UDERSTANDING HOUSEHOLD FOOD WASTE: A RATIONAL INEFFICIENCY APPROACH

by

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(Under the Direction of Craig Landry and Travis Smith)

ABSTRACT

It is estimated that globally over 30% of the food that they purchased for consumption is wasted. This paper examines the relationship that food stores have on food waste. Using waste data from the Texas Commission on Environmental Quality and food store data from the USDA's Food Environment Atlas, we attempt to develop the microeconomic theory that is at the foundation of food waste behavior. We classify food waste as rational inefficiency such that households hedge against the uncertainty of planning future meals by stocking up on food purchases. It is when this food insurance is not used that there then is food waste. We hypothesize that as the availability of food increases due to additional location of food stores, then food waste decreases because the uncertainty of planning future meals is diminished. We find empirical evidence that supports this claim.

INDEX WORDS: Food waste, Grocery Stores, Microeconomics, Consumer theory, Municipal solid waste, Texas, Rational inefficiency

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APPROACH

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# CHAPTER 1

# INTRODUCTION

Food waste is a pervasive problem around the world and across the nation. It is estimated that around one third of the food that is produced globally goes to waste (Buzby & Hyman, 2012). This growing level of food waste has direct environmental and natural resource effects. Grown but uneaten food has costs associated with it that are not internalized. Included in these unaccounted for costs are the waste of natural resources as well as the creation of excess pollution (Hall et al., 2009). One environmental concern is the anaerobic rotting of organic material in landfills is the second highest producer of methane in the atmosphere, a direct contributor to climate change (Hall et al., 2009). Methane is estimated to be twenty five times more damaging to the atmosphere than carbon dioxide (Munesue, Masui, & Fushima, 2015).

The basic definition of economics is deciding how to allocate scare goods to consumer's unlimited wants and needs. This underlying premise is the basis for all economic decisions. The conundrum of food waste is that is seems to contradict the economic theory that consumers value their money and time and therefore would not so carelessly discard food. This leaves analysts with the difficult task of identifying why there is such an absorbent amount of food waste in the world. Consumers use their income to purchase food goods, and then throw a portion of those purchased goods away. One would expect that money used on a good would be valuable to the consumer and therefore not so easily discarded. Food for consumption is clearly a normal good and we believe that food waste can be categorized similarly. It is illogical to think that a consumer would purchase three t-shirts and then discard one of them without ever using it. However, when food waste is examined through the lens similar to that of an insurance policy against running out of food, it is quite logical that there would be some "waste" (i.e., unused insurance). The money used to purchase extra food provides utility because it hedges against unfavorable states of nature. These excess purchases could be viewed as rational behavior in the same manner as purchasing health insurance is rational behavior.

The motivation for this paper is to posit a microeconomic theory of food waste as it relates to consumers. Empirically, we look at the location of food stores as a determinant of waste. Attempting to determine any causal relationship in regards to food waste can further efforts to mitigate future 'waste' – or the over consumption of food insurance. This will provide several benefits including economic security, responsible governance of natural resources and a decrease in the negative externalities associated with the over use of natural resources, as well as providing the ability to feed the world's growing population. A society, one that is expected to surpass 9.3 billion people by 2050, which understands and is able to characterize the behaviors of waste in the food supply chain will begin to take the next step in better providing for the inhabitants of such a society (Buzby & Hyman, 2012).

Until now, previous research has focused on consumers' awareness of food waste and their attitudes and behaviors linked to such waste (Ellison, & Lusk, 2016; Cecere, Mancinelli, & Mazzanti, 2014; Graham-Rowe, Jessop, & Sparks, 2014). While focusing on consumer awareness and attitudes is an important area of discovery, the findings that consumers generally do not want to waste their money is one that is not earthshattering. It is the goal of this research to determine if a change in the price of food causes a change in the waste produced by a community; we use the addition of a new food store in the vicinity as a tool to measure this lowered transaction cost.

There has been a cultural shift in American society that has resulted in a change in the opportunity cost of time for many households. Increases in wages as well as the addition of more women in the labor force made it more expensive to cook at home and thus cheaper to dine out. The trend toward smaller household sizes could also be a contributing factor due to a decrease in economies of scale when cooking. (Guthrie, Lin, & Smith, 2016).

American society once had a connection with food because it was produced locally (Bloom, 2011). Today, technological innovation has made any food that one could desire available in any season. While these advancements in technology have led to the capability to feed countless more individuals than our predecessors were, they also contribute to the factors of consumer waste (Bernstad Saraiva Schott & Anderson, 2015).

While trying to mitigate the effects of climate change by limiting the amount of methane emitted is reason enough to act on the problem of food waste, making the best use of land, water, and other inputs of production are also vital in the discussion for economic planning. Basic economics tells us that if as a society we are producing more than is consumed, there is a surplus created. However, the perishable nature of food does not allow for long term warehousing in order to meet future demand. The products that are cultivated must be sold to the consumer in a relatively short period of time.

Beyond the environmental aspects and monetary value of food waste, the allocation of resources away from the agricultural sector may be necessary if it is no longer efficient.  There is also the possibility for use of food in other regions of the world that do not have the same abundance that is found in the United States.

# CHAPTER 2

## BACKGROUND AND LITERATURE REVIEW

Papers that have examined food waste range from examining the difficulties of trying to quantify the amount of food that goes uneaten to examination of the impact on natural resources. Questions about the economic rationality of food waste remain. First, it is of importance to distinguish the difference between food loss and food waste. As defined by the United States Department of Agriculture (USDA), food loss is the edible amount of food, postharvest, that is available for human consumption but is not consumed for any reason. It includes cooking loss and natural shrinkage (for example, moisture loss); loss from mold, pests, or inadequate climate control; and food waste (Buzby & Hyman, 2012). Food waste therefore is a subset of food loss and is when an item is prepared for consumption but goes uneaten. Admittedly, there are limitations to quantifying exactly how much of food loss is actually food waste. There is also a cultural dimension that blurs the line between food loss and food waste. This includes items such as potato peels or the ends of a loaf of bread which in some cultures are viewed as garbage while in other cultures these items are perfectly suitable for consumption (Kantor et al., 1997). Another grey area is the efficiency of converting food ingredients into food meals, i.e. the efficiency parameter in the production function.

The perishable nature of food products makes it a commodity that is difficult to achieve no loss. In fact, for the safety of the public, some foods must be culled in order to preserve a healthy human population. This can range from livestock showing indication of disease, fruit that has begun to grow mold, or milk that has begun to curdle. A specific amount of food waste is desirable in some capacity to ensure the health of society. It is determining what the desirable amount is that proves to be troublesome. To gain a better understanding of what an acceptable amount of food waste is and take action to meet this level, several analyses must be undertaken. One can begin by quantifying the extent of the situation that is currently in existence but ultimately it will be paramount to understand the array of behaviors that influence this complex phenomenon.

There have been several attempts to quantify the state of the food waste situation. These studies vary slightly in their findings but there is consistency in the theme of the results. As previously stated, an estimated one third of global food production is wasted. The most recent study as of this writing shows that in the United States this amount is higher at around 40% in total with 31% wasted at the retail and consumer level; this translates to a $161.6 billion loss (Buzby, Wells, Hyman, 2014; Hall et al., 2009). The top three food groups in terms of share of total value of food loss were meat, poultry, and fish (30 percent, $48 billion); vegetables (19 percent, $30 billion); and dairy products (17 percent, $27 billion). The paper that has served as the seminal piece for subsequent research on food waste is Kantor et al. (1997). Using data from USDA's Economic Research Service's (ERS) 1995 dataset, Kantor et al. (1997) used food loss estimates that were obtained from published studies and discussions with commodity experts and then applied to the amount of food available for human consumption in the United States in 1995. They then used these estimates to compile a basket of 260 different foods consumed at the retail, consumer, and foodservice levels. They were able to estimate that 5.4 billion pounds of food were lost at the retail level and 91 billion pounds of food were lost at the consumer level which includes meals prepared at home as well as away from home.

A subsequent attempt at quantifying the magnitude of the food loss situation was conducted by Buzby and Hyman (2012). A study using data from a 2008 ERS dataset identified percentages of the amount of food lost as a proportion of how much was cultivated. The study, using the loss adjusted food availability (LAFA) data set available from the ERS, found that the major culprits to food loss were meat, poultry, and fish at 41 percent of total lost food, vegetables at 17 percent of total lost food, and dairy at 14 percent of total lost food (Buzby & Hyman, 2012). These figures were later updated using the 2010 data from the ERS. The resulting proportions of food loss were meat, poultry, and fish at 30 percent, vegetables at 19%, and dairy products at 17% (Buzby, Wells, & Hyman, 2014).

Throughout the food system there is waste. Food loss can occur in one of four main stages of production. This include at the farm, during processing, at retail locations, and at the consumption stage (Lundqvist et al., 2008). In each stage there are areas that can be seen as the greatest culprits to the problem of food loss. From the moment that a seed is planted in the earth, there are resources that are utilized in its growth and development. Any waste of food from the development of the seed to the presentation of a meal at a restaurant represents a waste of resources: time, money, natural resources, and energy when waste is defined in the traditional sense. As all of these resources are valuable to the population, it is of great importance to view the problem of food waste through an economic lens in hopes of mitigating the problem.

The inputs required to produce food are many. Countless hours go into the cultivation, distribution, and preparation of food. Agricultural production around the globe accounts for over 80 percent of the world's freshwater use (Buzby, Wells, & Hyman, 2014; Kummu et al., 2012). It has been estimated that the resources required for producing wasted food account for over 25% of total freshwater usage in the United States as well as approximately 300 million barrels of oil (Hall et al. 2009). The proportionally small percentage of accessible freshwater on the planet, less than one percent of the total amount of water on the Earth, makes wasting any good with freshwater as an input one that should be well planned. Lundqvist et al. (2008) has shown the dramatic impact that agriculture has on the freshwater supply. The cost that is required to treat, store, and deliver water to consumers, including applicable agricultural growers, are compounded when this water is used to cultivate food that is bound for the garbage can.

Several authors have been able to identify rough underlying causes in the stages of the food life-cycle chain that are not in the scope of this paper. Bloom (2011) identifies losses in the production stage as well as the distribution stage. These include not enough hands to pick produce during the harvest season, intentionally leaving some produce in the field as they contain blemishes that reduce their marketability, or losses in transportation due to equipment malfunction or infestation.

The examination as to the causes and areas of improvement on the subject are found all along the food supply chain including production, handling and storage, processing and packaging, distribution, as well as in consumption. Several authors have been able to quantify the amount of waste in and along the supply chain. These figures vary depending on the stage of development of the country in which the losses occur. This is mainly due to the infrastructure or lack thereof in developing countries (Hodges, Buzby, & Bennett, 2010). In developed countries, such as the United States, the stage at which the biggest losses occur are in the final stage of consumption (Lipinski et al., 2013).

There are sources of loss in the food chain that are not the scope of this paper. Food losses in the distribution and marketing sector can be attributed to larger than necessary grocery store displays (Fehr, Calcado, & Romao, 2002) and confusing labeling on packages with regards to expiration dates (Parfitt, Barthel & Macnaughton, 2010). Buzby et al. (2011) examine consumer waste in restaurants and find that one possibly cause of food waste can be associated with leftovers taken home and discarded either in part or in total before spoilage. Unexpected fluctuations in foods sales in restaurants, larger portion sizes, spillage, and breakage also play a role in the portion of consumer waste produced in restaurants (Buzby et al., 2011).

The sector of food loss that amounts to the greatest portion of waste in developed countries is that of the consumer and is the focus of this paper. Consumer food loss encompasses both food consumed in the home such as a home cooked meal, as well as food away from home such as food consumed at a restaurant.

Food purchased for in-home consumption also ends up being discarded rather than consumed. There are several factors that contribute to this outcome. The lure of the sale at the grocery store has often been a culprit in unintended purchases at the grocery store. Grocers often provide discounts on bulk purchases of goods. These extra items may end up in the back of consumer's refrigerators for weeks until they are finally discarded without ever being consumed. However, uncertainty in meal planning may cause the greatest sway in consumer food waste decisions (Lee & Paik, 2011). If a consumer makes a trip to the grocery store every other week, then they are purchasing enough food to last them until the next grocery visit. In essence, they are planning the next fourteen days of 3 meals a day per person in their household – 42 meals. Any unexpected event could cause the meals that where originally planned to be prepared to go uneaten. In the best case scenario, the shelf life would extend into the next grocery week. However, when purchasing groceries one time every two weeks, sometimes the food is too far gone and must be discarded.

The USDA estimates that twenty five percent of all consumer grocery store purchases are discarded before consumption (Buzby, Wells, and Hyman, 2014). It is obvious that consumers do not willingly purchase something that they know they will not use in the future. There may be a lack of planning that goes into unintended grocery store purchases. When an item is put on sale by a grocer, the price may meet the consumers' willingness to pay for the good and they make the purchase. If the item is one that is not regularly consumed by the household, then the unfamiliarity of it might lead to it spoiling before consumption. Thus, some food waste in the household may reflect limited information and learning processes.

It is of great importance to understand why there is food loss in the supply of food from farms to consumers for several reasons. There are large numbers of people around the world that do not have enough food to eat and are either malnourished or undernourished. Extrapolations of food loss estimates to caloric values suggest that 387 billion calories are lost each day, enough for approximately an additional 190 million people (Kantor et al. 1997; Buzby, Wells, & Hyman, 2014)).

The growing global population is expected to surpass 9.3 billion people by 2050. Feeding a population of this size with a fixed amount of agricultural lands may prove troublesome if the continued trend of between thirty and forty percent of food is lost (Munesue, Masui, & Fushima 2015). Kummu et al. (2012) states that from their findings, food supply losses could be halved if all areas if everyone in the world only wasted as much as Sub-Saharan Africa – the region with the lowest amount of food waste. This is most likely an unobtainable goal but it is a noble one none the less. By doing this, there would be enough food for approximately one billion extra people.

Recent research done by Ellison and Lusk (2016) has found that food waste is a function of consumers' demographic characteristics, and that the decisions to discard food vary with economic incentives. Specifically the paper draws fundamental economic comparisons of utility maximization in deriving consumers' aptitude for food waste. If a consumer gets greater utility from consuming the food item than they do in discarding it, the item will be eaten.

# CHAPTER 3

# THEORY

In examining the theory as to the drivers of food waste, we suspect that uncertainty plays a major role in the outcome of purchased goods. The inputs for making meals at home are not purchased ad hoc; one does not simply go to the grocery store every time they want a bowl of cereal. Conversely, they are purchased in volumes that allow for the consumer to hold a reserve of inputs in their home. This manner of purchasing introduces that possibility of what Andersen and Bogetoft (2005) refer to as rational inefficiency. Simply stated, any excess food inputs that are purchased and not consumed by the consumer are not considered an inefficient use but are viewed as a rational choice made by the consumer to allow for a buffer zone to manage uncertainty. Ideally a household would consume exactly the amount that they purchase. However given the option of wasting or running out of food, there may be a conscious decision to err on the side of "too much" food which can lead to some being discarded..

To derive the microeconomic theory that exists at the foundation of food waste, we begin with a consumer utility function,

(1) $$U(f_h, f_a, z, L; \tau)$$

where $f_h$ is food produced at home, $f_a$ is food consumed away from home, z is a numeraire for other goods in the market, L is leisure time, and $\tau$ is a taste parameter. Conventional microeconomic theory tells us that in maximizing this utility function, the consumer makes decisions on what to do with their time and money. Examining household food waste through the economic lens of a household production function allows for the consumer to wear the hat of a firm (Becker, 1965); in this case the firm is producing meals at home ($f_h$) as a consumption good. For simplicity, we consider the required inputs to produce $f_h$ via the production function

(2) $f_h = f(x, l_h ; \varphi)$

where x are food items $l_h$ is labor time spent at home in producing a meal, and $\varphi$ is an efficiency parameter. We assume $f_h$ to be strictly concave which ensures that employing more of every input results in more output..

The consumer maximizes their utility while adhering to a budget constraint

(3) $I + lw = P_x x + P_z z + f_a P_a$

where I is unearned income, l is market labor, w is the wage rate, and $P_j$ is the market price of commodity j = x, z, a (food away from home). Assuming labor market equilibrium, we can substitute the time constraint, $T = l + l_h + L$, into equation (3). The full utility maximization problem, then, can be written as:

(4) $L = U(f(x, l_h ; \varphi), f_a, z, L; \tau) + \lambda(I + Tw - P_x x - P_z z - (L + l_h)w - f_a P_a)$

where $\lambda$ is the marginal utility of full income. Note that the production function is $f(x, l_h ;$ $(\varphi)$ is embedded in the utility function, which is interchangeable with $f_h$. This is useful for interpreting the first order conditions:

(5) $L_x$: $MU_{fh} MP_x = \lambda P_x$

(6) $L_{lh}$: $MU_{fh} MP_{lh} = \lambda w$

(7) $L_j$: $MU_j = \lambda P_j$ for $j= f_a, z, L$

(8) $L_\lambda$: $I + Tw = P_x x + P_z z + (L + l_h)w + f_a P_a$,

where $MU_i$ is the marginal utility of commodity i and $MP_i$ is the marginal product of input i in the home food production function.

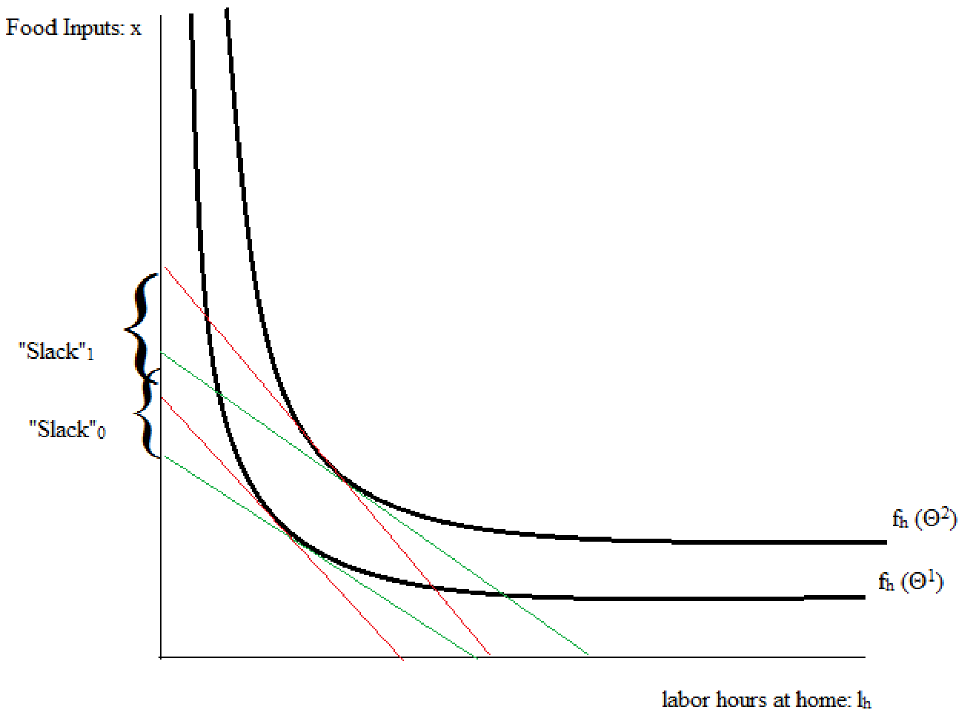
We will concentrate on the first two conditions (i.e., the choice variables associated with producing home food production, x and $l_h$). By taking the ratio of these two conditions, we arrive at the shadow price (or shadow cost) of food produced at home $f_h$,

(9) $$\pi_{fh}(w, P_x; \varphi) = MC_{fh} = MP_{lh} / MP_x = w/P_x$$

where $MC_{fh}$ denotes the marginal cost of producing food at home $f_h$. In other words, the marginal cost of producing a meal at home is a function of the input prices conditional on the efficiency of production, φ. As will become apparent shortly, the price of food inputs $P_x$ includes not only the sticker price of food at the grocery store, but also all transaction costs such as the cost of traveling to the store.

An isoquant curve of household production of $f_h$ amount of food can be found in Figure 1. The isoquant curve $f_h$ ($\Theta^1$) represents a state of certainty where the consumer knows exactly how many inputs they will need to produce a given level of home-produced meals. In this case, all inputs are used and no food inputs are wasted. However, in a world of uncertainty, the consumer does not know exactly how many inputs will be required to produce a given level of home-produced meals. It can be shown (see, Andersen and Bogetoft) that a risk-averse household will therefore purchase more than enough inputs to hedge against a state of the world where the household is deficient in food inputs. Put simply, the disutility of having more than enough food is less than the disutility of not having enough food.

Figure 1 – Household Isoquant Curves




In Figure 1, the isoquant curve $f_h$ ($\Theta^2$) represents a state of uncertainty, where an extra amount of inputs are purchased to be able to meet the dietary needs of an unknown future. The distance between the curves is the rational inefficient amount of food waste that the consumer creates. The isocost slope defined as: - $\pi_{fh}$(w, $P_x$; φ) = $\frac{-w}{Px}$. We define the isoquant curve $f_h$ ($\Theta^2$) the state of excess goods purchased for an uncertain future. The isoquant curve $f_h$ ($\Theta^1$) is the state of absolute certainty in household meal production. The distance between isoquant lines $f_h$ ($\Theta^2$) and $f_h$ ($\Theta^1$) decreases as uncertainty decreases. The green isocost lines are the natural state of the world. The red isocost lines represent a change in the slope due to a change in $P_x$. We hypothesize that with the addition of food stores in the area of consumers, a consumers' access to food will increase; therefore, food waste or "slack" as it is referred to in Andersen and

Bogetoft (2005) will increase due to the reduced transaction costs associated with purchasing food inputs.  This change in slope of the food insurance isocost line will cause a steeper line which will increase the area of food waste on the graph.  Lowering access cost will decrease the price of food insurance so people buy and waste more.

# CHAPTER 4

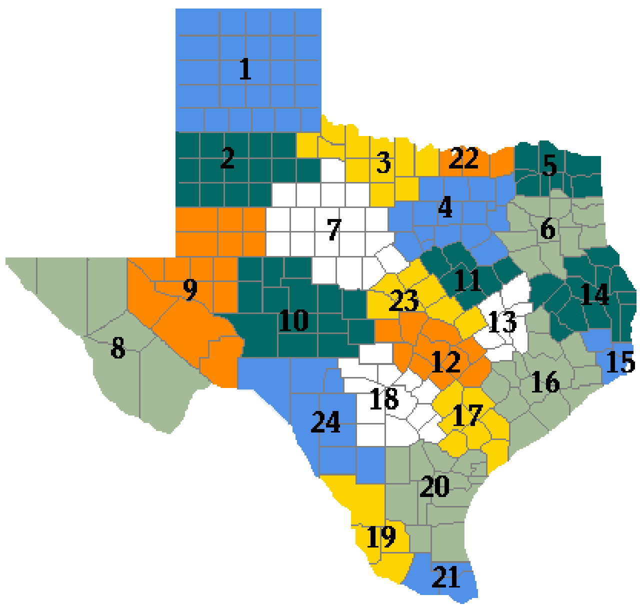
# DATA

The waste data for this analysis comes from the Texas Commission on Environmental Quality (TCEQ), which is tasked with regulating the landfills in the state of Texas. There are approximately 190 municipal solid waste (MSW) disposal sites across the state; the number changes over time because some sites reach capacity and close while others open. Each site is required to report the collected amount received at the site as it is weighed, in tons, upon delivery to the site. The data for all sites is then published by the TCEQ in an annual report entitled *Municipal Solid Waste in Texas: A Year in Review*. These reports are published online and go back to the year 2003. At the time of the writing of this paper, data from 2014 were the most recent data that have been published. The Environmental Protection Agency (EPA) publishes municipal solid waste data estimates on the national level annually. The most recent publishing in June of 2015 is a report for the year 2013. Their report shows that approximately 21 percent of municipal solid waste is comprised of food waste (EPA, 2015), and food waste represents the largest proportion of solid waste in landfills by weight.

The TCEQ publishes data from all of the waste landfill sites across the state. There is a distinction made between Type I and Type IV facilities. Type I facilities are the standard landfill for the disposal of municipal solid waste. Type IV facilities accept waste that will not putrefy or decompose slowly over time by natural processes such as brush or construction debris. Type I facilities are the focus of this study as they are the sites that receive waste from consumers.

Each landfill site is governed by municipal bodies known as Councils of Government (COG). There are 24 different COGs in the state and each is responsible for deciding which type(s) and the number of landfills that will be allowed in their own region. Figure 2 depicts the location of each COG.

Figure 2: Texas COG Map



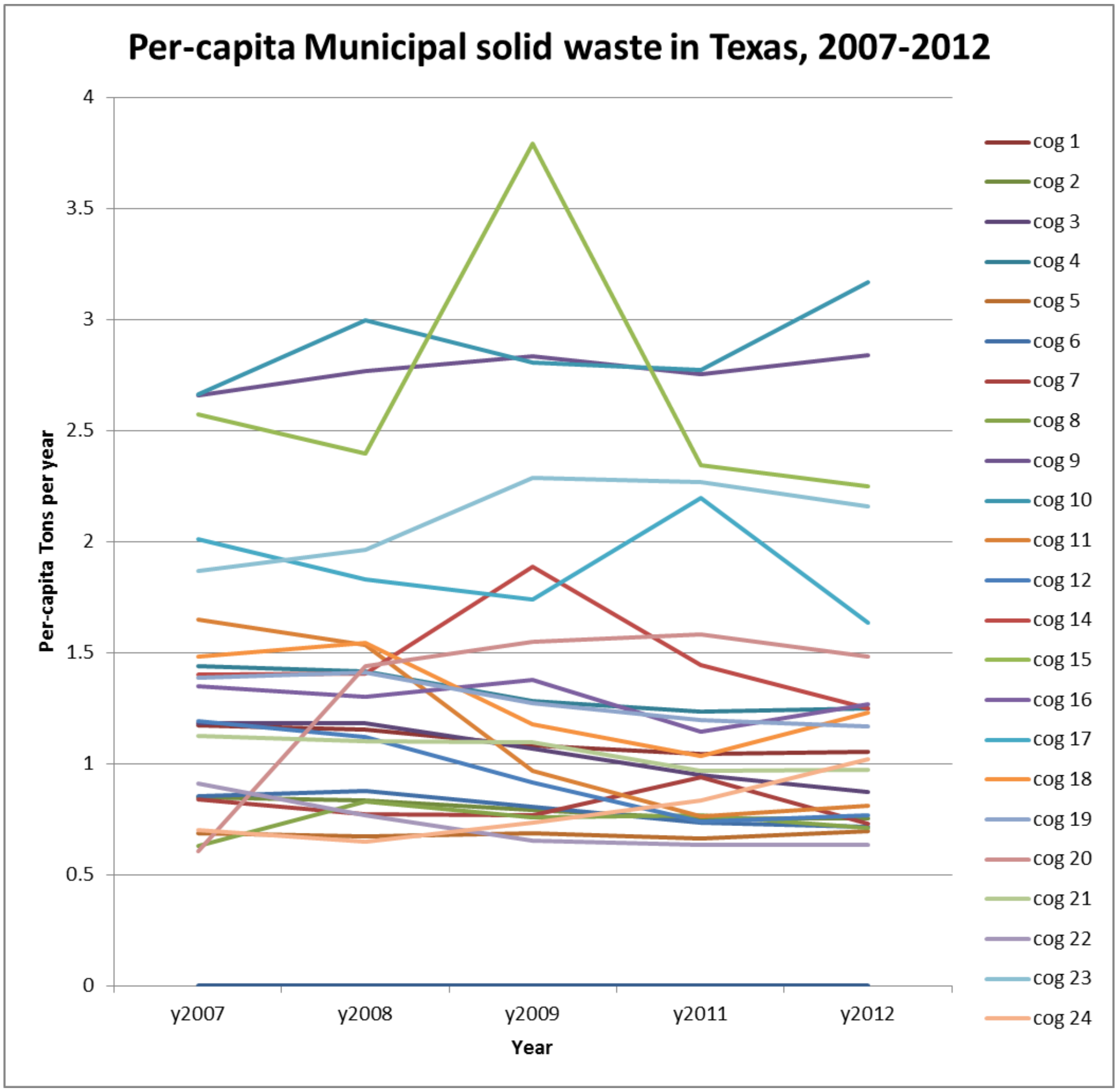

An examination of the waste summary statistics found in Table 1 show that there can be great variation between COGs in the levels of waste reported.

Table 1: Summary Statistics - Waste Data

| Variable | Variable Description | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| site_waste | Amount of waste (Tons) | 1,219,288 | 1,958,298 | 79,605 | 8,165,145 |
| wastepc | Per capita waste | 1.346 | 0.688 | 0.607 | 3.794 |
| lwastepc | Log of per capita waste | 0.186 | 0.457 | -0.500 | 1.333 |

According to the EPA (2015), the national average for MSW produced daily is about 4.5 pounds per day. This translates to approximately 1,642 pounds per year or about 0.82 tons. The per capita average of 1.35 of waste in Texas COGs is higher in most cases than the national average. A visual representation is shown in Figure 3.

Figure 3: Per-capita Municipal solid waste in Texas, 2007-2012



Food store data for this study was provided by the United States Department of Agriculture Economic Research Service's Food Environment Atlas (Ver Ploeg et. al, 2012). The data from the Atlas spans from 2007 through 2012. The data describes food availability on a county level in regards to store location as well as the abundance of stores. The Food Atlas breaks food store data down into four types of stores where food can be purchased. These include grocery stores e.g. Publix, supercenters e.g. Walmart, convenience stores e.g. QuikTrip, and specialty food stores e.g. a butcher shop. A summary of these data can be found in Table 2.

Table 2: Summary Statistics- COG Food Stores

| Variable | Variable Description | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| groc | Number of grocery stores | 136.086 | 212.821 | 9.083 | 857.829 |
| superc | Number of supercenters | 17.135 | 25.539 | 0.667 | 126.167 |
| convs | Number of convenience stores | 484.319 | 686.122 | 40.8 | 2,770.262 |
| specs | Number of specialty stores | 51.485 | 79.944 | 2.5 | 344.199 |
| ffr | Number of fast food restaurants | 692.461 | 1,055.199 | 38.767 | 4,748.139 |
| fsr | Number full service restaurants | 621.914 | 928.926 | 49 | 3,942.004 |

*Note:* Sample includes 23 COGS over 5 years for a total of 115 observations.

We also include county level demographic information from the U.S. Census. Specifically, we use the Small Area Income and Poverty Estimates. The ERS (2016) sets a level of poverty of 20% to be classified as one that is persistently in poverty. These data contain counts of the number of non-Hispanic whites, non-Hispanic blacks, Hispanics, and other race/ethnicities to which we aggregate at the COG level. We also include age statistics broken down into three broad categories. We divided the age groups into categories that seem relevant to grocery store purchases and at home meal preparation. These age groups are: (1) 0-19 still living with parents, (2) 20-64 adults supporting themselves, (3) 65-89 retired senior citizens.

When examining these data in summary (see, Table 3), we can see that on average approximately 90% of the population of Texas is either white (49.4%) or Hispanic (40.8%). We also notice that on average approximately 60% of the population of all COGs are in the 20 to 64 age group classification. This is similar to the national average of 63% provided by the US Census Bureau.

Table 3: Summary Statistics- COG Control Variables

| Variable | Variable Description | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| pop_sum | The number of people in the COG | 1,007,169 | 1,503,536 | 59,980.77 | 6,209,571 |
| wastepc | Per capita waste measurement | 1.346 | 0.688 | 0.607 | 3.794 |
| ratio_white | Percent white in the COG | 0.494 | 0.206 | 0.037 | 0.752 |
| ratio_black | Percent black in the COG | 0.086 | 0.061 | 0.002 | 0.197 |
| ratio_hisp | Percent Hispanic in the COG | 0.408 | 0.260 | 0.105 | 0.955 |
| ratio_u20 | Percent of people under the age of 20 | 0.308 | 0.045 | 0.265 | 0.470 |
| ratio_20to64 | Percent of people between the ages of 20 and 64 | 0.593 | 0.068 | 0.525 | 0.901 |
| ratio_o65 | Percent of people 65 and over | 0.124 | 0.025 | 0.081 | 0.181 |
| pov_all | Percent in poverty in the COG | 0.178 | 0.057 | 0.086 | 0.356 |
| pcmed_inc | Per capita median income of the COG in dollars | 437,643 | 307,398.5 | 79,958.08 | 1,192,218 |
| estabpt | Number of business establishments in the COG per thousand people | 25.179 | 13.540 | 8.141 | 64.637 |

There were 4 of the 24 COGs in which were found to be in a state of persistent poverty. They include COGs 8, 19, 21 and 24 which, as can be seen in Figure 2, are COGs that share a border with Mexico. COG 13 was dropped from our analysis. This is due to fact that there was only one landfill that serves the entire COG and there were inconsistencies in the reporting from this landfill which include missing years in the waste data due to non-reporting.

# CHAPTER 5

# METHOD

To analyze the effect that food stores have on waste, we begin with a pooled Ordinary Least Squares (OLS) regression model of the form:

$$ln(wastepc_{it}) = \beta_0 + \beta_1 grocpt + \beta_{2t} supercpt + \beta_{3t} specspt + \beta_{4t} convspt + \beta_{5t} ffrpt + \beta_{6t} fsrpt + \beta_{7t} pov\_all + \beta_{8t} ratio\_white + \beta_{9t} ratio\_black + \beta_{10t} ratio\_hisp + \beta_{11t} ratio\_u20 + \beta_{12t} ratio\_20to64 + \beta_{13t} ratio\_o65 + d_t year + COG_i + u_{it}$$

The variable descriptions are found in tables 1, 2, and 3; the variable $COG_i$ is a COG effect. From this model, we can estimate the percent change in per-capita waste when an explanatory variable changes by one unit. We also perform random effects and fixed effects regressions for robustness of our results. When a fixed effects model is used the model takes the form:

$$ln(wastepc_{it}) = \beta_1 grocpt + \beta_{2t} supercpt + \beta_{3t} specspt + \beta_{4t} convspt + \beta_{5t} ffrpt + \beta_{6t} fsrpt + \beta_{7t} pov\_all + \beta_{8t} ratio\_white + \beta_{9t} ratio\_black + \beta_{10t} ratio\_hisp + \beta_{11t} ratio\_u20 + \beta_{12t} ratio\_20to64 + \beta_{13t} ratio\_o65 + \beta_{14t} med\_inc + \beta_{15t} estabpt + d_t year + COG_i + u_{it}$$

where the COG fixed-effect approach allows for us to control for time-invariant fixed characteristics of the COG; the average of the COG fixed effect is reported as the intercept in the results. The dummies for each year allow for us to control for overall trends affecting all COGs simultaneously (e.g., broad economic factors related to business cycles). We use a 90% confidence level to determine significance.

# CHAPTER 6*

## RESULTS

After running the data in Stata using pooled OLS, fixed effects and random effects we were able to find evidence that both supports and contradicts our theory at the 90 percent confidence level. Table 4 shows the food store results of all three regressions.

Table 4: Results – Food Stores

| Coef. Name | Pooled OLS | Fixed Effects | Random Effects |
|---|---|---|---|
| grocpt | -4.445*** | 0.556 | -1.338 |
| | (-2.93) | (0.18) | (-0.49) |
| supercpt | -0.839 | 22.42* | 12.50 |
| | (-0.06) | (1.85) | (1.04) |
| convspt | 0.745 | -0.134 | -1.133 |
| | (1.11) | (-0.11) | (-1.46) |
| specspt | 6.885 | 5.173 | 6.497* |
| | (1.33) | (1.11) | (1.80) |
| ffrpt | -0.124 | -0.268 | -0.510 |
| | (-0.21) | (-0.25) | (-0.61) |
| fsrpt | -1.505* | 0.795 | -0.322 |
| | (-1.81) | (0.71) | (-0.36) |

*Note:* t statistics in parentheses

* p<0.10, ** p<0.05, *** p<0.01

As is visible in the pooled OLS model results, we find a negative coefficient on grocery stores. This coefficient can be interpreted as a one unit increase in grocery stores per thousand people will decrease municipal solid waste by 4.445 percent, this is contrary to the theory that we suggest. The results of the fixed effects model show that supercenters have a large positive coefficient that can be interpreted as a one unit increase in supercenters per thousand people will result in an increase of municipal solid waste by 22.42 percent. The random effects results of the regressions show significance in the specialty store coefficient. This result can be interpreted as a one unit increase in specialty store per thousand people will result in an increase of municipal solid waste by 6.497 percent. There is also significance at the 90% level in the pooled OLS model on the full service restaurant coefficient. The negative number suggests that as a one unit increase in the number of full service restaurants per thousand people increases, municipal solid waste decreases by 1.505 percent.

Table 5: Results – Control Variables

| Coef. Name | Pooled OLS | Fixed Effects | Random Effects |
|---|---|---|---|
| ratio_white | 8.269* | 5.563 | -0.296 |
| | (1.94) | (0.28) | (-0.04) |
| ratio_black | 10.48** | -22.92 | 3.775 |
| | (2.30) | (-0.68) | (0.50) |
| ratio_hisp | 8.272** | 2.677 | 1.007 |
| | (2.10) | (0.10) | (0.16) |
| ratio_u20 | -7.134 | 85.86 | -3.283 |
| | (-1.26) | (0.70) | (-0.40) |
| ratio_20to64 | -5.701 | 105.9 | 3.440 |
| | (-1.37) | (1.02) | (0.47) |
| ratio_o65 | -18.16** | 113.5 | 0.268 |
| | (-2.28) | (1.09) | (0.02) |
| pcmed_inc | 0.195** | 1.949** | 0.272 |
| | (2.36) | (2.49) | (1.25) |
| pov_all | -1.958 | -1.935 | -1.236 |
| | (-0.85) | (-0.77) | (-0.53) |
| estabpt | 0.0246*** | -0.146** | 0.0115 |
| | (5.26) | (-2.06) | (0.84) |
| year2008 | 0.0563 | -0.150 | -0.0476 |
| | (0.49) | (-1.35) | (-0.55) |
| year2009 | 0.0663 | -0.242 | -0.0925 |
| | (0.59) | (-1.59) | (-0.98) |
| year2011 | 0.0489 | -0.464 | -0.199 |
| | (0.33) | (-1.60) | (-1.45) |
| year2012 | 0.174 | -0.479 | -0.150 |
| | (0.97) | (-1.28) | (-0.91) |
| intercept | 0.0350 | -100.0 | -0.949 |
| | (0.05) | (-1.04) | (-0.63) |

*Note:* t statistics in parentheses

* p<0.10, ** p<0.05, *** p<0.01

The results of the control variables are shown in Table 5. We find significance in the demographic variable when the pooled OLS model is run. The fixed effects as well as the pooled OLS regression yields significance in the number of establishments per thousand people as well as per-capita median income. The findings of a positive coefficient on per-capita median income is what one would expect as economic theory states that as income increases, consumption increases which results in a greater amount of waste.

We believe that the reason we see opposite effects in regards to different food store types is due to the nature of goods being purchased at the respective stores. Food goods that are purchased at supercenters tend to be in larger quantities. Food goods that are purchased at specialty stores would lead one to believe that a higher level of waste is associated with those purchases due to the specialization in retail and diseconomies of scale. The positive coefficient on supercenters as predicted by our model: when a food store opens it reduces (on average) the fixed cost of transacting food inputs (x). These food inputs are used to produce food for at-home consumption $f_h$ as well as hedging against uncertain shortages (i.e., insurance). The law of demand states when the price of a good falls, demand will increase. Thus, we see an increase in municipal waste when a food store opens because the price of insuring against food shortfalls as decreased.

However, the negative coefficient on grocery stores may be due to more frequent purchasing trips to these stores as a general rule. A consumer who purchases their fresh produce from a grocery retailer would need to make larger, bulk purchases for every trip to the grocery store if there was a great distance to travel. This would lead to greater waste due to a higher level of uncertainty. With the addition of a new grocery store in the vicinity, the consumer would experience a decrease in the cost to get to the grocery store and therefore be able to take more frequent trips. This would result in less bulk purchases i.e. only purchasing one head of lettuce at a time instead of two because the consumer could get back to the grocery store more readily. As the number of grocery stores increase in an area, the uncertainty of future purchases decreases and the consumer is able to purchase less and therefore waste less as empirically shown in the results.

# CHAPTER 7

# DISCUSSION

Through empirical analyses, we were able to support our theory of the food waste as a rational inefficiency approach. Specifically, super centers and specialty stores show evidence of a positive relationship between the number of stores and the amount of waste. While grocery stores depict a negative relationship between the amount of stores and the level of waste, we believe that this is due to the nature of the purchases that are taking place at the stores. With these findings in mind, we are aware of several obstacles that we have attempted to overcome in our research.

One problem is that we must aggregate the data on such a large scale because of overlap in the collection area that landfills serve. The smallest unit of observation where we could make sure that the data was a true representation of what was occurring was at the COG level. It would have been much more advantageous for this research if data were collected at the household level at the time of pick up. This would allow for an accurate level of waste to be measured. But this leads to another problem with the data.

We are using municipal solid waste figures from landfill sites instead of actual food waste data. It is difficult to gain an understanding of the exact amount of food waste that can be attributed to the municipal solid waste numbers that are counted. Without a method of tabulating what proportion of food goes into landfills, any estimate derived from other sources has a greater chance of being made in error. However, to the extent that the level of non-food municipal waste is conditionally stable over time, our estimates will be unbiased.

There have been several attempts in multiple states to see exactly what people are throwing into landfills (Bloom, 2011). These are performed by individuals digging through small plots of the landfill and recording every article. This is not only extremely tedious and time consuming; the excavator only looks at a small portion of the landfill so homogeneity of the site must be assumed. These digs are also only a one time snapshot of the landfill site with rare occurrences taking place two times the same year at the same site. While these studies may be effective in realizing what is in the landfill at the current time, a more systematic approach over time would be more beneficial to research such as that conducted in this paper.

This study was restricted to Texas because of the record keeping over time of municipal solid waste data that was made available. This is both advantageous and restrictive as the state has a good mix of both urban and rural towns and cities but it is also the second largest state in both population and land area. Other states with not as much land mass or population may exhibit different waste patterns. It may be also beneficial to examine other states that keep track of waste to see if there are variations in regions.

As the topic of food waste continues to gain momentum, future studies would be well served to examine how food recycling programs affect food waste. Also, an examination into the effects that anaerobic digestion plants have on curbing food waste will be important in the future as they may provide the financial incentive to do something with food waste rather than letting it rot in a landfill.

It is the hope of this researcher that we are able to reduce the amount of food being wasted and sent to landfills. Not only does food waste result in a misallocation of resources directed in agricultural production, but it also is a misuse of finances that could be used in other areas of need.

Many children are told as children to "finish your dinner, there are children starving somewhere in the world who don't have anything to eat". This prodding of a child to finish a plate of vegetables should serve as a reminder that there are actually millions of people who are undernourished in the world, including in developed countries. Food banks and donation centers do a lot to fix this problem, but the perishable nature of food poses logistic problems for a widespread solution.

As the population of the world steadily increases and pundits and policy makers decide on how to fill the bellies of close to 10 billion people, one fact is clear. The present capacity of the global food supply is enough food today to feed a population of that size. It is due to wasting over 30% of that global food supply that has many clamoring for a solution to increase production. While an increase or more efficient means of production may be part of the answer, it is only a portion of the answer. There must be a consorted effort to decrease the vast amounts of food that never finds its way to the dinner table.

The importance of this study is paramount in attempting to understand the reasons why nearly half of the food produced in the world goes uneaten. Once a better understanding has been obtained as to the culprits of food waste, policy makers can attempt to fix the broken method in which the world's population is fed. For example, one policy may be large scale food waste reclamation for anaerobic digestion and the creation of energy. Using the inevitable level of food waste that we refer to a food insurance or slack, will allow for the resources that went into production of the food. While human consumption will always be the primary end result of a food product, being able to recapture the resources used in the form of new energy production will at the very least aid in new energy production. This will not only help to feed a growing population by drawing more attention to the amounts of food waste being created but will also conserve the precious resources that are pumped into production of agricultural products and slow down the rapid release of greenhouse gases into the atmosphere. While any of these reasons stands alone in its capacity to move people into action, it the most obvious reason of all that will probably succeed in serving as the catalyst; it will save a lot of money.

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