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SUBMITTED ARTICLE

Consumer perceptions after long-term use of alternative irrigation water: A field experiment in Israel

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Abstract

This study provides the first revealed preference estimates of Israelis' willingness to pay for produce irrigated with alternative water. Results show that Israelis prefer produce irrigated with conventional water over any type of alternative water and that their preferences for alternative water varies by type. These results indicate that there may be long-run limits to how high consumer demand for alternative water can rise. Policymakers should be cognizant of these findings and gradually expose the public to the unavoidable future of widespread alternative water use. Increased public awareness of water scarcity and alternative water technology will encourage adoption when it is possible and necessary.

KEYWORDS

desalinated water, field experiments, irrigation water, recycled wastewater, stigma

JEL CLASSIFICATION

D12; Q13; Q15

Strains on fresh water supplies are increasing as global-warming-induced climate change hastens shifts in the global water cycle, increasing the disparity between wet and dry regions (Intergovernmental Panel on Climate Change, 2014). A commonly proposed solution to water scarcity is new, alternative sources of water. Any water source other than conventional ones, such as groundwater and treated surface water, is considered alternative, including desalinated seawater and recycled household wastewater, the sources specifically examined in this paper (U.S. Department of Agriculture [USDA], 2017). It has been posited that widespread adoption of alternative irrigation water in Western countries and around the globe is dependent on consumers' willingness to purchase food irrigated with it. Over recent decades, several studies have measured consumer preferences towards alternative irrigation water and found broad resistance. However, these studies have been conducted in countries where alternative water sources are novel and represent a small percentage of fresh water supplies, such as the United States, Australia, and Greece (Bakopoulou et al., 2008; Dolnicar & Hurlimann, 2009; Hui & Cain, 2017). Israel, on the other hand, has been using alternative irrigation water on a nation-wide scale for over three decades, but surprisingly few studies have investigated Israeli consumers' perceptions of this strategy. Understanding consumer preferences of different types of alternative water after decades of use in a country with dwindling fresh water supplies can provide insight into how consumer preferences across the world might change or remain the same as water scarcity increases.

Using an economic field experiment involving 202 adult Israeli citizens, this study seeks to inform the sparse literature on consumer preferences for alternative irrigation water after long-term implementation. In doing so, this study provides the first revealed preference estimates of Israeli citizens' willingness to pay (WTP) for produce irrigated with alternative water compared to produce irrigated with conventional water. It also evaluates how information treatments affect consumer choices: specifically, how information and messaging about the benefits and risks of recycled water may change consumers' purchasing behavior with respect to foods that have come in contact with it. Providing information and messaging has previously been shown to influence food purchasing behavior (Dillaway et al., 2011; Hayes et al., 2002; Marette et al., 2010; McFadden & Huffman, 2017; Wu et al., 2015), including for food irrigated with recycled wastewater (Savchenko et al., 2018; Whiting et al., 2019).

BACKGROUND

Severe water shortages and increasing agricultural demand for water prompted Israel in the 1990s to pioneer not only new irrigation technologies but also new sources of water (Feitelson, 2013; Menahem & Gilad, 2013). By 2013, Israel's use of recycled wastewater exceeded its use of natural water by 45%, with 60% of the irrigation water used in agricultural production coming from alternative sources (Lipchin & Pennycock, 2015). Innovations such as drip irrigation and the large-scale adoption of alternative water in Israel have mitigated one of the most serious water crises in the world and enabled the country's agricultural output to increase 12-fold over 30 years. However, when Israel began moving aggressively towards implementing recycled water policies in the early 1990s, through the national water commissioner and Mekorot, Israel's national water company, there was little public discussion and no formal referendum (Feitelson, 2013; Menahem & Gilad, 2013). The same was true in the early 2000s when the first large-scale seawater desalination plant began operation. This was because Israel's water management system is centralized and the government views water as a priority for national security that precludes individual rights (Gelpe, 2010; Kislev, 2013). To gain public support for desalinated water, Mekorot has heavily invested in multiple public advertising campaigns, which also emphasized water conservation (Rosenthal & Katz, 2010; Sedley, 2018).

Consequently, little work has been done and is thus known about Israeli consumers' preferences for alternative water, specifically in agricultural production. Hurlimann and Dolnicar (2016) evaluated consumer perceptions of desalinated and recycled water for various uses in Israel and eight other countries using a hypothetical, stated preference model. Israeli consumers preferred desalinated water over recycled water for laundering, showering, drinking, cooking, and cleaning, but preferred recycled water over desalinated water for watering their garden and toilet-flushing. It was unclear whether in the survey a distinction was made between food and non-food items in personal gardens. Friedler et al. (2006) found 86% support among Israeli residents in the city of Haifa for using recycled wastewater in food crop irrigation.

Table 1 summarizes the literature on consumer perceptions of alternative water. Studies conducted in Australia (Dolnicar & Hurlimann, 2009) and the United States (Kecinski & Messer, 2018) have measured consumer preferences for ingesting recycled drinking water and found that people have had little interest in such water despite it being safe to drink. Another handful of studies conducted in Greece (Bakopoulou et al., 2008; Menegaki et al., 2007) and the United States (Hui & Cain, 2017; Savchenko et al., 2019b) examined consumers' concerns about purchasing produce irrigated with recycled water and found that consumers' WTP declined when recycled water was used as opposed to "conventional water". Further, Fielding et al. (2015) found that Australian consumers prefer certain types of alternative sources for drinking water over others, while Savchenko et al. (2019a) found the same was true for US consumers and irrigation water.

Consumers' resistance to purchase and ingest produce irrigated with recycled water is believed to be a result of stigma (Rozin et al., 2015), or in other words, an overreaction to the true, objective risks it possesses (Fischhoff, 2001; Walker, 2001). The primary obstacle for recycled drinking water seems to be the "toilet-to-tap" perception (Dingfelder, 2004): the idea that "once in contact, always in contact" (Rozin & Nemeroff, 2002),[1] a concern that is believed to be transferred to produce irrigated with recycled wastewater (Savchenko et al., 2018). However, there is evidence that the stigma may be partially mitigated through framing and the introduction of additional physical treatments (Ellis et al., 2020; Kecinski & Messer, 2018; Rozin et al., 2015). An increase in the need for recycled water has also been shown to increase its acceptance (Dolnicar & Schäfer, 2009). Informing people that they have been using recycled water for an extended period without incident has also been shown to increase their acceptance of it (Hui & Cain, 2017). Even just rebranding recycled water with a name that evokes the purity of the water and its environmental benefits has been shown to increase consumers' preference for it (Ellis et al., 2019).

On the other hand, information might increase the repulsion individuals have concerning recycled water. There is evidence that the effect of risk preferences on food choice depends on the interaction between risk preferences and risk perceptions (Petrolia, 2016). Exposing consumers to information about the potential health risks has been shown to lower WTP for vegetables irrigated with it (Savchenko et al., 2018). An extensive campaign that raised health concerns about recycled water coupled with scientists' inability to guarantee that there would never be an issue with it derailed a plan to incorporate recycled water into the municipal drinking water supply in Toowoomba, Australia (Morgan & Grant-Smith, 2015; Sedlak, 2014). Just telling consumers about the type of water the grapes in their wine were irrigated with lowers their WTP, regardless of whether it is conventional or recycled (Li et al., 2018). Salient attributes in risky and riskless choices can draw consumers' attention and be assigned disproportionately high weights in the decision process (Bordalo et al., 2012, 2013; Chetty et al., 2009). Studies also

TABLE 1 Summary of literature on consumer preferences for alternative water

Citation	Sample	Method	Findings
Drinking water			
Kecinski and Messer (2018)	109 adults (United States)	Revealed preference experiment	Median willingness-to-accept drinking three ounces of recycled drinking water was $30
Hurlimann and Dolnicar (2016)	200 adults (Israel)	Hypothetical stated preference survey	52% supported desalinated drinking water, and 13% supported recycled drinking water
Fielding et al. (2015)	1262 adults (Australia)	Hypothetical stated preference survey	Prefer desalinated drinking water over recycled drinking water
Dolnicar and Hurlimann (2009)	66 adults (Australia)	Qualitative interviews	8% had negative view of desalinated drinking water, 27% had negative view of recycled drinking water
Irrigation water			
Savchenko et al. (2019a)	540 adults, 220 students (United States)	Hypothetical stated preference survey	Prefer rain water and stormwater for crop irrigation over gray, brackish, black, and industrial water
Savchenko et al. (2019b)	329 adults (United States)	Revealed preference experiment	WTP for fresh foods irrigated with recycled water decreases $1.23 compared to conventional water
Li et al. (2018)	230 adults (United States)	Revealed preference experiment	10% drop in WTP for wine made with grapes irrigated with recycled water compared to wine made with grapes irrigated with unspecified water
Savchenko et al. (2018)	211 adults, 182 students (United States)	Revealed preference experiment	22% drop in WTP for produce irrigated with recycled water relative to conventional
Hui and Cain (2017)	1500 adults (United States)	Hypothetical stated preference survey	60% willing to pay for and eat crops irrigated with recycled water
Bakopoulou et al. (2008)	200 adults (Greece)	Hypothetical stated preference survey	15% unwilling to use agricultural products irrigated with recycled water
Menegaki et al. (2007)	342 adults (Greece)	Hypothetical stated preference survey	12% drop in WTP for olive oil made with olives irrigated with recycled water compared to olive oil made with olives irrigated with conventional water; 63% willing to pay for and eat tomatoes irrigated with recycled water

TABLE 1 (Continued)

Citation	Sample	Method	Findings
Friedler et al. (2006)	256 adults (Israel)	Hypothetical stated preference survey	86% support using recycled wastewater in food crop irrigation

TABLE 2 Research questions and results

Question	Hypothesis statement	Results
1. Does Israeli consumers' WTP for produce vary by irrigation water type (conventional, desalinated, recycled)?	For each type of water *a* and all other types of water *b* $H_0: WTP_a = WTP_b$ $H_A: WTP_a \neq WTP_b$	Reject H_0 (displayed in Tables 4 and 5). Israeli consumers prefer produce irrigated with conventional water over any type of alternative water, and that preferences for alternative water varies by type.
2. Does exposure to different types of scientific information about recycled water (benefits, risks, and both benefits and risks) *change* Israeli consumers WTP for produce irrigated with various types of water?	For each type of water *a*, information type *c*, and all other information types *d* $H_0: WTP_{ac} = WTP_{ad}$ $H_A: WTP_{ac} \neq WTP_{ad}$	Fail to reject H_0 (displayed in Tables 4 and 6). Exposure to information about the benefits and risks of recycled water did not significantly affect participant behavior.

suggest it is not just the information provided that is important, but also the source conveying it, the perspective of the source, and the receiver's prior beliefs (McFadden & Huffman, 2017; McFadden & Lusk, 2015; Whiting et al., 2019).

This study contributes to this literature by addressing two overarching questions:

1. After three decades of alternative water use in Israeli agriculture, does Israeli consumers' WTP for produce vary based on the irrigation water type (conventional, desalinated, recycled)?
2. Does exposure to different types of scientific information about recycled water—its benefits, its risks, and the combination of both its benefits and risks—change Israeli consumers' WTP for produce irrigated with various types of water?

Table 2 summarizes our hypotheses regarding these questions and the conclusions drawn from the experiments. Overall, Israelis still have concerns with water from alternative sources even after decades of safe use and extensive campaigns to increase public awareness of alternative water sources such as desalination. Results show that use of alternative water diminishes consumer demand for produce irrigated with it relative to the same produce irrigated with conventional water. The reduction in WTP for alternative water does vary by type, with demand for produce irrigated with recycled wastewater decreasing more than that for produce irrigated by desalinated water. Exposure to information about the benefits and risks of recycled wastewater, when presented separately and conjointly, does not seem to influence consumers' WTP for produce irrigated with it.

EXPERIMENT DESIGN

To assess consumers' WTP for produce irrigated with different types of water, a field experiment was conducted using a revealed-preference, single-bounded, dichotomous-choice design. Multiple studies have suggested that a dichotomous-choice mechanism is more robust and less biased than other formats such as auctions because it is more representative of the type of decisions consumers typically make when considering an item—they either purchase it at the posted price, or pass on buying it (Arrow et al., 1993; Frykblom & Shogren, 2000; Loomis et al., 1997; Wu et al., 2014). If the price of a product was less than or equal to a participant's expected utility, the participant purchased the product; otherwise, the participant did not. In accord with Fehr and Rangel (2011), a participant's expected utility for a product was generated by integrating attributes, such as water type, over various dimensions such as taste, healthfulness, sense of disgust, and self-image.

Data collection occurred at a public promenade in Eilat, southern Israel, so a sample more representative of consumers than undergraduate students in a traditional experimental economics lab could be obtained. All participants were required to be Israeli citizens; however, owing to financial constraints, the sample is not perfectly representative of the Israeli population (see Table 3). Participants completed the experiment on tablet computers using a Python-based program, which both administered the experiment and collected the data.

To generate incentive-compatible, demand-revealing data, participants were endowed with 40 Israeli shekels (ILS), the equivalent of around $10, at the start of the experiment as payment for their time. In the instructions (see Appendix A), they were told to think of the money as a bank account from which they could withdraw funds to make real, non-hypothetical purchasing decisions about produce irrigated with different types of water. They were also informed that one of their decisions would be randomly chosen and implemented, encouraging them to carefully consider each decision independent of the others.

Participants were presented with eight purchase opportunities (see Figure 1) as a within-subjects treatment—four versions of two types of produce, clementines and dates. The first version did not specify the type of irrigation water used on the produce and served as a control by replicating how most produce is currently labeled in Israel. The three treatments were conventional, desalinated, and recycled irrigation water.

Presentation of the purchase opportunities was randomized across participants to avoid ordering effects. All the purchase opportunities were presented on a single page, so participants could go back and change previous decisions after making the final one to avoid bias associated with the discovered preference hypothesis (Plott, 1996). Prices were randomly generated and drawn from a normal distribution by the Python-based program, ranging from ILS0 to ILS40 ($0 to $10); the maximum possible price was the entirety of their allotment. The standard

TABLE 3 Summary statistics

		Sample	Israel
	Total participants	202	
Treatment	No information	48	
	Benefits	52	
	Risks	50	
	Benefits and risks	52	
Gender	Female	47%	50%
Educational attainment	High school or less	58%	48%
	Some college or associate degree	16%	14%
	Bachelor's degree	14%	23%
	Graduate degree	11%	13%
Prior knowledge	Desalinated	85%	
	Recycled	75%	
Annual household income	Minimum	< ILS40,000	
	Maximum	≥ ILS960,000	
	Median	ILS40,000-ILS79,999	ILS95,856
	Mean	ILS80,000-ILS119,999	ILS118,140
Age	Minimum	18	
	Maximum	76	
	Median	47	30
	Mean	44	

Note: Israel data is from the following sources: World Bank (gender, 2017); OECD (educational attainment, 2017); Israel Central Bureau of Statistics (income, 2017); CIA World Factbook (age, 2018). The exchange rate is 1 USD for 3.85 ILS.

deviation was half of the respective mean price.[2] Mean prices were calculated from the prices observed at several local grocery stores in Eilat, Israel.

The products offered in the experiment were "debranded" by removing all identifying labels and displayed in one area so participants could examine them before making decisions. Definitions for each type of irrigation water were provided to the participants at the beginning of the experiment, as well as displayed on the top of the purchase opportunities page. The definitions shown to the participants were as follows:

Conventional water: Traditional sources of irrigation water, such as surface water (rivers, lakes, ponds, and reservoirs) and well water.

Desalinated water: Saline water that has had its dissolved salts removed.

Recycled wastewater: Treated wastewater from washing, laundering, bathing, showering, toilets, and urinals.

The experiments also had a 2 × 2 factorial, between-subjects design to test the effects of various kinds of scientific information about recycled water (see Figure 2). There was a no-information control group and three treatments—its benefits, its risks, and its benefits and risks. Each participant was randomly assigned to one of the four groups and given the information at the beginning of the experiment. Participants in the benefits and risks treatment group

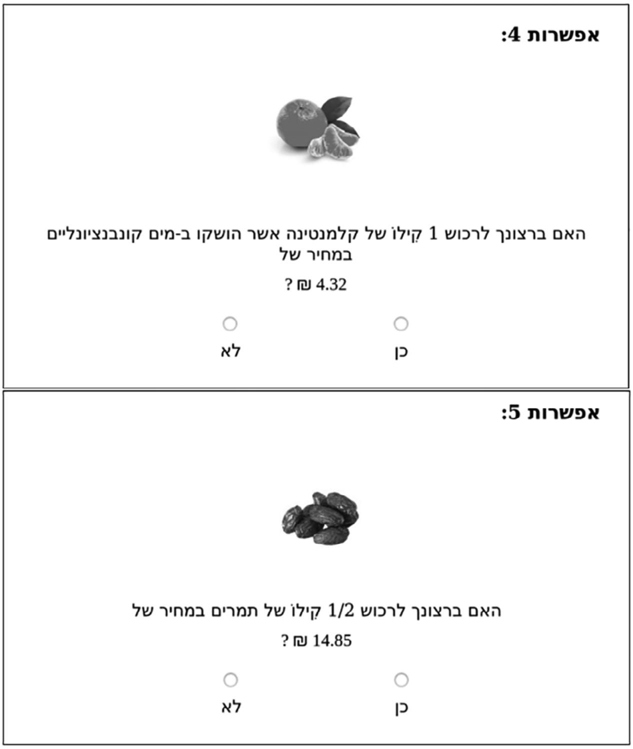

FIGURE 1 Examples of food purchase options

Benefit Information \ Risk Information	*No*	*Yes*
No	**No Information**	**Risk Information**
Yes	**Benefit Information**	**Benefit and Risk Information**

FIGURE 2 Between-subjects experiment design

saw the information in a random order. The treatments focused on recycled and not desalinated water, as consumers' concerns about recycled water's benefits and risks are well documented in the literature, whereas research on desalinated water, let alone consumers' interactions with it, is sparse.

Benefit information treatment: According to the United States Environmental Protection Agency (EPA), "In addition to providing a dependable, locally controlled water supply, water recycling provides tremendous environmental benefits. By providing an additional source of water, water recycling can help us find ways to decrease the diversion of water from sensitive ecosystems." Other benefits include "decreasing wastewater discharges and reducing and preventing pollution." "Recycled water can also be used to create or enhance wetlands and [riverside] habitats."

Risk information treatment: According to cropscience.org, "There have been a number of risk factors identified for using recycled waters for purposes such as agricultural irrigation. Some risk factors are short term and vary in severity depending on the potential for human, animal or environmental contact (e.g., microbial pathogens), while others have longer term impacts which increase with continued use of recycled water (e.g., [effects of salt and heavy metals] on soil)."

Each information treatment aimed to affect how a participant calculated their expected utility for a product by changing how they weight the attribute of recycled water. The information treatments emphasized some dimension of recycled water, either its relative risk to humans or relative benefits to the environment.

After reviewing the information, the participants responded to the purchase opportunities by selecting "yes" or "no" and then completed a post-experiment survey (see Appendix B). At the end of the experiment, a digital dice was "rolled" to select the purchase opportunity to be

TABLE 4 Random effects OLS models: Irrigation water preferences and the effect of scientific information on them

		Linear Prob. model			Linear Prob. model with interaction term		
		Coef.	S.E.	*p*-val	Coef.	S.E.	*p*-val
	Price	−0.086	0.014	0.000	−0.085	0.014	0.000
Treatment	Benefits	−0.037	0.051	0.467	−0.030	0.060	0.618
	Risks	−0.046	0.054	0.398	−0.042	0.064	0.513
	Benefits and risks	0.012	0.054	0.825	0.025	0.062	0.685
Produce	Clementines	−1.300	0.227	0.000	−1.281	0.230	0.000
Water type	Unspecified	−0.050	0.033	0.134			
	Desalinated	−0.137	0.039	0.000			
	Recycled	−0.302	0.042	0.000	−0.215	0.069	0.002
Interaction terms	Recycled * benefits				−0.027	0.093	0.770
	Recycled * risks				−0.012	0.099	0.907
	Recycled * benefits and Risks				−0.053	0.089	0.551
Prior knowledge	Desalinated	0.008	0.060	0.899			
	Recycled	0.003	0.054	0.955	0.006	0.044	0.894
Demographics	Female	0.032	0.037	0.394	0.032	0.037	0.379
	Age	−0.001	0.001	0.461	−0.001	0.001	0.469
	Annual household income	−0.008	0.008	0.311	−0.008	0.007	0.311
Education	Some college	0.039	0.064	0.539	0.039	0.063	0.541
	Associate degree	0.096	0.082	0.242	0.096	0.082	0.242
	Bachelor's degree	0.087	0.050	0.084	0.087	0.050	0.084
	Graduate Degree	−0.030	0.064	0.638	−0.030	0.064	0.638
Order effects	Question number	0.000	0.005	0.992	−0.001	0.005	0.788
constant		2.266	0.294	0.000	2.181	0.297	0.000
Total *N*		1616			1616		
Individuals		202			202		

implemented. Participants who selected "yes" for the implemented option received the produce and the balance of their ILS40 allotment after deducting the purchase price. For example, if the purchase price for the binding option in one of the United States experiments was ILS15, they received the produce and the remaining ILS25. Participants who selected "no" for the implemented option received the entire ILS40 participation fee and received no produce.

The experiment was administered in Hebrew, with the wording, including that for the information treatments, being drafted in English and then translated into Hebrew by a professional translator associated with the Arava Institute for Environmental Studies.

RESULTS

Random effects linear probability model

The experiment successfully collected data from 202 adult Israeli citizens, resulting in a total of 1,616 observations. Table 3 presents summary statistics for the treatments and the demographic characteristics. Because of the binary nature of the data (yes/no decisions), a linear probability model was estimated using OLS to isolate the effect of each between-subject treatment and irrigation water type on the likelihood of purchasing a product. Price, produce type, prior knowledge about desalinated water and recycled wastewater, gender, age, annual household income, highest educational attainment, and question order were included in the model as control variables. Given the within-subjects design (eight observations per participant), the coefficients were estimated using clustered standard errors and with a random effects specification.

Since our analysis involved multiple comparisons, we used a Bonferroni correction of the Wald test probability values to account for the family-wise error rate. It corrects for multiple comparisons by dividing the overall alpha level by the number of hypotheses being tested in a family of hypotheses, which in this case is 18.[3] The Bonferroni correction, however, ignores dependence between probability values, which can produce conservative estimates and lead to Type II errors (List et al., 2019). We therefore also estimated the Westfall–Young stepdown adjusted probability values, which account for dependence and allow for clustered assignment (Jones et al., 2019; Westfall & Young, 1993). Both the original probability values, namely the Bonferroni corrected probability values and the Westfall–Young stepdown adjusted probability values, are reported in Tables 5 and 6.

The regression results for the linear probability model are presented in Table 4. We find that price, as expected, has a statistically significant ($\rho = 0.000$) and negative effect on a participant's likelihood of purchasing produce. However, the other control variables, namely prior knowledge about desalinated water and recycled wastewater, gender, age, annual household income, highest educational attainment, and question order, have no statistically significant effect ($\rho \geq 0.242$), with the exception of a marginally significant effect for participants who had obtained a bachelor's degree ($\rho = 0.084$).

The Wald test results, examining the relationships between participants' preferences for the different types of water, which are based on the regression results from Table 4, are presented in Table 5. Table 5 shows that participants do not differentiate (Bonferroni-corrected $\rho = 1.000$) between produce irrigated with conventional or unspecified irrigation water.[4] However, participants do prefer (Bonferroni-corrected $\rho \leq 0.011$) produce irrigated with water from

TABLE 5 Wald's tests for irrigation water preferences

Wald's test	χ2	Prob.	BCP	WYP
Water type				
Conventional = Unspecified	2.245	0.134	1.000	0.699
Conventional = Desalinated	12.400	0.000	0.008	0.011
Conventional = Recycled	51.002	0.000	0.000	0.000
Unspecified = Desalinated	6.527	0.011	0.191	0.139
Unspecified = Recycled	44.197	0.000	0.000	0.000
Desalinated = Recycled	21.426	0.000	0.000	0.000
Treatment				
No Information = Benefits	0.528	0.467	1.000	0.971
No Information = Risks	0.715	0.398	1.000	0.957
No Information = Benefits & Risks	0.049	0.825	1.000	0.998
Benefits = Risks	0.029	0.864	1.000	0.998
Benefits = Benefits and Risks	0.969	0.325	1.000	0.915
Risks = Benefits and Risks	1.123	0.289	1.000	0.888

Note: Wald's tests are for the linear probability model displayed in Table 4.
Abbreviations: BCP, Bonferroni-corrected probability value; WYP, Westfall–Young stepdown adjusted probability value.

TABLE 6 Wald's tests for effect of scientific information on recycled irrigation water preferences

Water type	Wald's test	χ2	Prob.	BCP	WYP
Recycled	No Information = Benefits	0.537	0.464	1.000	0.971
Recycled	No Information = Risks	0.428	0.513	1.000	0.975
Recycled	No Information = Benefits & Risks	0.134	0.715	1.000	0.998
Recycled	Benefits = Risks	0.002	0.963	1.000	0.998
Recycled	Benefits = Benefits & Risks	0.165	0.685	1.000	0.998
Recycled	Risks = Benefits & Risks	0.113	0.736	1.000	0.998

Note: Wald's tests are for the linear probability model with an interaction term that is displayed in Table 4.
Abbreviations: BCP, Bonferroni-corrected probability value; WYP, Westfall–Young stepdown adjusted probability value.

conventional sources over any type of alternative water, despite general public awareness of the use of recycled and desalinated water. The results also show that participants prefer produce irrigated with desalinated water over recycled (Bonferroni-corrected $\rho < 0.001$, see Table 5). This decrease in WTP for recycled irrigation water relative to the other types is likely a psychological reaction of disgust because of the salience of its source and/or a concern for the potential health risks it poses (Menegaki et al., 2007; Rozin et al., 2015; Savchenko et al., 2019a). However, it is less clear what is driving the decrease in WTP for desalinated irrigation water relative to conventional sources. Perhaps, as Hurlimann and Dolnicar (2016) found, consumer preference for desalinated water is shaped by their perception of it as a costly and energy-intensive alternative to conventional water.

A post hoc power analysis using this study's parameter estimates and involving 1,000 simulations was conducted. The results indicated that, at the 80% power level, a sample of 202 participants was sufficient to detect changes that are statistically significant at the Bonferroni-corrected 5% significance level ($\rho = 0.050/18 = 0.003$) for the key within-subjects irrigation water type treatments. However, the between-subjects scientific information treatments are underpowered. To detect changes at the 80% power level in at least one of the between-subject treatments that are statistically significant at the Bonferroni-corrected 5% significance level, a sample size of 408 participants is needed. This study's sample size of 202 participants is only 30% powered.

Between-subjects scientific information treatments

The regression and Wald test results for the linear probability model (see Tables 4 and 5) show that the between-subjects scientific information treatments did not have any overall statistically significant (Bonferroni-corrected $\rho = 1.000$) effects on participants, possibly a result of this part of the experiment being underpowered. To see if the information treatments had any effect on participants' preferences for recycled water, an iteration of the above linear probability model that collapses the nonrecycled water variables (conventional, unspecified, desalinated) into a single term and incorporates an interaction term between water type and information treatment was carried out. The nonrecycled water variables were collapsed into a single term because the scientific information treatments focused on recycled water and not on any of the other water types.

Regression results for the linear probability model with an interaction term are presented in Table 4. Results from Wald's tests examining how the between-subjects treatments affect participants preferences for recycled water, which are based on the regression results from Table 4, are presented in Table 6. We find no statistically significant differences between the treatment groups using Bonferroni-corrected values ($\rho = 1.000$), adjusted Westfall–Young stepdown values ($\rho \geq 0.971$), and the unadjusted probability values ($\rho \geq 0.464$). These results contrasts those of Savchenko et al. (2018), who found that information about the risks of recycled water decreased consumer demand for produce irrigated with recycled water in the United States by 50%.

Mean willingness-to-pay estimates

Using a logistic version of the linear probability model, estimates of participants' mean WTP for produce irrigated with each type of water were generated following Hanemann (1984), with the 95% confidence intervals calculated using the Krinsky–Robb parametric bootstrap method (Hole, 2007).[5] Table 7 shows the WTP estimates for clementines and dates by water type. In line with the regression results from the linear probability model, we find that WTP estimates are lower for produce irrigated with desalinated and recycled water. The WTP estimate for dates irrigated with recycled water is 17% below the typical ILS20 price for dates, whereas the WTP estimate for clementines irrigated with recycled water is more than half the average price of ILS4. It is important to point out that these decreases in WTP are in spite of its dominant and widespread use—Israel has been using these types of water for several decades and they make up approximately 60% of the water supply for irrigation (Lipchin & Pennycock, 2015). Israel has also invested in campaigns to increase public awareness of desalinated water.

TABLE 7 Willingness-to-pay estimates by produce type[6]

	Clementines		Dates	
Water type	**WTP**	**Sig. lev.**	**WTP**	**Sig. Lev.**
Conventional	ILS5.00 ($1.30)	0.000	ILS20.11 ($5.22)	0.000
Unspecified	ILS4.46 ($1.16)	0.000	ILS19.57 ($5.08)	0.000
Desalinated	ILS3.48 ($0.90)	0.000	ILS18.59 ($4.83)	0.000
Recycled	ILS1.47 ($0.38)	0.035	ILS16.58 ($4.31)	0.000

The lower demand for nontraditional irrigation water found in this study is in line with other studies (see Table 1). Savchenko et al. (2018) found a 22% drop in WTP for produce irrigated with recycled water relative to conventional water in the mid-Atlantic United States. However, the sample in Savchenko et al. (2018) was skewed towards highly educated adults and college students, populations that may be more responsive to the need for new, alternative sources of water because of increasing water scarcity. Thus, the drop in demand may be higher among the wider public. In California, Hui and Cain (2017) found that only 60% of consumers would purchase and eat crops irrigated with recycled water, while Menegaki et al. (2007) found that only 63% of consumers in Crete, Greece, were willing to purchase and eat tomatoes irrigated with recycled water. Smaller decreases in WTP have been found for processed products. Li et al. (2018) found a 10% drop in WTP among US consumers for wine made from grapes irrigated with recycled water, while Menegaki et al. (2007) saw a 12% decline in WTP for olive oil made with olives irrigated with recycled water.

CONCLUSIONS

As water scarcity increases across the globe, new sources of water are essential to maintain agricultural production in the future, given the sector's large share of water consumption. A commonly proposed solution to water scarcity is finding alternative sources. However, over recent decades, several studies conducted in the United States, Australia, and Greece have found broad opposition among consumers. Alternative sources of water are novel and represent a small portion of fresh water supplies in these countries. In Israel, though, desalinated water and recycled wastewater have been safely used on a nationwide scale for decades, but little work had been done to evaluate consumers' perceptions on how these waters are used. Understanding consumer preferences for different types of alternative water after decades of use in a country with dwindling fresh water supplies can provide insight into how consumer preferences across the world might change or remain the same as the need for alternative water increases. Using an economic field experiment, this study provided the first revealed preference estimates of Israeli citizens' WTP for produce irrigated with alternative water, specifically desalinated and recycled, compared to produce irrigated with conventional water. It also evaluated how information treatments affected consumer choices. Specifically, how information and messaging about the benefits and risks of recycled water may change consumer purchasing behavior.

Generally, the results show that, despite the apparent safety of the food and broad public awareness of its use, Israeli consumers prefer produce irrigated with conventional sources over produce irrigated with alternative sources of water. Of the two types of alternative water tested, the drop in demand was greatest for produce irrigated with recycled wastewater, which decreased 71% for clementines and 18% for dates, compared to conventional irrigation water. It has been suggested that consumers' negative reaction to recycled wastewater is driven by a psychological reaction of disgust and/or concern for the potential health risks it poses because of the salience of its source, which comprises household wastewater from the kitchen, laundry room, and bathroom. The drop in WTP for desalinated water was less, but still 30% for clementines and 8% for dates. Future research should explore what is driving this decline in demand. An interesting hypothesis to test is Hurlimann and Dolnicar's (2016) suggestion that consumer preference for desalinated water is shaped by their perception of it as costly and energy-intensive. Dorner et al. (2019) found that water-source-specific risk plays a significant role in preferences for alternative water sources among Australian consumers who frequently experience drought. Desalinated and recycled water were perceived as less risky than other sources because they are drought-resistant. This effect should be investigated in Israel: for example, are consumers' declines in WTP minimized or eliminated during periods of drought? Do their declines in WTP return when drought subsides?

Israeli consumers' drop in demand for desalinated water and recycled wastewater, relative to conventional water, despite their safe use on a national scale for over 30 years and extensive government campaigns to increase public awareness for desalinated water, indicates that there may be a limit to how high consumer demand for alternative water can rise over the long term. This is particularly important for countries that are using alternative water on a small, but growing scale, such as the United States, Australia, and Greece. The decline in WTP seen in this study is in line with the decrease in WTP seen in studies conducted in these countries.

This study also found that information about the benefits and risks of recycled water, when presented separately and conjointly, had no significant effect on Israeli consumer's demand for recycled water. This is what Savchenko et al. (2019b) found in the United States. However, this could also be a result of the between-subject treatments being underpowered. Future research should examine this further, as well as how scientific information on desalinated water affects consumers' preferences for it.

For Israeli researchers, farmers, and water utility officials, this study provides the first revealed preference data for produce irrigated with alternative water compared to produce irrigated with conventional water. If stakeholders in Israel and other countries want to increase consumer demand for alternative water, whether for irrigation or potable use, future research should examine ways to destigmatize recycled water and investigate what is driving consumers' decreased demand for desalinated water.

Our findings provide valuable, policy-relevant insights into how consumers across the world may view alternative sources of water after long-term, large-scale implementation. Specifically, there may be a limit to how high consumer demand for alternative irrigation water may rise over time. It seems that consumers will always prefer conventional over alternative water sources, even after long-term alternative water use. However, alternative water use is expected to grow owing to increases in global water scarcity and increases in water demand. How people think about water and how it is used and sourced will probably always be controversial to some extent. Therefore, greater transparency on solutions to water scarcity must be incorporated into policymaking so that the public is gradually exposed to the unavoidable future of widespread alternative water use. Increased public awareness and understanding of water scarcity and alternative water technology will encourage government officials and regulators to adopt alternative water sources when it is possible and they are necessary. This, in turn, will promote technological advances in safe and low-risk water treatment technologies. Greater public awareness and understanding will also help avoid dire situations like Cape Town, South Africa's 2018 water crisis. For years, city officials had resisted calls to diversify their water supplies (Onishi & Sengupta, 2018). As a result, their drinking water supplies nearly ran dry and the affected farmers lost up to 25% of their crops (Mahr, 2018). Public acceptance of alternative water sources will take time; so the sooner policymakers are transparent about water issues, the sooner perceptions will start to change.

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ENDNOTES

[1] Rozin and Nemeroff (2002) studied disgust and how disgust produces psychological barriers. These barriers may not be founded in logical or objective reasoning. The idea of "once in contact, always in contact" suggests that once a clean item or substance (such as water) has come into contact with a contagion (such as human waste), the substance itself will be contaminated. In fact, the substance will remain contaminated indefinitely even if the contagion is removed (such as through a single water treatment), as the essence of the contagion remains with the water forever. However, Kecinski et al. (2016) found that multiple treatments can be helpful in mitigating consumer concern about water that had been previously stigmatized by coming into contact with a potential contaminant.

[2] The mean price for clementines (1 pound) was ILS4 ($1.04), and for dates (1/2 pound) it was ILS20 ($5.20).

[3] The Bonferroni-adjusted significance level is $\rho = \frac{\alpha}{h}$, where h is the total number of hypotheses tested. Our Bonferroni-corrected 5% significance level is therefore $\rho = \frac{0.050}{18} = 0.003$. In Tables 5 and 6, we report the Bonferroni-corrected probability value, which we calculated by multiplying the Wald test probability value by the total number of hypotheses being tested (i.e., $h * \rho = \alpha$, which in our case is $18 * \rho = \alpha$).

[4] Unspecified irrigation water was included in the experimental design to establish a baseline for the consumer preferences. It replicated how most produce is currently labeled in Israel. However, having this be the first type of water presented and the other three types of water presented randomly afterwards, and enabling participants to go back and change their choices after considering all options, prevents us from empirically disentangling the ordering effects from the effect of not labeling the irrigation water source. The results about produce irrigated with water from an unspecified source should be considered with this issue in mind. Our findings, though, are in line with Savchenko et al. (2018) and Li et al. (2018) in the United States.

[5] The Krinsky–Robb parametric bootstrap method can be estimated only after the estimation of a logit or probit model (Hole, 2007). The linear probability model and the logistic version of it produce equivalent results (see Appendix C for logit model results).

[6] Significance level is derived from a Wald's test with a null hypothesis that the WTP estimate is less than or equal to zero.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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