We are pleased to submit the enclosed paper titles THE WELFARE GAIN FROM WATER AUCTIONS FOR AGRICULTURE IN ISRAEL for presentation at the 25th Annual BIOECON Conference, Cambridge, 2013. We consider it relevant for the section on "Different institutional frameworks for resource conservation".

Authors: Dafna M. DISEGNI, Amity FEDER and Zvika NEEMAN. Contact author: Dafna M. DISEGNI, Natural Resources and Environmental Research Center at the university of Haifa, and School of Economics at Tel Aviv University. Please contact us by Email at disegni.dafna@gmail.com.

1

The Welfare Gain from Running Water Auctions for Agriculture in Israel

Dafna M. DiSegni[†] Amity Feder[‡] Zvika Neeman[§]

10th May, 2013

Abstract

Water for agriculture in Israel is currently allocated to farmers at fixed quantities and block rates prices. We calculate the welfare gain that would be generated by a switch into a new institutional framework: the auction one. We compare three different multi-unit auction protocols to the current institutional framework, as well as a regional vs. a state level auction on water for agriculture. Data on water pricing, water quotas and water usage within the agricultural sector in Israel is used to simulate the performance of the auctions and to estimate the social welfare generated by the different allocation methods. The bottom line is that changing the institutional framework of water allocation and water use rights is expected to generate a welfare gain of approximately six per cent to the agricultural sector.

JEL classification: D44, D61, Q25.

Keywords: Water Auctions, Allocation Efficiency, State vs. Regional Economic Policy.

[*]Paper submitted for presentation at the BIOECON 15th annual conference, Cambridge 2013. Please do not cite of quote.

[†]Natural Resources and Environmental Research Center at University of Haifa, and the School of Economics at Tel Aviv University. Contact author at: *disegni.dafna@gmail.com*

[‡]Graduate School of Mathematics, Tel Aviv University

[§]Professor, Berglas School of Economics, Tel Aviv University

1 Introduction

Water for agriculture in Israel is currently allocated by quotas at fixed prices (block rates). We calculate the welfare gain that would be generated by a switch into an allocation of water for agriculture through an auction. We compare three different multi-unit auction protocols to the current practice. Data on water pricing, water quotas and water usage within the agricultural sector in Israel is used to simulate the performance of the auctions and to estimate the social welfare generated by the different allocation methods. The bottom line is that a switch into an allocation of water for agriculture by an auction is expected to generate a welfare gain of approximately six percent.

The recent worldwide interest in water markets is a reflection of a growing pressure to increase water use efficiency in order to cope with limitations on water resources and an increasing demand for water (Brooks and Harris, 2008; Crase et al., 2000; Easter et al., 1998; A. Dinar and Meinzen-Dick, 1991). Among the countries that have adopted official water markets are the states of California, Texas, Colorado, Georgia, and Oregon in the United States, as well as Chile, Mexico, Morocco, Spain and Australia. Australia's water market (since 1983 in New South Wales, 1988 in Victoria) is widely-cited as the largest in the world in volume, value, and percentage of total water rights traded (K. J. Landford and Malcolm, 1998; Crase et al., 2000; Brooks and Harris, 2008; Rolfe and Windle, 2011). Most of these states and countries have adopted auctions for allocating their water, but the auction structure adopted vary across states.

In part, the auction structure results from different institutional water rights that vary greatly in terms of reliability, volume, and delivery cost. In some cases, auction bidders were required to place their entire entitlement amount in auction (Cummings et al., 2004) while in other auctions participants were able to auction a portion of their entitlement amount (Hartwell and Aylward, 2007). The auctions also vary in their method of bidding: for instance, in Oregon state, the Deschutes River Conservancy (DRC) proposed a first-price English (ascending-bid) auction (Hartwell and Aylward, 2007). Under this approach, bidders submit open bids to purchase mitigation credits. Bidding information is public, and as auction participants learn of others bids, they can in turn submit bids at higher levels; the Murray Darling Basin Commission in Australia adopted the sealed bid approach (Crase et al., 2000). Variation exists also in the pricing mechanism, either setting uniform pricing or discriminatory pricing.

However, the relative performance of auction mechanisms compared to other types of allocation methods and the direct effect that auctions have on the redistribution of water among farmers, the relative benefit to farmers and society have hardly been assessed for most markets. Simon and Anderson (1990) describe the results of the use of an auction to allocate water in Victoria, Australia, during 1988, and point to differences in market prices for water across regions that are characterized by similar agricultural crops. Heaney et al. (2004) identify key potential third-party effects of water trade under existing property rights structures in Australia and have assessed the relative impacts of these effects. This study indicates that removal of administrative impediments to the trade of water will result in around 600 giga liters (around 15 percent of total water entitlements in the region at that time) of additional trade in permanent water entitlements. Peterson et al. (2005) examined the effects of hypothetical reductions in water availability at the southern Murray-Darling Basin, in Australia, under scenarios of no-trade, intra-regional trade (by irrigators) only, and both intra- and inter-regional trade by irrigators. Their study indicates that allowing for both intra- and inter-regional trade by irrigators would halve reductions in gross regional product due to a hypothetical decrease in irrigation water availability of 10 percent. Brooks and Harris (2008) explain that some efficiency enhancing trades are prevented because of physical limitations of the delivery system which generates different prices for water in different areas. However, they find that altogether, in Murray-Darling Basin, relatively large gains have been made thus far, suggesting that water markets will expand and generate additional increases in consumer and producer surplus in the future.

In the present paper we evaluate the welfare gains to the farmer and to the society from three mechanisms of water auctions and compare them to the step-pricing mechanism, for allocation of water among farmers. We also compare the relative efficiency of a regional rather than a state level auction. To this end, we conduct a simulation that is based on water consumption in Israel, where water consumption within the agricultural sector is regulated via step-pricing mechanism and auctions are not in use. We start with a short description of the current method for allocating water within the agricultural sector in Israel and discuss the potential gain from trade in water (Section 2). In Section 3 we describe three different methods for allocating water through an auction. These are the Vickrey auction, the Uniform Auction and the Discriminatory Auction. In Section 4 we describe how we simulated the demand for water within the agricultural sector in Israel using a detailed data on water allocation and consumption in 2008. The simulated demand is subsequently used to simulate the performance and welfare gains from three auction types described in Section 3, relative to the current practice.

2 The current allocation system in Israel

Israel exemplifies a country that struggles to reconcile the demand and supply for water. 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. Approximately 60 percent of the country is classified as arid. In this part, agriculture requires year-round irrigation; in the relatively wet north-western region, crops require irrigation only between April and October. In the last five years the agricultural sector used about 1120 million cubic meters of water, of which about 40% were fresh water and 60% were secondary water (effluents, saline, and runoff). Secondary water use in agriculture have steady increased in the last two decades.[1]

Water authorities in Israel decide how much water to supply to farmers in a given year based on the current amount available and the estimated level of precipitation and treated waste water. In principle, the allotments to farmers (relative shares) were set based on the land area cultivated by the farmer during the 80s and in practice, it has not changed much in the last several decades. The current pricing of water follows a three block pricing (tier) approach. The lowest price is applied to consumption of up to 50% of the (historically fixed) quota. The medium tariff (2nd tire price) is levied on consumption between 50% and 80% of the quota and consumption above 80% is charged the 3ed tire price. Farmers are not supposed to exceed their quotas. In practice, farmers who did exceed their quotas were charged the third tier price for the excess amount of water that is consumed.[2] Notably, the use of historical quotas as benchmarks for price blocks creates exogenous variation across farmers regarding the price schedules they face.

The inefficiency of the block pricing scheme relative to a uniform water price in Israel was simulated by Bar-Shira et al. (2006), who noted two interesting phenomena:[3] First, that switching to a single price lowered the welfare of all groups of farmers (while raising the revenues of the water supplier); and, second, that block rate trading favors small farmers. A move to a uniform price mostly affect the smallest farmers (lower quartile) who suffer a 20% loss in welfare, while the least affected are the largest water users, who lose only 4%. The flat price was set such that aggregate water use under flat price is fixed at the aggregate water used under block pricing. A further examination of a flat price set such that average costs are set fixed resulted in similar finding. Nonetheless, The imposition of constraints to set a flat price imply a bias in the estimated welfare gain that could result from a switch between flat

[1] Water shortage in Israel has fostered an extensive use of water from different sources, including fresh water, saline water, recycled water and desalinated water. Israel's ministry of agriculture encourages the use of secondary water types by replacement of quotas of fresh water with a larger amount of water from lower quality. We have used the ratio of replacement used by the ministry to compute farmers' demand for equal-valued units of fresh water. Rates of substitutions are 1.75 : 1 between saline and fresh water, 1.6 : 1 between Dan district treated waste water and fresh water, and 2 : 1 between recycled effluents and fresh water. Desalinated water is valued equally as fresh water.

[2] In practice, we don't observe a fine on access consumption of water, but officially there is such a fine.

[3] Study was based on consumption of fresh water in Israel in 1997).

pricing and block pricing of water in general. The overall welfare gain from a switch to a uniform price set by market forces has not been computed.

In the simulation that follows we show that the auction mechanism results in similar trends as of the relative benefit among groups, but at different from Bar-Shira et al. (2006) we demonstrate that large water users may benefit from the move to one price auction while small farmers mights undergo a significant decrease in welfare and even exit the market. We also compute the overall welfare gain from setting a flat price by auction, and characterize its impact on small vs. large farmers.

Table 1 below describes the distribution of farmers and water usage across the three tiers of prices during 2008.[4] Farmers whose level of water consumption belongs to the 1st tier (first column) used up to 50% of their quota, farmers whose level of water consumption belongs to the second tier used between 50%−80% of their quota, and farmers whose level of water consumption belongs to the third tier used 80% and more of their quota. In 2008, the 29% of the farmers belong to the first tier and consumed 2.16% of the water. The 11% of the farmers in the second tier consumed 11% of the water, and the remaining farmers, almost 60% in all, who all belonged to the third tier, consumed 86.8% of the available water for agriculture, which was higher than the allocation of water to these farmers.[5]

The revealed consumption suggests that the allocation of water for agriculture in Israel is inefficient. This inefficiency is due to at least three principal reasons:

1. Marginal units of water are allocated to farmers at different prices, independently of their personal valuation for water. There seems to exist a significant potential for improvement in efficiency from transfers of water between farmers in the first and third tiers, especially given the fact that the latter's consumption of water was larger than their quotas.

2. Some farmers do not consume all of their allotted quota, while others need more water than their given allotment. Transfer of the water is illegal, because the water was given to the farmers for agricultural use only. The consequence is unused available water while farmers who need more water are limited.

[4]The pattern of consumption described in the table persisted throughout the decade and in the preceding decade as well.

[5]The data displayed in Table 1 includes water transfers within regions at an aggregate volume of 1.15% of fresh water allotments. Transfers were approved for the first time in 2008 by the Ministry of Agriculture under three strict conditions: Transfers are between two farmers in the dame region; they are restricted to 30 % or less of the farmer's annual quota; and that the quota of any farmer plus the water transferred to him will not be larger than the quota set to this farmer in 1989. That is, there exists an upper limit for the total quantity of water that a farmer can receive, including transfers.

3. During dry years, crosswise cuts on all allotments are made without personal consideration, whereas the influence of dry years may differ among farmers.

3 Trade of Water through Auctions

We consider three auction mechanisms: the Uniform, the Discriminatory, and the Vickrey auctions. In all three auction mechanisms the bidders make sealed bids for each of the units they demand, and if k units are sold in the auction overall, then the highest k bids win. The auctions are distinguished by the prices paid by the winning bidders for the winning units (losers do not pay anything in any of the auctions). In the uniform auction, all winning bids pay a price that is equal to the $k+1$ highest bid; in the discriminatory auction, each winning bid pays the value of the bid itself; and in the Vickrey auction, each bidder pays an amount that is equal to the total value of other bidders' bids it displaces. Both the Uniform and Discriminatory auction are widely used for the sale of Treasury bonds, water, oil, natural gas, and pollution permits (Brooks and Harris, 2008). The Vickrey auction has the least transparent payment rule of the three auctions and is less used, if at all, but is attractive theoretically because it induces bidding of the true values as weakly dominant strategies (Krishna, 2002).

The main advantages of the uniform price auction consist of its simplicity and ease of implementation and in the fact that it induces the same identical price for all units of water sold. Its main disadvantage is that it may induce the bidders to engage in strategic "demand reduction" in order to lower the price of water and decrease their total payment for water.

The main advantages of the discriminatory auction also consist of its simplicity and ease of implementation, and the fact that each bidder knows in advance how much it will pay for each of its winning bids. The disadvantage is that different bidders and even the same bidder are likely to pay different prices for identical units of water.

The main advantage of the Vickrey auction consists of the fact that it induces bidding the true value as a weakly dominant strategy as mentioned above. Its main disadvantages are that it employs a complex payment rule, that payment for different units may be different across different bidders and even for the same bidder, and in addition, the auction has the unattractive property that high winning bids may pay less than low winning bids.

General analysis of the three auctions is complex, but Swinkels (1999, 2001) shows that the uniform and discriminatory auctions are asymptotically efficient (the Vickrey auction is obviously efficient because it induces truthful bidding). Swinkels shows that in uniform auctions, bidding the true value converges asymptotically to an equilibrium strategy, and in discriminatory auctions, bidding the highest expected bid of the other bidders, conditional on that bid being smaller than the bidder's own valuation is an equilibrium strategy. These theoretical results imply that all three auctions would generate the same allocation, asymptotically, and would differ, if at all, only in the payments made by the bidders. Furthermore, once we simulate the bidders' demand functions as described below, these results also allow us to compute the bidders' bids, the resulting allocations, the benefits to the bidders and to the seller, and total surplus or social welfare.

We assume throughout that an auction consists of one seller (the government) who sells a large number, denoted K, of indivisible units of water to a large group of bidders (farmers). We assume that auctions would be held on an annual basis, and that water cannot be stored for future use. In addition, it is also assumed that the bidders know the rules of the auction in which they participate, bid according to the theoretical results above, and are risk neutral. We shall assume that the bidders' marginal benefit from water is decreasing and linear.[6] An explanation of how the bidders' demand is simulated is provided in the next section.

4 Simulation of Demand and Strategic Behavior

Our database includes 7780 observations on all operating farmers in Israel during the year 2008. We excluded from our sample farmers with almost zero allocations and zero use of water. This left us with 6173 observations on which we performed our analysis. The database includes information on each farmer's location, water quota, types of water used, and the volume of water used of each type (fresh or secondary water). We obtained the price each farmer paid for the water it got from the Israeli Water authority. During 2008 water prices were set by the Israeli Water Authority at $p_1 = NIS1.32$ per cubic meter for water in the first tier, $p_2 = NIS1.53$ per cubic meter for water in the second tier, and $p_3 = NIS2.005$ per cubic meter for water in the third tier.

The total amount of water allocated to the $N = 6,173$ farmers in our sample in the year 2008 was $906,429$ cubic meters of water. Following the usual custom in Israel, we divided the country into six different regions (See Figure 1): The Northern region that includes the Galil and Golan highs (about 60,000 hectares of cultivated agricultural land); Valleys region that includes the districts of Afula, Beit-Shean, Emek-Hayarden, Zvulun and Sammaria (about 80,000 hectares agricultural land); The Jordan Valley that spans from

[6] See Bar-Shira et al. (2006) for a justification of this assumption in the Israeli context, and its slight bias relative to the best fit function computed by the Cox-Box estimated coefficients.

South of Beit-Shean to the North of the Dead Sea (about 20,000 hectares cultivated land); The Central region includes the landscape from south Haifa in the north to Tel Aviv in the south (60,000 hectares of cultivated agricultural area), the Plain and Mountains region spans from Tel Aviv in its northern border to Ashkelon in the south, the Judea district and Jerusalem on its east border (55,000 hectares of agricultural land); the Southern region covers the landscape from the south of Ashkelon plain, to the Negev and Arava (100,000 hectares of cultivated landscape). Each of these regions is distinguished by its annual rainfall, topography and soils, and hence by the type of crops suitable for growth in it.

As detailed in Table 2, most farmers are located in the central region (47%) and the rest are about equally distributed in the Northern region, Valleys, Plain and Mountain region, and Southern region (between 11-15 % of the farmers). Only 1% of the farmers are located in the Jordan Valley. The farmers in peripheral regions posses on average a larger cultivated land area, and their mean allocation of water under the block rate pricing mechanism is larger, respectively. Mean allocation to farmers in the Jordan valley is about ten times larger than the allocation to farmers in the central region of Israel (548.7 and 49.4 thousand cubic meter of water, respectively). Mean allocations of water to farmers in Southern district (Arid gradient) is 351,700 cubic meter per year and in the Coastal Plain, Center and Northern regions (Mediterranean gradient) the average allocation ranges from 105,200 to 253,100 cubic meter of water. Large cultivated land area along with low precipitations (like in the Southern district and Jordan Valley) are expected to increase the value of water to agriculture, and consequently, increase their bidding for water.

4.1 Calibration of Farmers' Demand for Water

As mentioned above, we assume that the farmers' demand or marginal valuation for water is decreasing and linear. We fitted the marginal valuation function of each bidder to a linear function that coincides with the farmer's true quantity consumed and marginal price paid for the year 2008, which was available for us from the data set. The slope of each farmer's linear demand function was sampled from a uniform distribution on the interval $[-0.008, -0.0002]$ in such a way that the calibrated demand functions correspond to observed water consumption limits and prices paid during 2008 in Israel. The calibrated demand functions are characterized by the short run elasticities specified in Tables 3. Elasticities are specified for the six regions in Israel and their mean range from -0.31 (in the Jordan valley) to -1.56 (in the center).[7] Notably,

[7] The estimated elasticities are close to the average state level elasticity of demand specified in Bar-Shira et al. (2006) for the short run, for the overall consumption of water for irrigation in Israel. There, the short run elasticity of demand for the estimated Box-Cox specification is -0.3, and -0.146 for the linear specification.

demand for water in the South District and Jordan Valley is more rigid. This reflects their regionally implied lack of flexibility in choosing the type of crops to grow and high dependency on irrigation.

4.2 Simulation of Strategic Behavior

As mentioned above, we assume that bidders bid according to their asymptotically optimal strategies. Accordingly, we assume that in a uniform auction bidders bid their true values for water, and the price of water is set equal to the value of the $K+1$th highest unit of water.

In the discriminatory auction it is optimal for bidders to bid the expected value of water to the highest bidder except for themselves conditional on that value being lower than the bidder's own valuation. However, instead of inputting this value as the bidders' bids, which would have required us to compute the bidders' beliefs, we used the realized highest value of the other bidders, or the bidder's own valuation, if the former was larger than the latter. Since the number of bidders is large, and each bidder is small relative to the total demand for water, we believe that this substitution provides a close approximation to the expected results. In this auction, for each unit of water it wins, each bidder pays a price that is equal to the bid it made for it.

Finally, for the case of the Vickrey auction, we assumed that bidders simply bid their true values, which is the weakly dominant strategy. The price paid by each bidder was computed accordingly: A bidder who wins k units pays the k highest losing bid of the other bidders. Each player will pay the bid that the mechanism would gain if he did not participate. Simulation of each auction was run using R program.

5 Results

We compare the three auction mechanisms to the block rate based allocation according to the following parameters of interest:

1. the number of units won by each bidder;
2. the total amount of water supplied to N bidders.
3. the payment made by each bidder;
4. the benefit to each bidder (total value less payments).

5. the total (aggregate) benefit to the bidders;

6. aggregate total payments;

7. aggregate social welfare (aggregate total payments and aggregate bidders' benefits);

5.1 A Comparison of the Uniform, Discriminatory, and Vickrey Auctions

Our assumptions and the results cited at the beginning of this article imply that all three auction mechanisms should generate the same allocation of water asymptotically. Therefore, since the number of farmers in our sample is rather large, the difference among the three auction mechanisms should consist mainly in the payments made by the farmers, their benefits, and social welfare. As shown in Table 4 these differences are negligible. Consumption of water under auction is 906.741 Million Cubic Meter (MCM) under the Vickrey and Uniform pricing, and slightly higher under the discriminatory auction. Total social welfare from water used for irrigation

Given that the three auction mechanisms are essentially equivalent, we proceed to compare the block rate allocation to the allocation that is generated by the uniform auction, which is the simplest auction of the three auctions considered.

5.2 A Comparison of the Uniform Auction and the Block Rate Allocation Method

Table 5 presents the comparison between the allocation generated by the currently practiced block-rate allocation and the allocation that is generated by the uniform auction. We note the following differences:

1. Unlike the block-rate allocation, all the supplied water is demanded through the uniform auction, resulting in an increase of 6.2% in the total amount of water used.

2. Social welfare under the auction is 6.35% higher than under the block-rate allocation. The increase in social welfare is due both to the fact that more water is allocated through the auction and to the better efficiency of the allocation under the auction (as reflected by the higher average social welfare per unit of water under the auction).

3. The bidders are made worse off by the auction because they have to pay a lot more for the water they get. The uniform auction market clearing price is 1.989NIS, which is higher than the first and second block prices p_1 (1.302) and p_2 (1.53), respectively, and higher than the average price

paid,[8] but lower than the third block price p_3 (2.005). This implies that farmers who consume large quantities of water under the block rate system relative to their allotment would made worse off from a switch to allocation by auction, whereas farmers who did not consume most of their allotment (less than 80%) would be made better off. As shown by Table 6, if we divide the farmers into three groups according to the tier to which they belong (the proportion of their allotment that they consumed), then we see that farmers who belong to the first tier won almost no units in the auction. Farmers from the second tier won and consumed less units in the auction compared to the block price system. All the allotted units that were not consumed by the first and second tiers plus the additional units that are sold in the auction were consumed by the farmers in the third tier.

4. Finally, as to be expected from the fact that farmers pay more for water, water revenue to the state increase by almost 38%.

The detailed impacts of the auction mechanism on the farmers at the individual level is presented in Figures 2 and 3. Figure 2 describes the relationship between the initial allotment of water to farmers (in $1000m^3$) and anticipated consumption of water under the block rate method and under the uniform auction (in $1000m^3$). The farmers' initial allotment appears on the horizontal axis and consumption under the block rate method and anticipated consumption under the auction appears on the vertical axis. The smooth line in the figure represents the fitted regression line and the dashed line has slope one ($45°$). The statistical characteristics of the fitted regression line is given in Table 8.

Observe that under the block price system (actual consumption), farmers are encouraged to consume around the quota and therefore the consumption is strongly correlated with the given allotment($R^2 = 0.936$). In the auction, the correlation decreases compared to the correlation in the block pricing system, as expected ($R^2 = 0.878$). Another interesting difference between the two systems is the number of bidders with zero consumption. In the block pricing system, only 24% of the bidders did not consume any of their quotas, while in the auction, although more units were consumed, almost 40% of the bidders did not win or consume any units. It seems that these are the farmers who consumed significantly low share of their allotment.

The average profit (farmer's average welfare) per unit of water consumed increases with farm size (in volume consumption) and is presented in Figure 3. In the auction, the correlation between consumption and the average profits is $R^2 = 0.94$, while in the block pricing system the correlation is $R^2 = 0.55$.

[8] The average price is equal to the average price when the total allotment is purchased and given by: $0.5p_1 + 0.3p_2 + 0.2p_3$. It is equal to 1.534.

The correlation in the auction is higher since consumption is driven by market forces and not by allotment.

5.3 Regional vs. State level auction

Finally, it is also interesting to note the regions that benefit from a change in the water allocation mechanism and pricing. In the section that follows we compare the current water pricing mechanism to two possible auction design: a state level auction and multi-regional auctions, where the auction is carried independently in each region and is subject to the available quantity of water available for irrigation in the specified region. Moving from a state auction to a multi region auction promises the historical allotment given to the regions. The regions are geographically distinct and include different number of farmers in the region and water usage. Most of the farmers operate in the Central district, but possess relatively low quotas of water, which corresponds to smaller cultivated land area. Farmers in the Southern district and the Jordan Valley have a larger cultivated land area and therefore higher quantity of allotments. Table 9 describes the current distribution of farmers across regions and their relative allocation of water under the block-price system.

Imposing restrictions on transferability of water potentially lowers the overall efficiency of the auction mechanism. However, it seems that the overall loss in social welfare is low in the Israeli case study relative to the aggregate social welfare in a multiple auction framework (about 1.5% decrease in welfare).

Table 9 and the Figures 4 and 5 summarize the impact of the auction system on each region, under a state-level auction and under multi regional-auctions in Israel. It turns out that farmers in the Central and Coastal Plain Districts are worse off under the regional-auction relative to the state level auction, but still better off under the auction relative to the block pricing. The central district include 47% of the operating farmers and farmers poses the lowest mean allocation, which is associated with the farmer's plot size and cultivation (see Table 2). Adoption of regional auctions maintains the constraints already present on farmers in the central district and coastal plain of low water availability, and thus maintain the water availability constraints within this region. Main gain in these regions is from a more efficient reallocation of water among farmers. Moving into a state-level auction relax water constraint for farmers in the Central and Coastal Plain regions and consequently increases their profits.

The only region that is worse off in auction (either state or regional auction) relative to the step pricing auction is the Jordan Valley. While under a step pricing this region used more than available as did not pay a third step pricing as it should, under the regional auction it is constraint to maintain the quantity it is allocated (6% lower consumption) and under the state level auction it compete with high demand from other regions, resulting in an 11.4% decrease in its consumption (see Table 9).

In the regional auctions the districts with high historical allotment like the South and the Valleys regions gain a number of advantages: higher consumption of water (up to 10% in the North and South regions, about 6% in the Jordan Valley and 2% in the Valleys) and Lower average payments (up to 1.11% shekel per cubic meter in the South and Jordan Valley). The South and North Valley districts receive the highest benefit from water auctions (see Figute 5: the bidders in these regions benefit most from regional auctions (benefits are higher by 4.72 % and 1.5 %, respectively, relative to the state level auction). These regions increased their water consumption by about 10% when shifting from a state auction to a regional auction, and their average payments decreased by 1.11 % and 0.077 %, respectively. Contrarily, the Center receives 17% less units and its average payment increase by 0.43%. These in return decrease the farmers' benefits by 2.29 % and social welfare decreases by 0.67 % in the center with a shift to a regional auction. In sum, shifting from a state auction to a regional auction decreases the bidders' payments by 0.44%, increases average farmers' profits by 1.5% and decrease total social welfare by 1.47%.

6 Concluding Remarks

In this study we have used a detailed data set on water allocation, water pricing and water use within the agricultural sector in Israel to simulate and analyze the impact of using auction trading mechanisms to reallocated water more efficiently within the agricultural sector. We have quantified the potential gain from trade in water via an auction mechanism at the regional and state level and characterized its impact on the reallocation of water among farmers in different regions and of different farm size.

A state-level auctions results in higher aggregate benefit to the economy at the cost of higher farmers' payments for water in peripheral regions. Our state-level auction simulation suggests that moving to the auction mechanism would increase social welfare by 6.4 percent (considering the step pricing benchmark of 2008) and would increase farmers' payments by 37.8 percent, relative to the existing three block rate pricing. The increase in welfare is attributed to the rise in water consumption (6.21 percent higher consumption in auction than in the allotment system), and more efficient allocation among farmers, where water is allocated to farmers who value them the most. Adoption of alternative pricing mechanisms, as the Vickrey or Discriminatory pricing was demonstrated to perform equally to the uniform price auction in the Israeli framework that include a relatively large population of farmers who use water for irrigation, and thus maintain a high level of competition in the market for water.

References

A. Dinar, M. W. R. and Meinzen-Dick, R. (1991). *Water Allocation Mechanism Principles and Examples*. Oxford University Press, New York.

Bar-Shira, Z., Finkelshtain, I., and Simhon, A. (2006). Block-rate versus uniform water pricing in agriculture: An empirical analysis. *American Journal of Agricultural Economics*, 88(4):986–999.

Brooks, R. and Harris, E. (2008). Efficiency gains from water markets: Empirical analysis of water move in australia. *Agricultural Water Management Journal*, 95(4):391–399.

Crase, L., OReilly, L., and Dollery, B. (2000). Water markets as a vehicle for water reform: the case of new south wales. *Australian Journal of Agricultural and Resource Economics*, 44(2):299–321.

Cummings, R. G., Holt, C. A., and K.Laury, S. (2004). Using laboratory experiments for policymaking: An example from the georgia irrigation reduction auction. *Journal of Policy Analysis and Management*, 23(4):341–363.

Easter, W. K., A., M. W. R., and Dinar (1998). *Markets for Water: Potential and Performance*. Kluwer Academic Publishers.

Hartwell, R. and Aylward, B. (2007). Auctions and the reallocation of water rights in central oregon. River Paper Serier No. 1, Deschute River Conservancy.

Heaney, A., Dwyer, S., Beare, D., Peterson, and Pechey, L. (2004). Third-party effects of water trading and potential policy responses. *The Australian Journal of Agricultural and Resource Economics*, 50:277–293.

K. J. Landford, C. F. and Malcolm, D. M. (1998). Towards a financially sustainable irrigation system: Lessons from the state of victoria, australia 1984-1994. *World Bank Technical Paper*, 413.

Peterson, D., Dwyer, G., Appels, D., and Fry, J. (2005). Water trade in the southern murraydarling basin. *The Economic Record*, 81:115–127.

Rolfe, J. and Windle, J. (2011). Using auction mechanisms to reveal costs for water quality improvements in great barrier reef catchments in australia. *Agricultural Water Management*, 98(4):493–501.

Simon, B. and Anderson, D. (1990). Water auctions as an allocation mechanism in victoria, australia. *Water Resources Bulletin*, 26(3):387–395.

Swinkels, J. M. (1999). Asymptotic efficiency for discriminatory private value auctions. *Review of Economic Studies Journal*, 66:509.

Swinkels, J. M. (2001). Efficiency of large private value auctions. *Econometrica Journal*, 69(1):37–68.

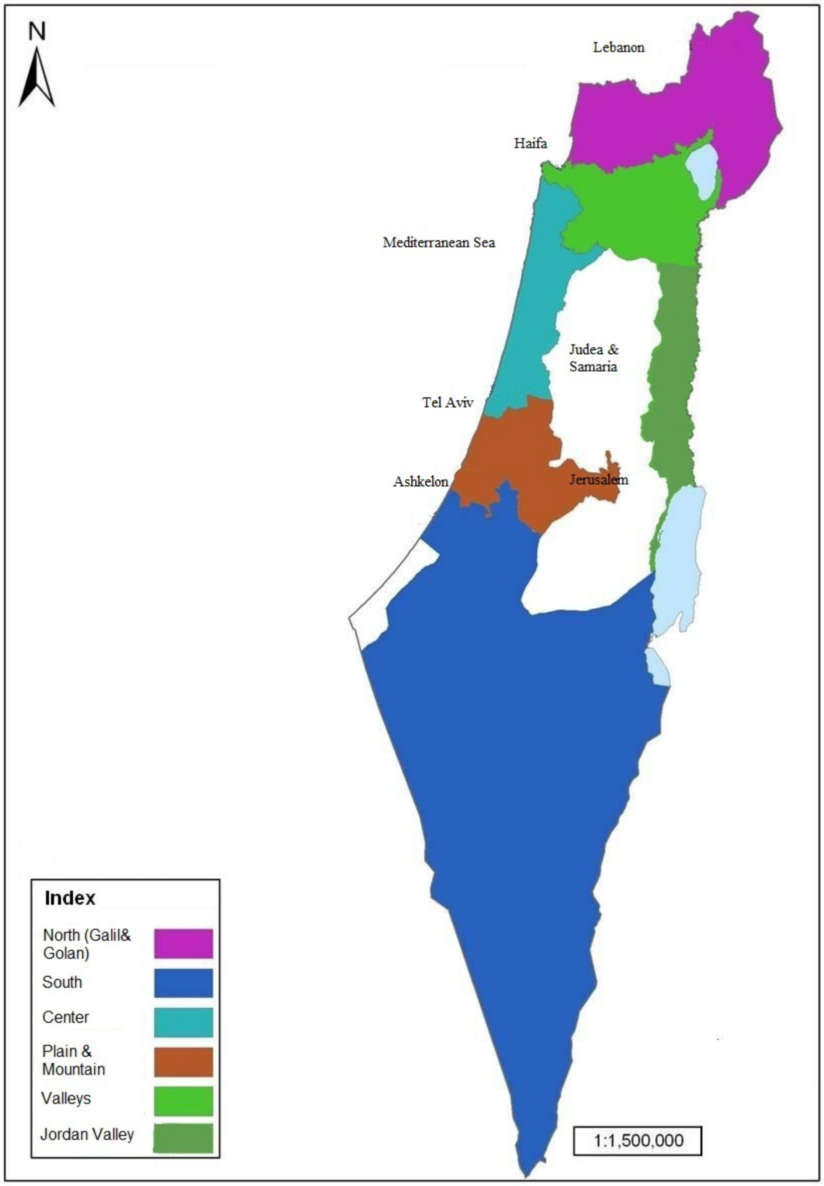


Figure 1: The State of Israel is split into 6 geographical regions: The Northern region that includes the Galil and Golan highs; Valleys region that includes the districts of Afula, Beit-Shean, Emek-Hayarden, Zvulun and Sammaria; The Jordan Valley spread from South of Beit-Shean to the North of the Dead Sea; The Central region includes the landscape from south Haifa in the north to Tel Aviv in the south; the Plain and Mountains region goes from Tel Aviv in its northern border to Ashkelon in the south, the Judea district and Jerusalem on its east border; Southern region covers the landscape from the south of Ashkelon plain, to the Negev and Arava.

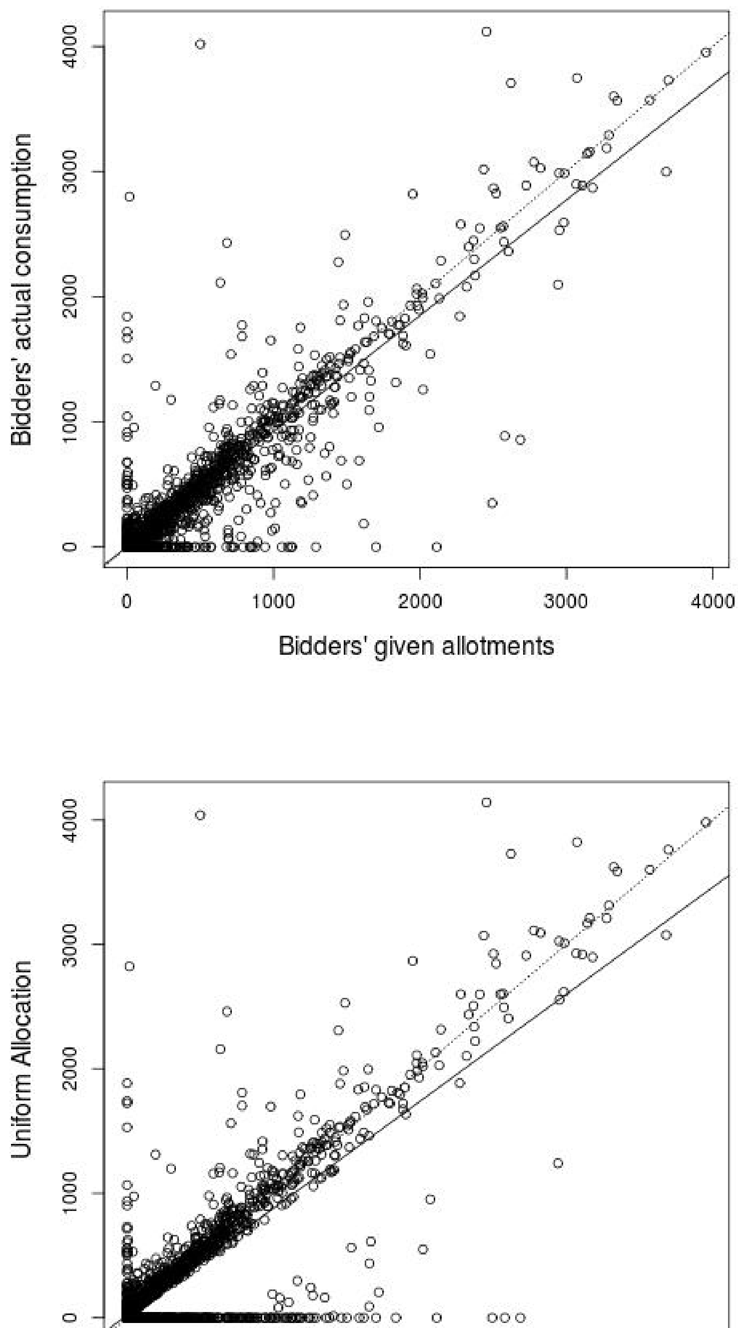


Figure 2: Consumption of water under block pricing (upper panel) and consumption of water under uniform auction pricing. Horizontal axis specify the initial allocation of water (in $1000m^3$) and is proportional to cultivated land area. Farmers' allotment (size) and water consumption are positively correlated. Stronger correlation is observes in step pricing (adjusted $R^2 = 0.876$) relative to auction (Adjusted $R^2 = 0.7713$).

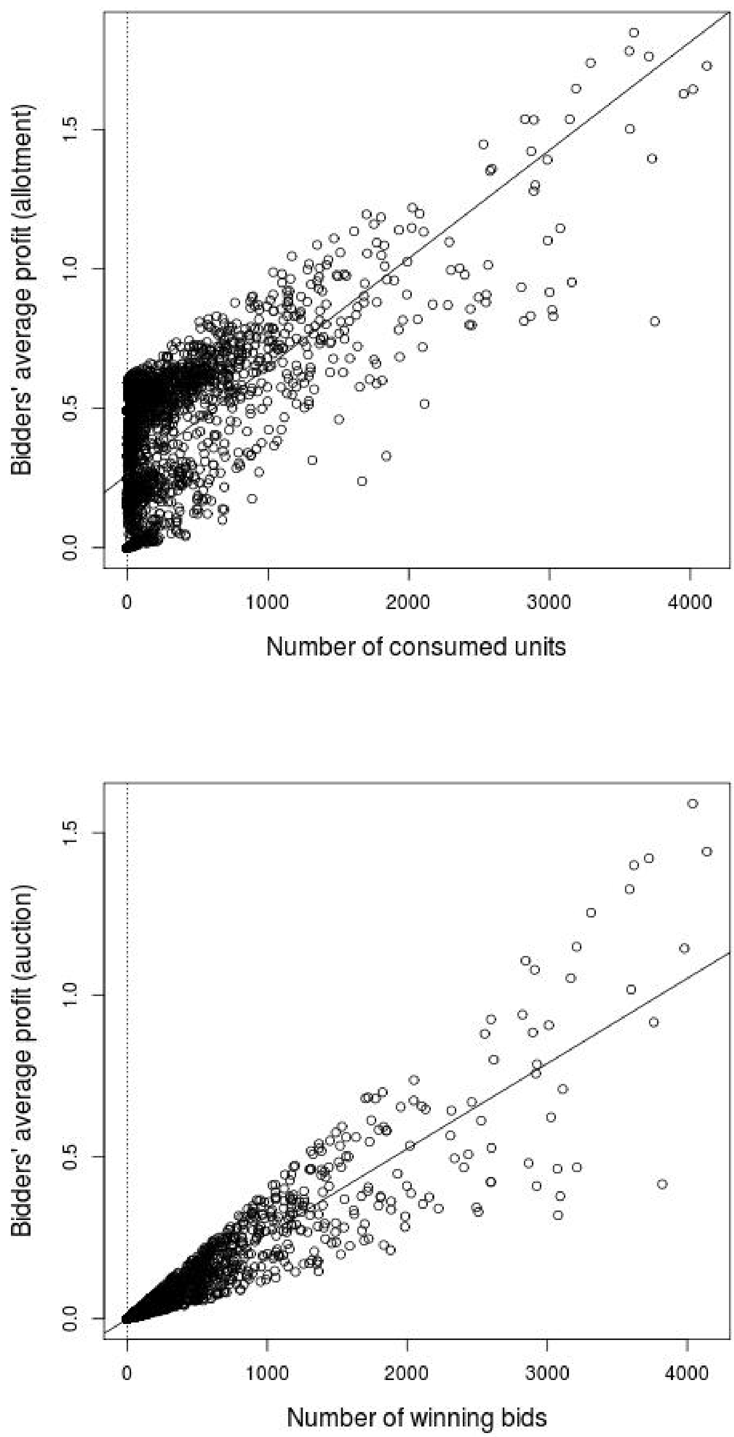
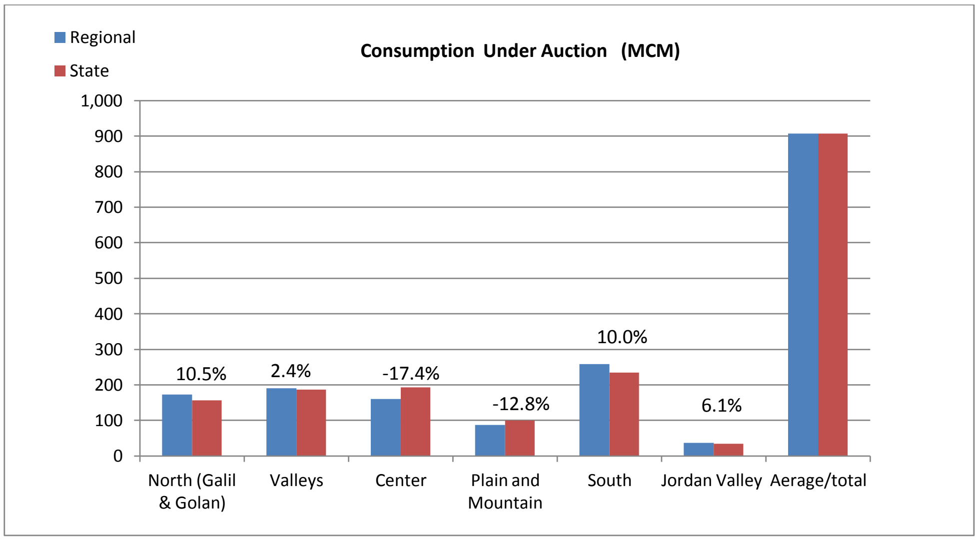


Figure 3: Consumption influences on average bidders' profit in auction and blocking price system



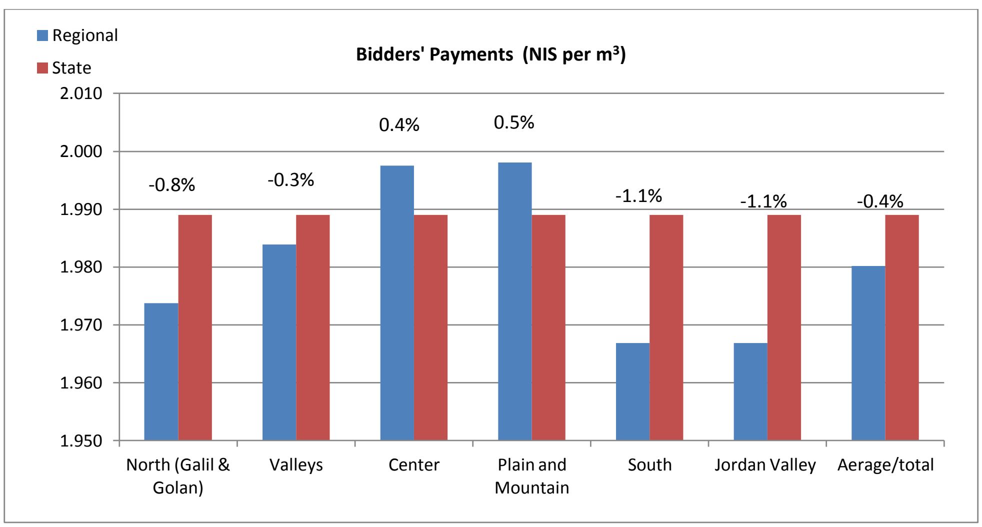
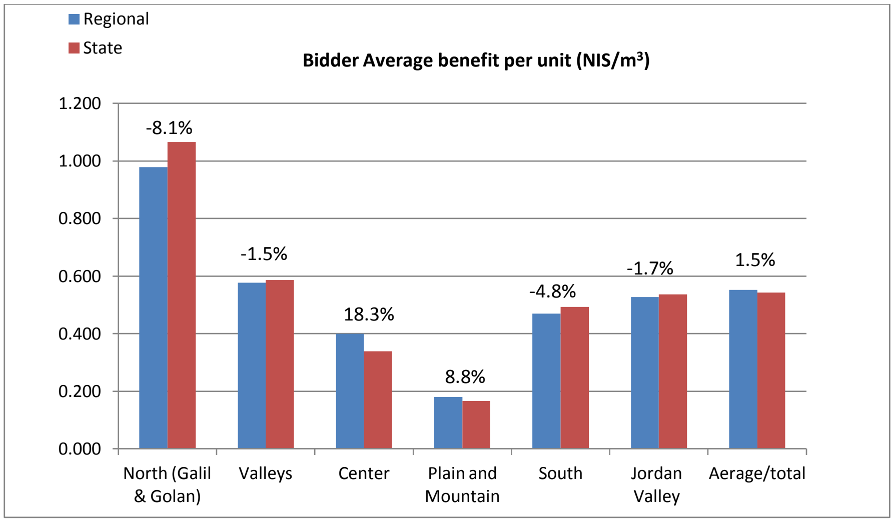


Figure 4: Comparison between a Multi Regional Auction and a State Auction: The graphs represent the Consumption and payments per unit in a multi region auction and a state auction. The horizontal axes display the regions of study. Percent difference between the two auction schemes is displayed on the colones.



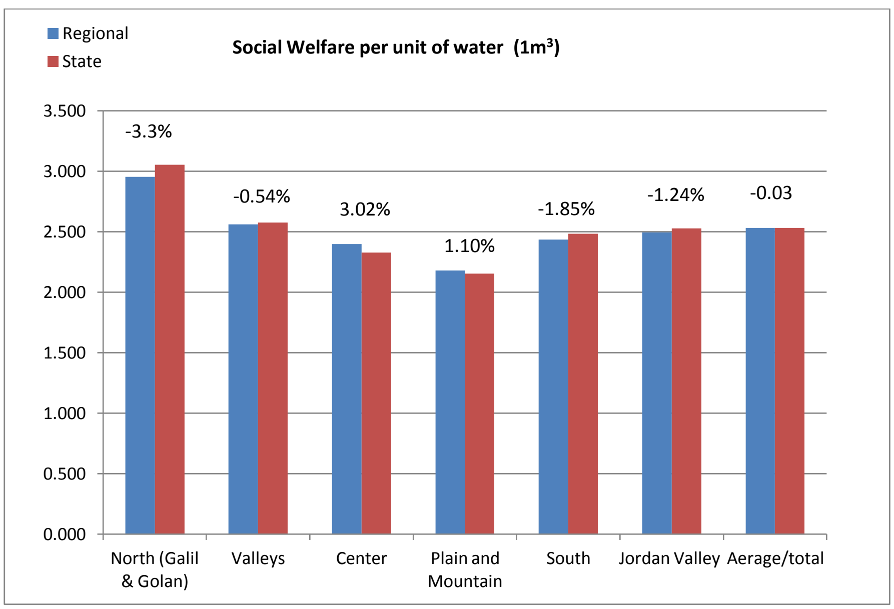


Figure 5: Comparison between a Multi Regional Auction and a State Auction: Farmers' total profits from use of water and average Social Welfare. Percent difference between the two auction schemes is displayed on the colones.

	1st tier (% from total)			2nd tier (% from total)			3ed tier (% from total)			total (MCM)		
	farmers	allotment	used	farmers	allotment	used	farmers	allotment	used	farmers	allotment	used
North	35.07	13.79	1.79	12.38	15.16	11.63	52.55	71.05	86.58	921	172.74	156.96
Valleys	41.32	4.83	0.70	9.14	9.38	6.61	49.54	85.79	92.69	755	191.04	184.61
Center	27.54	12.92	3.27	12.78	22.91	18.08	59.68	64.17	78.65	2,887	159.86	149.62
Plain and Mountain	17.45	10.66	1.91	7.94	9.24	6.73	74.61	80.10	91.36	831	87.41	85.30
South	27.23	12.62	2.21	7.93	14.94	11.39	64.84	72.44	86.40	694	248.74	237.82
Jordan Valley	36.47	22.22	6.49	10.59	13.34	10.02	52.94	64.44	83.49	85	46.63	39.29
All Israel	29.08	11.56	2.16	11.05	14.58	11.05	59.87	73.86	86.80	6,173	906.43	853.59

Table 1: Water allocation and water use in Israel 2008, under an increasing three-block water pricing mechanism. Water quantities include at types of water used for irrigation. Non fresh water was converted to an equivalent amount of fresh water, using the exchange rate used by the Israeli Ministry of Agriculture.

Region	Number of farmers	Allotments of water Mean (MCM)	Min (MCM)	Max (MCM)	s.d.
North (Galil & Golan)	921	0.188	0	27.120	0.982
valleys	755	0.253	0	5.792	0.701
center	2887	0.055	0	17.420	0.381
Plain and Mountain	831	0.105	0	1.903	0.218
South	694	0.359	0	7.657	0.767
Jordan Valley	85	0.549	0	3.275	0.699
All Israel (aggregate)	6173	0.147	0	27.120	0.603

Table 2: The distribution of farmers among regions in 2008, and their mean allocation of water. Allocation of water is proportional to cultivated land area by the farmers, and thus taken as a proxy for farmer size.

Region	Mean	Median	Min	Max	s.d.
North (Galil & Golan)	-0.9632	-0.2177	-9.7350	-0.0006	1.5850
Valleys	-1.3360	-0.1013	-9.9610	-0.0006	2.1210
Center	-1.5670	-0.8401	-9.9310	-0.0007	1.8570
Plain and Mountain	-1.1160	-0.3543	-10.0000	-0.0017	1.7250
South	-0.3313	-0.0364	-6.3560	-0.0004	0.8489
Jordan Valley	-0.3116	-0.0205	-5.2120	-0.0008	0.9092
All Israel	-1.228	-0.41360	-10.000	-0.000368	1.7800

Table 3: Elasticities of the calibrated demand functions in six regions in Israel, based on 2008 consumption data.

	Discriminatory	Vickrey	Uniform
Consumption of water (MCM)	906.766	906.741	906.741
Total social WF (MILLION NIS)	2,296.312	2,296.262	2,296.262
Total bidder payment (MILLION NIS)	1,803.273	1,803.382	1,803.517
Total benefit to bidder (MILLION NIS)	493.038	492.880	492.745
Average Social Welfare (m^3)	2.53242	2.532435	2.532435
Average Bidder's welfare (m^3)	0.54373	0.54357	0.54342

Table 4: Comparison among the Uniform, Discriminatory and Vickrey auctions at the sector level and individual

	Current Block pricing	Uniform auction	Difference
Sold units (MCM)	854	907	6.21%
Total social WF (MILLION NIS)	2.159	2.296	6.35%
Total bidder payment (MILLION NIS)	1.309	1.804	37.77%
Total bidder WF (MILLION NIS)	0.850	0.493	-42.03%
Social WF per unit (NIS)	2.529	2.532	0.13%
Bidder WF per unit (NIS)	0.996	0.543	-45.42%

Table 5: Auction performance compared to Block pricing performance.

	percentage of water used relative to their allotment		bidders' welfare per unit according to given consumption (NIS/m^3)		% difference between the mechanisms
Farmers by tiers	Auction	Block	Auction	Block	
Farmers in 1st tier	1.26%	17.85%	0.430	0.180	139%
Farmers in 2nd tier	23.84%	71.51%	1.592	0.930	71%
Farmers in 3ed tier	130.64%	110.70%	0.506	1.025	-51%

Table 6: Auction performance compared to Block pricing performance by types of farmers. Performance differs for farmers in different tiers. On average, farmers who did not use more than 50% of their quota will increase their welfare by 130% when switching to an auction mechanism. Farmers who use between 50%−80% of their quota increase their welfare by 71% when switching to an auction. The average benefit of farmers who used between 80 − 100% of their quota will decrease by 51%. The total social benefit increases by 8% under auction compared to the block pricing mechanism, and total bidders' payments increase by 10%.

	Consumption under step pricing	**consumption under auction**
Residuals		
min	-3030.8	-3871.40
median	1.1	10.40
max	7162.6	7402.90
s.e.	182.2	226.90
Intercept	**-1.03719**	**13.66587*** **
s.e.	2.3866E+00	2.9728E+00
p-(> |t|)	6.6400E-01	4.3700E-06
allotment	**0.94858*** **	**0.90697*** **
s.e.	3.85E-03	4.79E-03
p(>|t|)	2.00E-16	2.00E-16
Adjusted R^2	0.9079	0.8531
F statistic (1,6171 d.f.)	60860	35860
degrees of freedom	6171	6171
P-value	<2.2e-16	<2.2e-16

Significance levels: 0***, 0.001**,0.01*

Table 7: Statistical characteristics of the fitted regression line between farmer's allotment (farm size) and consumption (dependent variable) under auction and under step pricing mechanisms.

	Average profit under step pricing	Average profit under auction
Residuals		
min	-2.0184	-0.815600
median	0.09255	-0.000290
max	1.2449	1.485600
s.e.	0.2744	0.067050
Intercept	**0.2762*** **	**0.008071*** **
s.e.	3.1420E-03	8.7830E-04
p-(> |t|)	2.0000E-12	2.0000E-12
allotment	**0.0002445*** **	**0.00019**
s.e.	5.06E-06	1.42E-06
p(>|t|)	2.0000E-12	2.0000E-12
Adjusted R^2	0.2743	0.7509
F statistic (1,6171 d.f.)	2334	18610
degrees of freedom	6171	6171
P-value	<2.2e-16	<2.2e-16

Significance levels: 0***, 0.001**,0.01*

Table 8: Statistical characteristics of the fitted regression line between farmer's allotment (farm size) and farmer's welfare (dependent variable) under auction and under step pricing mechanisms.

Region	Consumption in Blcok Pricing	Consumption in Regional Auction		Consumption in State Auction	
	Quantity (MCM)	Quantity (MCM)	% increase relative to Block Pricing	Quantity (MCM)	% increase relative to Block Pricing
North (Galil & Golan)	128.6	172.8	34.4	156.4	21.7
Valleys	184.6	191.1	3.5	186.6	1.1
Center	135.8	160.0	17.9	193.7	42.6
Plain and Mountain	85.3	87.4	2.5	100.3	17.6
South	225.9	258.5	14.4	234.9	4.0
Jordan Valley	39.3	36.9	-6.0	34.8	-11.4
Average/all	799.4	906.7	13.4	906.7	13.4

Table 9: Comparison of the consumption of Water under Block rate Pricing, regional auction and state auction.