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Consumer Perceptions After Long Term Use or Alternative Irrigation Water: An Israeli Field Experiment

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ABSTRACT

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Keywords: Recycled wastewater, desalinated water, stigma, field experiments, irrigation water

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Abstract

This study provides the first revealed preference estimates of Israeli's willingness-to-pay for produce irrigated with alternative water. It also investigates how exposure to information about the benefits and risks of recycled water affects these preferences. Results show that Israeli's prefer produce irrigated with conventional water over any type of alternative water, and that preferences for alternative water varies by type. Exposure to information about the risks of recycled water increases consumers' willingness-to-pay for produce irrigated with desalinated water. These results indicate there may be limits to how high consumer demand for alternative water can rise even after long term implementation.

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JEL Classification: D12; Q13; Q15; Q18

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Introduction

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 and Hurlimann, 2009; Hui and Cain, 2017). Israel, on the other hand, has used alternative irrigation water on a nation-wide scale for over three decades, but surprisingly little research has 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 consumer 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 (Hayes et al., 2002; Marette et al., 2010; Dillaway et al., 2011; Wu et al., 2015; McFadden and Huffman, 2017), 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 forced Israel in the 1990s to pioneer not only new irrigation technologies but also new sources of water (Feitelson, 2013; Menahem and 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 and 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 twelve-fold over thirty years. However, when Israel began moving aggressively toward 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 and Gilad, 2013). The same was true in the early 2000's when the first large-scale seawater desalination project began. 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 that also emphasized water conservation (Rosenthal and Katz, 2010; Sedley, 2018).

Consequently, little research 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 for laundering, showering, drinking, cooking, and cleaning, but preferred recycled water over desalinated for watering their garden and toilet flushing. It is unclear if in the survey a distinction was made between food and non-food items in personal gardens. Friedler et al. (2006) found 86% support amongst 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 and Hurlimann, 2009) and the United States (Kecinski and Messer, 2018) have measured consumers' 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 (Menegaki et al., 2007; Bakopoulou et al., 2008) and the United States (Hui and 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." 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 U.S. consumers and irrigation water.

Consumers' refusal 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 and Nemeroff, 2002) , a concern that is believed to be transferred to produce irrigated with recycled wastewater (Savchenko et al., 2018). However, there is evidence that stigma may be partially mitigated through framing and the introduction of additional physical treatments (Rozin et al., 2015; Kecinski and Messer, 2018; Ellis et al., 2019a). An increase in the need for recycled water has also been shown to increase acceptance of it (Dolnicar and Schäfer, 2009), as has informing people that they have been using it for an extended period of time without incident (Hui and 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., 2019b).

On the other hand, information might increase the repulsion individuals have concerning recycled water. For example, exposing consumers to information about the potential health risks has been shown to lower WTP for vegetables irrigated with it (Savchenko et al., 2018). Further, a plan to incorporate recycled water into the municipal drinking water supply in Toowoomba, Australia was derailed when scientists could not guarantee that there would never be any issues with it (Morgan and 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 if it is

[3] Rozin and Nemeroff (2002) study 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.

conventional or recycled (Li et al., 2018). Studies 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 and Lusk, 2015; McFadden and Huffman, 2017; Whiting et al., 2019).

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

1. After three decades of alternative water use in Israeli agriculture, does Israeli consumers' WTP for produce vary by irrigation water type (conventional, unspecified, 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, Israeli's still have concerns with water from alternative sources even after decades of safe use and extensive campaigns to increase public acceptance. Results show that use of alternative water diminishes consumer demand for produce irrigated with it relative to the same produce irrigated with conventional or unspecified water. The reduction in WTP for alternative water does vary by type, with demand for produce irrigated with recycled wastewater decreasing more than desalinated water. Exposure to information about the risks of recycled wastewater, even when coupled with information about its benefits, increases consumers' WTP for produce irrigated with desalinated water.

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; Loomis et al., 1997; Frykblom and Shogren, 2000; Wu, et al. 2014). Formally in this case, participant i was offered purchase opportunity j at listed price P and they decide to either accept and purchase it (D = 1) or reject it (D = 0):

$$D_{ij} = \begin{cases} 1 \; if \; P_{ij} \leq EU_{ij} \\ 0 \; if \; P_{ij} > EU_{ij} \end{cases} \qquad (1)$$

If the price of P_{ij} was less than or equal to a participant's expected utility, EU_{ij}, the participant purchased the product, otherwise, the participant did not. In accord with Fehr and Rangel (2011), the expected utility for participant i's purchase opportunity j was generated by integrating attributes, such as water type, over various dimensions such as taste, healthfulness, sense of disgust, and self-image. The model assumes that:

$$EU_{ij} = \sum W_{ij} A_{jk}\,(k), \qquad (2)$$

where A_{jk} is a vector of attributes for dimension k of purchase opportunity j, and W_{ij} is a vector of weights participant i applies to each dimension of purchase opportunity j.

Data collection occurred at a public promenade in Eilat, 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, due 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 that 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 $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 independently of the others.

Participants were presented with eight purchase opportunities (see Figure 1) as a within subject 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 endowment. The standard deviation was half of the respective mean price . Mean prices were calculated from the prices observed at several local grocery stores in Eilat, Israel.

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

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 2x2 factorial, between subject 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 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 t, aimed to affect how a participant calculated a value for a product’s attribute (water type) and how this attribute was weighted. The information treatments emphasized some dimension of the water type, either its relative risk to humans or relative benefits to the environment, potentially affecting how a participant generated their expected utility. Incorporating the information treatments, Equation 2 becomes:

$$EU_{ij} = \sum W_{ij}(t)A_{jk}(k,t). \qquad (3)$$

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 implemented. Participants who selected yes for the implemented option received the produce and the balance of their ILS40 endowment 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 Logit 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 logit model was used to isolate the effect of each treatment and type of irrigation water on the likelihood of purchasing produce. Given the within subject design (eight observations per participant), a random effects specification was implemented, and the coefficients were estimated using clustered standard errors:

$$log \frac{D_{ij}}{1-D_{ij}} = \alpha + \beta_1{}'P_{ij} + \beta_2{}'W_{ij} + \beta_3{}'T_i + \beta_4{}'X_i + \mu_i + \varepsilon_{ij} \qquad (4)$$

where $\mu_i \sim N(0, \sigma_\mu^2)$ and $\varepsilon_{ij} \sim N(0, \sigma^2)$, W_ij is a matrix of dummy variables for irrigation water type, T_i is a vector of dummy variables for participant i's information treatment, and X_i is a matrix of control variables including produce type, prior knowledge about desalinated water and recycled wastewater, gender, age, annual household income, and highest educational attainment.

Since our analysis involves multiple comparisons, we used a Bonferroni correction of the Wald test probability values to account for the family-wise error rate, or in other words, to guard against Type I errors. It corrects for multiple comparisons by dividing the overall alpha level by the number of hypotheses being tested in a family of hypotheses. Both the original probability values and the Bonferroni corrected probability values are reported in the tables below.

Regression results for Equation 4 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 demographic characteristics of prior knowledge about desalinated water and recycled wastewater, gender, age, annual household income, and highest educational attainment have no statistically significant effect ($\rho \geq 0.073$).

Wald test results, examining the relationships between participants preferences for the different type of water, which are based the regression results from Table 4 are presented in Table 5. Findings in Table 5 show that participants do not differentiate (ρ = 0.353) between produce irrigated with conventional or unspecified irrigation water. However, participants do prefer (ρ < 0.020) produce irrigated with water from conventional or unspecified sources over any type of alternative water. These results are in-line with those found by Savchenko et al. (2018) and Li et al., (2018) in the United States and suggests that it might be best to not tell consumers what type of water their food is irrigated with, which is the current practice in Israel as there are no labeling requirements. The results also show that participants prefer produce irrigated with desalinated water over recycled (ρ < 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 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 or unspecified sources. Perhaps, as Hurlimann and Dolnicar (2016) found, consumers view it as a costly and energy intensive alternative to conventional water.

Between Subject Scientific Information Treatments

The regression and Wald test results for Equation 4 (see Tables 4 and 5) show that the between subject scientific information treatments did not have any overall statistically significant (ρ ≥ 0.82) effects on participants. To see if the information treatments had any effect on participants preferences for specific types of water, an iteration of Equation 4 that incorporates an interaction term between water type and information treatment was estimated

$$log \frac{D_{ij}}{1-D_{ij}} = \alpha + \beta_1{'}P_{ij} + \beta_2{'}W_{ij} + \beta_3{'}T_i + \beta_4{'}W_{ij}T_i + \beta_5{'}X_i + \mu_i + \varepsilon_{ij} \quad (5)$$

Regression results for Equation 5 are presented in Table 4. Results from Wald tests examining how the between subject treatments affect participants preferences for the different types of water, which are based on the regression results from Table 4, are presented in Table 6. Between the treatment groups, there are only marginally significant differences ($\rho \geq 0.090$) in demand for each water type (see Table 6). However, there are statistically significant differences in preferences for each type of water within each group. When participants are exposed to information about the risks of recycled water, even when coupled with information about the benefits, they no longer prefer ($\rho = 1.000$) produce irrigated with conventional or unspecified water over desalinated water. The results also show that when exposed to no information about recycled water or just the benefits of it, consumers do not prefer ($\rho \geq 0.249$) produce irrigated with desalinated water over that with recycled. These results imply that being reminded of the risks of recycled water increases participants WTP for produce irrigated with desalinated water. Similar to Savchenko et al. (2019b), information about recycled water had no statistically significant effect on consumers' preferences for it. Which contrasts with Savchenko et al. (2018), which 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 Equation 5, 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).

$$WTP = \frac{1}{\hat{P}}(\hat{\alpha} + \hat{\beta}_3'\bar{T} + \hat{\beta}_4'\bar{T}\bar{W} + \hat{\beta}_5'\bar{X}) \qquad (6)$$

where $\hat{P}$ is the absolute value of the price coefficient, $\hat{\alpha}$, $\hat{\beta}_3$, $\hat{\beta}_4$, and $\hat{\beta}_5$ are the estimated parameters, and $\bar{T}$, $\bar{T}\bar{W}$, and $\bar{X}$ are matrices of the means of the explanatory variables.

Table 7 shows the WTP estimates for clementines and dates by water type ($\rho \leq 0.046$). In line with the regression results from Equation 4, we find a 43% drop in WTP for clementines irrigated with desalinated water, compared to conventional, and a 66% drop for those irrigated with recycled wastewater. For dates the pattern is similar, although the magnitude of the decrease in WTP is less for both desalinated water (11%) and recycled wastewater (17%). These decreases in WTP are in spite of alternative irrigation water being used nation-wide in Israel for several decades and making up approximately 60% of the water supply for irrigation (Lipchin and Pennycock, 2015). As well as, Israel having heavily invested in campaigns to increase public acceptance of desalinated water.

The drop in demand observed in this study is in line with Savchenko et al. (2018), which found a 22% drop in WTP for produce irrigated with recycled water relative to conventional in the mid-Atlantic, United States (see Table 1). 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 amongst 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 amongst U.S. 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.

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Figure 3 displays the effect of the scientific information treatments on WTP for produce irrigated with different types of water ($\rho = 0.000$). As the regression results from Equation 5 indicated, negative information about recycled water increased participants WTP for produce irrigated with desalinated water. In the no information control group and the benefits information treatment group the drop in WTP for produce irrigated with desalinated water was 17% and 21%, respectively. However, in the risk information treatment group and the benefits and risks information treatment group the decreases in WTP were 7% and 3%, respectively. Whereas for produce irrigated with recycled wastewater there was no statistically significant effect from the scientific information; the drop in WTP compared to conventional was relatively similar across the treatment groups (26% to 33%).

Conclusions

As water scarcity increases across the globe, new sources of water are needed to maintain agricultural production in the future, given the sectors large share of water consumption. A commonly proposed solution to water scarcity is new, alternative sources of water. However, over recent decades, several studies conducted in the United States, Australia, and Greece have found broad opposition amongst 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 research has been done to evaluate consumers' perceptions. Understanding consumer acceptance 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 this study provides the first revealed preference estimates of Israeli citizens willingness-to-pay (WTP) for produce irrigated with alternative water, specifically desalinated and recycled, 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 consumer purchasing behavior.

Generally, the results show that despite the apparent safety of the food, Israeli consumers prefer produce irrigated with conventional or unspecified sources over produce irrigated with alternative water. Of the two types of alternative water tested, the drop in demand was greatest for produce irrigated with recycled wastewater, which decreased 66% for clementines and 17% 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 its source, which is comprised of household wastewater from the kitchen, laundry room, and bathroom. The drop in WTP for desalinated water was less, but still 43% for clementines and 11% for dates. Future research should explore what is driving this decline in demand, starting with Hurlimann and Dolnicar's (2016) suggestion that consumers view desalinated water as costly and energy intensive.

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 thirty years and extensive government campaigns to increase public acceptance 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 finds that information about the risks of recycled water plays a crucial role in Israeli consumers' demand for desalinated water. When exposed to no information or only information about the benefits of recycled water, there is no statistically significant difference between produce irrigated with desalinated water and produce irrigated with recycled wastewater. However, when consumers are exposed to information about the risks of recycled water, even when coupled with information about the benefits, their demand for produce irrigated with desalinated irrigation water increases, making it statistically the same as produce irrigated with conventional or unspecified water, and statistically greater than produce irrigated with recycled wastewater. However, information about the risks of recycled water has no statistically significant effect on consumers WTP for recycled wastewater.

Our findings provide valuable 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. 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.

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Figure 1. Examples of food purchase options

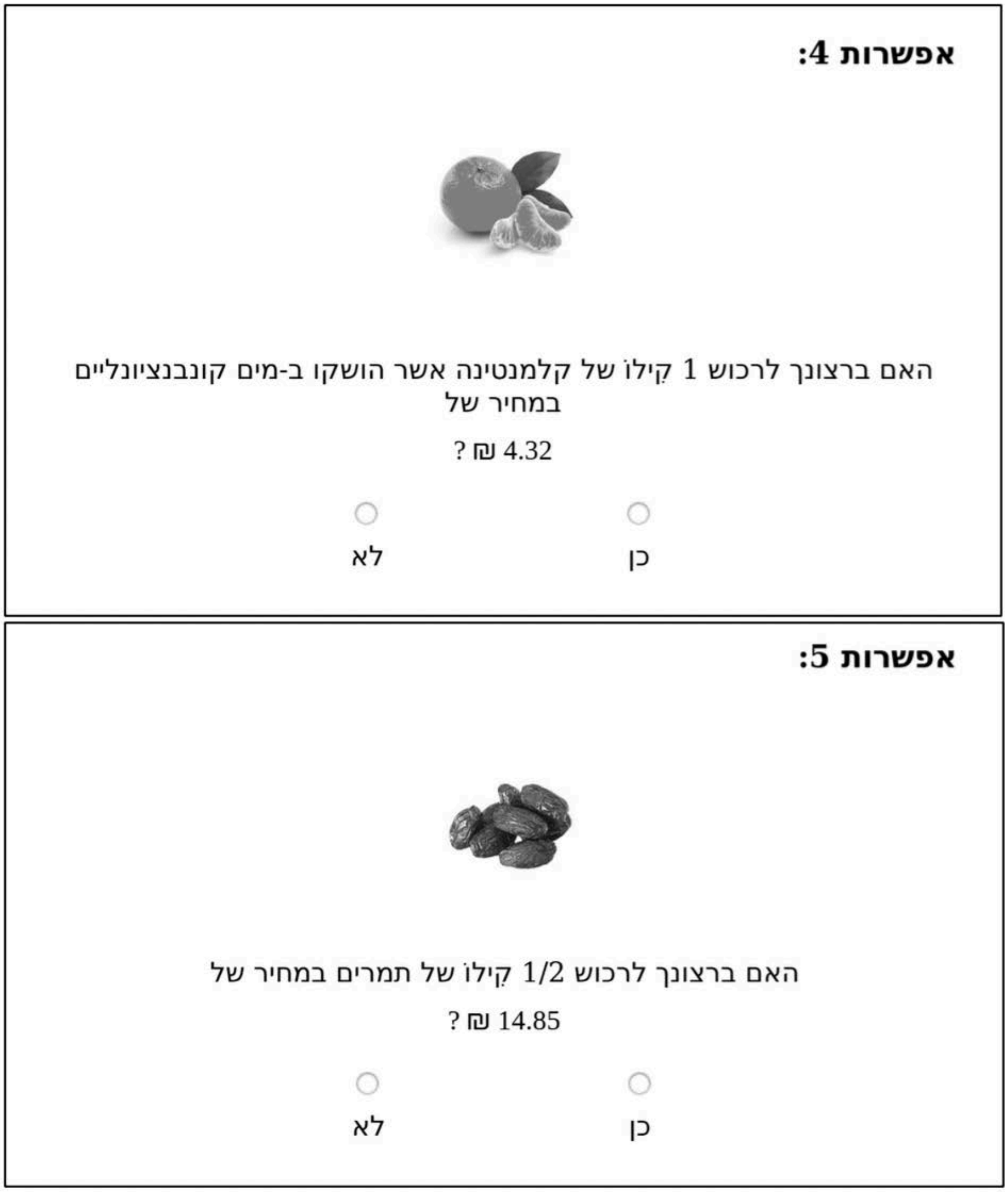
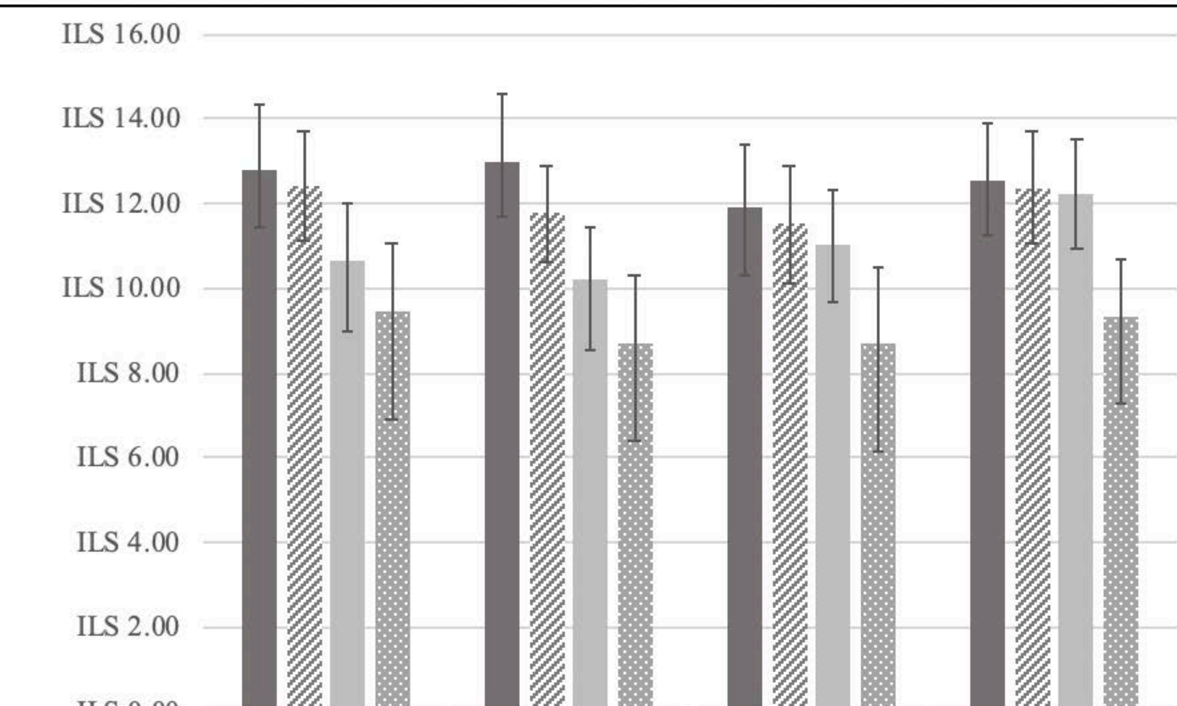


Figure 2. Between subject experiment design

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

Figure 3. Mean willingness-to-pay by scientific information treatment



	No Information	Benefits	Risks	Benefits & Risks
Conventional	ILS 12.79	ILS 13.00	ILS 11.89	ILS 12.52
Unspecified	ILS 12.40	ILS 11.78	ILS 11.55	ILS 12.32
Desalinated	ILS 10.62	ILS 10.23	ILS 11.01	ILS 12.20
Recycled	ILS 9.43	ILS 8.71	ILS 8.68	ILS 9.31

Note: Error bars represent 95% confidence interval for WTP estimates obtained through the Krinsky—Robb parametric bootstrap method. The exchange rate is 1 USD for 3.85 ILS.

Table 1. Summary of literature on consumer preferences for alternative water

Drinking Water			
Citation	*Sample*	*Method*	*Findings*
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, 13% supported recycled drinking water
Fielding et al. (2015)	1,262 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			
Citation	*Sample*	*Method*	*Findings*
Savchenko (2019a)	540 Adults, 220 Students (United States)	Hypothetical stated preference survey	Prefer rain- 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)	1,500 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
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, unspecified, desalinated, recycled)?	For each type of water *a* and all other types of water *b* $H_0: WTP_a = WTP_b$ $H_A: WTP_a \neq WTP_b$	Fail to reject H_0 (displayed in Tables 3 and 4). There is no statistically significant difference in WTP for produce irrigated with conventional water compared to water from an unspecified source. Reject H_0 (displayed in Tables 3 and 4). There is a decrease in WTP for produce irrigated with alternative water compared to water from conventional or unspecified sources. There is also a difference in WTP for different types of alternative water, with WTP for produce irrigated with recycled wastewater decreasing more than produce irrigated with desalinated water, relative to conventional water.
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* $H_0: WTP_{ac} = WTP_{ad}$ $H_A: WTP_{ac} \neq WTP_{ad}$	Reject H_0 (displayed in Tables 3 and 5). Exposure to information about the risks of recycled water, even when coupled with information about its benefits, increases WTP for produce irrigated with desalinated water.

Table 3. Summary statistics

		Sample	Israel
	Total Participants	202	
Treatment	*No Information*	48	
	Benefits	52	
	Risks	50	
	Benefits & 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.

Table 4. Random effects logistic models: Irrigation water preferences and the effect of scientific information on them

		Equation 4			Equation 5		
		Coef.	S.E.	P-Val	Coef.	S.E.	P-Val
	Price	-0.476	(0.079)	0.000	-0.477	(0.079)	0.000
Treatment	*Benefits*	-0.210	(0.289)	0.466	0.055	(0.452)	0.903
	Risks	-0.269	(0.309)	0.384	-0.449	(0.483)	0.353
	Benefits & Risks	0.065	(0.298)	0.827	-0.207	(0.446)	0.642
Produce	*Clementines*	-7.193	(1.267)	0.000	-7.209	(1.270)	0.000
Water Type	*Unspecified*	-0.258	(0.165)	0.118	-0.186	(0.309)	0.547
	Desalinated	-0.723	(0.207)	0.000	-1.038	(0.419)	0.013
	Recycled	-1.677	(0.257)	0.000	-1.605	(0.511)	0.002
Water Type*Benefits	*Unspecified*				-0.396	(0.447)	0.375
	Desalinated				-0.284	(0.570)	0.618
	Recycled				-0.442	(0.724)	0.541
Water Type*Risks	*Unspecified*				0.022	(0.469)	0.963
	Desalinated				0.616	(0.615)	0.316
	Recycled				0.073	(0.784)	0.926
Water Type*Benefits & Risks	*Unspecified*				0.092	(0.448)	0.838
	Desalinated				0.885	(0.570)	0.121
	Recycled				0.072	(0.640)	0.910
Prior Knowledge	*Desalinated*	0.041	(0.331)	0.902	0.041	(0.334)	0.901
	Recycled	-0.001	(0.303)	0.996	-0.001	(0.306)	0.997
Demographics	*Female*	0.176	(0.211)	0.404	0.175	(0.212)	0.410
	Age	-0.004	(0.006)	0.500	-0.004	(0.006)	0.503
	Annual Household Income	-0.048	(0.045)	0.286	-0.050	(0.046)	0.277
Education	*Some College*	0.188	(0.359)	0.600	0.194	(0.362)	0.592
	Associate Degree	0.536	(0.436)	0.219	0.543	(0.437)	0.214
	Bachelor's Degree	0.503	(0.280)	0.073	0.511	(0.283)	0.071
	Graduate Degree	-0.205	(0.377)	0.586	-0.209	(0.380)	0.582
Constant		9.763	(1.622)	0.000	9.834	(1.623)	0.000
Total N		1,616			1,616		
Individuals		202			202		

Table 5. Wald tests for irrigation water preferences

Water Type			
	χ^2	Prob.	BCP
Conventional = Unspecified	2.45	0.118	0.353
Conventional = Desalinated	12.16	0.001	0.002
Conventional = Recycled	42.72	0.000	0.000
Unspecified = Desalinated	7.38	0.007	0.020
Unspecified = Recycled	42.08	0.000	0.000
Desalinated = Recycled	19.88	0.000	0.000
Treatment			
	χ^2	Prob.	BCP
No Information = Benefits	0.53	0.466	1.000
No Information = Risks	0.76	0.384	1.000
No Information = Benefits & Risks	0.05	0.827	1.000
Benefits = Risks	0.04	0.838	1.000
Benefits = Benefits & Risks	0.99	0.319	0.957
Risks = Benefits & Risks	1.19	0.274	0.823
BCP: Bonferroni Corrected Probability Value			

Table 6. Wald tests for effect of scientific information on irrigation water preferences

	Water Type											
	Conventional			*Unspecified*			*Desalinated*			*Recycled*		
Wald Test	χ2	Prob.	BCP	χ2	Prob.	BCP	χ2	Prob.	BCP	χ2	Prob.	BCP
No Information = Benefits	0.01	0.903	1.000	0.71	0.401	1.000	0.27	0.605	1.000	0.53	0.467	1.000
No Information = Risks	0.86	0.353	1.000	0.90	0.342	1.000	0.14	0.712	1.000	0.46	0.499	1.000
No Information = Benefits & Risks	0.22	0.642	1.000	0.07	0.789	1.000	2.33	0.127	0.380	0.08	0.784	1.000
Benefits = Risks	1.14	0.286	0.858	0.04	0.839	1.000	0.86	0.355	1.000	0.00	0.984	1.000
Benefits = Benefits & Risks	0.37	0.545	1.000	0.31	0.579	1.000	4.72	0.030	0.090	0.27	0.602	1.000
Risks = Benefits & Risks	0.26	0.608	1.000	0.47	0.495	1.000	1.36	0.244	0.731	0.22	0.638	1.000
	Treatment											
	No Information			*Benefits*			*Risks*			*Benefits & Risks*		
Wald Test	χ2	Prob.	BCP	χ2	Prob.	BCP	χ2	Prob.	BCP	χ2	Prob.	BCP
Conventional = Unspecified	0.36	0.547	1.000	3.23	0.072	0.216	0.22	0.641	1.000	0.08	0.773	1.000
Conventional = Desalinated	6.13	0.013	0.040	11.79	0.001	0.002	0.86	0.355	1.000	0.16	0.691	1.000
Conventional = Recycled	9.89	0.002	0.005	15.68	0.000	0.000	6.51	0.011	0.032	15.38	0.000	0.000
Unspecified = Desalinated	5.74	0.017	0.050	5.35	0.021	0.062	0.52	0.471	1.000	0.03	0.860	1.000
Unspecified = Recycled	9.64	0.002	0.006	12.67	0.000	0.001	9.17	0.003	0.007	12.46	0.000	0.001
Desalinated = Recycled	1.71	0.191	0.574	3.00	0.083	0.249	5.53	0.019	0.056	12.71	0.000	0.001
BCP: Bonferroni Corrected Probability Value												

Table 7. Willingness-to-pay estimates by produce type[5]

	Clementines		*Dates*	
Water Type	WTP	Sig. Lev.	WTP	Sig. Lev.
Conventional	ILS5.08 ($1.32)	0.000	ILS20.19 ($5.24)	0.000
Unspecified	ILS4.69 ($1.22)	0.000	ILS19.80 ($5.14)	0.000
Desalinated	ILS2.91 ($0.76)	0.000	ILS18.01($4.68)	0.000
Recycled	ILS1.72 ($0.45)	0.046	ILS16.82 ($4.37)	0.000

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

Appendix A: English Version of Experiment Instructions

Appendix A-1: English Version of Experiment Instructions

Instructions:

Please read these instructions carefully and do not communicate with anyone while you are making your decisions.

- **You will earn ILS40 by participating in this experiment that you may keep and/or use to purchase produce. You may think of this money as a bank account from which you can withdraw money.**
- Depending on the decisions you make, you may receive a combination of cash and/or produce. Your decisions are just like the ones you make in a store: you either buy the produce at the listed price or you do not. Please remember that all decisions are real purchasing decisions.

Steps:

1. You will face a series of "options" where you have the opportunity to buy produce. For each option, decide if you want to buy the produce at the listed price by selecting 'Yes' or 'No'.
2. Complete a short survey.
3. Roll a digital dice to determine which option will be selected. Only one option will be selected. This means that each decision you make is equally likely to be your final decision.
4. Receive cash and/or produce.

Consider the following examples:

- **Example 1:** If your decision is 'Yes' for an option that costs ILS12, and this option is randomly selected by the digital die, you will receive the produce and ILS28 cash (ILS40 – ILS12 = ILS28).
- **Example 2:** If your decision is 'No' for an option, and this option is randomly selected by the digital die, you will receive ILS40 and will not receive any produce.

Appendix A-2: Hebrew Version of Experiment Instructions

הנחיות

הינך מתבקש לקרוא הנחיות אלה בעיון ולא לתקשר עם אדם כלשהו במהלך קבלת ההחלטות.

- אנו נשלם לך 40 ₪ עבור השתתפותך בניסוי זה. תוכל לשמור סכום זה ו/או להשתמש בו לרכישת מוצרים. כסף זה הינו כמו חשבון בנק, ממנו תוכל למשוך ולהשתמש בכסף.
- בהתאם להחלטות שתקבל, תזכה לשילוב של מזומן ו/או מוצרים. החלטותיך הן בדיוק כמו ההחלטות שהינך מקבל בכל חנות: או שתקנה את המוצרים במחיר המצוין עליהם, או שלא. זכור כי כל החלטותיך הן החלטות רכישה אמיתיות.

שלבים

1. יוצגו בפניך מספר "אפשרויות", בהן תהיה לך הזדמנות לרכוש מוצרים. בכל אפשרות, עליך להחליט אם ברצונך לרכוש את המוצרים במחיר המוצע, על ידי בחירת "כן" או "לא".
2. עליך להשלים סקר קצר.
3. זרוק קוביה דיגיטלית, כדי לקבוע באיזו אפשרות לבחור. רק אפשרות אחת תיבחר. משמעות הדבר הוא שלכל החלטה שתקבל סבירות זהה להיות ההחלטה האחרונה שלך.
4. קבל מזומן ו/או מוצרים.

חשוב על הדוגמאות הבאות:

- **דוגמא א'**: אם הבחירה שלך היא "כן" עבור מוצר העולה 12 ₪ ואפשרות זו נבחרה באופן אקראי בידי הקוביה הדיגיטלית, תקבל את המוצר ו- 28 ₪ במזומן (40 ₪ - 12 ₪ = 28 ₪).
- **דוגמא ב'**: אם הבחירה שלך היא "לא" עבור מוצר ואפשרות זו נבחרה באופן אקראי בידי הקוביה הדיגיטלית, תקבל 40 ₪ ולא תקבל את המוצר.

Appendix B: English Version of Survey

Please answer the following questions:

1. What is your age?
2. What is your gender?
    a. Male
    b. Female
    c. Prefer not to answer
3. Do you live in Israel?
    a. Yes
    b. No
4. What is your postal code?
5. What is your profession?
    a. Government
    b. Military
    c. Education
    d. Business
    e. Agriculture
    f. Student
    g. Other (please specify)
6. Are you:
    a. Politically liberal
    b. Politically moderate
    c. Politically conservative
    d. Other (please specify
7. How would you identify your ethnicity?
    a. Jewish
    b. Arab
    c. Other
8. Which category best describes your household income (before taxes) in 2015?
    a. Less than ILS40,000
    b. ILS40,000-ILS79,999 (39,999)
    c. ILS80,000-ILS119,999 (39,999)
    d. ILS120,000-ILS179,999 (59,999)
    e. ILS180,000-ILS239,999 (59,999)
    f. ILS240,000-ILS299,999 (59,999)
    g. ILS300,000-ILS359,999 (59,999)
    h. ILS360,000-ILS559,999 (199,999)
    i. ILS560,000-ILS759,999 (199,999)
    j. ILS760,000-ILS959,999 (199,999)
    k. ILS960,000 and above

9. What is the highest level of education that you have completed?
    a. Primary school
    b. Some secondary school
    c. Secondary school graduate
    d. Some college credit
    e. Associate degree
    f. Bachelor's degree
    g. Graduate degree/Professional
10. Do you have a child/children under 18 years old in your household?
    a. Yes
    b. No
11. How often do you consume the following produce:
    a. Clementines: _____ times per month
    b. Dates: _____ times per month
12. Are you the primary shopper in your household?
    a. Yes
    b. No
13. What is the percentage of fresh foods compared to canned or frozen foods in your overall **fruit** consumption?
    a. Less than 20% fresh
    b. 20-50% fresh
    c. 50-80% fresh
    d. More than 80% fresh
14. What is the percentage of fresh foods compared to canned or frozen foods in your overall **vegetable** consumption?
    a. Less than 20% fresh
    b. 20-50% fresh
    c. 50-80% fresh
    d. More than 80% fresh
15. Do you grow your own food?
    a. Yes
    b. No
16. How important are the following food attributes to you?
    a. Price: Not Important (1) Very Important (5)
    b. I want the time it takes to prepare my food to be as minimal as possible: Not Important (1) Very Important (5)
    c. Organic: Not Important (1) Very Important (5)
    d. I prefer to purchase foods that are GMO (Genetically Modified Organisms) free: Not Important (1) Very Important (5)
    e. Locally grown/produced: Not Important (1) Very Important (5)
17. What type of water do you typically drink?
    a. Bottled Water
    b. Tap Water
    c. Filtered Water
    d. Other (Please specify)

18. How concerned are you about water availability in the future in these areas?
    a. Your community: Not Concerned at all (1) Very Concerned (5)
    b. Israel: Not Concerned at all (1) Very Concerned (5)
    c. Globally: Not Concerned at all (1) Very Concerned (5)
19. How concerned are you about water availability **in your community** over these time periods?
    a. Present: Not Concerned at all (1) Very Concerned (5)
    b. Next 10 years: Not Concerned at all (1) Very Concerned (5)
    c. Next 50 years: Not Concerned at all (1) Very Concerned (5)
    d. Beyond the next 50 years: Not Concerned at all (1) Very Concerned (5)
20. How concerned are you about climate change in these areas?
    a. Your community: Not Concerned at all (1) Very Concerned (5)
    b. Israel: Not Concerned at all (1) Very Concerned (5)
    c. Globally: Not Concerned at all (1) Very Concerned (5)
21. How concerned are you about climate change **in your community** over these time periods?
    a. Present: Not Concerned at all (1) Very Concerned (5)
    b. Next 10 years: Not Concerned at all (1) Very Concerned (5)
    c. Next 50 years: Not Concerned at all (1) Very Concerned (5)
    d. Beyond the next 50 years: Not Concerned at all (1) Very Concerned (5)
22. Before this survey had you ever heard of:
    a. Desalinized water:
        i. Yes
        ii. No
    b. Recycled wastewater:
        i. Yes
        ii. No
23. Compared to conventional water, the standards for these types of water should be (where 3 means the same standards as conventional water):
    a. Desalinized water: Greatly lower (1) Greatly higher (5)
    b. Recycled wastewater: Greatly lower (1) Greatly higher (5)
24. I trust these groups to test and monitor recycled irrigation water:
    a. The Israeli government: Strongly Disagree (1) Strongly Agree (5)
    b. My local government: Strongly Disagree (1) Strongly Agree (5)
    c. Environmental groups: Strongly Disagree (1) Strongly Agree (5)
    d. Wastewater treatment plants: Strongly Disagree (1) Strongly Agree (5)
    e. Universities: Strongly Disagree (1) Strongly Agree (5)

The Department of Applied Economics and Statistics
College of Agriculture and Natural Resources
University of Delaware

The Department of Applied Economics and Statistics carries on an extensive and coordinated program of teaching, organized research, and public service in a wide variety of the following professional subject matter areas:

Subject Matter Areas

Agricultural Policy	Environmental and Resource Economics
Food and Agribusiness Management and Marketing	International Agricultural Trade
Natural Resource Management	Price and Demand Analysis
Rural and Community Development	Statistical Analysis and Research Methods

The department's research in these areas is part of the organized research program of the Delaware Agricultural Experiment Station, College of Agriculture and Natural Resources. Much of the research is in cooperation with industry partners, the USDA, and other State and Federal agencies. The combination of teaching, research, and service provides an efficient, effective, and productive use of resources invested in higher education and service to the public. Emphasis in research is on solving practical problems important to various segments of the economy.

The mission and goals of our department are to provide quality education to undergraduate and graduate students, foster free exchange of ideas, and engage in scholarly and outreach activities that generate new knowledge capital that could help inform policy and business decisions in the public and private sectors of the society. APEC has a strong record and tradition of productive programs and personnel who are engaged in innovative teaching, cutting-edge social science research, and public service in a wide variety of professional areas. The areas of expertise include: agricultural policy; environmental and resource economics; food and agribusiness marketing and management; international agricultural trade; natural resource management; operations research and decision analysis; rural and community development; and statistical analysis and research methods.

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