levin, 2008). For those bidders who are also sellers

[7]The Dutch government is auctioning petrol stations to current owners and new entrants over the next 15 years, but those auctions have strong strategic and dynamic effects (NIS, 2008).

[8]Parente et al. (2008) frame their auction by making sellers into buyers, but they do not examine participation effects or strong endowment effects on items owned outside the lab.

in the AiA, this incentive is weakened or even reversed (for big net sellers), so it's not clear that prices will be too low in the AiA.[9]

3.1. **Theoretical Framework.** Let the economic system include I actors that produce the output of y_i, where $i \in I$. y_i is a function of water and other inputs, $y_i = f(w_i, \mathbf{x}_i; \alpha_i)$, where w_i is the $i's$ water right and is equivalent to i's water use (i.e., use it or lose it), $\mathbf{x}_i$ are other inputs and α_i is a parameter representing individual heterogeneity. In this baseline case of autarky, total output is $Y_0 = \sum_i y_i$, and total water use is $W = \sum_i w_i$.

If we assume that marginal value products vary (e.g., $f'_{w_j} \leq f'_{w_k}$) and that $f'_{w_i} > 0 \quad \forall i$, then a reallocation of water from j to k—and, potentially, others—will result in output greater than Y_0. Reallocation can happen in several ways:

With *voluntary bilateral trades*, transfers between buyers and sellers who can find each other and can agree on a price (e.g., $WTP_k \geq p \geq WTA_j$) will result in an output of $Y_1 > Y_0$ at a transactions cost of $C_1 > 0$. We assume that the benefit of trading is $B_1 = Y_1 - C_1$ is greater than Y_0 in equilibrium.

Multilateral two-sided auctions will have more buyers and sellers and price discovery will be faster. We assume that total output (Y_2) will exceed Y_1, and total transactions costs (C_2) will be less than C_1. In equilibrium, the benefit of voluntary auctions is $B_2 = Y_2 - C_2 > B_1$.

Now voluntary two-sided auctions may not maximize trades if either of the following is true:

Participation: j does not enter the auction to trade.

Endowment: j wants to be paid more than the market price *but* j's value of water is less than that price, i.e., $WTA_j > p > WTP_j$.

The proposed AiA framework overcomes participation and endowment effects by, respectively, requiring that all water be offered for sale and requiring that all actors *bid* to buy water. After the auction is over, net buyers pay p per unit, and net sellers receive p per unit. Sellers who buy back their endowment ("wash sellers") thus pay themselves.

[9]Prices may not matter in the AiA if redistribution is more important than revenue, but incentive-compatible bidding is important for efficient reallocation.

Unfortunately, the AiA imposes additional costs for agents who did not participate in voluntary auctions (non-participation agents) or did not sell water when prices were below their willingness to accept (endowment agents). We label these costs, respectively, the cost of participating (c_i^p) and the cost of discovering their willingness to pay, i.e., their demand curve (c_i^d,).[10] These AiA-specific costs total $C^p = \sum_i c_i^p$ plus $C^d = \sum_i c_i^d$. Note that wash sellers (the group with the least to gain from the AiA) can avoid these costs (i.e., $c_i^p = c_i^d \approx 0$) by submitting bids far above the market-clearing price.

If we assume that total output under the AiA (Y_3) exceeds Y_2 and the transactions costs of operating the AiA are $C_3 = C_2$, then the net benefit of the AiA will be $B_3 = Y_3 - C^s - C^d$. From this result, two hypotheses are raised:

(1) Is the AiA better than the next-best alternative in terms of aggregated social welfare (i.e., is B_3 greater than B_2,)?
(2) Is the AiA better than the next-best alternative for all individuals (i.e., is b_3 greater than b_2 for all i agents) ?

We will point out conditions where the AiA promises to be welfare improving.

From the perspective of Society, the AiA will improve welfare when participation and endowment effects are large and participation and discovery costs are small. It is easier to imagine that participation and endowment effects are large with water but not with, say, shares of IBM. Participation costs are both logistical and psychic, but they can be minimized by equating the AiA to other markets (e.g., auction markets for livestock, futures markets for commodities). Discovery costs can be minimized by evaluating water as an input and then deciding how much water to buy—and at what prices—in making production plans.[11]

[10]One might also claim that involuntary participants incur the psychic cost equal to the difference in what they *think* their water is worth (WTA) and what they are willing to pay for it (WTP_i), but we ignore this cost of "delusion" in favor of the more-concrete c_i^p and c_i^d.

[11]Note that we are ignoring changes in welfare to non-participants who may benefit/lose through either pecuniary or non-pecuniary externalities. Although a net loss to this group is possible, reallocation is more likely to result in a net benefit—especially when these non-participants can affect participants through price signals.

In the individual case, the AiA will improve welfare for those who were already in the market, i.e., voluntary auction participants will gain from greater liqidity/lower prices because new participants in the AiA are either net or wash sellers. If—as argued above—wash sellers are not worse off, then the only group left are net AiA sellers who did not participate in the voluntary auction. Their benefit from selling n_i units $b_{3,i} = n_i p - \sum_1^n WTP_{i,n} - c_i^s - c_i^d$, which may be positive or negative.

In sum, the AiA is probably welfare enhancing but not necessarily beneficial to all water rights holders. Given water's status as a good owned by the People, this results rule out the relevance or utility of the AiA.

3.2. **Methodological Variation.** Taking structure as given, we will also want to test alternative pricing mechanisms (probably in the experimental lab). The simplest mechanism sets a uniform-price auction equal to the highest, rejected bid. Although this format may encourage bid shading (lowering one's bid), the presence of buyers cum sellers (who have an incentive to bid high) weakens shading. An alternative mechanism would use Ausubel's clinching mechanism, i.e., bids are ordered, and the highest n (for number of units available) bids pay the next-lowest bid (Ausubel, 2004). Sellers are paid in order of *their* bids, i.e., the seller with the highest bid receives the highest payment. This process transfers units from those value them least (those who submit bids lower than the n^{th} bid) to those who value them the most. Wash sellers end up dividing net buyer payments in proportion to their own value of water. Although uniform prices may leave money on the table, they are easy to understand and result in a single price. An Ausubel mechanism will result in multiple prices, but it transfers more surplus to all rights holders (net and wash sellers). The relative performance of these mechanisms needs to be explored in experiments.

4. Application of the Mechanism

We plan to test the AiA mechanism in three stages: lab, field-simple and field-Smart. In the lab experiments, we will compare the AiA to other auction formats (voluntary participation, two-sided, Ausubel) to clarify the factors that affect traders' choices and efficiency.

In our simple field experiments, we will run the AiA with farmers in Israel and California to control for fixed effects of culture, population size, heterogeneity among traders etc. The field experiments require that:

(1) All rights are adjudicated.
(2) Environmental flows are defined, and water in excess of that minimum is available to rights holders. If there is less water than rights, junior rights are "dry", i.e., no water.
(3) All wet rights are put up for sale.
(4) Everyone who wants to *use* water bids. Those who bid the most get water at the same price (the highest rejected bid). Sales revenue goes to wet rights holders.

After the simple-field sessions, we will design and test a Smart Market version that integrates constraints for groundwater levels, infrastructure capacity, etc. (Murphy et al., 2000; Raffensperger and Milke, 2005; Plagmann and Raffensperger, 2007; Raffensperger, 2008).

If the AiA works as planned, it will take us a long way towards the goal of developing water markets that are efficient yet functional within current institutional constraints (property rights, infrastructure, etc.) Besides the usual value of using markets to allocating resources when demand exceeds supply, the value of the AiA will increase as the adverse impacts of climate change on existing supplies strengthens.

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