Household Food Waste Generation and Organics Recycling: Too Time Consuming or for the Better [Public] Good?

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1. Abstract

In the United States, estimates suggest over 30% of the food produced is wasted throughout the supply chain, with households accounting for the highest proportion. Despite calls for food recovery and re-use, food scraps remain the largest category of materials that are landfilled, substantially contributing to the emission of methane gas. In addition to prevention strategies that curb the negative impacts of food waste, recycling presents an opportunity to convert environmentally harmful materials into valuable economic downstream products such as animal feed, compost and biofuel. However, engaging in activities to reduce food waste generated at home or dedicating time towards meticulous source separation of food scraps and organics may impose significant costs to households, especially in terms of forgone leisure time. We follow and expand on existing recycling literature to model the economic relationship between household food waste reduction and organics recycling efforts in a public goods framework. A national household survey is used to gauge willingness to undertake food waste reduction and recycling efforts and collect information on other key behavioral drivers following the theoretical model. We use contingent valuation methods to determine the opportunity cost of time of leaving recycling and food waste reduction efforts to others. Honing in on organics recycling, we use a choice experiment to determine willingness to pay for a curbside collection program with several key attributes. We examine the willingness to pay values from the two methods to gauge households' preferences on organics recycling. Finally, we use implement a small scale organics recycling program locally to examine the differences in *predicted* willingness to undertake food waste reduction and organics recycling efforts and *actual* effort in those activities.

2. Introduction

In the U.S., households currently generate the highest proportion of food waste in the food supply chain (ReFED, 2016). Food scraps make up about 22% of the weight of material that goes to landfills, making food the largest category of landfill waste. The decomposition of uneaten food alone accounts for 23% of all methane emissions in the U.S. (Gunders, 2012), a gas that is 25-fold more potent with global warming potential than carbon dioxide (Hall et al., 2009). This poses a serious threat to the already constrained food and agricultural system as both the food production and decomposition ends are afflicted.

While prevention and reduction are essential, recovery and re-utilization of food scraps and organics constitute attractive, complementary strategies for curbing the environment consequences of food waste. Specifically, recycling food that households discard, which accounts for almost half of the total food waste landfilled, represents an important opportunity to convert environmentally harmful materials into economic *downstream* resources, such as compost, animal feed, and biofuel. Such large-scale solutions to minimize waste and loss is an opportunity to alleviate this burden for more sustainable agricultural outcomes.

As the literature grows, there are more insights on what drives people to generate or prevent food waste. However, little is known about the behavioral aspects of household food scraps and organics recycling tendencies. Yet, from a practical perspective, there has been increasing interest to reduce, re-use and recycle organic materials throughout the supply chain. This is especially evidenced by an increasing number of policies aiming at source reduction, recycling and composting at the state and local levels. Recent statistics indicate that 326 communities spanning 20 states, provide variations of curbside collection of food scraps (Streeter & Platt, 2017).

Currently about 4% of U.S. households have access to organics curbside collection programs (Streeter & Platt, 2017). This represents a significant growth from 1.9% in 2014 (Yepsen, 2015). Granted that organics collection programs offer access to household food scraps, it is uncertain whether households can meaningfully contribute high quality organics for downstream processing by maintaining their compliance with instructions. This skepticism is substantiated by the concern that current enthusiasm outweighs the quantifiable progress in residential food scraps collection (Yepsen, 2015). For instance, Alameda County in California, where organics recycling is mandatory, saw an alarming rise in the amount of food scraps that the residents put in their garbage instead of collection bins. Other examples include Cities of Oakland and Berkeley, where the amount of food in garbage bins rose from about 15% to 38-39% between 2013 and 2014 (StopWaste Benchmark Service, 2015).

Various factors may dictate people's efforts towards food waste reduction and organics recycling activities at home. The role of the household cost of time on recycling efforts, especially of items such as paper or plastic, has been previously documented (Halvorsen, 2008; Jakus, Tiller & Park, 1996; Hong, Adams, & Love, 1993). Reducing food waste at home requires making a host of changes in household routines which may be time consuming. This includes planning meals in advance, sticking to meal plans, cooking all the meals intended for at home, and so on. In a recent study, Ellison and Lusk (2018) highlighted the roles of trade-offs and economic incentives in food waste decisions. A brief look at the intricacies of separating organics for recycling would also substantiate why it may be challenging to keep up with the tasks required. However, many households, albeit a small proportion, are motivated and voluntarily contribute towards food waste reduction and organics recycling daily.

Diversion of food from the landfill through both prevention and recycling activities contribute to higher environmental quality, a public good. Utility gained from higher environmental quality may motivate households to engage in conscious food waste prevention activities and careful recycling towards downstream resources. Utility effects from feelings of warm glow à la Andreoni (1990) or bettering one's self-image (Brekke, Kverndokk, and Nyborg, 2003) may also incentivize households to dedicate efforts towards these activities. However, these activities may represent significant time costs which the households have to weigh against. We follow and build on Halvorsen's (2008) modeling of household choice to recycle in a time cost, moral norms and public goods framework. Existing conceptual models regard increases in the recycling effort as a public good. In addition, our model explicitly considers not only recycling efforts, but also how food waste prevention efforts and activities at home increases environmental quality.

As more communities move towards food waste diversion strategies, understanding the behavior of the main agents - the households - becomes essential. The success, efficacy and long-term sustainability of food waste reduction and recycling programs depend critically on households' commitment and source separating efforts. Since only a small proportion of U.S households currently participate in organics recycling programs, instead of *actual* efforts, we elicit *willingness to participate* in given food waste reduction and recycling efforts. This is similar to previous work by Aadland & Caplan (2003) who elicited willingness to participate in a curbside recycling program in Utah. Although it is uncertain whether hypothetical behavior reflects real actions, we use cheap talk, which has been documented in the literature (Cummings, Taylor &

List, 1999; Aadland & Caplan, 2003) to help mitigate possible hypothetical bias. However, consistent with previous findings, we may still expect some upward hypothetical bias in our willingness to pay or willingness to participate measures. Notwithstanding, this inquiry presents an opportunity to gauge the roles of the cost of time and moral norms on potential food waste reduction and recycling efforts.

A national household survey is used to identify key factors that drive food waste generation and recycling behaviors following the theoretical model. We employ contingent valuation methods to determine the opportunity cost of time of leaving food waste reduction and recycling efforts to others. We then focus on organics recycling and use a choice experiment to determine willingness to pay for a curbside collection program with several key attributes. Particularly, we estimate the consumers' perceived values of different disposal services and downstream uses of their organics. We assess the willingness to pay values from both methods to gauge households' preferences on organics recycling. Finally, we implement a small scale organics recycling program at the local level. We examine the differences in *predicted* willingness to undertake food waste reduction and organics recycling efforts and *actual* effort in those activities. This paper contributes to the literature by clarifying the missing connection between household food waste generation and recycling behaviors, and the role that policy nudges may play in mitigating the problem.

The rest of the article proceeds as follows. We provide a background on the food waste situation in the U.S, especially drawing on relevant prevention and recycling trends in section II. In section III, we give a review of the relevant literature drawing a clear connection between food waste prevention and recycling as contributions to higher environmental quality. Section IV establishes the conceptual framework of household choice for food waste prevention and recycling efforts from a public good approach. We present the design of the consumer survey in Section V. We further describe key attributes and levels used in the choice experiment. We illustrate the results drawn from the empirical approach and econometric analysis as well as the discussion of these in Section VII (*results not available currently*).

3. Background on food waste prevention and recycling in the U.S.

The Environmental Protection Agency (EPA) prioritizes food waste disposal activities through the Food Recovery Hierarchy. Namely, in the order of preference, efforts should be allocated to (i) reduce food waste, (ii) donate food to hunger relief agencies, (iii) recycle for feeding animals, (iv) recover energy through conversion, (v) compost, and lastly (vi) landfill or incinerate. The 2016 Food Recovery Summit convened by the EPA and the United States Department of Agriculture (USDA) brought together stakeholders from across the food supply chain. The first key activity identified in the Summit was for businesses, individuals, and organizations to use the Food Recovery Hierarchy to maximize economic gains while increasing social and environmental benefits. They further identified food waste diversion and recovery using new technologies and innovation as a critical action to capitalize on key economic opportunities in the broader food management system.

These priorities however do not reflect current practices. In 2014, of 38 million pounds of municipal food disposed in the US, only 5.1% was composted, 18.6% was used in combustion for energy recovery, and the remaining 76.3% was landfilled (EPA, 2016b). In contrast, the European Union (EU) legislation requires landfill disposal of food waste, which is about 48% of total food discarded in the United Kingdom, to be phased out (House of Lords, 2014). Further, many European countries have adopted plans to become circular economies by minimizing the amount of municipal waste that is landfilled and increasing their recycling and preparation of solid waste for the most efficient re-use. The European Commission adopted a legislative proposal to recycle and reuse waste up to 70% by 2030 (Sahimaa et al., 2015). Recent trends suggest that waste management strategies in the US will likely follow suit. The EPA has set a goal to reduce food waste by 50% by 2030 (EPA, 2016a).

Current policy objectives mainly aim at reducing overall generation of food waste through prevention measures (Schneider, 2013). However, there is a robust, growing trend toward also ensuring proper avenues for diversion and reuse employing advanced technologies. Diversion and reuse objectives involve finding suitable strategies to prevent the waste from going to landfills and instead being converted into productive, high-value resources (Levis et al., 2010).

Existing food waste diversion efforts are mostly concentrated in combustion for energy generation and to a lesser extent composting for fertilizer. Yet, environmental stresses still persist when organics are combusted with other municipal wastes for energy generation (Kiran et al., 2014).

3.1 Food waste downstream usages

Food waste, because of its complex biological composition, poses both challenges and opportunities for efficient re-use and valuation. Determining the multiple, competitive, and most efficient ways to recycle post-consumer food waste is vital. A growing body of research highlights the value of considering an array of alternative downstream uses for food waste as resources. Conversions into animal feed, incineration, fertilizer and composting, biofuel energy, and other reusable by-products have been identified as potential approaches to capture valuable compounds (Galanakis, 2015). Other emerging technologies enable converting food waste into biomass and related chemicals. The following elaborates on a few main approaches to converting food waste for productive resources: compost, biogas and animal feed.

3.1.1 Compost

Given the high-moisture content and physical structure of FW, composting is a good possibility for resource efficiency (Chang and Hsu, 2008). An estimated 1.94 million tons of postconsumer food was diverted through composting in 2014 (EPA, 2015). Composting technologies vary in sophistication and have been widely researched and applied (Lemus and Lau, 2002; Seo et al., 2004; Chang, Tsai, and Wu, 2006). Mounting landfill costs and high market prices make composting a promising and economically sustainable FW diversion solution; however, current inefficiencies in hauling and collection as well as lack of adequate infrastructure pose challenges to realize higher composting potential (ReFED, 2016).

3.1.2 Energy recovery

Other technological advances in digestion and fermentation processes allow FW to be converted into biogas, hydrogen, ethanol, and biodiesel, as well as other key renewable energy sources as final products with improved valorization (Kiran et al., 2014). The manufacturing, retail, wholesale and restaurant industries combined process less than 5% of their FW through anaerobic digestion (AD) which yields biogas for energy (EPA, 2015). In contrast, the AD industry has grown by 82% between 2013 and 2014 in the United Kingdom with plans to double or triple by 2019 (WRAP, 2017). US farmers are encouraged to install on-farm anaerobic digesters, which have the potential to reduce energy and waste management costs, generate additional revenue streams, and further make farm operations more environmentally friendly (Minnesota Project, 2010). Emerging research shows that FW processed through AD, in the form of renewable natural gas or biomethane, can be utilized in the natural gas pipeline for household, commercial, and industrial purposes (Deublein and Steinhauser, 2011).

3.1.2 Animal feed

The nutrient content in food waste makes it a good animal feed (Westendorf, 2000). While animals have been fed food scraps historically (Stuart, 2009), there has been a decline because of animal health and food safety concerns related to outbreaks of diseases such as the Foot and Mouth Disease, African Swine Fever, and Bovine Spongiform Encephalopathy (Van Zanten et al., 2016). In 2007, only three percent of US swine farms fed food scraps (USDA, 2009). This is primarily the result of isolated efforts around the US to use food waste as an animal feed ingredient. Since food waste is not consistent in nutritional content and value, its widespread acceptance by the feed industry may be limited unless accurate, fast, and inexpensive methods can be developed and implemented to manage variable nutrient content when formulating animal feeds. Despite these challenges, processing discarded food into animal feed offers vast potential for economic, environmental, and food security sustainability. Many promising advances have been made in the development of efficient technologies to convert organic waste into feed (Salemdeeb et al., 2017; Surendra et al., 2016; Van Zanten et al., 2015). Ground-breaking work from the University of Minnesota evaluated samples of food waste from different sources for its suitability for animal feed (Fung et al., 2017). The food manufacturing industry sends over 85% of its food waste towards animal feed (Food Waste Reduction Alliance, 2014). A concerted effort at the household level may have the prospect to yield a similar success level. In fact, just recently, the City of San Clara and City of San Jose in California piloted residential curbside collection of food waste towards animal feed in an effort to divert food waste.

4. Literature Review

4.1 Food waste generation and recycling

Consumers throw away over 25% of food and beverages they purchase (Bloom, 2011). Buzby and Hyman (2012) translated this food loss to almost 10% of the average amount spent on food or equivalently consumer-level losses of 0.7 pounds of food per capita valued at $1.07 per day. A report by ReFED (2016) estimates that households' food waste accounts for 42% of 63 million tons of food wasted in the US, followed by restaurants at 22%. Further, this makes up 51% of the total food that is landfilled. This wasted food places a burden on society in multiple ways, including opportunity costs of scarce resources such as water, oil, and energy used to produce the food and unprecedented amounts of methane emissions generated from accumulated food in landfills.

Understanding contributors to food discarding habits has been a critical goal of a handful of consumer food waste research to date. A body of research have highlighted the socio-economic, cultural and behavioral determinants in context of household food waste generation. The main focus has been on food choices and food-related activities such as shopping routines, meal planning, and food handling skills as well as underlying behaviors, attitudes, cultural valuations, and environmental awareness (Dusoruth and Peterson, 2017; Stancu, Haugaard, and Lähteenmäki, 2016; Stefan et al., 2013; Gunders, 2012; Parfitt, Barthel, and Macnaughton, 2010). From food acquisition, to preparing, cooking, consuming, and finally discarding food, individuals make multiple interrelated choices, which determine how much of what is acquired is consumed or wasted.

As research exploring household food waste generation is sought, behavior of food and organics recycling remains little understood. Mainly, it is unknown whether or not the same factors, identified in the literature, are at play in food waste generation as it relates to its recycling. These questions have been extensively researched on recyclables such as plastic or paper. For instance, Berger (1997) found that the size of residential area, type of housing, education, and income were significant determinants of whether recycling services were utilized. In a national survey of over 2,000 households, Saphores and Nixon (2014) found that the most important determinants of household recycling were people's attitudes. There was less evidence for the role of socio-economic variables, but knowledge and moral norms were found to be important predictors of recycling. Other studies highlight factors such as information, habits or perceptions (Thomas and Sharp, 2013; Schultz, Oskamp, and Mainieri, 1995). Whether the same motivations are at play in food waste generation and recycling is an inquiry with increasing significance as more communities move towards waste reduction and diversion strategies, including organics drop-off or curbside pickup programs for consumers.

The terms avoidable and unavoidable food waste are particularly relevant in this case. Avoidable food waste is defined as food that once was once edible and is discarded as it is no longer wanted or edible (Quested and Johnson, 2009). Examples include food discarded as it is past its expiration date or has gone moldy. On the other hand, unavoidable food waste relates to food that, for most people and normally, has not been edible. For instance, vegetable peels, meat bones, and fruit cores would be unavoidable food waste. That being said, the line between avoidable and unavoidable food waste is blurry as these definitions can be subjective and may vary from individual to individual (Papargyropoulou et al., 2014). Ideally, the amount of food disposed can be mitigated through waste prevention activities mainly targeted towards avoidable food waste and waste management activities can be undertaken through recycling particularly in regards to unavoidable food waste.

4.2 Food waste as an environmental problem

Food waste has serious environmental consequences. Accounting for over a quarter of freshwater supply and millions of barrels of oil (Hall et al., 2009), this presents a profound burden on the total food supply. Garnett (2008) argues that emissions embedded in the movement of food through the supply chain, including stages such as production, processing, retailing, and transport, generate a significant amount of greenhouse gases. A recent study suggests that almost 29% of annual food production, representing 55 million metric tonnes per year, is avoidable food waste (Venkat, 2011). Contributing to 2% of annual carbon emissions, this costs the U.S. $198 billion. From this life-cycle view, food waste is a problem with grave impacts on climate change.

Further, decomposing food in landfills generates methane, carbon dioxide and other greenhouse gases, all by-products of landfilling solid wastes (Melikoglu, Lin, and Webb, 2013). Most food waste are dumped in unregulated landfills where generated methane, instead of being potentially harvested for biogas, is emitted in the atmosphere (Themelis and Ulloa, 2007). Currently, less than 10% of the methane in landfills is captured and used for renewable energy. When unharvested and allowed to escape into the atmosphere, these gases contribute to global warming.

Given the extent of the environmental consequences of food waste, there is an urgent need to adopt sustainable food production and consumption practices to ease the burden on the food system. That would however take a complete re-imagination of the food supply chain and joint efforts from all the agents along the chain to change practices and norms that currently necessitate the movement of such a volume of food that goes uneaten. Concurrently, the food waste disposal end of the chain is, relatively speaking, simpler and arguably another critical side of the problem. There are clear opportunities to curb these negative environmental impacts by minimizing the amounts of food that end up in the landfills in the first place. Minimizing avoidable food waste through prevention efforts and unavoidable food waste through recycling present potential for these goals, especially at the household level.

4.3 Environmental quality as a public good

Samuelson (1954) described a public good as one that is consumed in equal amounts by all. Environmental quality is a public good in its role as a supplier of public-consumption goods such as landscape, clean air, and other types of life-supporting systems (Siebert and Siebert, 1981). To date, many have used a public-goods approach to environmental problems. Individuals make choices for contributing to the public good by weighing incentives, private benefits, motivations, and existing policy (Halvorsen, 2008; Brekke et al., 2003; Andreoni, 1990).

Particularly relevant is the literature on household recycling of plastic, paper, glass from the public goods perspective. Brekke et al. (2003) develop a model of motivation to show that individuals, viewing themselves as socially responsible individuals, make voluntary contributions to the public good. Applying the model to recycling behavior, the authors show that individuals dedicate effort, in the form of time, and use a household production function to generate morally ideal levels of contributions to the public good. In their survey data, they find that public policies providing economic incentives affecting budget, time and relative prices may result in negative effects for voluntary contributions. This would happen if those incentives reduce morally driven contributions resulting in a "crowding-out" effect. Similar outcomes had been noted in previous recycling literature (Thøgersen, 1994). Information effects, such as an understanding that recycling is good for the environment, are found to increase people's self-reported likelihood to dedicate more efforts towards recycling.

Halvorsen (2008) extends and develops a similar public good model to include other social and moral norms such as self-respect in community, self-respect for oneself, and warm-glow. In the empirical analysis, the author finds that household recycling efforts decrease when there is an increased opportunity cost of time. However, other indicators social and moral norms increase recycling efforts. In contrast to Brekke et al. (2003), the author does not find strong evidence of "crowding-out" in the presence of economic incentives to increase recycling.

Parallels can be drawn between the non-food material recycling and the food recycling activities, where increases in both recycling activities contribute to higher levels of environmental quality, a public good. Both types of recycling can be costly and time-consuming to households suggesting trade-offs that affect levels of contributions to the public good. Further, similar moral norms may be at play in both types of decisions.

4.4 Behavioral interventions

Experiments, while imperfect, are suitable to address public policy issues. RCT's have been historically used to determine the impact of nudges on consumer behavior. For instance, in a UK-based study, feedback postcard cards with smiley or frown faces, were sent to households in treatment groups informing them on their performance on food waste recycling compared to the average in their neighborhoods (John et al., 2013). They found that households in the treatment groups raised their recycling rates by 3 percentage points compared to the control groups with no feedback in the short-run. Timlett and Williams (2008) also encouraged recycling through feedback and found less contamination from non-targeted materials in recyclables in treated households.

It has however been argued that interventions based on what others are doing may not be as sustainable as those based on personal involvement and self-identity (Castro et al., 2009). There may be gains from using strategies, such as providing information, that would encourage behavioral change at a personal level (Dilling and Lemos, 2011; Lee et al., 2015). However, simply giving information and environmental appeals may really not be effective interventions to promote pro-environmental consumer behavior (Fernandes and Schubert, 2016). Instead, message framing, incentivizing, removing barriers and structurally facilitating pro-environmental activities have been recognized as effective solutions to drive behavioral change (Frederiks, Stenner, and Hobman, 2015; Fernandes and Schubert, 2016).

Given the behavioral nature of household recycling, it is no surprise that various food waste mitigation efforts in other countries have framed the waste issue as an economic resource opportunity (Stenmarck et al., 2016). Early efforts in Canada addressing the overall solid waste problem emphasized the critical need to frame the issue as an economic resource opportunity versus a landfill crisis or public health threat (Wagner, 2007). A paradigm shift in their waste management strategies showed that certain efficiencies and economies of scale could be realized through collaborative efforts at regional levels. There is reason to believe that from a behavioral standpoint, households are likely to act differently based on their perception of how their food will be utilized in the downstream processes. In the US, the plateauing trend in non-organic recycling and decreased compliance in organics recycling (Yepsen, 2015) may be due to households being uninformed of the economic value of their contribution to a sustainable food and environmental system.

5. Conceptual Model

Our conceptual framework models how moral norms, opportunity cost of time, and household production functions come together to affect household choices to engage in food waste reduction and food recycling efforts. Assume that the household, i, gains utility ($\mathcal{U}_i$) from meals

(F_i), other private goods excluding meals (x_i), leisure $(t_{L,i})$, environmental quality as the public good (G), and self-image (I_i). Brekke et al. (2003) describe I_i as a moral behavior that would serve as private interest for the individual i to contribute to the public good G. For simplicity, the utility function, assumed to be increasing and strictly quasi-concave, is given by:

$$\mathcal{U}_i = \mathcal{U}_i\left(x_i, F_i, t_{L,i}, G, I_i\right) \tag{1}$$

This framework is comparable to previous work by Halvorsen (2008) who modeled recycling behavior in Norway. However, we do not assume only one type of contribution towards the public good, for instance, the share of food scraps as recyclables. It would not make sense that households simply purchasing a large volume of food and recycling a big share would count as an activity that contributes to environmental quality. The reality is a little more nuanced. Instead, we explicitly model two types of contributions: tangible $(g_{R,i})$ and intangible $(g_{A,i})$ contributions. Higher environmental quality can be achieved when individuals contribute a higher food waste share towards recycling $(g_{R,i})$ as well as when they engage in activities that minimize the generation of discarded food $(g_{A,i})$. Ideally, avoidable food waste is mitigated through $g_{A,i}$ and unavoidable food waste is curbed through $g_{R,i}$, both contributing to the public good. The total amount of the public good depends on the private provisions of contributions $G_i(g_{R,i}, g_{A,i})$ and provisions from other households $G_{-i}\left(g_{R,-i}, g_{A,-i}\right)$. The total public good can be defined as:

$$G = G(G_i\left(g_{R,i}, g_{A,i}\right) + G_{-i}\left(g_{R,-i}, g_{A,-i}\right)) \tag{2}$$

The recycled share $g_{R,i}$ and intangible contribution $g_{A,i}$ are generated through their respective public good production functions given by:

$$g_{R,i} = \psi_R(e_{R,i}, \theta_R) \tag{3}$$

$$g_{A,i} = \psi_A(e_{A,i}, \theta_A) \tag{4}$$

In the ψ_R function, $e_{R,i}$ is the person's effort, measured in units of time, to contribute to an increased supply of the public good through recycling efforts. θ_R, as explained by Brekke et al. (2003), indicates technical and institutional factors affecting recycling that are exogenous to the individual. An example could be availability of curbside pickup which would facilitate food recycling for households and increase the parameter θ_R. Similarly, in our context, increased and improved perception of food recycling as they relate to the downstream resources would be expected to increase the parameter θ_R. Thus, we have $\frac{\partial \psi_R}{\partial e_{R,i}} > 0$ and $\frac{\partial \psi_R}{\partial \theta_R} > 0$, that is, increases in recycling efforts and technical efficiency both raise contributions to the public good in the form of higher levels of food scraps as recyclables, $g_{R,i}$.

ψ_A is a function of effort, also measured in units of time $e_{A,i}$ dedicated towards activities such as meal planning, disciplined shopping, meal preparation, cooking and so on. Ideally, engaging in these activities lead to improved use of food inputs, hence preventing larger amounts of avoidable food disposed. Spending time in these household food production related activities is assumed to be equivalent to engaging in food waste prevention activities which increases the public good, that is, $\frac{\partial \psi_A}{\partial e_{A,i}} > 0$ and $\frac{\partial \psi_A}{\partial t_{f,i}} > 0$. θ_A are similar exogenous factors that impact these prevention endeavors, with $\frac{\partial \psi_A}{\partial \theta_A} > 0$. For instance, information that would improve household's knowledge of food storage would increase the efficiency parameter, θ_A.

The household production function approach introduced by Becker (1995) has been used to explain material recycling behavior (Morris and Holthausen, 1994) and more recently, food waste decisions (Landry and Smith, 2017; Ellison and Lusk, 2016). Households combine purchased food inputs z_i and time spent in cooking and preparation $e_{A,i}$ to convert them into meals, $F_i = f(z_i, e_{A,i})$. Waste proportion can then be defined as $W_i = \sum_{j=1}^{J} z_{ji} / F_{ji}$, for J inputs.

Accordingly, the individual's self-image is a function of both types of contributions towards the public good, $I_i(g_{R,i}, g_{A,i})$. The individual maximizes utility given standard time and budget constraints given by (*5*) and (*6*):

(5) $$T = t_{L,i} + e_{A,i} + e_{R,i}$$

(6) $$\sum_{j=1}^{J} p_j z_{ji} + \sum_{n=1}^{N} p_n x_{ni} = Y_i$$

We assume that labor supply decisions are long-term and given for the period. As such, income Y_i is also given. Further, we also assume that total time available, excess of work, also consist of some "non-negotiable" hours spent on activities that are necessary and less flexible for the household. This may include time in personal care, child care, or adult care activities. Total time endowment T is hence excess of work hours and other non-negotiable hours. This time can be spent as leisure ($t_{L,i}$), food–related household production and waste prevention activities ($e_{A,i}$) and food recycling activities ($e_{R,i}$). Household income, Y_i, is spent on raw food input z_j at price p_j and other private goods x_n at price p_n. Individual i maximizes utility with respect to consumption of private non-food goods (x_i), food inputs (z_i), time in leisure ($t_{L,i}$), effort to dedicate towards her recycled share of food and organics ($e_{R,i}$), and efforts towards food waste prevention ($e_{A,i}$). Denote λ_i as the Lagrange multiplier on money budget and μ_i as the Lagrange Multiplier on the time budget.

(7) $$\mathcal{L} = \mathcal{U}_i\big(x_i, F_i, t_{L,i}, G, I_i\big)$$

$$+ \lambda_i \left\{ Y_i - \sum_{j=1}^{J} p_j z_{ji} - \sum_{n=1}^{N} p_n x_{ni} \right\}$$

$$+ \mu_i \ \{T - t_{L,i} - e_{A,i} - e_{R,i}\}$$

Recall that the utility function can be expressed as:

(8) $$\mathcal{U}_i\big(x_i, F_i, t_{L,i}, G, I_i\big) = \mathcal{U}_i\left(x_i, f(z_i, e_{A,i}), t_{L,i}, G_i\left(\psi_R\big(e_{R,i}, \theta_R\big), \psi_A\big(e_{A,i}, \theta_A\big)\right) + G_{-i}\big(g_{R,-i}, g_{A,-i}\big), I_i(\psi_R\big(e_{R,i}, \theta_R\big), \psi_A\big(e_{A,i}, \theta_A\big))\right)$$

In the optimum the time and money budget will bind and the first-order conditions for the problem are expressed as:

$$(9)\quad \frac{\partial \mathcal{L}}{\partial x_{ni}} = \frac{\partial \mathcal{U}_i}{\partial x_{ni}} - \lambda_i p_n = 0$$

$$(10)\quad \frac{\partial \mathcal{L}}{\partial z_{ji}} = \frac{\partial \mathcal{U}_i}{\partial f} \cdot \frac{\partial f}{\partial z_{ji}} - \lambda_i p_j = 0$$

$$(11)\quad \frac{\partial \mathcal{L}}{\partial t_{L,i}} = \frac{\partial \mathcal{U}_i}{\partial t_{L,i}} - \mu_i = 0$$

$$(12)\quad \frac{\partial \mathcal{L}}{\partial e_{R,i}} = \frac{\partial \mathcal{U}_i}{\partial G_i} \cdot \frac{\partial G_i}{\partial \psi_R} \cdot \frac{\partial \psi_R}{\partial e_{R,i}} + \frac{\partial \mathcal{U}_i}{\partial I_i} \cdot \frac{\partial I_i}{\partial \psi_R} \cdot \frac{\partial \psi_R}{\partial e_{R,i}} - \mu_i = 0$$

$$(13)\quad \frac{\partial \mathcal{L}}{\partial e_{A,i}} = \frac{\partial \mathcal{U}_i}{\partial f} \cdot \frac{\partial f}{\partial e_{A,i}} + \frac{\partial \mathcal{U}_i}{\partial G_i} \cdot \frac{\partial G_i}{\partial \psi_A} \cdot \frac{\partial \psi_A}{\partial e_{A,i}} + \frac{\partial \mathcal{U}_i}{\partial I_i} \cdot \frac{\partial I_i}{\partial \psi_A} \cdot \frac{\partial \psi_A}{\partial e_{A,i}} - \mu_i = 0$$

Equation (*11*) tells us that the Lagrange Multiplier for the time budget (μ_i) is equal to the marginal utility of leisure time. When choosing recycling efforts ($e_{R,i}$), equations (*12*) shows that the household assesses the marginal utility gained from increased environmental quality (positive) as well as increased self-image (positive). When making choices about how much time to dedicate towards food production and food waste reduction efforts ($e_{A,i}$), the household not only evaluates the effects from the marginal utility of time spent in the production of meals but also the marginal utility from the increase in environmental quality and the feeling of positive self-image through I_i. All three terms making up (*13*) are positive implying that there are added effects to spending more time in $e_{A,i}$ than simply the marginal utility of meal production.

The arguments of the utility function can be expressed in terms of the exogenous factors which include total time (T), prices (p_j and p_n), income (Y_i), efficiency parameters (θ_A and θ_R), total recycling and food waste prevention contributions by other households (G_{-i}) as well as the shadow price of time (μ_i) when we solve all first order conditions except for one:

$$x_{ni} = x_{ni}\,(T, p_j, p_n, Y_i, \theta_A, \theta_R, G_{-i}, \mu_i)$$
$$t_{L,i} = t_{L,i}\,(T, p_j, p_n, Y_i, \theta_A, \theta_R, G_{-i}, \mu_i)$$
$$z_{ji} = z_{ji}\,(T, p_j, p_n, Y_i, \theta_A, \theta_R, G_{-i}, \mu_i)$$
$$e_{R,i} = e_{R,i}\,(T, p_j, p_n, Y_i, \theta_A, \theta_R, G_{-i}, \mu_i)$$
$$e_{A,i} = e_{A,i}\,(T, p_j, p_n, Y_i, \theta_A, \theta_R, G_{-i}, \mu_i)$$

Solving all first-order conditions and plugging the Lagrange multiplier, $\mu_i\left(T, p_j, p_n, Y_i, \theta_A, \theta_R, G_{-i}\right)$, in terms of all exogenous variables, we obtain the respective demands:

$$x_{ni} = x_{ni}\,(T, p_j, p_n, Y_i, \theta_A, \theta_R, G_{-i})$$
$$t_{L,i} = t_{L,i}\,(T, p_j, p_n, Y_i, \theta_A, \theta_R, G_{-i})$$
$$z_{ji} = z_{ji}\,(T, p_j, p_n, Y_i, \theta_A, \theta_R, G_{-i})$$
$$e_{R,i} = e_{R,i}\,(T, p_j, p_n, Y_i, \theta_A, \theta_R, G_{-i})$$
$$e_{A,i} = e_{A,i}\,(T, p_j, p_n, Y_i, \theta_A, \theta_R, G_{-i})$$

Plugging the demands in the utility function gives us the indirect utility:

$$V_i = V_i(Y_i, t_{L,i}^* - e_{A,i}^* - e_{R,i}^*, G((\psi_R\left(e_{\mathrm{R},i}^*, \theta_{\mathrm{R}}\right), (\psi_{\mathrm{A}}\left(e_{\mathrm{A},i}^*, \theta_{\mathrm{A}}\right)), I_i(\psi_R\left(e_{\mathrm{R},i}^*, \theta_{\mathrm{R}}\right), (\psi_{\mathrm{A}}\left(e_{\mathrm{A},i}^*, \theta_{\mathrm{A}}\right))$$

To determine the effect of the opportunity cost of time on willingness to dedicate efforts towards household food production and waste prevention or recycling, we are interested in estimating equations for $e_{R,i}$ and $e_{A,i}$ as a function of the Lagrange multiplier on the time budget and the exogenous variables. To determine the opportunity cost of time, we seek estimates of the household' Compensating Variation (CV) that is the change in income required to maintain utility at a given level when the household does not recycle compared to when they recycle. This is equivalent to the willingness to pay to leave food waste reduction and recycling to a third party. The CV is given as follows:

$$CV = e_{A,i}\,(T, p_j, p_n, Y_i, \theta_A, \theta_R, G_{-i})$$

The empirical challenges of estimating willingness to pay measures have been extensively discussed in the literature. Particularly, although environmental quality is an important exogenous factor that determines willingness to pay, respondents are known to hold heterogeneous subjective information and existing knowledge about quality of the good (Whitehead, 2006). Some survey instruments include extensive descriptions of the environmental good but also tend to be expensive, or worse run the risk of fatiguing and tuning off their respondents (Berrens et al., 2002). Standardizing the information on the environmental good

(Berrens et al., 2002) and using key quality perception indicators in an instrumental variables framework (Whitehead 2006) have been identified as possible solutions to the problem.

Further, these measures are also dependent on other households' recycling effort. What others are doing may weaken norms and reduce efforts or on the other hand, may improve outcomes as the activity is perceived as joint community effort (Halvorsen, 2008).

6. Data and methods

We collect data on willingness to participate in food waste reduction and recycling efforts using a nationally representative survey of 1,000 respondents. We also elicit key variables pertinent to the conceptual framework including the willing to pay (CV) measures. At the local level, household-level information was collected through a survey and a food scrap pick-up program in a RCT setting. All collected food scraps were weighed, sorted, and composted. Food waste data was examined for any short-term behavioral patterns over the collection period and by treatment. Household-level responses were also used to examine the effect of socioeconomic, and attitudinal factors affecting amount of food disposed and recycling levels. Lastly, responses to contingent valuation questions in the survey were analyzed to estimate consumer valuation of various downstream uses of food waste and willingness to pay for food and organics recycling programs.

6.1 Household survey and choice experiment

The household survey was designed to collect information that have been identified as contributing to food waste or food-related behavior in the literature. We collected information on socioeconomic characteristics including age, education, income, household size amongst others. At the local level, prior to the treatment intervention, we implement a baseline survey to gauge willingness to participate in the food waste reduction and recycling efforts. After the intervention, we measure *actual* efforts in those activities by measuring levels of food waste generated as well as the amount of organics recycled (for the treatment group).

In addition, a choice experiment (CE) was designed to estimate consumer valuation of food waste allocated for different downstream resources. CE is a suitable method to value changes in the quality or quantity of non-market services (Alpizar et al., 2001). Respondents were asked to choose an organic waste disposal program that varied in cost, format, source separation, and end use. The most popular ways to provide organic waste disposal system services to residents include curbside food scraps collection and organics drop-off sites. For this study, we chose curbside collection. The selected attributes and levels are summarized in Table 1.

The costs for organics recycling vary greatly across the country. For instance, the City of Minneapolis (2017) subsidizes the curbside collection of food scraps, which is currently free of charge. Other parts of the country charge a monthly fee ranging from $4 in the City of Portland (2017) to $20 in New jersey (Yepsen, 2012). In Denver, Colorado (2017), residents paid a rate of $29.25 each quarter for an average price of $9.99 per month. We used local and regional trash collection prices as a reference to decide on prices to use in the choice experiment.

Cities with organic waste curbside programs usually provide residents with recycling carts specific to organic waste that are picked up weekly or biweekly similar to regular trash (Layzer and Shulman, 2014). Others may offer compostable biobags that are filled with organic waste and simply placed in the regular garbage cart for curbside pickup (Randy Environmental Services, 2017).

Organic waste disposal programs can specify required levels of source separation, which are particularly relevant for the feasibility of large-scale recycling of household FW for various downstream uses. For instance, wood and garden waste are examples of organic wastes that are not suitable for anaerobic digestion into biofuel, but they can be treated using alternative technologies, such as composting or combustion for energy recovery (Seadi et al., 2013). Source separation efforts that align with current practices include (i) separating food scraps and yard waste together, that is all organics, (ii) separating all food scraps but no yard waste, or (iii) separating food scraps, no meats and dairy allowed (Goldstein, 2005).

A key question for our study is whether or not consumers care about how their FW is used in the downstream conversion processes. Consumers' values associated with FW recycling are hypothesized to differ across end uses, which we test. Given current and emerging technologies, FW can be processed into compost, animal feed, or biofuel, combusted for energy recovery, or landfilled (Galanakis, 2015).

Table 1. Summary of attributes included in the choice experiment design

Attributes	Levels
Cost	Low, medium, high ($/month for weekly curbside pickup)
Disposal format	Separate cart, biobags, combined cart
Source separation	All organics, food scraps only, food scraps only without meats or dairy
End use	Compost, animal feed, biofuel

6.2 Subject recruitment

A total of 200 resident households in the local Ramsey County were recruited through community partners to participate in a 6-week food scrap curbside pickup program. They were asked to complete the consumer survey, and respond to a follow-up survey at the end, for which they received $100 for their time and effort. It was communicated to the households that the intent was not to pay them for putting out the food scraps. To avoid any confounding effects, only households that did not participate in any private organics pick-up program, backyard composting or organics drop-off program at the time of the study were eligible. After they provided consent to participate in the study, they started by setting their regular trash for sorting for 2 weeks. Then they received an email link to the survey to be completed before the treatment interventions began. To enhance the external validity of our study we aimed to use a stratified randomization method including a range of key demographic characteristics (e.g., gender, ethnicity, socioeconomic status) to match the US population (Kendall, 2003), however, due to lower response rate, we used all interested households who were eligible.

6.3 Randomized control trial (RCT)

The households were randomly assigned to one of three groups: two (one experimental or treatment group) which received the intervention that is being tested, and the other two (the comparison group or control) received only part of the intervention. To achieve a significance level of 5% and sufficient statistical power (80%), our power calculations suggest that groups of 63 households is satisfactory (Rosner, 2011). Hence, the total of 200 households recruited for participation allowed for potential attrition. A minimum of 189 households was required to conduct the analysis. The treatment groups obtained similar information to current municipal food scrap collection programs, which outline the basics of what can or cannot be recycled. The guidelines for organic recycling for this study was adopted from those available from organizations such as the Penn State's Sustainability Institute and Hennepin County. All households received the same food waste reduction information at the beginning of the study.

In collaboration with organics recycling professionals and scientists, awareness and training informational videos tailored for each treatment group are used as a delivery method for treatment. All households in control and treatment groups were asked to view the tailored informational videos designed to communicate the negative economic, environmental and social impact of throwing away food scraps. The video included a short quiz to confirm their understanding. Each group received a different quiz. Households were asked to view the video prior to the beginning of the collection program. Households in the treatment group further received information on food scraps recycling framed as a resource generating opportunity. Treatment interventions educated households on how their food waste would be recycled and explained source separation for proper conversion into respective downstream resources: compost or biogas. Thus, all treatment households received instructions and information about food scrap recycling. The driving rationale is that in the absence of framing food waste recycling in a resource recovery and reutilization context, behavior would be different.

Control households received no further information on recycling but to account for cognitive efforts for information processing, they were given "filler" information on the University of Minnesota. The first control group was asked to separate their food scraps for us to be able to examine what goes uneaten in the household and the types of organics that get disposed. This is identical to other food waste characterization or composition studies that examine the types of food that are more likely to go uneaten. There was no mention of downstream processing. The second control group also were told that their regular trash will be examined to see what goes uneaten in the household and the types of organics that are disposed.

This staging allowed us to identify and compare the behaviors linked to understanding the importance of food waste reduction as well as information on food scraps recycling into resources on the treatment households. We attempted to isolate the impact of understanding the importance of food waste reduction only on the second control group. We were able to identify the impact of the importance of food waste reduction accounting for any efforts that need to be dedicated towards source separation through the first control group. Irrespective of what households were told, all organics obtained was weighed, sorted, examined, and eventually composted. It would not have been environmentally viable to combust the organics for the control groups. Further, currently there are not readily accessible facilities to convert organic materials into energy through anaerobic digestion, but the local county has plans to realize such endeavors in the next few years.

In the absence of this staging, households may have changed their behavior if they knew the nature of how their food scraps will be actually converted. For instance, we needed households in the control groups to believe that their food scraps will be sent to be combusted with trash to mimic the status quo of what usually happens to food scraps in the absence of organic processing. Similarly, we need the second treatment group to believe that their food scraps would be converted into biogas for them to act accordingly. This helped evaluate their behavior as close as possible to reality. Sending the food scraps to be composted rather than turned into biogas does not have a negative environmental impact and still counts as a productive re-use of the material. This staging is harmless for both the participants and the environment. A debrief statement was communicated to the households at the end of the study to inform them of the staging, what happened to the organic materials, and the study goals. We also shared the regular Ramsey County's website information on their organics drop off services in case households were interested in keeping participating in an organics recycling drop-off program.

The results from the subsequent analyses were used to assess the impacts of the treatments. Further, we also compare *predicted* versus *actual* efforts in food waste reduction and recycling efforts. Impacts were evaluated in terms of the changes in the level and variability in the amounts of food waste recycled by households as well as its content. That is, it was the extent to which treatment affects achieving the goals of obtaining viable quality and quantity of food scraps and organics to be processed as downstream economic resources. The RCT approach allowed us to rigorously determine whether a causal relationship exists between the treatments and the outcomes (Kendall, 2003).

6.4 Food scrap collection and sorting

Simulating a curbside pickup program, participating treatment households as well as the first control group, received two buckets and compostable bags with unique household identifiers. The buckets and compostable bags were dropped off at the residences by the research staff at the beginning of the study. Households in these groups were instructed to collect their food scraps and food-soiled paper products in one of the buckets lined with the compostable bags; the second bucket was used to deposit the compostable bags as they got full. Households in the second control group continued disposing of food scraps as usual, that is, in their regular trash can. All households were asked to line their regular trash cart. This allowed us to identify the contents by household for these groups. On a weekly 'collection day,' all trash was picked up by a licensed hauler. The hauler emptied the trash into their collection unit, securing the identified compostable bags. The trash collected which contained the food scraps and organics in compostable bags was brought to the University of Minnesota for sorting by staff.

The food scraps and organics remained identified by household through the sorting process, while two main items were recorded: total quantity and total volume of uncontaminated food scraps that can be used in downstream processing which is regarded as the quality indicator for this study. Quantity is in terms of pounds of uncontaminated food scraps that the household recycles. Materials that contaminate food scraps may include yard waste, pet waste, Styrofoam or other recyclable items including cartons, glass, metal, paper, and plastic, which would need to be separated before any downstream processing. The process was repeated for 6 weeks, allowing us to obtain (1) quantities and (2) qualities of food scraps by household.

6.5 Empirical strategy

Let y_{Rit} denote the amount of food scraps, measured in pounds, recycled by household i at time t and y_{Cit} the percentage of food scraps uncontaminated by other elements and deemed appropriate for downstream processing for a particular use. These are our two dependent variables of interest. $COMP_{it}$, and BIO_{it}, represent dummy variables for treatment groups for composting, and biogas respectively. Further, for the households in the control groups, $COMP_{it} = BIO_{it} = 0$. The relationship between FW quantity (y_{Rit}) or FW quality (y_{Cit}), treatment groups ($COMP_{it}$, and BIO_{it}) and household characteristics X_{it} is given as:

(14)

$$y_{Rit} = \beta_0 + \beta_1 COMP_{it} + \beta_2 BIO_{it} + $$

$$+\sum_{k=1}^{K} \partial_k X_{it} + \epsilon_{it}$$

X_{it} consists of household characteristics such as age, income, education level, presence of children in the household and so on.

7. Next Steps and Conclusions

The research team is still in the process of collecting data from the national survey and the local RCT is poised to start on September 19th 2018. We will use the national survey to determine the effect of the opportunity cost of time on willingness to dedicate efforts towards food waste reduction and recycling efforts. Then, we will implement the same survey locally to obtain the same predicted efforts in those food-related activities. We will compare the *predicted* and *actual* efforts using the local organics collection pilot. Our hypothesis is that those with a high opportunity cost of time are likely to report lower willingness to participate in food waste reduction and recycling activities. However, we expect that *actual* efforts will be even lower than anticipated. This would offer a possible explanation to why even the most enthusiastic and concerned citizens often are unable to keep up with food waste reduction and recycling even if they have the noblest intentions. Further, insights from the RCT will also help us evaluate the effectiveness of food waste and recycling information on behavior.

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