Back to the Source: Consumer Behavior in Response to Different Sources of Recycled Irrigation Water

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Abstract

Using recycled water to irrigate agricultural products can be an effective solution to water scarcity. However, a better understanding of how society evaluates different sources of recycled water provides insights into potential demand-side barriers to adoption of these solutions. This paper implements a field economic experiment conducted in the Southwest and Mid-Atlantic regions of the United States that evaluates consumers' willingness-to-pay for three sources of recycled irrigation water: "gray", "black", and "produced". Our analysis indicates that people consider certain sources of recycled water more acceptable for irrigating produce than others. Recycled gray water is preferred to recycled produced water, and both are preferred to recycled black water. We also explore how adult consumers respond to scientific information about the benefits and risks of using recycled irrigation water, and find that it does not mitigate consumers' concerns.

Keywords: Reused water, reclaimed water, drought, water management, stigma,

JEL Classification: C93; D12; Q13; Q15

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1. Introduction

In light of the pressing nature of current and future water scarcity issues, this study focuses on providing a better understanding of how consumers respond to agricultural products irrigated with recycled water. Any treated water source other than groundwater and treated surface water is considered recycled, including recycled "gray", recycled "black", and recycled "produced" water, the three sources we specifically examine. Widespread adoption of recycled irrigation water in the United States and across the world depends, among other things, on consumer acceptance of it. Other technologies in food production, such as genetically modified foods, irradiation, and use of growth hormones and antibiotics have faced consumer backlash because of perceived risks (Eckley and McEowen 2012; Messer et al. 2017). Prior studies have portrayed recycled water as a homogenous commodity, describing it with catch-all terms such as recycled, reclaimed, and reused (Menegaki et al. 2007; Bakopoulou et al. 2008; Hui and Cain 2017).

Using an economic field experiment conducted in the Southwest and Mid-Atlantic regions of the United States that involved 458 adult subjects, we seek to enhance the relatively sparse literature investigating whether consumers' preferences vary by recycled water source. Since information and messaging have been shown to influence consumers' food purchasing behavior (Hayes, et al. 2002; Marette et al. 2010; Dillaway et al. 2011; Wu et al. 2015), we also examine the effect of presenting scientific information about recycled water's benefits and risks.

1.1 Background

According to the Intergovernmental Panel on Climate Change's IPCC's Sixth Assessment Report, strains on freshwater supplies will only increase pressure on renewable surface water and groundwater resources as climate change continues to unfold, increasing the disparity between wet and dry regions (IPCC 2022). Addressing these water shortages is particularly pressing for farmers in the western United States, which encompasses 74% of the country's irrigated acres (U.S. Geologic Survey 2016). Agriculture is a major user of "blue" water (groundwater and surface water) with irrigation accounting for 42% of withdrawals. The 2017 U.S. Census of Agriculture states that farms employing some form of irrigation accounted for 54% of total crop sales (Economic Research Service (ERS), U.S. Department of Agriculture 2017). The U.S. food system, including agricultural production and supply chain stages, constitutes one-third of the country's freshwater use (ERS 2021). On average in the first quarter of 2022, approximately 57% of the continental United States was experiencing some degree of drought with 38% suffering from severe drought (USDA 2022).

A potential solution to drought is the use of recycled water in irrigation. Conventional irrigation water comes from a variety of sources, including surface water (i.e., rivers, lakes, ponds, and reservoirs) and groundwater supplies (Centers for Disease Control and Prevention 2009). Recycled irrigation water typically refers to recycled wastewater (WateReuse 2019), which comes from a variety of sources, such as gray, black, and produced water. Gray water is household wastewater from washing, laundering, bathing, and showering (Environmental Protection Agency (EPA) 2021) while black water, includes wastewater that comes from toilets and urinals (EPA 2021). Produced water comes from oil and gas drilling and is a mixture of water naturally stored in oil and gas pockets and water injected into wells to extract oil (Igunnu and Chen 2014). Produced water is not the same as the mixture of water and chemicals used in hydraulic fracturing.

Consumers' refusal to purchase and ingest produce irrigated with recycled water has been widely documented (Menegaki et al. 2007; Rozin et al. 2015; Savchenko et al. 2018). A primary reason for the rejection may be explained by stigma-- consumers rejection of recycled water because they perceive the water as posing health risks or inducing feelings of disgust (Fischhoff 2001; Walker 2001, Rozin and Nemeroff 2002, Dingfelder 2004; Rozin et al. 2015,). Previous research has found evidence to support this hypothesis in the context of produce irrigated with recycled water (Savchenko et al. 2018, Whiting et al. 2019; Li et al. 2018; Savchenko et al. 2019a, 2019b; Ellis et al. 2019; 2021a, 2021b). However, there is also evidence from these studies and more that stigma can be partially mitigated through message framing and additional physical purification treatments (Rozin et al. 2015; Kecinski and Messer 2018). Furthermore, Savchenko et al. (2019b) and Ellis et al. (2021b) show that simple processing (e.g., drying or liquifying) of produce and explicitly disclosing the trophic levels of agricultural products, mitigates consumers' stigma attached to produce irrigated with recycled water. An increase in the need for recycled water has also been shown to increase acceptance (Dolnicar and Schäfer 2009), as has informing consumers that recycled water has been used extensively without incident (Hui and Cain 2017). Even simply rebranding recycled water with a name that evokes its fresh, clean, and purse status has been shown to increase acceptance (Ellis et al. 2019).

On the other hand, information could increase consumers' repulsion. For example, exposing consumers to information about potential health risks from recycled water has been found to reduce willingness to pay (WTP) for vegetables irrigated with it (Savchenko et al. 2018). A plan to incorporate recycled water into the municipal drinking supply in Toowoomba, Australia in 2006, was rejected by the public when scientists could not guarantee that there would never be any issues associated with it (Morgan and Grant-Smith 2015;). In the United States, plans to use recycled potable water in Tampa, Florida, and Brownwood, Texas, were delayed indefinitely and then cancelled due to public concerns (Hummer and Eden 2016; Wester et al. 2016). Ellis et al. (2021a) and Savchenko et al. (2018) found that consumers displayed negative responses to the use of recycled irrigation water. Interventions with framed messages showed that messages regarding the environmental benefits of this recycled water did not alleviate these concerns. Furthermore, it is not just the information provided that is important but also the source providing it, the perspective of the source, and the receivers' beliefs (McFadden and Lusk 2015; McFadden and Huffman 2017; Whiting et al. 2019).

A key contribution to this literature is the fact that this study analyzes three sources of recycled water rather than describing it with a generic term such as recycled, reused, and reclaimed. In doing so, we address three key concerns about recycled water. First, we explore whether consumers' WTP for agricultural produce irrigated with recycled water varies in response to the source of recycled water used (gray, black, and produced). This additional layer of information can identify the kinds of projects most likely to be accepted by the public.

Additionally, this study assesses the effects of exposing participants to three types of scientific information about recycled water – its environmental benefits, its risks, and both its benefits and risks – on consumer WTP for produce irrigated with each source of water. Finally, this study also explores the effect of prior knowledge about sources of recycled water on consumer WTP for produce irrigated with it.

We find that use of recycled water diminishes consumer demand for produce irrigated with it. Our analysis indicates that consumers consider some sources of recycled irrigation water more acceptable than others. Recycled gray water is preferred to recycled produced, and both are preferred to recycled black water. We also find that providing scientific information about the risks posed by and environmental benefits of using recycled water does not mitigate consumer concerns and does not affect their purchasing decisions. Furthermore, we find exploratory evidence that possessing prior knowledge about recycled gray water is associated with consumers being more likely to purchase produce irrigated with gray water than consumers with no prior knowledge about it.

2. Experiment Design

To assess consumer WTP for produce irrigated with different sources of recycled water, we conducted a field experiment in two regions of the climate-diverse United States – the Southwest, which is prone to drought and the Mid-Atlantic, which is a historically water-abundant area. To ensure incentive compatibility of this revealed preference study, we used a single-bounded, dichotomous-choice mechanism to solicit consumer decisions. Multiple studies have shown that dichotomous-choice mechanisms are more robust and less biased than other formats such as auctions because they are more representative of the type of decisions consumers typically make. When considering an item, consumers 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. 2021). Formally in this case, participant *i* is offered purchase opportunity j at listed price P and chooses to accept it (purchase) (D = 1) or reject it (passes) (D = 0):

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

If the price of P_{ij} is less than or equal to a participant's expected utility, EU_{ij}, the participant accepts it; otherwise, the participant rejects it. In the experiment, all 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).

In the Southwest region, participants were recruited in a single location – a festival in Yuma, Arizona. In the Mid-Atlantic region, the data were collected at a regional transportation depot and an urban farmer's market. These field locations were chosen to obtain samples that were more representative of adult consumers than could be recruited at a traditional university experimental economics laboratory.[3]

At the start of the experiment, all participants were endowed with $10 as payment for their participation. 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 purchase various items. All participants were also informed that only one of their decisions would be randomly chosen and implemented, encouraging them to carefully consider each decision independently of the others. The following definitions from the EPA(EPA) were used for each source of irrigation water. They were provided to the participants at the beginning of the experiment and were displayed on the purchase opportunities page:

Conventional Water:	Traditional sources of irrigation water, such as surface water (rivers, lakes, ponds, and reservoirs) and well water.
Recycled Black Water:	Treated wastewater from toilets and urinals.
Recycled Gray Water:	Treated wastewater from washing, laundering, bathing, and showering.
Recycled Produced Water:	Treated wastewater from oil and gas drilling operations.

The experiment was completed on tablet computers using a Willow-based software program that both administered the experiment and collected the data. The products offered to

[3] We acknowledge the fact that recruitment at these locations does not guarantee a perfectly representative population.

participants were "debranded" by removing all identifying labels and were displayed in one area so participants could examine them. Since this design followed the general prohibition on deception in experimental economics (Rousu et al. 2015), the types of produce used in each region varied based on what was available at the time and that we could identify as having been grown with the various water sources.

Participants were presented with fifteen purchase opportunities as a within-subject treatment – five versions of three types of produce. The first version did not specify the source of irrigation water used on the produce and served as a control by replicating how produce is currently commonly labeled in the United States. The other four versions were treatments that specified the irrigation water as conventional, recycled gray, recycled black, or recycled produced. The produce offered in the Mid-Atlantic experiment consisted of baby carrots, almonds, and grapes; in the Southwest experiment, participants were offered baby carrots, almonds, and clementines.

Presentation of the purchase opportunities was randomized across participants to avoid order effects. Prices were randomly generated and drawn from a normal distribution ranging from $0 to $10. The standard deviation was half of the respective mean price, which was a 2015 food inflation adjustment of the 2013 national mean price for each type of produce.

The experiment also employed a 2x2 between-subject design to test the effects of scientific information about recycled water. We used a no-information control group and three information treatment groups that presented recycled irrigation water's (1) benefits, (2) risks, and (3) both benefits and risks, presented in a randomized order. Each participant was randomly assigned to one of the four groups and, if in a treatment, given the information at the beginning of the experiment.

Risk Information Treatment (T1)
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)."

Benefit Information Treatment (T2)
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."

After reviewing the information, the participants responded to the fifteen purchase opportunities, selecting yes or no to purchase the product, and then completed a survey that collected information on their previous knowledge of different sources of recycled water and demographic characteristics (see Appendix B).

At the end of the experiment, a digital die 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 the $10 endowments after deducting the purchase price. For example, if the purchase price for the binding option was $2, they received the produce and $8. Participants who selected no for the implemented option received the entire $10 participation fee and no produce.

3. Results

The experiment successfully collected data from 458 adult consumers: 199 in the Southwest and 260 in the Mid-Atlantic, resulting in 6,870 observations. The field experiment in the Southwest was collected at a festival in Arizona. In the Mid-Atlantic, the data were collected from 125 participants at the regional transportation hub in Delaware and 135 participants at a farmer's market in Washington, D.C. Table 1 presents summary statistics of the demographic characteristics of participants at each field site. Though the overall sample is representative nationally and regionally based on sex, it is skewed toward non-Hispanic white consumers aged 55 and older who earned $50,000 to $99,000 annually. It also oversamples consumers whose highest educational attainment is a bachelor's degree and undersamples those whose highest educational attainment is a high school diploma or less.

3.1 Effect of Irrigation Water Source on Consumer Likelihood to Purchase Produce

Because of the binary nature of the data (yes/no decisions), we used a linear probability model to isolate the effect of each treatment, source of irrigation water, field site, and previous knowledge of different sources of recycled water on the likelihood of purchasing produce. Given the within-subject design (fifteen observations per participant), we implemented a random effects specification and estimated the coefficients using clustered standard errors:

$$D_{ij} = \alpha + \beta_1{}'P_{ij} + \beta_2{}'W_{ij} + \beta_3{}'T_i + \beta_4{}'S_i + \beta_5{}'K_i + \beta_6{}'X_i + \mu_i + \varepsilon_{ij} \qquad (2)$$

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 source, T_i is a matrix of dummy variables for the scientific information treatment received by participant *i*, S_i is a matrix of dummy variables identifying the field site, K_i is a matrix of dummy variables for participant *i*'s knowledge of different sources of recycled water prior to participating in the experiment, and X_i is a matrix of control variables for produce type, gender, age, annual household income, and highest educational attainment.[4]

[4] As a robustness check, we re-estimated equation 2 using logit and probit specifications (see Appendix C). All results are consistent with those of the linear probability model.

Our analysis involves multiple hypothesis testing, which increases the likelihood of rejecting a true null hypothesis. To account for the family-wise error rate and guard against Type I errors, we use the Bonferroni-Holm method. It corrects for multiple comparisons by dividing the overall alpha level by the number of hypotheses being tested in a family of hypothesis.[5] The Bonferroni-Holm corrected Wald test probability values (BCP) are reported alongside the unadjusted Wald test probability values in Tables 3, 5, and 7.

The estimates from equation 2 are reported in Table 2. We find that price, as expected, has a statistically significant ($\rho = 0.000$) and negative effect on participants' likelihood of purchasing produce. Whereas, prior knowledge of recycled gray water, some college or higher (relative to a high school diploma or less), and annual household income, have statistically significant ($\rho \leq 0.027$) and positive effects on participants' likelihood of purchasing produce..

The results of the Wald tests examining participant preferences for each source of water using the regression results shown in Table 2 are presented in Table 3. We find that participants did not differentiate ($\rho = 0.763, BCP = 1.000$) between produce irrigated with conventional and unspecified irrigation water. These results are in line with findings by Savchenko et al. (2018) and Ellis et al. (2021a). However, it does diverge from the findings of Savchenko et al. (2019b) which found that consumers marginally significantly preferred food produced with unspecified irrigation water over food produced with conventional irrigation water. Li et al. (2018) found mixed evidence.

Participants in our study, however, were more likely ($\rho \leq 0.000, BCP \leq 0.000$) to purchase foods irrigated with either conventional or unspecified irrigation water than produce irrigated with any source of recycled water. Decreased demand for produce irrigated with

[5] The Bonferroni-Holm correction used in our analysis is $\frac{\rho}{31}$.

recycled water is widely believed to result from psychological reactions of disgust because of the salience of its sources for consumers, concerns about potential health risks, and/or fear of trying new and/or possibly risky foods (i.e., neophobia) (Menegaki et al. 2007; Rozin et al. 2015; Savchenko et al. 2019a). The results of the Wald tests (see Table 3) also show that participants differentiate between sources of recycled water. Produce irrigated with recycled gray water was preferred ($\rho \leq 0.001, BCP \leq 0.032$) over produce irrigated with recycled black and recycled produced water and produce irrigated with recycled produced water was preferred ($\rho \leq 0.000, BCP = 0.000$) over produce irrigated with recycled black water.

To quantify these preferences, we estimated participants' mean WTP for products produced with the five descriptions of irrigation water (see Table 4). Participants mean WTP for produce is highest for conventional irrigation water ($7.86), followed by unspecified ($7.81), recycled gray ($5.65), recycled produced ($5.02), and recycled black ($3.83). Figure 1 displays the decrease in WTP for produce irrigated with each of the recycled water types relative to conventional water. WTP dropped 28% for recycled gray water, 36% for recycled produced water, and 51% for recycled black water.

Recycled gray water likely prompts less disgust than the recycled black water and probably provokes less perceived risk than recycled produced water. What is less clear is why participants preferred recycled produced water over recycled black water. A potential explanation is that fecal matter evokes "pathogen disgust," a cognitive response humans developed to avoid disease (Sparks et al. 2018). Produced water likely evokes concern about health risks associated with ingesting water that was once in contact with fossil fuels, chemicals that are harmful if consumed.

3.2 Effect of Scientific Information on Recycled Irrigation Water Preferences

The regression results for the linear probability model in in Table 3 show that the between-subjects scientific information treatments did not have any overall significant ($\rho \geq 0.662$) effects on consumer willingness-to-purchase produce. To see if the scientific information treatments had any effect on consumer preferences for the different types of recycled irrigation water, we estimated an iteration of equation 2 that collapses the nonrecycled water variables (conventional and unspecified) into a single term and incorporates interaction terms between water types and the scientific information treatments. The regression results presented in Table 2 and Wald Test results shown in Table 5 indicate that, exposure to scientific information about the health risks associated with recycled water significantly ($\rho \leq 0.069$) decreased consumer willingness to purchase produce irrigated with recycled gray water (relative to the control and the other two treatments) and recycled produced water (relative to information about the environmental benefits of recycled water). There was also marginal evidence ($\rho = 0.089$) that exposure to the benefits and risks of recycled water decreased consumer willingness to purchase produce irrigated with recycled produced water relative to being shown only information about recycled water's benefits. However, after correcting for multiple-hypothesis testing, these results do not hold ($BCP \geq 0.279$). These results are consistent with, but far weaker and more limited than the findings by Savchenko et al. (2018), in which providing risk information decreased consumer demand for produce irrigated with recycled water by 50%.

3.3 Exploratory Analysis of the Effect of Prior Knowledge of Recycled Water on Recycled Water Preferences

To explore whether knowing about a particular source of recycled water increases participants' WTP for produce irrigated with it, we estimated an expanded version of equation 2 that collapses the nonrecycled water variables (conventional and unspecified) into a single term. We included an interaction term between each recycled irrigation water source and prior knowledge about each water source. The results, reported in Table 6, and the Wald test results, displayed in Table 7, suggest that prior knowledge about recycled gray water has a significant ($\rho = 0.000, BCP = 0.000$) and positive effect on consumer willingness to purchase produce irrigated with it relative to no prior knowledge about it. There is also evidence ($\rho = 0.044$) that prior about recycled produced water increases consumer willingness to purchase produce irrigated with it, however, this result does not hold after correcting for multiple hypothesis testing ($BCP = 1.000$). We find no evidence that prior knowledge about recycled black water has any effect on consumer willingness to purchase produce irrigated with it.

4. **Conclusion**

Recycled irrigation water is a technologically feasible and safe solution for addressing the growing need for water by the agricultural sector in the United States. This study takes a step toward differentiating the effects of sources of recycled water using an economic field experiment that evaluates U.S. consumers' WTP for recycled gray, recycled black, and recycled produced water.

Despite the safety of irrigating produce with recycled water, we find that once they are aware of the use of this water that consumers in the Southwest and Mid-Atlantic regions of the US have a diminished WTP to pay for produce irrigated with recycled water. The analysis also indicates that consumers consider certain sources of recycled irrigation water more acceptable than others. Recycled gray water is preferred over recycled produced water, which is preferred over recycled black water. These differences in valuation persist even after multiple-hypothesis correction. We also find that providing scientific information about risks posed and benefits of recycled water does not mitigate consumer concerns and does not have an impact on their purchasing decisions. This is a clear indication that toilet-to-tap perceptions of recycled water play a strong role in their rejection and that information alone cannot relieve the resulting stigma. Irrigation with recycled gray water induces less stigma than irrigation with recycled black water and produced water and should be prioritized by policymakers and industry stakeholders.

Efforts to increase consumers' familiarity with different sources of recycled water would also mitigate their concerns about its safety. We find that having prior knowledge of recycled gray water increased consumers' WTP for produce irrigated with it. This points to an important next step for research – determining what kind of information about each source of recycled water would reduce stigmatization of these crucial alternative water sources. Moreover, a greater number of steps in the food chain between organisms and use of recycled water reduces the stigma consumers attach to food products. Future research can explore how these factors interact with each source of recycled water used in agriculture to promote large-scale adoption and use of recycled water by the agricultural industry.

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Figure 1. Bias against Recycled Irrigation Water

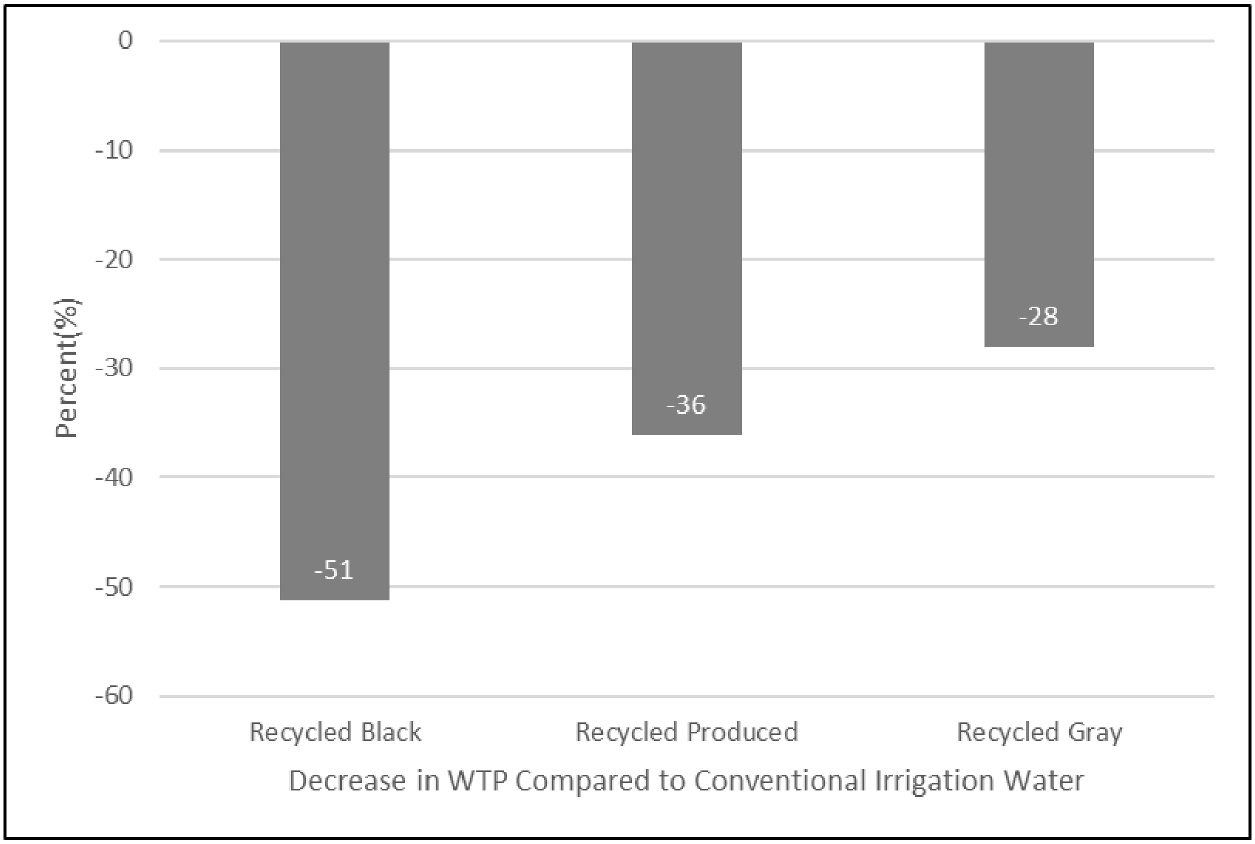

Table 1. Summary Statistics

		Sample				
		Arizona	**Delaware**	**U.S.**	**Mid-Atlantic**	**Southwest**
	Total Participants				260	199
Sex	Female	50%	52%	51%	59%	54%
Educational Attainment	High School or Less	37%	42%	40%	15%	21%
	Some College	25%	19%	21%	22%	26%
	Associate Degree	9%	7.8%	8%	10%	14%
	Bachelor's Degree	18%	18.3%	19%	29%	24%
	Graduate Degree	11%	13.1%	12%	23%	16%
Ethnicity	Non-Hispanic White	54%	63%	61%	84%	75%
	Black	4%	22%	12%	7%	2%
	Hispanic	32%	9%	18%	6%	12%
	Asian	3%	4%	5%	2%	1%
	Other	7%	3%	3%	2%	10%
Income	*$49,999 or less*	45%	38%	40%	25%	44%
	$50,000 to $99,999	31%	32%	30%	38%	41%
	$100,000 to $149,999	14%	15.9%	15%	21%	10%
	$150,000 or more	11%	14%	15%	16%	5%
Age	*18–34*	27%	26%	27%	35%	22%
	35–54	25%	25%	26%	30%	12%
	55 and older	29%	31%	29%	35%	66%

Table 2. Regression-estimated Effects of Irrigation Water Source and Scientific Information Treatments on Consumer Likelihood to Purchase Produce

		Linear Probability Model			Linear Probability Model with Treatment Interaction Terms		
		Coef.	S.E.	p-value	Coef.	S.E.	p-value
	Price	-0.094	0.005	0.000	-0.094	0.005	0.000
Treatment	*Benefits*	0.013	0.029	0.662	0.023	0.042	0.585
	Risks	-0.007	0.028	0.803	0.079	0.045	0.083
	Benefits and Risks	-0.012	0.028	0.675	0.001	0.044	0.977
Produce	*Clementines*	0.112	0.015	0.000	0.112	0.015	0.000
	Almonds	0.105	0.013	0.000	0.106	0.013	0.000
	Grapes	0.079	0.014	0.000	0.079	0.014	0.000
Water source	*Unspecified*	-0.005	0.018	0.763			
	Recycled Gray	-0.209	0.021	0.000	-0.167	0.038	0.000
	Recycled Black	-0.380	0.021	0.000	-0.323	0.039	0.000

	Recycled Produced	-0.268	0.022	0.000	-0.227	0.039	0.000
Prior Knowledge	*Recycled Gray*	0.057	0.026	0.027	0.057	0.026	0.027
	Recycled Black	-0.012	0.025	0.637	-0.012	0.025	0.637
	Recycled Produced	-0.025	0.021	0.234	-0.025	0.021	0.234
Interactions	*Recycled Gray*Benefits*				-0.014	0.050	0.777
	*Recycled Gray*Risks*				-0.158	0.056	0.005
	*Recycled Gray*Benefits and Risks*				0.009	0.053	0.860
	*Recycled Black*Benefits*				-0.058	0.052	0.264
	*Recycled Black*Risks*				-0.122	0.056	0.030
	*Recycled Black*Benefits and Risks*				-0.042	0.053	0.431
	*Recycled Produced*Benefits*				0.020	0.052	0.706
	*Recycled Produced*Risks*				-0.150	0.056	0.008
	*Recycled Produced*Benefits and Risks*				-0.033	0.054	0.542
Field Site	*Mid-Atlantic*	-0.014	0.023	0.534	-0.014	0.023	0.534
Demographics	*Annual Household Income*	0.011	0.004	0.005	0.011	0.004	0.005
	Grow Their Own Food	0.055	0.020	0.007	0.055	0.020	0.007
	Importance of Irrigation Water	-0.024	0.009	0.005	-0.024	0.009	0.005
Educational Attainment	*Some College*	0.063	0.033	0.054	0.063	0.033	0.055
	Associate Degree	0.052	0.040	0.195	0.052	0.040	0.195
	Bachelor's degree	0.084	0.032	0.008	0.084	0.032	0.008
	Graduate degree	0.156	0.033	0.000	0.156	0.033	0.000
Constant		0.584	0.058	0.000	0.555	0.061	0.000
Total *N*		6,870			6,870		
Individuals		458			458		

Table 3. Wald Tests of Effects of Water Source on Consumer Likelihood to Purchase Produce

Wald Test	χ^2	Prob.	BCP
Conventional = Unspecified	0.09	0.763	1.000
Conventional = Recycled Gray	95.58	0.000	0.000
Conventional = Recycled Black	325.78	0.000	0.000
Conventional = Recycled Produced	152.05	0.000	0.000
Unspecified = Recycled Gray	105.83	0.000	0.000
Unspecified = Recycled Black	346.96	0.000	0.000
Unspecified = Recycled Produced	166.77	0.000	0.000
Recycled Gray = Recycled Black	100.37	0.000	0.000
Recycled Gray = Recycled Produced	10.55	0.001	0.032
Recycled Black = Recycled Produced	39.58	0.000	0.000

Abbreviation: BCP, Bonferroni-corrected probability values.

Table 4. Consumer Mean Willingness to Pay

Water Source	Mean WTP	95% Conf. Interval	Prob.
Conventional	$7.86	[$7.37, $8.35]	0.000
Unspecified	$7.81	[$7.32, $8.29]	0.000
Recycled Gray	$5.65	[$5.35, $5.95]	0.000
Recycled Black	$3.83	[$3.62, $4.04]	0.000
Recycled Produced	$5.02	[$4.74, $5.30]	0.000

Note: The 95% confidence intervals were generated using a bootstrap method. The p-value is derived from a Wald test with a null hypothesis that the WTP estimate is less than or equal to zero.

Table 5. Wald Tests of Effects of Scientific Information on Consumer Preferences for Sources of Recycled Irrigation Water

Water Source	Wald Test	χ^2	Prob.	BCP
Recycled Gray	*No Information = Benefits*	0.043	0.836	1.000
Recycled Gray	*No Information = Risks*	3.309	0.069	1.000
Recycled Gray	*No Information = Benefits and Risks*	0.057	0.811	1.000
Recycled Gray	*Benefits = Risks*	4.123	0.042	1.000
Recycled Gray	*Benefits = Benefits and Risks*	0.001	0.972	1.000
Recycled Gray	*Risks = Benefits and Risks*	4.163	0.041	1.000
Recycled Black	*No Information = Benefits*	0.909	0.340	1.000
Recycled Black	*No Information = Risks*	1.378	0.240	1.000
Recycled Black	*No Information = Benefits and Risks*	1.443	0.230	1.000
Recycled Black	*Benefits = Risks*	0.058	0.810	1.000
Recycled Black	*Benefits = Benefits and Risks*	0.031	0.860	1.000
Recycled Black	*Risks = Benefits and Risks*	0.007	0.932	1.000
Recycled Produced	*No Information = Benefits*	0.863	0.353	1.000
Recycled Produced	*No Information = Risks*	2.657	0.103	1.000
Recycled Produced	*No Information = Benefits and Risks*	0.528	0.467	1.000
Recycled Produced	*Benefits = Risks*	6.820	0.009	0.279
Recycled Produced	*Benefits = Benefits and Risks*	3.049	0.081	1.000
Recycled Produced	*Risks = Benefits and Risks*	0.982	0.322	1.000

Abbreviation: BCP, Bonferroni-corrected probability values.

Table 6. Regression-estimated Effects of Prior Knowledge about Recycled Water on Consumer Preferences for Sources of Recycled Irrigation Water

		Coef.	S.E.	p-val
	Price	-0.094	0.005	0.000
Treatment	*Benefits*	0.013	0.029	0.662
	Risks	-0.007	0.028	0.803
	Benefits and Risks	-0.012	0.028	0.676
Produce	*Clementines*	0.111	0.015	0.000
	Almonds	0.105	0.013	0.000
	Grapes	0.079	0.014	0.000
Water Source	*Recycled Gray*	-0.318	0.030	0.000
	Recycled Black	-0.400	0.030	0.000
	Recycled Produced	-0.288	0.032	0.000
Prior Knowledge	*Recycled Gray*	0.011	0.040	0.782
	Recycled Black	0.042	0.040	0.295
	Recycled Produced	-0.085	0.034	0.013
Interactions	*Prior Knowledge Recycled Gray*Recycled Gray*	0.208	0.049	0.000
	*Prior Knowledge Recycled Gray*Recycled Black*	0.001	0.052	0.986
	*Prior Knowledge Recycled Gray*Recycled Produced*	0.022	0.052	0.665
	*Prior Knowledge Recycled Black*Recycled Gray*	-0.105	0.053	0.046
	*Prior Knowledge Recycled Black*Recycled Black*	-0.017	0.054	0.753
	*Prior Knowledge Recycled Black*Recycled Produced*	-0.146	0.053	0.006
	*Prior Knowledge Recycled Produced*Recycled Gray*	0.083	0.042	0.048
	*Prior Knowledge Recycled Produced*Recycled Black*	0.062	0.044	0.154
	*Prior Knowledge Recycled Produced*Recycled Produced*	0.153	0.043	0.000
Field Site	*Mid-Atlantic*	-0.014	0.023	0.534
Demographics	*Annual Household Income*	0.011	0.004	0.005
	Grows Their Own Food	0.055	0.020	0.007
	Importance of Irrigation Water	-0.024	0.009	0.005
Educational Attainment	*Some College*	0.063	0.033	0.055
	Associate Degree	0.052	0.040	0.195
	Bachelor's Degree	0.084	0.032	0.008
	Graduate Degree	0.156	0.033	0.000
Constant		0.612	0.060	0.000
Total *N*		6,870		
Individuals		458		

Table 7. Wald Tests of Effects of Prior Knowledge about Recycled Water on Consumer Preferences for Recycled Irrigation Water

Water Source	Wald Test	χ^2	Prob.	BCP
Recycled Gray	*No Prior Knowledge = Previously Heard of Recycled Gray Water*	26.06	0.000	0.000
Recycled Black	*No Prior Knowledge = Previously Heard of Recycled Black Water*	0.48	0.487	1.000
Recycled Produced	*No Prior Knowledge = Previously Heard of Recycled Produced Water*	4.05	0.044	1.000

Abbreviation: BCP, Bonferroni-corrected probability value.

Appendix A: Instructions for Experiments

Instructions:

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

- **You will earn $10 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 $3, and this option is randomly selected by the digital dice, you will receive the produce and $7 cash ($10 - $3 = $7).
- **Example 2:** If your decision is 'No' for an option, and this option is randomly selected by the digital dice, you will receive $10 and will not receive any produce.

Appendix B: Post-Experiment Survey[6]

1. What is your age?

2. What is your gender?
    a. Male
    b. Female
    c. Prefer not to answer

3. Do you live in the United States?
    a. Yes
    b. No

4. What is your ZIP Code?

5. What is your profession?
    a. Government
    b. Education
    c. Business
    d. Agriculture
    e. Student
    f. 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. Non-Hispanic White
    b. Hispanic or Latino
    c. Middle Eastern or Arab
    d. Black
    e. East Asian
    f. South Asian
    g. Pacific Islander
    h. Native American
    i. Other (please specify)

[6] The Mid-Atlantic Survey was identical except for the following: Question 10 asked about grapes instead of clementines; it did not include Question 23.

8. Which category best describes your household income (before taxes) in 2015?
    a. Less than $10,000
    b. $10,000-$14,999
    c. $15,000-$24,999
    d. $25,000-$34,999
    e. $35,000-$49,999
    f. $50,000-$74,999
    g. $75,000-$99,999
    h. $100,000-$149,999
    i. $150,000-$199,999
    j. $200,000-$249,999
    k. $250,000 and above

9. What is the highest level of education that you have completed?
    a. Some high school
    b. High school graduate
    c. Some college
    d. Associate degree
    e. Bachelor's degree
    f. Graduate degree/Professional

10. How often do you consume the following produce?
    a. Clementines: _____ times per month
    b. Almonds: _____ times per month
    c. Baby carrots: _____ times per month

11. Are you the primary shopper in your household?
    a. Yes
    b. No

12. What is the percentage of fresh foods compared to canned or frozen foods in you overall **fruit** consumption?
    a. Less than 20% fresh
    b. 20-50% fresh
    c. 50-80% fresh
    d. More than 80% fresh

13. 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

14. Do you grow your own food?
    a. Yes
    b. No

15. How important are the following food attributes to you?
    a. Price: Not Important(1) Very Important(5)
    b. I want the time it takes me 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. The type of water my produce is irrigated with: Not Important(1) Very Important(5)
    f. Locally grown/produced: Not Important(1) Very Important(5)

16. What type of water do you typically drink?
    a. Bottled Water
    b. Filtered Tap Water
    c. Tap Water
    d. Other (please specify)

17. Do you know where the water in your home comes from (private well, public well, municipal water supply)?
    a. Yes
    b. No

18. How concerned are you about water availability in the future in these areas?
    a. Your Community: Not at all(1) Very Concerned(5)
    b. Your State: Not at all(1) Very Concerned(5)
    c. United States: Not at all(1) Very Concerned(5)
    d. Globally: Not at all(1) Very Concerned(5)

19. How concerned are you about water availability **in your community** over these following time periods?
    a. Present: Not at all(1) Very Concerned(5)
    b. Next 10 years: Not at all(1) Very Concerned(5)
    c. Next 50 years: Not at all(1) Very Concerned(5)
    d. Beyond the next 50 years: Not at all(1) Very Concerned(5)

20. How concerned are you about climate change in these areas?
    a. Your Community: Not at all(1) Very Concerned(5)
    b. Your State: Not at all(1) Very Concerned(5)
    c. United States: Not at all(1) Very Concerned(5)
    d. Globally: Not at all(1) Very Concerned(5)

21. How concerned are you about climate change **in your community** over these following time periods?
    a. Present: Not at all(1) Very Concerned(5)
    b. Next 10 years: Not at all(1) Very Concerned(5)
    c. Next 50 years: Not at all(1) Very Concerned(5)
    d. Beyond the next 50 years: Not at all(1) Very Concerned(5)

22. Before this survey had you ever heard of:
    a. Recycled produced water
        i. Yes
        ii. No
    b. Recycled black water
        i. Yes
        ii. No
    c. Recycled gray water
        i. Yes
        ii. No

23. What percentage of the produce that **you typically buy** do you think is irrigated with:
    a. Recycled gray water: _____%
    b. Recycled black water: _____%
    c. Recycled produced water: _____%

24. Do you reuse or recycle water at home?
    a. Yes
    b. No
    c. Don't Know

25. Compared to conventional water, the standards for these types of water should be (where **3** means the same standards as conventional water):
    a. Recycled produced water: Greatly lower(1) Greatly higher(5)
    b. Recycled black water: Greatly lower(1) Greatly higher(5)
    c. Recycled gray water: Greatly lower(1) Greatly higher(5)

26. I trust these groups to test and monitor recycled irrigation water:
    a. The federal government: Strongly Disagree(1) Strongly Agree(5)
    b. My state government: Strongly Disagree(1) Strongly Agree(5)
    c. My local government: Strongly Disagree(1) Strongly Agree(5)
    d. Individual farmers: Strongly Disagree(1) Strongly Agree(5)
    e. Non-profit environmental groups: Strongly Disagree(1) Strongly Agree(5)
    f. Public wastewater treatment plants: Strongly Disagree(1) Strongly Agree(5)
    g. For-profit wastewater treatment plants: Strongly Disagree(1) Strongly Agree(5)

Appendix C. Robustness Tests

Table C.1. Random Effects Logit Models

		Logit Model			Logit Model with Treatment Interaction Terms		
		Coef.	S.E.	p-val	Coef.	S.E.	p-val
	Price	-0.734***	0.041	0.000	-0.741***	0.0414	0.000
Treatment	*Benefits*	0.104	0.227	0.646	0.111	0.271	0.683
	Risks	-0.00700	0.217	0.974	0.478	0.289	0.098
	Benefits and Risks	-0.116	0.220	0.597	-0.021	0.277	0.941
Produce	*Clementines*	0.825***	0.107	0.000	0.831***	0.107	0.000
	Almonds	0.770***	0.093	0.000	0.779***	0.094	0.000
	Grapes	0.566***	0.100	0.000	0.572***	0.100	0.000
Water source	*Unspecified*	-0.0374	0.106	0.725			
	Recycled Gray	-1.336***	0.138	0.000	-1.099***	0.251	0.000
	Recycled Black	-2.852***	0.176	0.000	-2.418***	0.318	0.000
	Recycled Produced	-1.781*** (0.149)	0.149	0.000	-1.519***	0.270	0.000
Prior Knowledge	*Recycled Gray*	0.439*	0.197	0.026	0.446*	0.197	0.023
	Recycled Black	-0.0926	0.184	0.615	-0.080	0.184	0.666
	Recycled Produced	-0.186	0.160	0.246	-0.201	0.161	0.212
Interactions	*Recycled Gray*Benefits*				-0.00984	0.318	0.975
	*Recycled Gray*Risks*				-1.001**	0.380	0.008
	*Recycled Gray*Benefits & Risks*				0.0648	0.350	0.853
	*Recycled Black*Benefits*				-0.347	0.433	0.423
	*Recycled Black*Risks*				-0.921	0.500	0.065
	*Recycled Black*Benefits and Risks*				-0.490	0.448	0.274
	*Recycled Produced*Benefits*				0.191	0.357	0.592
	*Recycled Produced*Risks*				-1.019*	0.414	0.014
	*Recycled Produced*Benefits and Risks*				-0.267	0.380	0.482
Field Site	*Mid-Atlantic*	-0.176	0.178	0.325	-0.175	0.179	0.329
Demographics	*Annual Household Income*	0.102**	0.033	0.002	0.102**	0.034	0.002
	Grows Their Own Food	0.420**	0.152	0.006	0.424**	0.153	0.006
	Importance of Irrigation Water	-0.177**	0.068	0.009	-0.179**	0.068	0.008
Educational Attainment	*Some College*	0.524	0.287	0.068	0.517	0.287	0.072

	Associate Degree	0.442	0.334	0.186	0.426	0.335	0.203
	Bachelor's Degree	0.724**	0.273	0.008	0.699*	0.273	0.010
	Graduate Degree	1.274***	0.272	0.000	1.259***	0.272	0.000
Constant		0.483	0.456	0.290	0.353	0.464	0.44
Total *N*		6,870			6,870		
Individuals		458			458		

Table C.1.1 Wald Tests on Effect of Water Source on Purchase Decision

Wald Test	χ^2	Prob.	BCP
Conventional = Unspecified	0.124	0.725	1.000
Conventional = Recycled Gray	93.725	0.000	0.000
Conventional = Recycled Black	262.714	0.000	0.000
Conventional = Recycled Produced	143.102	0.000	0.000
Unspecified = Recycled Gray	107.500	0.000	0.000
Unspecified = Recycled Black	287.474	0.000	0.000
Unspecified = Recycled Produced	161.046	0.000	0.000
Recycled Gray = Recycled Black	97.683	0.000	0.000
Recycled Gray = Recycled Produced	11.182	0.001	0.023
Recycled Black = Recycled Produced	39.462	0.000	0.000

Abbreviation: BCP, Bonferroni-corrected probability value.

Table C.1.2 Wald Tests on Scientific Information on Recycled Irrigation Water Preferences

Water Source	Wald Test	χ^2	Prob.	BCP
Recycled Gray	*No Information = Benefits*	0.112	0.738	1.000
Recycled Gray	*No Information = Risks*	2.579	0.108	1.000
Recycled Gray	*No Information = Benefits and Risks*	0.120	0.888	1.000
Recycled Gray	*Benefits = Risks*	4.043	0.044	1.000
Recycled Gray	*Benefits = Benefits and Risks*	0.036	0.849	1.000
Recycled Gray	*Risks = Benefits and Risks*	3.074	0.080	1.000
Recycled Black	*No Information = Benefits*	0.360	0.548	1.000
Recycled Black	*No Information = Risks*	1.056	0.304	1.000
Recycled Black	*No Information = Benefits and Risks*	1.658	0.198	1.000
Recycled Black	*Benefits = Risks*	0.231	0.631	1.000
Recycled Black	*Benefits = Benefits and Risks*	0.474	0.491	1.000
Recycled Black	*Risks = Benefits and Risks*	0.024	0.877	1.000
Recycled Produced	*No Information = Benefits*	0.733	0.392	1.000
Recycled Produced	*No Information = Risks*	2.146	0.143	1.000
Recycled Produced	*No Information = Benefits and Risks*	0.677	0.411	1.000
Recycled Produced	*Benefits = Risks*	5.630	0.018	0.547
Recycled Produced	*Benefits = Benefits and Risks*	3.190	0.074	1.000
Recycled Produced	*Risks = Benefits and Risks*	0.526	0.468	1.000

Table C.2. Random Effects Probit Models

		Probit Model			Probit Model with Treatment Interaction Terms		
		Coef.	S.E.	p-val	Coef.	S.E.	p-val
	Price	-0.421***	0.023	0.000	-0.425***	0.023	0.000
Treatment	*Benefits*	0.0505	0.130	0.698	0.061	0.158	0.702
	Risks	-0.0154	0.125	0.902	0.272	0.167	0.104
	Benefits and Risks	-0.0725	0.126	0.565	-0.010	0.161	0.953
Produce	*Clementines*	0.473***	0.061	0.000	0.478***	0.061	0.000
	Almonds	0.452***	0.054	0.000	0.456***	0.054	0.000
	Grapes	0.333***	0.058	0.000	0.336***	0.058	0.000
Water source	*Unspecified*	-0.0246	0.062	0.693			
	Recycled Gray	-0.785***	0.080	0.000	-0.642***	0.145	0.000
	Recycled Black	-1.632***	0.097	0.000	-1.376***	0.178	0.000
	Recycled Produced	-1.034***	0.085	0.000	-0.878***	0.151	0.000
Prior Knowledge	*Recycled Gray*	-0.0464	0.106	0.031	0.249*	0.114	0.028
	Recycled Black	-0.101	0.092	0.661	-0.040	0.106	0.708
	Recycled Produced	-0.025	0.021	0.273	-0.107	0.092	0.245
Interactions	*Recycled Gray*Benefits*				-0.0139	0.186	0.940
	*Recycled Gray*Risks*				-0.579**	0.217	0.008
	*Recycled Gray*Benefits and Risks*				0.0308	0.202	0.879
	*Recycled Black*Benefits*				-0.215	0.238	0.366
	*Recycled Black*Risks*				-0.520	0.277	0.060
	*Recycled Black*Benefits and Risks*				-0.284	0.245	0.247
	*Recycled Produced*Benefits*				0.105	0.203	0.606
	*Recycled Produced*Risks*				-0.580*	0.230	0.011
	*Recycled Produced*Benefits and Risks*				-0.162	0.213	0.449
Field Site	*Mid-Atlantic*	-0.101	0.103	0.325	-0.100	0.103	0.331
Demographics	*Annual Household Income*	0.0594**	0.019	0.002	0.059**	0.019	0.002
	Grow Their Own Food	0.241**	0.088	0.006	0.242**	0.088	0.006
	Importance of Irrigation Water	-0.108**	0.039	0.006	-0.110**	0.039	0.005
Educational Attainment	*Some College*	0.298	0.166	0.072	0.294	0.165	0.075
	Associate Degree	0.266	0.192	0.166	0.258	0.193	0.180
	Bachelor's Degree	0.416**	0.157	0.008	0.403*	0.157	0.010
	Graduate Degree	0.731***	0.156	0.000	0.724***	0.156	0.000
Constant		0.297	0.263	0.259	0.217	0.268	0.420
Total *N*		6,870			6,870		
Individuals		458			458		

Table C.2.1 Wald Tests on Effect of Water Source on Purchase Decision

Wald Tests	χ^2	Prob.	BCP
Conventional = Unspecified	0.156	0.693	1.000
Conventional = Recycled Gray	96.842	0.000	0.000
Conventional = Recycled Black	283.173	0.000	0.000
Conventional = Recycled Produced	149.591	0.000	0.000
Unspecified = Recycled Gray	109.273	0.000	0.000
Unspecified = Recycled Black	306.594	0.000	0.000
Unspecified = Recycled Produced	166.509	0.000	0.000
Recycled Gray = Recycled Black	98.905	0.000	0.000
Recycled Gray = Recycled Produced	10.718	0.001	0.029
Recycled Black = Recycled Produced	40.856	0.000	0.000

Abbreviation: BCP, Bonferroni-corrected probability values.

Table C.2.2 Wald Tests on Scientific Information on Recycled Irrigation Water Preferences

Water Source	Wald Tests	χ^2	Prob.	BCP
Recycled Gray	*No Information = Benefits*	0.071	0.790	1.000
Recycled Gray	*No Information = Risks*	2.712	0.010	1.000
Recycled Gray	*No Information = Benefits and Risks*	0.014	0.907	1.000
Recycled Gray	*Benefits = Risks*	3.895	0.048	1.000
Recycled Gray	*Benefits = Benefits and Risks*	0.021	0.884	1.000
Recycled Gray	*Risks = Benefits and Risks*	3.119	0.077	1.000
Recycled Black	*No Information = Benefits*	0.521	0.470	1.000
Recycled Black	*No Information = Risks*	1.094	0.296	1.000
Recycled Black	*No Information = Benefits and Risks*	1.878	0.171	1.000
Recycled Black	*Benefits = Risks*	0.162	0.687	1.000
Recycled Black	*Benefits = Benefits and Risks*	0.433	0.511	1.000
Recycled Black	*Risks = Benefits and Risks*	0.037	0.848	1.000
Recycled Produced	*No Information = Benefits*	0.678	0.410	1.000
Recycled Produced	*No Information = Risks*	2.263	0.133	1.000
Recycled Produced	*No Information = Benefits and Risks*	0.765	0.382	1.000
Recycled Produced	*Benefits = Risks*	5.630	0.178	0.547
Recycled Produced	*Benefits = Benefits and Risks*	3.215	0.073	1.000
Recycled Produced	*Risks = Benefits and Risks*	0.507	0.476	1.000

Abbreviation: BCP, Bonferroni-corrected probability values.