# AN EXAMINATION OF HEALTHY FOOD SUPPLY AND DEMAND IN AMERICA'S LOW-INCOME COMMUNITIES

By

Marie Edith Steele-Adjognon

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Agricultural, Food, and Resource Economics —Doctor of Philosophy

2017

## ABSTRACT

AN EXAMINATION OF HEALTHY FOOD SUPPLY AND DEMAND IN AMERICA'S LOW-INCOME COMMUNITIES

By

Marie Edith Steele-Adjognon

Trends in the over consumption of unhealthy foods paired with the under consumption of healthy foods have, in part, led to the current American obesity epidemic. Poor food consumption behavior trends are partly driven by market failures within the food industry. In order to efficiently address these market failures and the obesity crisis, the source of the market failure must be acknowledged and attended to, whether it be the supply side or the demand side or both. The goal of my dissertation is to provide a deeper understanding of low-income US consumers' access to and demand for healthy food in an attempt to help combat the increasing obesity rates in America. Contributing to this goal, my dissertation contains three chapters.

The first chapter models a supermarket chain's decision making process to determine the conditions under which a supermarket chain would enter a food desert, and how interventions and incentives could influence entry. To meet this objective, a game theoretical model is developed. The model shows that supermarket entry will occur once investment costs and marginal costs are low enough for the firms to make positive profits. However, this model also reveals two nuances for initiatives to consider. First, policy interventions do not need to completely subsidize marginal costs. Second, without urgency attached to cost saving initiatives, supermarket chains will continue to wait to follow other supermarket chains into the food desert to avoid facing demand uncertainty.

Demand uncertainty, is further explored in chapters 2 and 3 which analyze the receipt scanner data from an independent supermarket in a predominantly low-income, urban community of Detroit, Michigan with a majority of its customers classified as food desert residents.

The second chapter explores fruit and vegetable demand from the perspective of color, since different colored fruits and vegetables are associated with different health benefits. This novel modified two stage Quadratic Almost Ideal Demand System analysis of fruit and vegetable demand shows that most of the prices and customer shopping behaviors affect the different color purchase decisions. Each color class responds negatively to its own price and positively to fruit and vegetable expenditure increases. The fruit (vegetable) colors are generally complementary to other fruit (vegetable) colors and substitutes to the vegetable (fruit) colors. The elasticities suggest that policy interventions aimed at encouraging diverse fruit and vegetable colors should focus on expenditure based incentives rather than price based incentives and that supermarket chain managers should focus their price discounts on the fruits and vegetables within the yellow/orange fruit and red/blue/purple vegetable classes for the greatest increase in produce profits.

The final chapter offers an evaluation of the nutrition intervention Double Up Food Bucks. To encourage the consumption of more fresh fruits and vegetables, this program provided Supplemental Nutrition Assistance Program beneficiaries who spent $10 on fresh fruits and vegetables, in one transaction, with a $10 gift card exclusively for Michigan grown fruits and vegetables. This study analyzes how fruit and vegetable purchase behaviors were affected by the initiation and conclusion, as well as any persistent effects, of the program, using a difference in difference fixed effects estimation strategy. Participation is low; however, the program increased vegetable expenditures, fruit and vegetable expenditure shares, and the variety of fruits and vegetables purchased during its implementation, but the effects are modest and not sustainable without the financial incentive.

Together, these essays shed light on important considerations for initiatives aimed at improving nutrition and health in urban food deserts.

Copyright by
MARIE EDITH STEELE-ADJOGNON
2017

I dedicate this dissertation to my mother, Donna Steele, and my late father, Robert Steele. Thank you for your constant love, support and encouragement, and for all the sacrifices you made so that I could pursue my education. You both taught me the virtues of hard work and perseverance and I hope this accomplishment will serve as an expression of my eternal gratitude.

## ACKNOWLEDGEMENTS

First, I thank my major professor, Dr. Dave Weatherspoon, for the invaluable time he spent guiding me through the process. His availability, encouragement, and support both academically and personally made every step of my PhD experience memorable and enjoyable. I would also like to thank the other members of my committee, Dr. Robert Myers, Dr. Lorraine Weatherspoon, Dr. Arijit Mukherjee and the late Dr. David Schweikhardt for their advice and help throughout this project. I feel extremely privileged and honored to have had the opportunity to work with this committee.

Next, I would like to thank all the friends that I met during my time at Michigan State University. I am happy to say that I gained many friends during the program, who enabled me to keep a balanced lifestyle throughout my PhD program. I am particularly grateful for Hamza Haider, Awa Sanou and Joshua Gill.

I would like to give a special thanks to my husband and best friend, Serge Adjognon. I could not have done this without your constant love and motivation. You always push and inspire me to achieve my full potential.

Finally, I would like to recognize my mother, Donna Steele, and my sister, Kimberly Steele who encouraged me to apply to graduate school and supported me throughout the whole program.

## TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

## KEY TO ABBREVIATIONS

| | |
|---|---|
| AIDS | Almost Ideal Demand System |
| CRE | Correlated Random Effects |
| DD | Difference in Difference |
| DUFB | Double Up Food Bucks |
| F&V | Fruits and vegetables |
| HFFI | Healthy Food Financing Initiative |
| ITT | Intention to Treat |
| MSNE | Mixed Strategy Nash Equilibrium |
| PSNE | Pure Strategy Nash Equilibrium |
| QUAIDS | Quadratic Almost Ideal Demand System |
| SNAP | Supplemental Nutrition Assistance Program |
| USDA | United States Department of Agriculture |
| WIC | Women, Infants and Children |

# INTRODUCTION

Trends in the over consumption of unhealthy foods paired with the under consumption of healthy foods have, in part, led to the current American obesity epidemic. High obesity rates lead to high incidence rates of chronic diseases, high healthcare costs and high premature death and disability rates. Poor food consumption behavior trends are partly driven by market failures within the food industry. In order to efficiently address these market failures and the obesity crisis, the source of the market failure must be acknowledged and attended to, whether it be the supply side or the demand side or both. Though the association between the low demand and the low supply of healthy foods in low income communities is evident, it is unclear whether the lack of supply is causing low demand or if low demand is causing lack of supply. If the supply side is the source (e.g. operational costs too high to be profitable), then business financial incentives offered to the supermarket chains to incentivize entry are a viable solution. However, if market failure exists on the demand side (e.g. lack of nutrition education or financial resources), then nutrition education interventions and/or the Supplemental Nutrition Assistance Program benefit policies need to be adjusted. The goal of my dissertation is to provide a deeper understanding of low-income US consumers' access to and demand for healthy food in an attempt to help combat the increasing obesity rates in America. Contributing to this goal, my dissertation contains three chapters.

The first chapter, titled "A Theoretical Approach to Supermarket Chain Investment in Urban Food Deserts", explores supermarket entry decisions into an urban food desert. Over the past 30 years, food retail environments have changed, from many small grocery stores widely dispersed, to big supermarket chains concentrated in suburban areas, leading to food deserts developing in low-income urban communities. Policymakers have passed bills at the national, state, and local levels that finance initiatives to help improve the availability and quality of healthy

foods in low-income communities; however, food deserts remain a great concern. There are several reasons why supermarket chains may be reluctant to locate in food deserts, despite the increasing social and political pressure. This study models a supermarket chain's decision making process to determine the conditions under which a supermarket chain would enter a food desert, and how interventions and incentives could influence entry. To meet this objective, a game theoretical model is developed. The model shows that supermarket entry will occur once investment costs and marginal costs are low enough for the firms to make positive profits. However, this model also reveals two nuances for initiatives to consider. First, policy interventions do not need to completely subsidize marginal costs. The incentive has to be large enough for one supermarket to enter because if one supermarket enters and demand is favorable, then others will follow. Second, cost advantages given only to supermarket chains that invest early in food deserts are effective at speeding up entry. Without the urgency attached to cost saving initiatives, supermarket chains will continue to wait to follow other supermarket chains into the food desert to avoid facing demand uncertainty.

Demand uncertainty, that was found in Chapter 1, is further explored in chapters 2 and 3 which analyze the receipt scanner data from an independent supermarket in a predominantly Hispanic, low-income, urban community of Detroit, Michigan with a majority of its customers classified as food desert residents.

The second chapter, titled "Fruit and Vegetable Demand by Color", explores fruit and vegetable demand from the perspective of color, since different colored fruits and vegetables are associated with different health benefits. The nutrition and public health communities have researched fruit and vegetable colors extensively and the United States Department of Agriculture promotes fruit and vegetable consumption based on colors. However, the economics literature has

yet to explore the demand for the different fruit and vegetable colors, even though this could lead to many useful policy and business management insights. Fruit and vegetable color classification is a method of translating the science of phytochemical nutrition into dietary guidelines that the public can understand. There are different vitamins, minerals and phytonutrients contained in different colored fruits and vegetables, each associated with their own health benefits. This novel modified two stage Quadratic Almost Ideal Demand System analysis of fruit and vegetable consumer demand, based on four color classes: green, white, red/blue/purple and yellow/orange, shows that most of the prices and customer shopping behaviors affect the different fruit and vegetable color purchase decisions. Each color class responds negatively to its own price and positively to fruit and vegetable expenditure increases, in accordance with economic theory. The fruit (vegetable) colors are generally complementary to other fruit (vegetable) colors and substitutes to the vegetable (fruit) colors. The elasticities suggest that policy interventions aimed at encouraging diverse fruit and vegetable colors should focus on expenditure based incentives rather than price based incentives and that supermarket chain managers should focus their sales (price discounts) on the fruits and vegetables within the yellow/orange fruit and red/blue/purple vegetable classes for the greatest increase in produce profits.

The final chapter, titled "Double Up Food Bucks Program Effects on SNAP Recipients' Fruit and Vegetable Purchases", offers an evaluation of the nutrition intervention Double Up Food Bucks. To encourage the consumption of more fresh fruits and vegetables, the 2014 United States Farm Bill allocated funds to the Double Up Food Bucks Program. This program provided Supplemental Nutrition Assistance Program beneficiaries who spent $10 on fresh fruits and vegetables, in one transaction, with a $10 gift card exclusively for Michigan grown fresh fruits and vegetables. This study analyzes how fruit and vegetable expenditures, expenditure shares, variety

and purchase decisions were affected by the initiation and conclusion, as well as any persistent effects, of the program, using a difference in difference fixed effects estimation strategy. Participation was extremely low; however, the program increased vegetable expenditures, fruit and vegetable expenditure shares, and the variety of fruits and vegetables purchased during its implementation, but the effects are modest and not sustainable without the financial incentive. Fruit expenditures and the fruit and vegetable purchase decision are unaffected by the program. This study provides valuable insight on how this nutrition program affects a low-income, urban, Hispanic communities' fruit and vegetable purchase behaviors. Policy recommendations include removing or lowering the purchase hurdle for incentive eligibility and dropping the Michigan grown requirement to better align with the customers' preferences for fresh fruits and vegetables.

Together, these essays shed light on important considerations for initiatives aimed at improving nutrition and health in urban food deserts as well as for supermarkets located in or considering entry in urban food deserts.

# CHAPTER 1: A THEORETICAL APPROACH TO SUPERMARKET CHAIN INVESTMENT IN URBAN FOOD DESERTS

## Introduction

A key factor in the success of a retail firm is the location of its stores. The distance stores are from their distribution channels, competitors and customers all affect their demand, costs and profits. Over the past 30 years, food retail environments have changed, from many small, independent grocery stores widely dispersed in cities and suburbs to big supermarkets concentrated in suburban areas (Blanchard and Matthews, 2007). This has led to urban food deserts[1] developing in many low-income communities throughout the United States. Research on food deserts emphasize how limited access affects a community's food purchasing behaviors and health, which has in turn led to growing interest in how to address food desert challenges (Walker et al., 2010, Ball et al., 2009, Dubowitz et al., 2015).

Policymakers have passed bills at the national, state, and local levels that finance initiatives to help improve the availability and quality of healthy foods in low-income communities. In 2010, the Healthy Food Financing Initiative (HFFI), a key national program aimed at improving access of healthy food in food desert communities, was passed. It was the federal government's first coordinated effort to address the issue of food deserts through business incentives (CDFI, 2017). The Community Development Financial Institutions fund within the United States Department of Treasury, in collaboration with the United States Department of Agriculture (USDA) and Department of Health and Human Services, supplement private sector capital with federal money to tackle economically distressed communities (CDFI, 2017). Over $197 million has been

[1] The USDA defines an urban food desert as a low income (poverty rate of 20% or higher) urban area where at least one third of the population resides more than a mile away from a supermarket (FNS 2016).

allocated in underserved communities across 35 states through HFFI initiatives since 2011. Some examples of funded initiatives are the: Pennsylvania Fresh Food Financing Initiative; New Jersey Food Access Initiative; Michigan Good Food Fund; New Orleans Fresh Food Retailer Initiative; and Healthy Food for Ohio (PolicyLink, 2017). These initiatives offer a variety of technical assistance and financial products and services for firms investing in healthy food retail and systems in disadvantaged communities. HFFI helps attract investment into food deserts through providing one-time financing to help overcome the large initial barriers of entry and offering favorable financial loan terms with lower interest rates, longer maturities and other more flexible terms than what traditional banks offer (CDFI, 2017). Other incentives used to increase investment in food deserts involve tax breaks, zoning bonuses, or an expedited approval processes. Despite all these efforts, roughly ten percent of the 65,000 census tracts in the United States and 11.5 million low-income people are living in areas that are classified as food deserts (FNS, 2016b, Ver Ploeg et al., 2009).

In 2011, as part of the healthy eating initiative, major supermarket chains promised to open stores in or around food desert communities by 2017; however, many still have yet to invest (AssociatedPress, 2017). There are several reasons why supermarkets may be reluctant to locate in urban food deserts, despite the increasing social and political pressure. Market size and demand potential are key determinants in retail location decisions and the lack of supermarket demand history within in food deserts increases the risk of demand uncertainty. There is a common perception that consumer demand for healthy foods is low in food desert areas (Andreyeva et al., 2011a). One explanation for this is that healthy foods are generally classified as normal or superior goods so they will be demanded more as income increases, which is rarely the case in food desert communities (Bitler and Haider, 2011). Another explanation is that these consumers have adjusted

to not having a supermarket nearby and are accustomed to not buying and preparing healthy meals at home and prefer quick meals offered at convenience stores and fast food restaurants. The higher prices of healthy foods in food desert communities, making acquiring healthy food options even harder, further stimulates the perception of the residents' low healthy food demand (Mui et al., 2015). Supermarkets also look for population growth in their potential investment locations for long term returns on their investment and food desert communities often have declining or aging populations (Morton and Blanchard, 2007). These factors, along with other demand side factors like high racial minority composition, unemployment rates, poverty, and crime rates, paired with low education levels and vehicle availability within food deserts make them non-traditional retail environments for supermarket chains (Dutko et al., 2012).

There are also supply side factors that make food deserts less attractive to supermarkets. Logistic and distribution networks tend to be less developed in food desert communities, which leads to high sourcing costs for supermarket chains (Bonanno, 2012). The costs associated with training employees, security, construction and upkeep, and property tax rates are all higher in urban areas than the suburbs (Karpyn et al., 2010). Also in low-income urban areas, large parcels of land are scarce, making customer parking, and loading and unloading by distribution trucks more difficult compared to suburban communities (Pothukuchi, 2005). Lastly, many communities that are underserved by supermarkets also lack the amenities and services needed to attract and retain retail investment, such as sidewalks, lighting and good public transportation networks (Pothukuchi, 2005).

There are potential benefits of operating a supermarket in a food desert. Underserved markets can serve as a supermarket chain strategy to maintain their corporate growth while confronting supermarket saturation in suburban communities (Hagan and Rubin, 2013). Since low-

income urban residents spend money on groceries outside of the city limits, there is unmet demand within the inner cities (Pothukuchi, 2005). Upon entry into a food desert, a supermarket chain faces minimal competition for healthy food sales given that small convenience and corner stores lack the refrigeration and equipment necessary to stock and sell a variety of healthy foods. As a monopoly in the food desert, the supermarket could take advantage of the higher food prices often found in food deserts (Howlett et al., 2015, LeClair and Aksan, 2014). This implies that despite the greater risk associated with operating in a food desert, there is potential for increased long-term profit.

The United States supermarket industry is classified as a natural oligopoly (Ellickson, 2013); therefore, game theory is useful for modelling the firms' strategic decisions with interdependent choices. Many studies have applied game theory to analyze firm entry decisions into new markets, and even supermarket entry decisions, e.g. (Ellickson, 2007, Rob, 1991, Folta and O'Brien, 2004, Smit and Ankum, 1993); however, there remains a gap in the literature on supermarket strategic entry into food desert markets.

## Objective

This study models the conditions under which supermarket chains would enter food deserts, and how interventions and incentives could influence entry. The game theory model developed expands Folta et al. (2006), Kulatilaka and Perotti (1998) and Rob (1991), to supermarket chain entry in food deserts. The next section presents the game theoretic model, and the following section offers a discussion of the implications derived from the game.

**Model Formation**

The players of the game are two supermarket chains[2] that are able to open a store in a food desert. Both supermarket chain players currently have no stores located in the food desert. The food retail industry is highly concentrated (Wood, 2013), suggesting that the economies of scale (operational costs per unit declines as the store size increases) and scope (operational costs per unit declines with an increase in the diversity of products) are significant factors in this environment. Small grocery and convenience stores struggle to sell the variety and quality of healthy, perishable foods at competitive prices. Hence, only supermarket chains are considered in this analysis since they typically offer lower priced, higher quality goods and can supply an extensive assortment of fresh, nutritious food at competitive prices year round.

The two time period model can be easily extended to incorporate more potential entrants as well as infinite time, but a two player, two-time period game is analyzed for simplification.

Consumer Demand

Consumer demand for supermarket offerings follows a linear inverse demand function:

$$P(Q, \theta) = \theta - Q$$

where $\theta$ represents the demand intercept and is the unknown component of demand (Kulatilaka and Perotti, 1998, Zhu and Weyant, 2003). $\theta$ is a random variable drawn from a Uniform (0, 1) distribution, implying that every possible outcome has an equal likelihood of occurring. Healthy food demand has a high amount of uncertainty in food deserts. Without any supermarket chains in these communities, there is a lack of data to examine and evaluate market opportunity (Coleman

[2] A supermarket chain consists of 11 or more stores that offer a full line of groceries, meat, and produce with at least $2 million in annual sales per store and up to 15% of their sales coming from general merchandise and health/beauty care. Typically, each store carries between 15,000 to 60,000 stock keeping units and offers a service deli, a service bakery, and/or a pharmacy (FMI, 2016).

et al., 2011). The only potential reference available is the limited sales of healthy (and unhealthy) foods at the corner stores located in the food desert. However, these small stores have much higher costs associated with stocking and selling healthy foods than a supermarket chain would if they entered (Andreyeva et al., 2011b, Walker et al., 2010).

Another aspect of demand uncertainty is projecting future demand. Supermarket chains can increase demand in two major ways. First by accommodating the consumer base. Many supermarkets that have entered food desert communities have become profitable through adjusting their services offered to meet the needs of the community (e.g. offering nutrition education, opening earlier and staying open later, hiring bi-lingual service associates etc.). These service additions and adjustments are different than what they typically offer in their store locations outside of the food desert; hence, the chains are unsure how the consumers will respond. Second, supermarkets often serve as "anchors" for other businesses since they generate foot traffic and attract complementary stores and services like banks, pharmacies, and restaurants (Treuhaft and Karpyn, 2010). Successful supermarket operation in low income communities can drastically change the perception of the area as being an undesirable location to operate a business or to live (Treuhaft and Karpyn, 2010).

Neither supermarket knows the true value of $\theta$ in period 1. However, if one or both supermarket chains enter the food desert in period 1, $\theta$ is revealed to both in the second period. In reality, demand is not completely revealed to all competitors upon a chain's entry; however, this assumption captures the fact that once one supermarket chain enters a food desert, that community no longer represents a unique risk in terms demand uncertainty.

Branding and product differentiation could provide competitive advantages to supermarket chains. Some supermarket chains strategically decide to vertically differentiate themselves

(through offering more services or higher quality products) so they can reduce price competition and attain higher profits from less price sensitive consumers. However, food desert residents are often price sensitive, particularly to fruits and vegetables (Weatherspoon et al., 2015, Weatherspoon et al., 2013) so these types of supermarket chains are less likely to consider food desert investment (Bonanno, 2012). Also in uncertain environments, like food deserts, competitive advantages are seldom sustainable in the long run (Sirmon et al., 2007). For these reasons and the fact that food quality aspects are not as important as the accessibility aspect in these communities, this analysis assumes that supermarket chains' offerings are homogenous. Another assumption is that both supermarket chains have the same knowledge about the food desert community and that any feasible site provides both chains with an equivalent market potential.

Policy

There are different ways that the government (local, state or federal) can address the food desert problem. The government could open and operate stores in food desert communities. The government could also design rules to mandate entry into food deserts, such as prerequisites to opening more stores in non-food desert communities, store owners must open a store in a food desert community as well. Targeting specific supermarket chains with high likelihoods of being successful in inner-city markets is another way government can attempt to improve these food environments (Bassford et al., 2010). Alternatively government can align the supermarkets' business objectives with food desert entry through business financial incentives (Karpyn et al., 2010, Bassford et al., 2010), which is what is modelled here, through a marginal cost advantage associated with early food desert entry.

The dominant marginal operating costs supermarkets face come from purchasing the

goods, distributing the goods, and paying the store workers. Some other examples of marginal costs for a supermarket are insurance, rent, marketing, interest on loans and taxes. This model assumes that there is a policy initiative in place to reward early investment with cheaper marginal costs through a decrease in any of these marginal costs the supermarket faces. The model captures this marginal cost advantage by rewarding early investment (i.e. in period 1) with lower marginal costs later (in period 2). Both supermarket chains face the same cost schedule and there are two marginal costs possible: $\overline{c}$ and $\underline{c}$; where $\underline{c} = \overline{c} - \Delta c$.[3] If a supermarket chain enters the food desert in period 1 it will face higher costs, $\overline{c}$, in the first period but will face lower costs, $\underline{c}$, in the second period. If a supermarket chain enters the food desert in the second period it will face higher costs, $\overline{c}$. Both supermarket chains face the same investment costs (i.e. fixed costs), $\Phi$, no matter which period they enter.

Game Timeline

In period 1, both supermarket chains simultaneously decide whether to enter or not.

- If any one firm enters, $\theta$ is revealed and the entrant will receive a cost advantage in period 2.
- If both firms enter, they compete a la Cournot.[4]
- If only one firm enters, it enjoys monopoly power for that period.

In period 2, the game depends on the investment history in period 1.

[3] The cost advantage ($\Delta c$) is only defined on $[0, \overline{c}]$. $\Delta c$ cannot be less than 0 because it would be a cost disadvantage rather than a cost advantage and $\Delta c$ cannot be greater than $\overline{c}$ because then $\underline{c}$ would be negative.

[4] Cournot competition is where rival firms choose a quantity to produce independently and simultaneously under the assumptions that firms cannot collude. Firms seek to maximize profit based on their competitors' decisions and each firm's quantity decision affects the product's market price. Cournot competition is used in this analysis rather than Bertrand competition (based on prices) because the Bertrand model makes the strong assumption that consumers will always buy from the cheapest seller but in these communities most consumers face travelling constraints which limit their ability to search multiple locations for the lowest food prices.

- If no firm entered in period 1, both firms simultaneously decide whether to enter or not. θ still uncertain and no cost advantages exist since no firm entered in period 1.
- If both firms entered in period 1, they continue to compete a la Cournot but now have lower marginal costs, $\underline{c}$.
- If exactly one firm entered in period 1, the other firm first decides whether to enter or not based on the revealed θ (but faces the higher marginal costs, $\overline{c}$). The leader observes the follower's decision and a quantity competition follows.
    - If the follower does not enter, the leader continues to have monopoly power and lower marginal costs, $\underline{c}$.
    - If the follower enters, the two firms compete a la Cournot.

**Analysis**

The supermarket chain's action sets are to open a store in a food desert (invest) or not (do not invest). The disadvantages of deferment are the missed potential profits while not invested and the missed opportunity for cheaper costs later. The advantages of deferment are that they can learn more about market demand from observing the first firm and use that knowledge to decide whether to invest or not. Once a supermarket chain has invested, then its action is to choose quantity. Both supermarket chains make decisions to maximize their expected total profit.

Supermarkets operate on thin profit margins (roughly 1% on average), especially on perishable food items (Hagan and Rubin, 2013, FMI, 2016). The profit for each supermarket chain depends on whether they are invested, the other firm has invested, and market demand. If both supermarket chains are operating in the food desert at time t, they will share duopoly profits of Cournot competition. Duopoly profit is dependent on the costs that both supermarket chains are

facing. If both supermarket chains have the same cost (c) at time t, then the duopoly profit for supermarket i in period t is,

$$\pi_{it}^{D}\left(c_i, c_j\right) = \pi_{it}^{D}\left(c, c\right) = \left(\frac{\theta - c}{3}\right)^2.$$

However, if supermarket i faces the lower cost, $\underline{c}$, and supermarket j faces the higher cost, $\overline{c}$, at time t, then the two duopoly profits are:

$$\pi_{it}^{D}\left(c_i, c_j\right) = \pi_{it}^{D}\left(\underline{c}, \overline{c}\right) = \left(\frac{\theta + \overline{c} - 2\underline{c}}{3}\right)^2 \text{ and,}$$

$$\pi_{jt}^{D}\left(c_i, c_j\right) = \pi_{jt}^{D}\left(\underline{c}, \overline{c}\right) = \left(\frac{\theta + \underline{c} - 2\overline{c}}{3}\right)^2.$$

When there is sequential entry, one supermarket chain invests in period 1 (leader) and the other does not (follower). While the follower is outside the food desert, the leader is a monopoly within the food desert, earning the following monopoly profit,

$$\pi_{it}^{M}(c) = \left(\frac{\theta - c}{2}\right)^2.$$

Table 1.1 lists the different notation used throughout the game and the analysis. Since the game is completely symmetric (from the homogeneous supermarket assumption) all the equilibria will also be symmetric for both supermarket chains.

**Table 1.1: Game Notation**

| Symbol | Description |
|---|---|
| $\Delta c$ | cost advantage from investing early |
| $\underline{c}$ | low marginal cost |
| $\overline{c}$ | high marginal cost |
| $\Phi$ | investment costs |
| $\pi_{it}^{D}(c_i, c_j)$ | profit for supermarket i in period t when both supermarkets are in the food desert and supermarket i is facing costs $c_i$ and supermarket j is facing costs $c_j$ |
| $\pi_{it}^{M}(c)$ | profit for supermarket i in period t when they are the only supermarket in the food desert and they are facing marginal costs c |
| $\theta$ | demand parameter |
| $\hat{\theta}$ | minimum demand needed for follower entry |
| r | probability of entry in the first period |
| s | probability of entry in the second period given that no other supermarket has invested yet |
| t | probability that the follower supermarket will invest in the food desert in the second period given that the leader already has and $\theta$ has been revealed |

Characterization of Period 2 Subgames

The characterization of the second period subgames depends on who entered in the first period. The following three lemmas illustrate the three possible cases.

**Lemma 1** *If both supermarket chains entered in the first period, in the second period they will simultaneously compete a la Cournot with low costs. Their second period payoffs are:*

$$\left(E\left[\pi_{i2}^{D}(\underline{c},\underline{c})\right], E\left[\pi_{j2}^{D}(\underline{c},\underline{c})\right]\right).$$

**Explanation:** When both supermarket chains invested in period 1, both are still invested in period 2 (exiting is not an option in the model), but now both will compete a la Cournot while facing low marginal costs.

**Lemma 2** *If exactly one supermarket chain entered in period 1, the entry game in period 2 always has a unique Pure Strategy Nash Equilibrium (PSNE). There exists a cutoff value of demand, denoted* $\hat{\theta}$, *such that:*

*(a) If* $0 \leq \theta < \hat{\theta}$, *the follower will not enter, yielding the second period (leader, follower) payoffs of (*$E\left[\pi_{i2}^{M}(\underline{c}) \mid \theta\right], 0$*);*

*(b) If* $\hat{\theta} \leq \theta \leq 1$, *the follower firm will enter, yielding the second period (leader, follower) payoffs of (*$E\left[\pi_{i2}^{D}(\underline{c}, \overline{c}) \mid \theta\right], E\left[\pi_{j2}^{D}(\underline{c}, \overline{c}) \mid \theta\right] - \Phi$*).*

*Where* $\hat{\theta}$ *is defined as the value of* $\theta$ *that makes the follower indifferent to entry, i.e. when*

$$E\left[\pi_{j2}^{D}(\underline{c}, \overline{c}) \mid \hat{\theta}\right] - \Phi = 0.$$

**Explanation:** Once a supermarket chain has invested, the true demand is revealed and the follower supermarket chain will base their entry decision on whether expected profit will be positive. If the follower does not enter, the leader supermarket chain will remain a monopoly with low costs. If the follower does enter, both will get duopoly profit where the leader faces low costs and the follower faces high costs.

**Lemma 3** *If no entry has taken place in period 1, the entry game in period 2 always has a unique Nash equilibrium. There exist two entry cost cutoff values,* $\underline{\Phi}$ *and* $\overline{\Phi}$, *such that:*

*(a) If* $0 \leq \Phi < \underline{\Phi}$, *both supermarket chains invest;*

*(b) If* $\underline{\Phi} \leq \Phi < \overline{\Phi}$, *both supermarket chains use mixed strategies where each enters with probability*

$$s = \frac{9\,(1 - 3\overline{c} + 3\overline{c}^2 - 12\Phi)}{5\,(1 - 3\overline{c} + 3\overline{c}^2)};$$

*(c) If* $\Phi \geq \overline{\Phi}$, *neither supermarket chain invests.*

Table 1.2 provides the normal form representation of this subgame where each cell reveals the expected second period profit for the supermarket chains' actions which are dependent on the other supermarket chain's action. Appendix A provides the derivations of $\underline{\Phi}$ and $\overline{\Phi}$.

**Table 1.2: Normal Form Game Representation of Period 2 After No Entry in Period 1**

| | | s | **j** | (1-s) |
|---|---|---|---|---|
| | | **Invest** | | **Do Not Invest** |
| s | **Invest** | $E\left[\pi_{i2}^{D}(\overline{c},\overline{c})\right] - \Phi$<br>$E\left[\pi_{j2}^{D}(\overline{c},\overline{c})\right] - \Phi$ | | $E\left[\pi_{i2}^{M}(\overline{c})\right] - \Phi$<br>0 |
| **i** | | | | |
| (1-s) | **Do Not Invest** | 0<br>$E\left[\pi_{j2}^{M}(\overline{c})\right] - \Phi$ | | 0<br>0 |

**Explanation:** When investment costs are low enough, entry is profitable even though they must split the market and demand is still unknown, leading to a PSNE with simultaneous period 2 entry. When investment costs are moderate and demand is still unknown (no supermarket investment) it

is profitable for one supermarket chain to enter but not both, leading to a Mixed Strategy Nash Equilibrium (MSNE) where $0 < s < 1$. When investment costs are too high it is not profitable for either supermarket chain to enter, even if it would be a monopoly in the food desert, leading to a PSNE of no entry in period 2.

Characterization of Period 1

Table 1.3 shows the normal form representation of the game. Each cell reveals the total profit (over both periods) for the supermarket's actions which are dependent on its rival's action.

**Table 1.3: Normal Form Game Representation of Period 1**

| | | r | **j** | (1-r) |
|---|---|---|---|---|
| | | **Invest** | | **Do Not Invest** |
| r | **Invest** | $E\left[\pi_{i1}^{D}(\bar{c},\bar{c}) + \pi_{i2}^{D}(\underline{c},\underline{c})\right] - \Phi$<br><br>$E\left[\pi_{j1}^{D}(\bar{c},\bar{c}) + \pi_{j2}^{D}(\underline{c},\underline{c})\right] - \Phi$ | | $E\left[\pi_{i1}^{M}(\bar{c})\right] + E\left[\pi_{i2}^{D}(\underline{c},\bar{c}) \mid \theta > \hat{\theta}\right](1-\hat{\theta}) + E\left[\pi_{i2}^{M}(\underline{c}) \mid \theta \leq \hat{\theta}\right]\hat{\theta} - \Phi$<br><br>$E\left[\pi_{j2}^{D}(\underline{c},\bar{c}) - \Phi \mid \theta > \hat{\theta}\right](1-\hat{\theta})$ |
| **i** | | | | |
| (1-r) | **Do Not Invest** | $E\left[\pi_{i2}^{D}(\bar{c},\underline{c}) - \Phi \mid \theta > \hat{\theta}\right](1-\hat{\theta})$<br><br>$E\left[\pi_{j1}^{M}(\bar{c})\right] + E\left[\pi_{j2}^{D}(\bar{c},\underline{c}) \mid \theta > \hat{\theta}\right](1-\hat{\theta}) + E\left[\pi_{j2}^{M}(\underline{c}) \mid \theta \leq \hat{\theta}\right]\hat{\theta} - \Phi$ | | $s^2\left(E\left[\pi_{i2}^{D}(\bar{c},\bar{c})\right] - \Phi\right) + s(1-s) * \left(E\left[\pi_{i2}^{M}(\bar{c})\right] - \Phi\right)$<br><br>$s^2\left(E\left[\pi_{j2}^{D}(\bar{c},\bar{c})\right] - \Phi\right) + s(1-s) * \left(E\left[\pi_{j2}^{M}(\bar{c})\right] - \Phi\right)$ |

**Proposition:** *Characterization of the Subgame Perfect Nash Equilibrium*

*The entry game in the first period always has a unique Nash Equilibrium and it is characterized as follows. For a given* $\Phi$*, there exist two cutoff values of* $\Delta c$*, denoted as* $\underline{\Delta c(\Phi)}$ *and* $\overline{\Delta c(\Phi)}$*, such that:*

*(a) If* $\Delta c > \overline{\Delta c(\Phi)}$*, both supermarket chains invest;*

*(b) If* $\underline{\Delta c(\Phi)} \leq \Delta c < \overline{\Delta c(\Phi)}$ *both supermarket chains use mixed strategies where each enters with probability r;*

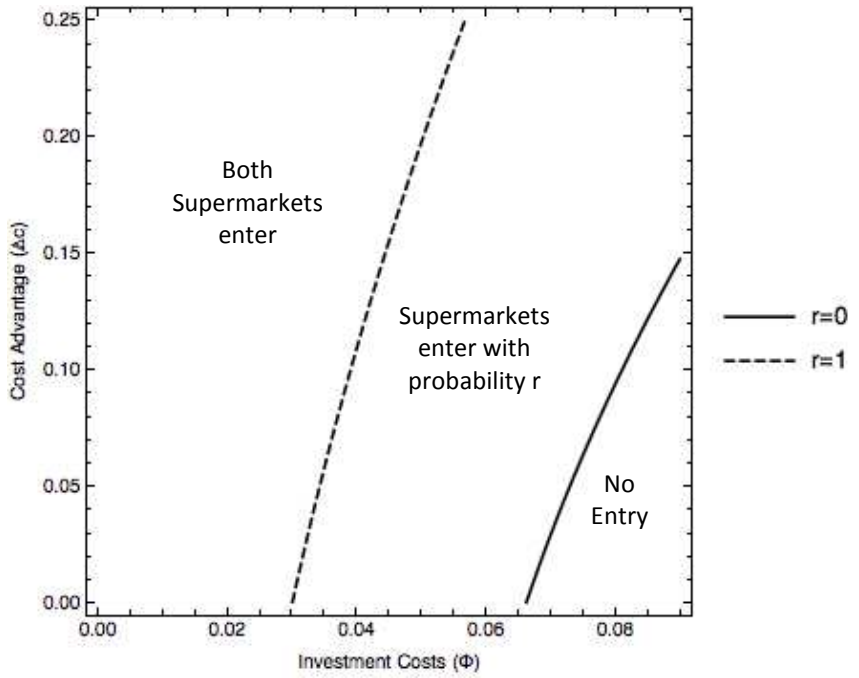
*(c) If* $\Delta c < \underline{\Delta c(\Phi)}$*, neither supermarket chain invests.*

See Appendix A for derivation of r, $\underline{\Delta c(\Phi)}$ and $\overline{\Delta c(\Phi)}$ values.

**Explanation:** For a given investment cost, there exists a cost advantage, $\overline{\Delta c(\Phi)}$, such that if the cost advantage is greater, then it is profitable for both supermarkets to enter in period 1, even with uncertain demand. If the cost advantage is between $\underline{\Delta c(\Phi)}$ and $\overline{\Delta c(\Phi)}$ then it is only profitable for one supermarket to enter in period 1 with uncertain demand; so, both supermarket chains will play a MSNE. If the cost advantage is less than $\underline{\Delta c(\Phi)}$, then it is not profitable for a supermarket chain to invest even with first period monopoly power. As the cost advantage increases, it becomes more profitable to invest early, despite the uncertainty of demand. The cost advantage cutoff values depend on the investment costs because the investment costs directly and indirectly (through its influence on whether the other chain will enter or not) influence profits. These cutoff values are when the probability of profitability is high enough or low enough to determine entry (i.e. when r = 0 and when r = 1). Figure 1.1 plots $\Phi$ against $\Delta c$ for the case where $\overline{c} = 0.25$ and distinguishes the different regions of entry in period 1. The figure shows that unless the cost advantage is very

low and investment costs are high, both supermarkets will invest in period 1 with a positive probability.

**Figure 1.1: Period 1 Investment Decisions**




Note: high marginal cost = 0.25 is assumed.[5]

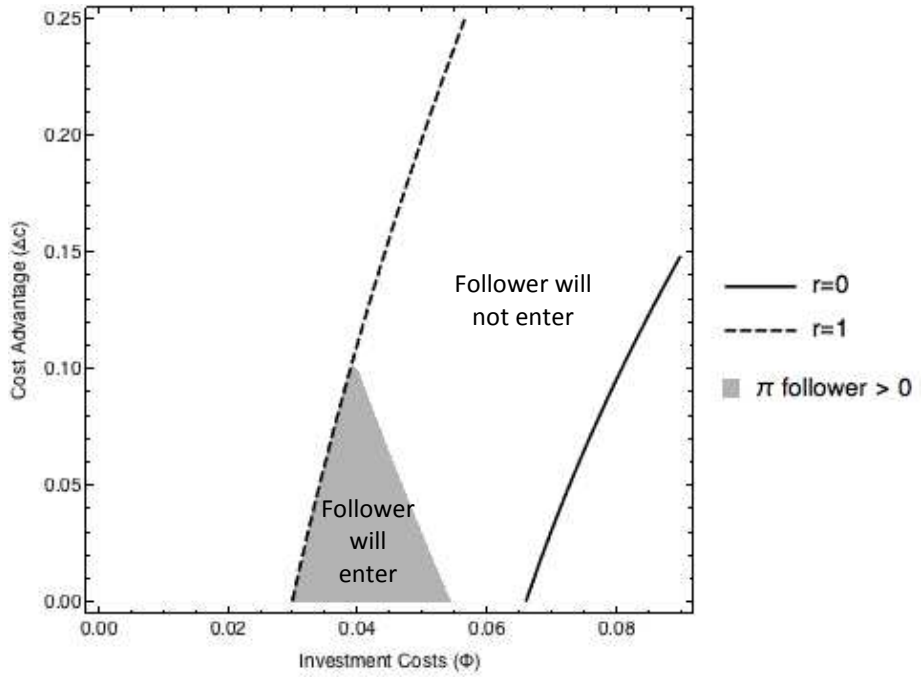
Figure 1.2 is the same as Figure 1.1 but with an additional shaded area, to distinguish the follower's entry decision once the true demand has been revealed ($\theta = 0.9$). Follower profits are dependent on the cost advantage indirectly because the leader has the cost advantage which enables them to increase their supply cheaper than the follower, so as the cost advantage increases, the follower is more disadvantaged (lower profit potential all else equal). Hence, as the investment

[5] Throughout the graphical analysis, the value $\bar{c} = 0.25$ was fixed; however, the analysis is not sensitive to the fixed $\bar{c}$ value; similar relationships exist across $\bar{c} \in (0,1)$. The domain for $\Phi$ was chosen so that all possible equilibrium cases would be shown, but $\Phi \geq 0$ since investment costs cannot be negative.

costs increase, the cost advantage needs to decrease in order for the follower to enter. When the true demand is known, the follower will enter when the cost advantage is low enough and the investment costs are low enough for them to be profitable.

Figures 1.1 and 1.2 show that even with moderate cost advantages from early entry, low investment costs and favorable demand, a food desert may still exist, due to the mixed strategy (enter with probability r) both supermarkets will play in period 1.

**Figure 1.2: Follower Investment Decision**




Note: high marginal costs = 0.25 and demand parameter = 0.9 are assumed.

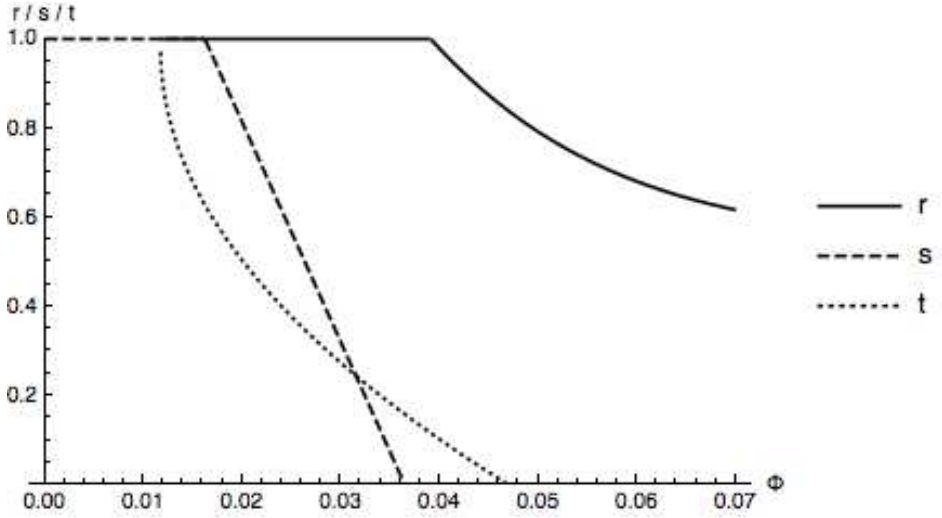
Examination of Entry Probabilities

There are three key probabilities in this analysis. First, the probability that a supermarket chain will invest in the food desert in the first period (r). Second, the probability that a supermarket

chain will enter in the second period given that there was no entry in the first period (s). Lastly, if one supermarket chain invests in period 1, the probability that the follower supermarket chain will enter the food desert (t).

Figure 1.3 displays how changes in investment costs (Φ) affect the three entry probabilities with fixed $\bar{c} = 0.25$ and $\Delta c = 0.1$.[6] All three probabilities decrease as the investment costs increase, the second period entry probability following no entry (s) decreases at a constant rate while the probability of first period entry (r) and sequential entry after the leader (t) decrease at a decreasing rate. Both probabilities of second period entry (s and t) become 0 over the possible

**Figure 1.3: Investment Cost Effect on the Entry Probabilities**



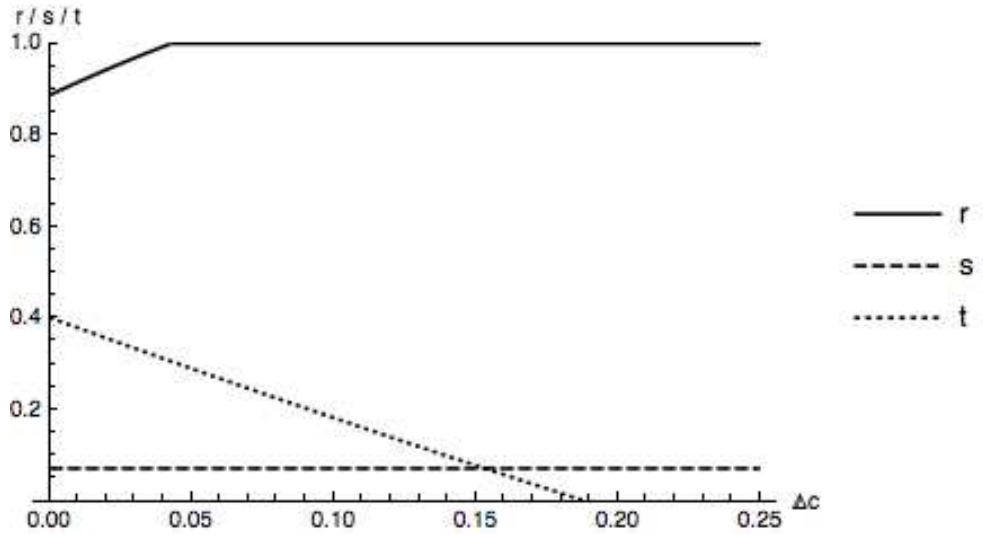

Note: r is the first period entry, s is the second period initial entry, and t is the sequential entry after leader, with fixed high marginal costs = 0.25 and delta c = 0.1.

investment costs; however, the probability of sequential entry (t) reaches 0 at a higher investment cost value than the probability of late entry after no entry (s). This implies that supermarket chains

[6] The variable values used for the figures are chosen for figure appearance, however the key relationships among the variables and analysis are not sensitive to these values.

are willing to accept higher investment costs in the second period if they are not among the first to invest, since the demand uncertainty is resolved.

**Figure 1.4: Cost Advantage from Early Investment Effect on the Entry Probabilities**




Note: r is the first period entry, s is the second period initial entry, and t is the sequential entry after leader, with fixed c = 0.25 and investment costs = 0.035.

Figure 1.4 displays how changes in the cost advantage from early investment (Δc) affect the three entry probabilities with fixed $\bar{c} = 0.25$ and $\Phi = 0.035$. As the cost advantage from early investment increases, the probability that a supermarket chain will invest in the food desert in period 1 (r) increases at a constant rate and then levels off at 1. This means that if the cost advantage is above a certain threshold, both supermarkets have an equilibrium strategy to enter in period 1. The probability of the follower supermarket entering the food desert (t) decreases as the cost advantage increases since the higher the cost advantage, the more disadvantaged the follower is compared to the leader. The probability of investment in the second period following no investment (s), is not dependent on Δc, since the cost advantage is no longer available to either

supermarket; hence, it is represented by the horizontal line.

As a robustness check, all the analysis was repeated for a policy that would decrease the investment costs (rather than marginal costs) for the supermarkets who enter in period 1. The same relationships among the variables exist. The figures for the investment cost advantage analysis are shown in Appendix A.

**Discussion**

Food desert communities are a prime example of a market failure in the U.S. food industry. Though the supermarket industry is a huge part of the food industry and relatively resilient in times of economic downturn (Hagan and Rubin, 2013), there are still millions of people with no access to supermarkets. A few supermarket chains have entered food desert communities profitably and were able to acquire customer loyalty, even as follower supermarkets entered the market. One notable case being the former food desert communities of Philadelphia, Pennsylvania. These successful cases were supermarkets that adjusted their services to effectively serve their respective communities; such as adding in a pharmacy, community center, credit union, staff nutritionists, social workers and a health clinic (Singh, 2015). Communicating with community leaders prior to entry influenced decisions to offer services, such as: shuttle rides home, calculators on the shopping carts, and bi-lingual employees in order to increase profits (Pothukuchi, 2005, Singh, 2015).

The game theoretical model shows that supermarket entry will occur once investment costs and marginal costs are low enough. Thus, the interventions subsidizing costs to influence entry are supported. However, this model reveals two nuances for policymakers to consider. First, the model shows that policies and initiatives do not need to completely subsidize costs for entry; an

intermediate range of interventions can lead to a more competitive market. Interventions need to incentivize one supermarket to enter and if demand is favorable, then others will follow. Even when the interventions are enough for a supermarket to be profitable in a food desert, there is a possibility that no supermarket will enter, due to their mixed strategy. Interventions aimed at influencing initial entry will decrease the probability of no entry, which leads to the second nuance: cost advantages specifically for early investment are effective. In general, when a firm faces no competition, demand uncertainty negatively influences their decision to enter (Folta and O'Brien, 2004). Conversely, whenever there are competitive advantages associated with early entry, the effect of demand uncertainty becomes ambiguous and dependent on the firm's relative valuations of the cost of uncertainty and early mover advantages (Folta and O'Brien, 2004). Supermarket chains place value on demand certainty (seen through their willingness to accept higher investment costs in the second period if another supermarket has invested profitably). The results appear to support the idea of supermarket inertia (Dilling, 2014). That is, even if supermarket chains think it may be profitable to enter a food desert, they are hesitant because their competitors have not invested. Another theoretical principle in retail location theory supported by the results is the Principle of Minimum Differentiation, which originates from Hotelling's hypothesis that retailers that sell similar merchandise tend to cluster together (Clarkson et al., 1996, Hotelling, 1990).

Without the urgency attached with the cost advantage, supermarket chains' primary strategy is to follow the leader into the food desert, in order to eliminate the demand uncertainty. Initiatives should consider offering first mover incentives, like cost advantages, to help initiate early entry. The first supermarket chain that enters the food desert is essentially providing a positive externality to the market. It takes on the full cost of unknown demand, but does not fully internalize the benefits if other supermarket chains follow. The other policies and initiatives, which

are currently in place through the HFFI (one-time financing, lower loan interest rates, and tax breaks) could be enhanced and more effective at incentivizing quick entry, if they were only offered to the supermarket chains that lead entry into the food desert communities.

Implications Behind Model Assumptions

There are two key assumptions that influence the results and implications which warrant discussion. First, the model assumes that both supermarkets have the same, limited information about consumer demand before entry. Relaxing this assumption to allow the supermarket chains to have their own knowledge about demand would change the entry decisions in both periods. The cutoff values for the investment costs would change when chains have prior knowledge about consumer demand. If the knowledge is favorable then the allowable investment costs would increase and if demand knowledge is unfavorable the allowable investment costs would decrease. The game becomes more complicated if the two chains have different knowledge (or perceptions) about the food desert demand and if they do not know what the other chain knows; however, there is no reason to believe a priori that the chains have different perceptions about demand. Relaxing this assumption would also change the structure of the subsidies the chains require to compensate them for the risk, because these subsidies would now depend on the chain's perception of the risk. Second, the model assumes that consumer demand is completely revealed to both chains once one chain enters, allowing the follower to use this information to reduce their risk of entry. This assumption is essentially creating an advantage for delaying entry. If demand is not completely revealed to the follower upon the leader's entry, the follower will be unable to base their entry decision on the true demand but rather it would be based on their updated knowledge of demand. Relaxing this assumption refutes the implication that the intervention needs to only incentivize one

supermarket chain to enter. It would still be risky for the follower chain to enter without complete demand revelation; however, it would still be less risky compared to the no first period entry case as long as demand is partially revealed upon one chain's entry. When the demand is not completely revealed upon entry, the cost advantage given through the initiative would not need to be as high to induce early entry. Since the demand uncertainty is only partially removed, rather than completely removed, the advantage in delay is lower; meaning the required cost advantage needed to incentivize early entry is lower as well. Though this model is highly stylized with strict assumptions it does provide keen insights as to why the food desert market failures still exist throughout urban communities in the U.S. and offers suggestions on how to address them.

# CHAPTER 2: FRUIT AND VEGETABLE DEMAND BY COLOR

## Introduction

Fruits and vegetables (F&V) of different colors contain diverse vitamins, minerals and phytonutrients associated with unique health benefits. Since the 1930's F&V color has been emphasized in the National Dietary Recommendations and Nutritional Guidelines (Davis and Saltos, 1999). The United States Department of Agriculture (USDA) promotes color diversity in F&V consumption through multiple nutrition programs nationally, such as: the Coordinated Approach to Child Health Nutrition Curriculum within a Farm to School Program (Moss et al., 2013); and the Color Me Healthy program (Witt and Dunn, 2012). The National Cancer Institute started the "5 A Day" campaign and the Center for Disease Control and Prevention sponsored the "Fruits & Veggies - More Matters" campaign, which encouraged F&V consumption based on color (Pennington and Fisher, 2009). Considerable resources have been expended to support medical and nutrition research on the different health benefits associated with F&V color diversity and to fund programs aimed at increasing F&V color consumption (Lee et al., 2017, Joseph et al., 2002, Heber, 2004).

Color has been shown to be instrumental in the marketing and promotion of food products. Consumers often use color as an initial indicator of food quality, though not always accurate (Andrés-Bello et al., 2013). Further, the color of food packaging has been found to influence demand (Ares and Deliza, 2010, Murray and Delahunty, 2000, Silayoi and Speece, 2007), including the color of the mesh surrounding bundled F&V (Bix et al., 2013). Given that color influences food demand and the F&V colors are associated with different health benefits, this raises the question of how demand varies across the different F&V color classes.

The objective of this study is to develop a new approach to analyzing F&V demand based on color and provide a novel understanding of how consumers behave with respect to their choice of F&V colors. Examining how responsive consumers are to changes in F&V color prices and expenditure can help design and modify interventions to incentivize F&V color diversity consumption and provide useful insight on how to increase the sales of F&V. The next section offers background information on the color classification scheme used in this study. The following sections describe the data and demand model. The final two sections close with results and discussion.

## Background

### F&V Color Classification

A healthy diet includes the consumption of a variety of F&V colors because color denotes the presence of specific vitamins, minerals and phytonutrients (Brown, 2016, Guitart et al., 2014, Griep et al., 2011, Vaughan and Geissler, 2009). Table 2.1 provides the color classification used in this analysis and examples of the variety of phytochemicals, vitamins and minerals found in the different color classes and their associated health benefits. This classification is similar to other color classifications found in the nutrition literature (Pennington and Fisher, 2010, Guitart et al., 2014, Griep et al., 2011, FNS, 2016a). The color classification groups F&V into four color classes: green, white, red/blue/purple and yellow/orange. If the peel is generally consumed, then the color of the peel determines color class (e.g. granny smith apples are green) but if the peel is not usually eaten then the edible portion determines color class (e.g. bananas are white) (PbhFoundation, 2016a, Langtree, 2005). Culinary traditions, rather than scientific or botanical classifications, are to define fruit or vegetable classification (e.g. tomatoes are classified as vegetables).

The health benefits associated with consuming an adequate amount of each color class are detailed in Table 2.1. Green F&V are deemed to prevent age related macular degeneration as well as promote retinal health and boost immune system activity (Heber, 2004, Garden-Robinson, 2009, Guitart et al., 2014). White colored F&V help maintain healthy cholesterol levels and prevent certain types of cancer (Langtree, 2005, Heber, 2004). Red/blue/purple F&V provide phytochemicals that improve heart health and memory function and are believed to prevent certain types of cancer (Brown, 2016, Joseph et al., 2002, Garden-Robinson, 2009). Lastly, yellow/orange F&V provide vitamins that enhance night vision and the immune system (PbhFoundation, 2016a, Joseph et al., 2002). Although some of the benefits overlap across color groups, all are necessary to ensure a diverse spectrum of phytochemicals, vitamins and minerals to maximize potential health outcomes (Guitart et al., 2014). Recommended dietary color proportions depend on age, gender, health status and level of physical activity. However, the key recommendations in the 2015-2020 Dietary Guidelines from the USDA Center for Nutrition Policy and Promotion emphasize the importance of dark green, red, and orange vegetable consumption (DeSalvo et al., 2016).

## F&V Demand Studies

F&V demand has been examined extensively in the literature; however, there is a gap with respect to demand for the different F&V colors. Previous F&V demand research either focuses on individual F&V (Seale et al., 2013, Weatherspoon et al., 2013) or aggregates of all fruits and all vegetables (Mhurchu et al., 2013, Reed and Levedahl, 2010). In both approaches, color is disregarded. This study is the first to consider the demand for F&V based on color, offering a more complete understanding of how the different F&V prices and expenditures impact demand.

**Table 2.1: F&V Color Classification, Color Specific Phytochemicals, Vitamins and Minerals, and Benefits**

| Color Group | Fruits and Vegetables in Group | Phytochemicals, Vitamins and Minerals Contained | Associated Health Benefits and Reference Examples |
|---|---|---|---|
| Green | **Fruits:** Green Grapes, Limes, Green Pears, Kiwi, Chayote, Honeydew, Avocados, Green Apples **Vegetables:** Asparagus, Broccoli, Brussel Sprouts, Celery, Greens, Collard Greens, Muster Greens, Turnip Greens, Spinach, Green Beans, Green Peppers, Cabbage, Zucchini, Packaged Salad Bags, Lettuce, Okra, Cucumbers | Lutein Glucosinolates Folate Isothiocyanates Vitamin K folic acid potassium chlorophyll Vitamin C | Prevent macular degeneration; boost immune system; maintain healthy bones and teeth (Heber, 2004, Garden-Robinson, 2009, Guitart et al., 2014, FNS, 2016a) |
| White | **Fruits:** Bananas, Coconuts, Bosc Pears **Vegetables:** Plantains, Cauliflower, White Onions, Mushrooms, Turnips, Russet Potatoes, Idaho Potatoes, Jicama, Yuca | Allyl Sulfides Allicin Potassium | Prevent certain cancers; maintain cholesterol levels (Langtree, 2005, Heber, 2004, FNS, 2016a) |
| Red / Blue / Purple | **Fruits:** Cherries, Strawberries, Grapefruit, Watermelon, Blueberries, Plums, Red Grapes, Black Grapes, Red Apples **Vegetables:** Beets, Radish, Tomatoes, Red Peppers, Red Onions | Lycopene Anthocyanins Calcium Vitamin D Flavonoids Resveratrol Vitamin C Folates | Reduce tumor growth, cancer and stroke risk; promote memory function, healthy aging, heart, and prostate health (Heber, 2004, Garden-Robinson, 2009, Joseph et al., 2002, Brown, 2016, FNS, 2016a) |
| Yellow / Orange | **Fruits:** Apricots, Cantaloupe, Pineapple, Yellow Apples, Oranges, Tangerines, Peaches, Mango, Nectarines, Lemons **Vegetables:** Carrots, Corn, Pumpkin, Yams, Squash, Yellow Peppers | Alpha-Carotene Beta-Carotene Vitamin A Vitamin C folate | Promote vision and immune system; reduce cancer risk, and heart disease (PbhFoundation, 2016b, Joseph et al., 2002, Brown, 2016, FNS, 2016a) |

In general, there are distinct differences in food price and expenditure elasticities among different ethnicities and income groups (Huang and Lin, 2000, Park et al., 1996). This study is based on a primarily Hispanic, low-income community (Office of Social and Economic Data Analysis 2010a), and is not representative of the entire U.S. The Hispanic population is the largest ethnic minority in the U.S. and is continually growing (Colby and Ortman, 2015). Hispanics consume more F&V than most Americans (pbhFoundation, 2015), but Hispanics who have migrated to the U.S. often perceive fresh F&V to be expensive and of low quality (Cason et al., 2006, Gray et al., 2005). Consequently, this study provides valuable insight on this unique population's F&V color demand preferences.

**Data and Aggregation Methods**

This study utilizes scanner receipt data from May 2014 through January 2015 from a supermarket located in a Detroit, Michigan (Office of Social and Economic Data Analysis 2010a). The Congressional District in which this supermarket is located has 89,788 (35%) households that receive Supplemental Nutrition Assistance Program (SNAP) benefits, as of 2013, with 60% of its residents below the poverty line (USDA, 2015a). The entire dataset has 373,714 purchase transactions over the 9-month period, with 113,873 of them including fresh fruits and/or vegetables. Roughly 68.5% of transactions were paid for with cash as compared to only 17% on average for the nation (FMI, 2016); 20.4% of the transactions were SNAP; 10% were debit; 1% were Women, Infants and Children (WIC); and 1% were credit. The number of monthly supermarket transactions ranged from 39,166 to 42,464 and were almost equally spread across the nine months. Per transaction, the average customer spent $22.41 and among those who purchased F&V, the average vegetable (fruit) expenditure was $3.77 ($3.51).

The transactions are aggregated up to two-week purchases for each consumer with a unique identifier created from the loyalty or payment card number (41% of the transactions used either loyalty, credit, or debit card, SNAP or WIC). The final dataset is an unbalanced panel with a total of 78,904 observations, each representing the purchases of a consumer for a two-week period.

In order to aggregate the individual F&V into their respective color classes the divisia indices are used. The divisia formula for price and quantity are:

$$\ln(P_{j,t}) - \ln(P_{j,t-1}) = \sum_{i=1}^{n} 0.5\left[V_{i,t} + V_{i,t-1}\right]\left[\ln(p_{i,t}) - \ln(p_{i,t-1})\right] \quad (1)$$

and

$$\ln(Q_{j,t}) - \ln(Q_{j,t-1}) = \sum_{i=1}^{n} 0.5\left[V_{i,t} + V_{i,t-1}\right]\left[\ln(q_{i,t}) - \ln(q_{i,t-1})\right] \quad (2)$$

where

$$V_{it} = \frac{p_{i,t}\, q_{i,t}}{\sum_{j=1}^{n} p_{j,t}\, q_{j,t}}.$$

In these equations, $p_{it}$ and $q_{it}$ are the price and quantity of individual fruit or vegetable i during the two-week period t and the $P_{j,t}$ and $Q_{j,t}$ are the price and quantity of the color class j during the two-week period t. Yellow/orange fruits and red/blue/purple vegetables have the largest price variation and range among the F&V classes over the nine months. However, these statistics could be driven by the differences in the number of individual F&V that fall into the color categories. For example, there are only five different types of yellow/orange vegetables while there are seventeen different types of green vegetables.

Expenditure statistics are shown in Table 2.2. Red/blue/purple fruit expenditure, conditional on purchase, is the highest; however, red/blue/purple fruits are the least frequently

purchased, making their expenditure share relatively low. Green fruits and green vegetables represent 24% and 16% of all F&V expenditures, respectively, while yellow vegetables only comprise 4.6% of F&V expenditures. Green vegetables are the most commonly purchased color class (based on the number of transactions), followed by the red/blue/purple vegetables.

**Table 2.2: Two-week Customer Expenditure (Conditional and Unconditional on Purchase), Customer Expenditure Shares and Number of Store-wide Purchases by Color Class**

| **Fruits** | Expenditure if Purchased ($) | Unconditional Expenditure ($) | F&V Expenditure Shares (%) | Number of Purchases |
|---|---|---|---|---|
| Green | 3.15 | 0.58 | 16.08 | 17618 |
| White | 1.98 | 0.31 | 12.39 | 14685 |
| Red/Blue/Purple | 4.45 | 0.29 | 5.78 | 6303 |
| Yellow/Orange | 3.70 | 0.28 | 5.61 | 7051 |
| **Vegetables** | | | | |
| Green | 2.96 | 0.78 | 24.18 | 25380 |
| White | 2.75 | 0.49 | 15.84 | 16162 |
| Red/Blue/Purple | 2.92 | 0.59 | 15.57 | 18780 |
| Yellow/Orange | 2.35 | 0.17 | 4.56 | 6765 |

The USDA Dietary Recommendations emphasize the importance of dark green, red and orange vegetables. Based on the descriptive statistics the green and red vegetables are not of concern since the orange vegetables are amongst lowest ranking in expenditure, expenditure share, and frequency of purchase.

**Model**

There are several consumer demand systems commonly used to analyze F&V demand, the most widely applied are the Rotterdam Model (Theil, 1965), Translog Demand System (Christensen et al., 1975), Almost Ideal Demand System (AIDS) Model (Deaton and Muellbauer,

1980) and the Linear (Blanciforti and Green, 1983) and Quadratic (Banks et al., 1997) variants of the AIDS Model. This study analyzes F&V demand using a Quadratic AIDS (QUAIDS) model because it satisfies the axioms of choice order and aggregating over consumers without assuming parallel linear Engel curves (Tafere et al., 2010); can be modified to control for large numbers of non-purchases; and has the flexibility to incorporate variables other than income and prices.

The separable QUAIDS model assumes a consumer has m dollars to spend on the goods in the model. The indirect utility function for consumer demand is then (Banks et al., 1997):

$$\ln V(p, m) = \left[\left\{\frac{\ln m - \ln a(p)}{\prod_i p_i^{\beta_i}}\right\}^{-1} + \sum_i \lambda_i \ln p_i\right]^{-1} \quad (3)$$

Where the $\ln a(p)$ term is the transcendental log function

$$\ln a(p) = \alpha_0 + \sum_i \alpha_i \ln p_i + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \ln p_i \ln p_j$$

The $p_i$ represents the price of the $i^{th}$ color class, m is total F&V expenditure and the Greek letters are the parameters to estimate. The exception are the $\alpha_0'$s, which are unidentified and in practice are given an assigned value slightly less than the lowest natural logged expenditure value in the data (-3.01) (Poi, 2012).

Additional variables are incorporated into the QUAIDS model by using a scaling technique (Ray, 1983, Poi, 2012, Poi, 2002). Consumer grocery shopping behaviors that have been found to affect food demand and are controlled for in this analysis are: payment method (captured through four indicator variables: cash, credit / debit, SNAP and WIC) and frequency of store visits (number of visits the customer made in the two-week period) (Wilde and Ranney, 2000). Month dummy variables are used to control for seasonality effects.

A two-stage method is used since there are a large number of customers who did not purchase any F&V during the two-week period blocks (Tafere et al., 2010, Stewart et al., 2004,

Lambert et al., 2006, Balié et al., 2016, Shonkwiler and Yen, 1999, Heien and Wessells, 1990). The first stage is to estimate a Probit model for each color class to calculate the probability a given household purchases that color class. Next the cumulative distribution and probability density functions for the normal distribution ($\Phi(\hat{\theta}_i' z)$ and $\phi(\hat{\theta}_i' z)$, respectively) are calculated and used to estimate the following system of observed color budget shares

$$y_i = \Phi(\hat{\theta}_i' z)\, w_i + \varphi_i\, \phi(\hat{\theta}_i' z) \tag{4}$$

where

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln p_j + (\beta_i + \eta_i' z) \ln\left(\frac{m}{(1+\rho' z)a(p)}\right) + \frac{\lambda_i}{[\prod_i p_i^{\beta_i}]\left[\prod_j p_j^{\eta_j' z}\right]} \left[\ln\left\{\frac{m}{(1+\rho' z)a(p)}\right\}\right]^2.$$

The $w_i$ is the share of total F&V expenditure m allocated to color class i, and z is a vector of explanatory variables. The estimated parameter $\varphi_i$ is the covariance between the first and second stage error terms. Since the disturbance terms are often heteroscedastic in these models (Tafere et al., 2010), robust standard errors clustered at the customer level are used. Clustering the standard errors also addresses any possible autocorrelation present in the model (Wooldridge, 2015). The model coefficient estimates are then used to calculate the color own-price, cross-price and expenditure elasticities. The uncompensated price elasticity of color class i with respect to changes in color class j are calculated using

$$\epsilon_{ij} = -\delta_{ij} + \frac{1}{w_i}\Bigg(\gamma_{ij} - \left[\beta_i + \eta_i' z + \frac{2\lambda_i}{[\prod_i p_i^{\beta_i}]\left[\prod_j p_j^{\eta_j' z}\right]} \ln\left\{\frac{m}{(1+\rho' z)\, a(p)}\right\}\right] * \left(\alpha_j + \sum_l \gamma_{jl} \ln p_l\right) - \frac{(\beta_j + \eta_j' z)\lambda_i}{[\prod_i p_i^{\beta_i}]\left[\prod_j p_j^{\eta_j' z}\right]} \left[\ln\left\{\frac{m}{(1+\rho' z)\, a(p)}\right\}\right]^2\Bigg) \Phi(\hat{\theta}_i' z) + \phi(\hat{\theta}_i' z)\, \theta_{ij} \left(1 - \frac{\varphi_i}{w_i}\right) \quad (5)$$

where $\delta_{ij}$ is the Kronecker delta ($\delta_{ij}$ =1 if i=j and $\delta_{ij}$=0 otherwise) and $\theta_{ij}$ indicates the coefficient on the price of good j in the good i first stage probit regression. Expenditure (income) elasticity for color class i are calculated using

$$\mu_i = 1 + \frac{1}{w_i}\left[\beta_i + \eta_i' z + \frac{2\lambda_i}{[\prod_i p_i^{\beta_i}]\left[\prod_j p_j^{\eta_j' z}\right]} \ln\left\{\frac{m}{(1+\rho' z)\, a(p)}\right\}\right] \Phi(\hat{\theta}_i' z). \quad (6)$$

Compensated price elasticities can be calculated from the Slutsky Equation $\epsilon_{ij}^c = \epsilon_{ij} + \mu_i w_j$ (Balié et al., 2016). The delta method is used to compute the standard errors of the computed elasticities (Poi, 2012, Ray, 1983, Shonkwiler and Yen, 1999).

Separability between fruits and vegetables is often assumed and separate demand models are estimated. If the weak separability assumption fails, endogeneity is present in the separable model due to missing variables, yielding biased regression coefficients which are then used in the elasticity calculations, causing them to be biased. To avoid this, non-homothetic weak separability

is tested using the method developed by Moschini, Moro, and Green (1994). Weak separability between fruits and vegetables implies that the marginal rate of substitution between two fruit (vegetable) color classes is independent of the amount of vegetables (fruits) purchased (Sellen and Goddard, 1997), implying that the ratio of price elasticities between two fruit (vegetable) categories and all vegetables (fruits) equals the ratio of expenditure elasticities of the two fruits (vegetables) (Moschini et al., 1994, Lakkakula et al., 2016):

$$\frac{\epsilon_{ik}}{\epsilon_{jk}} = \frac{\mu_i}{\mu_j} \tag{7}$$

where i and j are the fruit (vegetable) color classes and k is the aggregated vegetables (fruits). The Wilcoxon signed rank test results (Lambert et al., 2006), strongly reject weak separability; hence, the fruit color and vegetable color classes are analyzed as one system. The demand system is a set of eight equations, four for fruits and four for vegetables; one equation for each color class. Due to the large dataset, there are no degrees of freedom concerns.

To address the potential unobserved heterogeneity within the system, correlated random effects (CRE) probit regressions are run in the first stage and the CRE variables (means of time varying variables) are included as explanatory variables in the second stage. The theoretical restrictions derived from utility theory; homogeneity ($\sum_j \gamma_{ij} = 0$) and Slutsky symmetry ($\gamma_{ij} = \gamma_{ji}$), are imposed during estimation.[7] The traditional adding up restrictions are adjusted based on Shonkwiler and Yen (1999) changes to the expenditure share equations. Lastly, it is assumed that the consumers buy all their F&V from this supermarket, since no data was collected from any other food retail outlets and there are no other supermarkets nearby with the same level of quality and variety.

[7] In practice, these restrictions are typically imposed without testing (Lambert et al., 2006).

## Results

Stage 1: Probability of Purchase

The results from the first stage provide insights into what affects the different color class purchase decisions. Table 2.3 reports the marginal effects from the probit regressions, which show that all the color prices affect at least one color class purchase decision. Each of the color classes' purchase decision is negatively associated with (or independent from) their own price, except for green fruit. As the price of yellow/orange fruits, green vegetables and red/blue/purple vegetables goes up by 1 percent, the probability of purchasing those goods goes down by 0.09, 0.16 and 0.11 percent, respectively. For the green fruit, as price increases the probability of green fruit purchase increases along with the probabilities of purchasing white fruit, and green, red/blue/purple and yellow/orange vegetables. Out of all the color purchase decisions, the green fruit purchase decision is the most sensitive to price changes; six of the color prices significantly impact the probability of them being purchased.

Having a loyalty card significantly increases the probability of purchase for all the color classes. There were four payment method options used at this store: cash, credit/debit, WIC and SNAP and for this analysis cash was the base case. Customers using cash are more likely to purchase white vegetables than WIC customers, but the use of credit/debit, WIC and SNAP have a higher or equal probability of purchase for all the other color classes compared to the cash payment. This is noteworthy because this store, as well as other stores located in Hispanic communities, have many shoppers paying with cash (Wang and Wolman, 2016). Other department expenditure (total store expenditures minus F&V expenditure) is included in this first stage (but not in the second stage demand model) as a proxy for the customer's loyalty to this store, in general. The more money spent in the store on items other than F&V, the higher the purchase

probabilities are for all the color classes. The more frequently a customer shops at the store the more likely they are to purchase all the color classes. January 2015 is the base case so, all month dummy coefficients are in comparison to that month. All the coefficients are positive or insignificant across all the months and all color classes, meaning from May to December there is a higher probability of purchasing all the color classes compared to January, except for green fruits in July and red/blue/purple fruits in September and December, which are negative. As these results indicate, F&V color class purchase decisions are very sensitive to prices, customer purchase behaviors and seasonality; now we move to the demand analysis, which controls for these purchase decision.

Stage 2: Color Demand

Expenditure elasticities represent how responsive the quantity demanded of the colors are to changes in expenditure on all F&V. The expenditure elasticities, shown in the last column of Table 2.4, are all positive and statistically significant. The red/blue/purple and yellow/orange fruits are the most affected by an F&V expenditure increase, as F&V expenditure increases by 1%, the quantity purchased of red/blue/purple fruits increases by 1.04% and yellow/orange fruits increases by 1.03%. The white fruits are the least affected by a F&V expenditure increase, as F&V expenditure increases by 1%, the quantity purchased of white fruits increases by 0.95%. All the colors are classified as either normal or luxury goods in this low-income community meaning there is a willingness to spend more on them. Some examples of expenditure elasticity ranges found in the literature for popular individual F&V are banana (0.63, 1.18); oranges (0.89, 1.74); lettuce (0.63 to 1.39); and tomato (0.69 to 1.59) (Durham and Eales, 2010, Weatherspoon et al., 2013,

You et al., 1996, Lopez and Peckham, 2016, Weatherspoon et al., 2015, Naanwaab and Yeboah, 2012). Meaning the color elasticities are within the ranges found in the literature.

When a price increases there are two effects: the substitution to a relatively cheaper product (substitution effect); and the decrease in real income from the inability to purchase as much (income effect). The uncompensated price elasticities reflect both income and substitution effects of a price change (shown in Table 2.4) while the compensated elasticities capture solely substitution effects (shown in Table B.1 in Appendix B).

All the own-price elasticities are negative and statistically significant, similar to other F&V studies. Most of the color classes are own-price elastic (greater than 1) indicating a more than proportional demand response. Customers respond most to changes in prices of yellow/orange fruits; a 1% increase in the yellow/orange fruit price is associated with a 1.18% decrease in the quantity purchased. Customers are least responsive to the red/blue/purple fruit prices; a 1% increase in the red/blue/purple fruit price is associated with a 0.99% decrease in the quantity purchased. For each of the color classes, the own-price effect is the strongest price effect (largest elasticity magnitude out of all price elasticities), meaning the color classes demand is more responsive to its own price changes than to colors outsides its class.

In general, the more broadly defined the food group, the more inelastic the demand, meaning the F&V color classes are expected to be more inelastic than the individual F&V that make up the color class, but more elastic than the aggregated F&V classifications found in the literature. The color class own-price elasticities ranged from -1.14 to -0.99, which is close to unit elastic. Andreyeva et al. (2010) conducted a systematic review of food demand price elasticities and calculated the 95% confidence interval for fruit and vegetable own price elasticities of (-0.98, -0.41) and (-0.71, -0.44), respectively. These calculations are aggregate F&V categories; hence the

color findings are more elastic. Price sensitivities for commonly consumed individual fruits and vegetables have been examined in many studies. Weatherspoon et al. (2013), Durham and Eales (2010), Lin et al. (2010) among others have estimated banana uncompensated own price elasticities ranging from -0.98 to -0.42, implying consumers are more responsive to the white fruit class than bananas alone, which is unexpected. Oranges (the fruit) own price elasticities range from -1.37 to -0.72 (Durham and Eales, 2010, Weatherspoon et al., 2013, You et al., 1996); the yellow/orange fruit elasticity calculated in this study falls within this range. Lettuce uncompensated price elasticities range from -1.05 to -0.01 (Lopez and Peckham, 2015, Weatherspoon et al., 2014, Green, 1999, You et al., 1996, Naanwaab and Yeboah, 2012); in comparison, consumers are slightly more responsive to the green vegetables class than lettuce. Tomato uncompensated own price elasticities range from -1.71 to -0.41 (Lopez and Peckham, 2015, Weatherspoon et al., 2014, Naanwaab and Yeboah, 2012, You et al., 1996, Nzaku et al., 2010); hence, consumers are similarly price responsive to red vegetables as they are to tomatoes, specifically. One conclusion from these comparisons is that consumers are more responsive to the color prices than what is expected based on prior individual F&V elasticities.

**Table 2.3: Estimated Probit Marginal Effects per F&V Color Class**

| | G Fruit | W Fruit | R/B/P Fruit | Y/O Fruit | G Veg | W Veg | R/B/P Veg | Y/O Veg |
|---|---|---|---|---|---|---|---|---|
| G Fruit P | 0.114** | 0.147*** | -0.153*** | 0.026 | 0.125** | -0.036 | 0.174*** | 0.097*** |
| W Fruit P | -0.076 | -0.039 | 0.184*** | 0.143*** | -0.105* | 0.012 | 0.028 | 0.097** |
| R/B/P Fruit P | -0.051 | -0.026 | -0.018 | -0.032 | -0.049 | 0.094** | -0.034 | -0.020 |
| Y/O Fruit P | -0.189*** | 0.074 | -0.177*** | -0.091** | 0.043 | 0.033 | -0.005 | 0.063 |
| G Veg P | 0.157** | -0.044 | -0.115*** | -0.149*** | -0.157** | -0.123* | 0.035 | -0.136*** |
| W Veg P | -0.184*** | -0.098** | 0.024 | -0.072** | -0.086 | 0.042 | -0.181*** | -0.078** |
| R/B/P Veg P | -0.090*** | 0.033 | 0.017 | -0.029 | -0.020 | -0.084** | -0.110*** | -0.014 |
| Y/O Veg P | -0.159*** | -0.241*** | 0.089*** | 0.157*** | -0.051 | 0.024 | -0.236*** | -0.039 |
| Loyalty Card | 0.025*** | 0.031*** | 0.004** | 0.004* | 0.013*** | 0.014*** | 0.025*** | 0.104*** |
| Credit / Debit | 0.055*** | 0.019*** | 0.009*** | 0.017*** | 0.045*** | 0.031*** | 0.049*** | 0.013*** |
| WIC | 0.044*** | 0.126*** | 0.025*** | 0.040*** | 0.021** | -0.038*** | 0.041*** | -0.000 |
| SNAP | 0.013*** | 0.034*** | 0.024*** | 0.022*** | 0.067*** | 0.051*** | 0.026*** | 0.015*** |
| Other Dept Exp | -0.001*** | -0.001*** | -0.000*** | -0.000*** | -0.001*** | -0.001*** | -0.001*** | -0.001*** |
| Other Dept Exp | 0.001*** | 0.001*** | 0.000*** | 0.000*** | 0.001*** | 0.001*** | 0.001*** | 0.000*** |
| Number of Visits | -0.010*** | -0.005*** | -0.004*** | -0.005*** | -0.018*** | -0.013*** | -0.011*** | -0.004*** |
| Number of Visits | 0.016*** | 0.009*** | 0.005*** | 0.005*** | 0.024*** | 0.012*** | 0.017*** | 0.005*** |
| May 2014 | 0.029*** | 0.048*** | 0.004 | 0.010 | 0.005 | -0.005 | 0.025** | 0.023*** |
| June 2014 | 0.021*** | 0.036*** | 0.028*** | 0.017*** | 0019** | 0.012 | 0.044*** | 0.016*** |
| July 2014 | -0.011** | 0.011** | 0.032*** | 0.018*** | -0.002 | -0.002 | 0.014** | 0.008** |
| August 2014 | -0.003 | 0.012* | 0.007 | -0.003 | -0.014 | -0.007 | -0.010 | 0.001 |
| September 2014 | -0.009 | 0.010* | -0.012** | 0.001 | 0.009 | 0.009 | -0.008 | 0.012** |
| October 2014 | 0.019*** | 0.016** | 0.004 | 0.018*** | 0.001 | 0.005 | 0.001 | 0.013*** |
| November 2014 | 0.001 | 0.012* | -0.007 | 0.016*** | 0.026*** | 0.022*** | 0.018** | 0.029*** |
| December 2014 | 0.034*** | -0.004 | -0.018*** | 0.007 | 0.016* | -0.005 | 0.023*** | 0.004 |

n = 78904

*** p<0.01, ** p<0.05, * p<0.1

Table Abbreviations: G= Green, W = White, R/B/P = Red / Blue / Purple and Y/O = Yellow / Orange

**Table 2.4: Uncompensated Price and Expenditure Elasticities per F&V Color Class**

| | Green Fruit | White Fruit | Red / Blue / Purple Fruit | Yellow / Orange Fruit | Green Veg | White Veg | Red / Blue / Purple Veg | Yellow / Orange Veg | Expenditure Elasticity |
|---|---|---|---|---|---|---|---|---|---|
| **Green Fruit** | **-1.05*** (0.125)** | -0.11* (0.063) | -0.06 (0.050) | -0.16*** (0.052) | 0.01 (0.076) | 0.09 (0.078) | 0.11** (0.050) | 0.16*** (0.048) | 1.01*** (0.009) |
| **White Fruit** | -0.11 (0.066) | **-1.10*** (0.071)** | 0.04 (0.041) | 0.13*** (0.041) | -0.03 (0.063) | 0.08 (0.052) | 0.09** (0.041) | -0.05 (0.033) | 0.95*** (0.016) |
| **Red / Blue / Purple Fruit** | -0.07 (0.056) | 0.04 (0.045) | **-0.99*** (0.045)** | -0.06* (0.032) | -0.01 (0.048) | 0.01 (0.040) | 0.01 (0.029) | 0.04 (0.029) | 1.04*** (0.012) |
| **Yellow / Orange Fruit** | -0.19*** (0.060) | 0.13*** (0.044) | -0.05 (0.033) | **-1.18*** (0.053)** | -0.02 (0.051) | 0.10** (0.046) | 0.07* (0.032) | 0.11*** (0.032) | 1.03*** (0.015) |
| **Green Veg** | 0.02 (0.071) | -0.03 (0.056) | -0.00 (0.040) | -0.01 (0.042) | **-1.09*** (0.090)** | -0.05 (0.054) | 0.12*** (0.045) | 0.07 (0.042) | 0.98*** (0.015) |
| **White Veg** | 0.09 (0.079) | 0.07 (0.050) | 0.01 (0.036) | 0.10** (0.041) | -0.05 (0.058) | **-1.00*** (0.071)** | -0.08* (0.041) | -0.13*** (0.036) | 0.98** (0.025) |
| **Red / Blue / Purple Veg** | 0.11** (0.050) | 0.07* (0.039) | 0.01 (0.026) | 0.06** (0.029) | 0.12** (0.048) | -0.08* (0.041) | **-1.14*** (0.047)** | -0.17*** (0.026) | 1.02*** (0.013) |
| **Yellow / Orange Veg** | 0.19*** (0.056) | -0.06 (0.037) | 0.04 (0.029) | 0.11*** (0.033) | 0.08 (0.051) | -0.15*** (0.041) | -0.19 (0.029) | **-1.03*** (0.039)** | 1.00*** (0.004) |

Row names represent Quantities and Column names represent Prices.
Standard errors (delta method) are in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Among the 56 uncompensated cross-price elasticities, 15 are significantly positive, 9 are significantly negative and 32 are not significant. The 15 positive cross-price elasticities represent gross substitute relationships between the two color classes, so as the price of one color class increases the quantity demanded of the other color class increases. For example, as the green fruit price increases by 1% the quantity demanded of the red/blue/purple and yellow/orange vegetables increases by 0.11% and 0.19%, respectively. The nine negative cross-price elasticities represent gross complement relationships between the two color classes. For example, as the green fruit price increases by 1% the quantity demanded of the yellow/orange fruits decrease by 0.19%. The cross-price elasticities that are not significant are cases where the two color classes are independent. The red/blue/purple fruits price does not affect the quantity demanded of any other color class and only yellow/orange fruits affect quantity demanded; hence, the red/blue/purple fruits are almost independent from all color classes.

The majority of the fruit classes do not complement any vegetable class and the majority of the vegetable classes do not complement any fruit class; fruits colors are complementary to other fruit colors and vegetable colors are complementary to other vegetable colors. Also most of the fruit color class substitutes are vegetable color classes and vice versa. Thus, consumers are more likely to purchase more vegetable colors when the price of a fruit color class increases and more likely to purchase more fruit colors when the price of a vegetable color increases.

The uncompensated elasticities are similar to the own-price compensated elasticities, negative and significant. Examining the difference in magnitudes between the uncompensated price elasticities and their compensated counterparts, reveals that the substitution effect is stronger than the income effect. Strong substitution effect means consumers will replace a color class with a different color class when its price increases. Also of interest is that all the cross-price

compensated elasticities are positive or statistically insignificant, except for the relationship between the red/blue/purple vegetables and yellow/orange vegetables. This means that the red/blue/purple and yellow/orange vegetable color classes are net complements to one another and all the other F&V color classes are viewed as independent or net substitutes to one another.

Policy Extension

To explore nutrition policy and programs, a subset of SNAP customers are analyzed. There are no significant differences between the SNAP and non-SNAP customers' price and expenditure elasticities. In this case, the overall elasticity calculations can be used to mimic how consumers respond to different policy and program interventions that change prices and expenditures. For example, suppose there is an intervention aimed at increasing the quantity purchased of the three color classes the USDA is currently emphasizing: green, red, and orange vegetables. A proposed 1% decrease in each recommended color class' effect on the average consumer's color class i's quantity purchased is found by

$$\text{Total Intervention Effect on Color Class i} = \sum_{j} (-1)\, \epsilon_{ij} \tag{8}$$

$$\text{where j} = \{\text{green vegetable class, red vegetable class, orange vegetable class}\}.$$

The projected total percent changes in quantities purchased of each color class are shown in the first row of Table 2.5. These percent changes were then multiplied by the average quantities purchased to yield the average change in the quantity purchased of each color class due to the proposed intervention. This intervention is expected to decrease the purchases of all fruit classes while increasing all vegetable class purchases. This implies that the average consumer will respond

to this intervention by substituting fruits, primarily green fruits, for more vegetables, in particular, green and red/blue/purple vegetables.

**Table 2.5: Changes in Quantities Purchased from a Policy that provides a 1% Decrease in the Recommended Color Classes' Prices**

| | Green Fruit | White Fruit | R/B/P Fruit | Y/O Fruit | Green Veg | White Veg | R/B/P Veg | Y/O Veg |
|---|---|---|---|---|---|---|---|---|
| Percent | -0.283 | -0.005 | -0.038 | -0.158 | 0.906 | 0.251 | 1.188 | 0.972 |
| Pounds | -0.207 | -0.003 | -0.013 | -0.031 | 0.605 | 0.168 | 0.634 | 0.230 |

**Discussion**

Demand for four fruit color and four vegetable color classes is explored using a modified two-stage Quadratic AIDS approach. The first stage shows that most of the F&V color prices affect the different F&V color purchase decisions and that the green fruits purchase decision is the most sensitive to the different prices. Customer purchasing behaviors, like the method of payment other than cash, shopping more frequently, being a loyalty card member and spending more on goods other than F&V are associated with higher purchase probabilities of the different color classes. The second stage results reveal that all the color classes respond negatively to their own price and positively to the F&V expenditure increases, in accordance to economic theory and many empirical F&V analyses. The ranges for the F&V color elasticities are within the ranges from the literature on U.S. F&V demand, indicating the reliability of calculations in this analysis. Customers generally view the fruit colors as complementary to each other and the vegetable colors as complementary to each other, but fruit colors as substitutes to vegetable colors and vice versa. This

is contrary to what was expected because, in general, previous literature has found individual fruits (vegetables) to be substitutes to other fruits (vegetables) and independent from vegetables (fruits).

## Policy Implications

This analysis unites the public health and economics literature on how different F&V policies can influence F&V purchases. Policy makers' awareness of the impact fruit or vegetable price changes have on their respective color class demand is important to SNAP, WIC and other nutrition oriented programs. Understanding consumer relative price responsiveness before program implementation can assist in designing incentives which increase demand for the desired F&V color classes. Interventions that increase F&V expenditures will increase the quantity demanded of all the color classes suggesting that interventions aimed at, but not limited to, increasing F&V color diversity should do so through expenditure incentives rather than price incentives. The price elasticities found were not large enough to influence changes in prices alone to increase F&V demand sufficiently to meet the guidelines; however, when paired with public education programs/campaigns and improvements in food environments they can have multiplicative effects that can substantially increase purchases and improve consumption (Andreyeva et al., 2010).

## Supermarket Management Implications

Price elasticities are useful for supermarkets because they can guide pricing decisions. To increase overall profits, supermarket managers must focus sales (or price decreases) on the F&V within the most elastic color classes, which are the yellow/orange fruit and red/blue/purple

vegetable classes. These elasticities can also assist in planning and inventory management when prices are expected to change.

F&V should be displayed throughout the store since other department expenditures are positively correlated with the probability of purchasing all colors. The substitute and complement relationships found among the color classes can also guide overall supermarket shelf organization of the produce department. Complementary colors should be displayed close together, i.e. group fruit color classes together and vegetable color classes together, according to the findings. Based on the expenditure elasticities, there is a willingness to spend more on all the color classes, especially red/blue/purple and yellow/orange fruits and vegetables, which implies that managers should make these color displays central whenever there are store level interventions that increase F&V expenditures. The top three selling F&V at this store are bananas, tomatoes and avocadoes which all fall into different color classes and should be displayed near respective complementary colors to draw in consumers.

## Limitations and Future Research

Certain F&V were not available at this store throughout the nine-month period analyzed (see Table B.2 in Appendix B). For the F&V that were available during the entire period, the variation of (perceived) quality across the nine months could affect the purchases of individual F&V as well as color classes. This and other seasonality effects on F&V color demand are not examined here and should be investigated in future research. Perishability across the different individual F&V and across the color classes could affect elasticities but is also not captured in this analysis. In order to develop more definitive conclusions, future research on other populations

F&V color demand is needed. Additionally, other nutritional classifications for F&V should be explored.

# CHAPTER 3: DOUBLE UP FOOD BUCKS PROGRAM EFFECTS ON SNAP RECIPIENTS' FRUIT AND VEGETABLE PURCHASES

## Introduction

There is extensive evidence of the health benefits associated with eating fruits and vegetables (F&V); however, many Americans consume significantly less than the recommended daily level of F&V according to federal guidelines (Klerman et al., 2014, Rose and Richards, 2004). In an attempt to help address these dietary deficiencies, the 2014 Farm Bill allocated $100 million over five years for the Food Insecurity Nutrition Incentive, a grant program designed specifically to support programs aimed at increasing F&V consumption among Supplemental Nutrition Assistance Program (SNAP)[8] participants (USDA, 2015b, FFN, 2014, FNS, 2014). One of the programs selected to receive funding from the Food Insecurity Nutrition Incentive was the Double Up Food Bucks (DUFB) program.

The DUFB program provides SNAP customers that spend $10 on fresh F&V (in one transaction) with a $10 gift card exclusively for Michigan grown fresh F&V. The DUFB gift card was activated by the store cashier immediately after the completion of the $10 F&V purchase transaction and was valid until the end of the program. DUFB is unique in that it provides a financial incentive for Michigan grown F&V only, while most other programs do not have a locally grown F&V restriction (Klerman et al., 2014, Sturm et al., 2013). DUFB is also unique with respect to its relatively large purchase hurdle followed by a lump-sum financial transfer.

The pilot project for DUFB was conducted in Detroit, Michigan; partially because it has a large proportion of its residents living in a food desert, the largest depopulation rate from 2000 to

[8] SNAP is a federal entitlement and nutrition program that provides money to low income Americans to purchase food at grocery stores, convenience stores, and some farmers' markets and co-op food programs on an electronic benefits transfer card, which functions like a debit card.

2010, and in 2013 the city filed for bankruptcy and has yet to fully recover (Sugrue, 2014). Low income urban communities with high poverty rates, like this study site, typically have high obesity rates and substantial dietary deficiencies (including insufficient F&V consumption) (Irz et al., 2015, Lin et al., 2010). DUFB has expanded to 17 states (FFN, 2016); hence, determining if DUFB can increase the purchase and possibly the consumption of fresh F&V by SNAP recipients is critical to food policy.

The purpose of this paper is to evaluate the effects of the DUFB program on F&V purchases in a low-income community in Detroit, Michigan. Specifically, how DUFB implementation impacts F&V purchase behaviors, how the conclusion of DUFB impacts purchase behaviors and if DUFB has persistent effects. This evaluation is unique in that it utilizes scanner data from a supermarket to evaluate a nutrition program versus interviews (Baquero et al., 2014), surveys (Pitts et al., 2016), receipt collecting (Smith et al., 2013), and 24-hour food recalls (Geliebter et al., 2013). Hence, the data does not contain self-report response bias but reflects what is purchased, which may not represent what is consumed. Another unique aspect of this analysis is that fixed effects estimation is used to control for unobserved heterogeneity, which provides a more reliable estimate of program impact. Lastly, most studies conducted in the U.S. do not examine Hispanic neighborhoods, even though the literature shows that food demand differences exist among ethnic groups in America (Andreyeva et al., 2010, Storey and Anderson, 2014).

The next section offers background information on the study area and provides an in-depth description of the DUFB program and other types of supermarket interventions aimed at increasing F&V consumption. The data section describes the data collection process and the DUFB program usage. The subsequent section provides descriptions of the analytical techniques used and the rationale behind them. The results section details the DUFB program's effects on different F&V

purchase behaviors over different time periods. The concluding section provides program implications.

## Background

### Supermarket Interventions

Supermarket based programs aimed at increasing F&V consumption have been implemented within supermarkets over time. These interventions typically fall into one (or more) of four classifications: (1) point-of-purchase information, (2) increased availability, variety, and convenience, (3) promotion and advertising, and (4) financial incentives (Glanz and Yaroch, 2004). Interventions providing point-of-purchase information do so in a variety of ways, such as providing nutrition brochures, or having signage specifying which food items are healthy choices and/or suggesting healthy recipe ideas. These interventions are usually the simplest and cheapest to implement and do not require much from the supermarkets managers. How effective these programs are effective at increasing consumers' nutritional knowledge and consumption of F&V is debatable. The literature offers mixed results and among those which find influential effects, find the effects to not be sustainable over time (Colapinto and Malaviarachchi, 2009, Ogawa et al., 2011). Increased availability, variety and convenience can come through a wide range of interventions and business decisions, from a supermarket moving into a food desert community to a supermarket having fresh F&V pre-cut for convenient consumption. The costs and beneficial effects of such interventions vary greatly. Promotion and advertising of F&V can be done alone but is often done as an additional component of a larger intervention (Glanz and Yaroch, 2004). Typically, these interventions include the use of store displays and promotions, in addition to community outreach and nutrition education (Lee et al., 2015, Gittelsohn et al., 2009). Some of

these comprehensive interventions have relatively large impacts on healthy food choices (Baquero et al., 2014, Olstad et al., 2016).

Financial incentives to encourage F&V consumption are often costly and difficult to implement since they require technology support of the point of sale system for implementation. Programs with financial incentives are often only implemented for a short period of time (typically less than a year) (An, 2013). There are two types of financial incentives commonly implemented; a subsidy type (given immediately) and a rebate type (given after purchase to be used on another purchase). The Healthy Incentives Pilot Program, a subsidy program, provided SNAP customers with a 30% price reduction on targeted F&V purchases and was found to increase F&V expenditures among SNAP consumers in western Massachusetts by 20% (Klerman et al., 2014). An example of a rebate intervention is the Health Bucks Program which gave SNAP recipients a $2 coupon for every $5 they spent using their benefits at a participating farmers market. The average daily EBT sales at farmers markets in New York City significantly increased due to the program (Baronberg et al., 2013).

DUFB

The DUFB program is a financial incentive type intervention. DUFB provides SNAP customers that spend $10 on F&V (in one transaction) with a $10 gift card exclusively for Michigan grown F&V from that store during the DUFB implementation period (i.e. a financial incentive). A neighborhood promotion was launched through fliers informing residents of the program and signs were displayed throughout the store reminding shoppers of the program. Cashiers were trained to tell customers of the program and to alert them for every transaction that approaches program eligibility.

DUFB has a three-fold goal: (1) assist low income households in eating more F&V, (2) assist local farmers in selling more of their crops, and (3) keep more food dollars in the local economy (FFN, 2014). The DUFB program is expected to increase F&V purchases since it offers a financial incentive. Whether the program is more effective than other financial incentive interventions is unclear because of the requirement that customers must purchase $10 worth of F&V to receive the $10 gift card. This purchase hurdle requirement before any benefit is received in the DUFB program mirrors the early purchase requirements of the food stamps program which required low-income households to meet food purchase requirements in order to receive food stamps (Clarkson, 1975, Stucker and Boehm, 1978). The purchase hurdle could encourage more expenditures dedicated to F&V or deter consumers from participating in the program at all.

Heterogeneous Program Effects

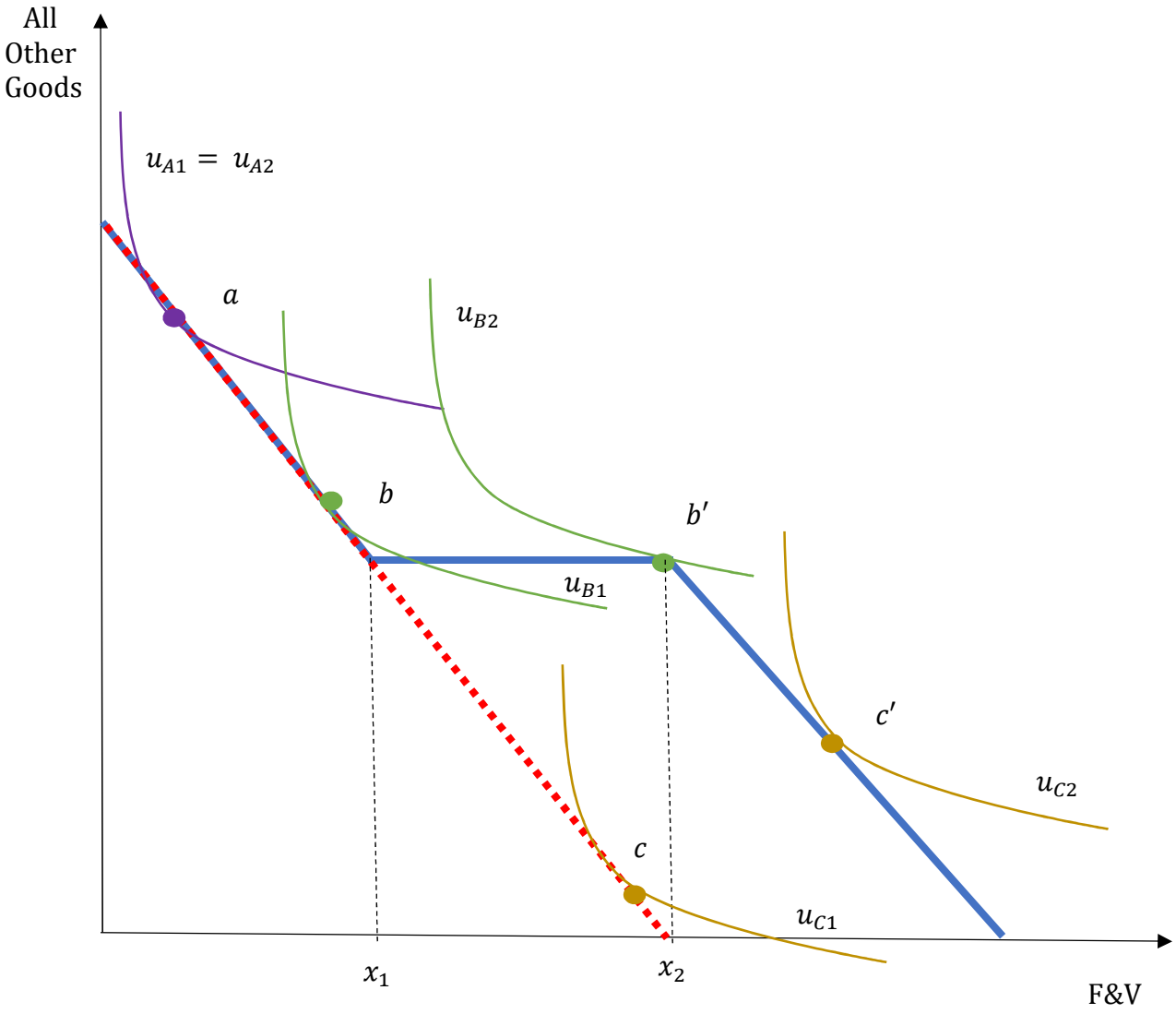
Focusing solely on the average effects of a nutrition intervention across all consumers can miss significant distributional effects. Figure 3.1 displays how DUFB works in terms of a lumpy government transfer to SNAP recipients that spend at least $10 on F&V. The budget line of the SNAP consumers without DUFB is the red dotted line while the solid blue line is the SNAP consumer budget line under the DUFB program. From 0 to $x_1$ these budget lines overlap but at $x_1$ the budget line under DUFB expands outward for F&V only. The gift card that DUFB provides is only valid for F&V which is represented by the flat segment of DUFB budget line from $x_1$ to $x_2$. Since the tradeoff between F&V and all other goods once the gift card is spent (at $x_2$ on figure) is the same before the gift card was received, the budget line after $x_2$ is parallel to the budget line before $x_1$. The indifference curves represent the bundles of F&V and all other goods that a consumer is indifferent between. The shape of the indifference curves reveal the assumption that

F&V as well as all other goods are classified as normal goods. Three SNAP consumer cases evolve based on the DUFB program:

1. Consumer Type A (purple utility curve): SNAP consumers whose F&V expenditure is far below the DUFB purchase hurdle and hence do not participate in DUFB.
2. Consumer Type B (green utility curve): SNAP consumers with moderate F&V expenditure, just below the DUFB purchase hurdle. In order to participate in and benefit from DUFB requires they trade part of their all other goods expenditure for more F&V, which would lead to higher utility (point b') as a result of acquiring the gift card.
3. Consumer Type C (yellow utility curves): SNAP customers whose F&V expenditure is above the DUFB purchase hurdle. They will earn and use the DUFB gift card, which gives them higher utility (point c compared to c').

As can be seen in the figure, the expected changes in F&V purchases vary across these consumer types. Consumer Type A will not change their F&V purchases (since they are not participating). If Consumer Type B participates in DUFB they will increase their F&V purchases the most out of the three types; their F&V purchases will increase by more than the gift card value due to the substitution from all other goods to F&V in order to participate. Consumer Type C will get more all other goods and more F&V under DUFB but their gain in F&V may be less than the gift card value because the gift card freed up money originally spent on F&V to buy all other goods. Throughout the remainder of the paper Consumer Type A refers to consumers who purchased little to no F&V, Consumer Type B refers to consumers who purchased moderate F&V, and Consumer Type C refers to consumers who had a high preference for F&V before DUFB was implemented.

**Figure 3.1: DUFB Effects on Different Consumer Types**




**Data**

Scanner data from a Detroit independent supermarket that participated in DUFB is used for this study. The store is located in a low-income predominantly Hispanic community (within the census tract Hispanic is the primary ethnicity; 69% of households are families; 90% have not attended any type of college and the median household annual income is under $30,000 (Office of

Social and Economic Data Analysis 2010b)). The data includes all store transactions from May 2014 through January 2015. The unformatted receipt text file was converted into a Stata file using Python version 2.7.2. A unique identifier was created for 41% of the transactions where the customer either had a loyalty card,[9] credit card, debit card, SNAP benefits card or a Women, Infants and Children (WIC) account. The data was then transformed into a panel dataset where each observation represents a customer's monthly purchases. The panel dataset structure allows the comparison of F&V expenditures over time for each consumer with a unique identifier.[10]

Store Expenditures

Table 3.1 provides descriptive statistics on the shopping behaviors of 12,699 unique identifiable customers (those customers with ID numbers). The average customer for this store spends $83.69 overall and $4.92 on F&V per month. For those customers that purchase F&V at least once per month, their average F&V expenditure is $8.60. The average F&V expenditure share is 6.21%, slightly more than half the national average F&V expenditure share from supermarkets (11.6%) (FMI, 2016). The average customer spends more on vegetables than fruits.

Comparing SNAP customers before DUFB with the rest of the customers at this store shows that they spend more overall and more on F&V, but have lower F&V expenditure shares, on average. SNAP customers who purchased F&V before DUFB, purchased on average $8.12 worth of F&V a month, which is less than the transaction level purchase hurdle that DUFB requires

[9] Although there are weekly sales at this store, the loyalty card was not needed for the customer to receive them; rather all customers received them automatically. The loyalty card at this store allows the customer to accumulate points from all their purchases and receive a free gift once they cross a spending threshold.

[10] The Kolmogorov-Smirnov equality of distributions test rejected the null hypothesis that the two group's F&V expenditures have the same distribution. Hence, the analysis in this study is valid for identifiable customers but may not be representative of the entire store.

($10). This is an initial indicator that the purchase hurdle may be too high to incentivize F&V purchases.

### Other Shopping Behaviors

Approximately 80% of the customers purchased a fruit or vegetable at least once in the nine-month period and 18% purchased a fruit or vegetable every month in the nine-month period. On average customers purchase 2.2 different types of F&V per month. The average shopping frequency at this store is 2.7 times a month, which is low compared to the national average of 6 supermarket visits a month (FMI, 2016). The number of identifiable customers that shopped during the individual months is relatively steady throughout the nine months, ranging from 6,051 to 6,332 customers per month (not shown in Table 3.1).

### Payment Method

The customer payment breakdown for this store is unique; 62.1% of customers paid with SNAP benefits, 40.6% cash, 6.6% Debit or Credit, and 1.7% WIC.[11] Nationally, there is a much lower prevalence of SNAP purchases and cash purchases and higher prevalence of credit and debit purchases (Statista, 2017); however, previous research has shown that Hispanics pay with cash more frequently than other races and ethnicities (Wang and Wolman, 2016) and this is a low-income community so SNAP participation is higher.

[11] Payment Methods are not mutually exclusive because if the customer uses a loyalty card they can pay with more than one method within the month and still have the same ID number.

**Table 3.1: Descriptive Statistics of the Panel Dataset**

| | Monthly Mean over the Entire Dataset | SNAP Customers Monthly Mean Before DUFB |
|---|---|---|
| **Store Expenditure** | $83.69 | $98.98 |
| **F&V Expenditure** | $4.92 | $5.21 |
| **Conditional F&V Exp** [a] | $8.60 | $8.12 |
| **F&V Expenditure Share** | 6.21% | 5.63% |
| **Fruit Expenditure** | $2.11 | $2.42 |
| **Vegetable Expenditure** | $2.82 | $2.86 |
| **F&V Variety** | 2.19 | 2.47 |
| **Number of Visits** | 2.67 | 2.79 |

| | Number of Unique Customers | Percent of All Unique Customers |
|---|---|---|
| **With ID** | 12699 | 100 |
| **Purchased F&V at least once** | 10152 | 79.9 |
| **Purchased F&V each month** | 2301 | 18.1 |
| **Paid with SNAP** [b] | 7880 | 62.1 |
| **Paid with Credit or Debit** [b] | 839 | 6.6 |
| **Paid with Cash** [b] | 5160 | 40.6 |
| **Paid with WIC** [b] | 211 | 1.7 |
| **Loyalty Card Members** | 3564 | 28.1 |

a. Conditional on F&V being purchased.
b. Payment Methods are not mutually exclusive because if the customer uses a loyalty card they can pay with more than one method within the month and still have the same ID number.

## Methods

This study estimates the causal effects of the DUFB program using a quasi-experimental approach. Eligibility of customers to participate was nonrandom given that only and all SNAP beneficiaries were eligible to participate in DUFB. Throughout the literature there are a couple common approaches for addressing nonrandom treatment assignment. Propensity Score Matching

(PSM) uses observed individual characteristics to calculate a probability of participating in the treatment and then matches the participants to nonparticipants with similar calculated participation probabilities (Khandker et al., 2010). This method is not used in this analysis because no personal information was collected on the customers. Since the cutoff for DUFB eligibility is based on income (SNAP eligibility), and this is not collected from the customers, Regression Discontinuity methods are not appropriate (Khandker et al., 2010). Pipeline methods use different program implementation periods to classify participants and nonparticipants but the DUFB program started and ended at the same time for all customers at this store; hence, is not a suitable method. Difference in Difference (DD) relies on data of both the treated and the control groups before and after treatment, to control for any confounding effects present, in order to estimate the treatment effects (Imbens and Wooldridge, 2008). This panel dataset permits the use of both a cross-sectional estimator and a time-series estimator to difference away any permanent differences between the groups and any common trends affecting both groups; hence, the non-random treatment assignment of DUFB is addressed by using DD.[12]

DUFB Low Participation

DUFB program participation was defined by whether the SNAP customer earned and used the DUFB gift card on Michigan F&V in another transaction. The DUFB gift card was activated by the store cashier immediately after the completion of the $10 F&V purchase transaction and was valid until the end of the program. The DUFB gift card usage was low at this store, only 535 transactions (1.87% of all SNAP transactions during implementation) used a DUFB card to purchase Michigan grown F&V. There were 156 unique customers who used the DUFB card once,

[12] The Parallel Trend Assumption is addressed in Appendix C.

23 who used it twice, seven who used it three times, and four who used it four or more times during the four-month implementation.[13] The number of times a customer can spend $10 on F&V and receive $10 for Michigan grown F&V was unlimited during the 4-month implementation period; however, eight was the maximum number of times that a single customer used the program.

DUFB participation was low enough that concerns of noncompliance are present; hence, the Intention to Treat (ITT) is estimated (Khandker et al., 2010). ITT interpretation of results are not biased from this noncompliance of the participants since it is based on the initial treatment assignment rather than based on whether or not the customer actually participated (Khandker et al., 2010). This categorizes all SNAP participants as being treated by DUFB, even though many did not receive or redeem their $10 gift card (the effect of being assigned to treatment rather than the effect of receiving treatment); hence the ITT analysis provides a conservative estimate of the treatment effect (Shadish et al., 2002).

Estimation Strategy

The program effect is estimated by the following regression:

$$Y_{it} = \alpha + \beta\,(SNAP_{it} * T) + \rho\, SNAP_{it} + \gamma\, \mathbf{month} + \delta\, \mathbf{x}_{it} + c_i + \epsilon_{it}$$

where $Y_{it}$ is the F&V purchase behavior for customer i during month t, $SNAP_{it}$ is a dummy for whether customer i is a SNAP customer (1) or a non-SNAP customer (0) in month t, T is a program time indicator variable and month is a vector of month indicator variables. The $x_{it}$ term is a vector comprised of the time variant customer specific covariates: monthly store non-F&V expenditure and number of shopping trips that month. The $c_i$ is the customer fixed effect and the $\epsilon_{it}$ is the error term. Fixed effects estimation is used to control for the time invariant unobserved customer

[13] Some DUFB transactions do not have an identifier associated with them because no loyalty card was used and the DUFB gift card was the only payment method used.

heterogeneity. The β parameter (the coefficient on the interaction between the time and the treatment variables) is capturing the average DD effect of the DUFB program.

F&V Purchase Behaviors

There are six different F&V purchase behaviors that are examined to determine the effects of DUFB: F&V expenditure; fruit expenditure; vegetable expenditure; F&V expenditure share; F&V variety; and F&V purchase decision. F&V expenditure is the aggregate dollar amount spent during the month on all fresh F&V. Fruit expenditure and vegetable expenditure are the independent allocation of those expenditures, which reveals how each are individually affected. F&V expenditure shares measure the ratio of fresh F&V purchases to all other store purchases to identify how the F&V expenditures change relative to expenditures in the rest of the store. Variety of F&V is a count of the different F&V purchased during the month, which captures whether the program increased the diversity of F&V purchased. The F&V purchase decision is the customer's binary decision to purchase F&V or not, to illustrate whether the program incentivized customers to purchase F&V. Evaluating these purchase behaviors reveals the potential effects of the program.

Program Time Indicator Variables

The dataset was divided into three time periods: before DUFB (May 1, 2014 – July 31, 2014), during DUFB (Aug 1, 2014 – Nov 30, 2014), and after DUFB (Dec 1, 2014 – Jan 31, 2015). The three time periods allow the analysis of the following purchase behavior comparisons: before versus during DUFB to determine how the implementation impacts purchase behaviors; during versus after DUFB to determine how the conclusion of DUFB impacts purchase behaviors; and before versus after to determine if DUFB has any persistent effects. To examine the initial DUFB

incentive effect, the time variable, T, is defined as 0 if the observation is before DUFB and 1 if during DUFB. To measure whether the conclusion of DUFB has an effect, the time variable, T, is redefined as 0 if the observation is during the DUFB implementation and 1 if after the implementation. Whether DUFB has a persistent effect or not is measured through redefining the time variable, T, to 0 if the observation is before the DUFB implementation and 1 if after the implementation.

Heterogeneous Program Effects

To empirically capture how the program affected each of the three different types of consumers described in Figure 3.1, all analysis is repeated for each consumer type separately. Customers are categorized based on their F&V monthly expenditures before DUFB: Consumer Type A for [$0, $5) F&V expenditure, Consumer Type B for [$5, $10] F&V expenditure, and Consumer Type C for ($10, ∞) F&V expenditure. Both the treated (SNAP customers) and comparison (non-SNAP customers) groups are divided so that changes in SNAP consumer type i shopping behaviors are compared to changes in non-SNAP consumer type i shopping behaviors only (i in $\{A, B, C\}$). Table 3.2 provides some insight to the different types of consumers. Out of all the SNAP and non-SNAP customers, the majority are type A, followed by type C and lastly type B. Three percent of customers classified as type A participated in DUFB, 4.1% for type B, and 8.2% for type C. When the DUFB participants are broken down by type of customer, 48.8% are type A, 16.4% are type B and 34.8% are type C.

**Table 3.2: Customer Types Descriptive Statistics**

| Customer Type | Percent of All Customers | Percent of SNAP Customers | Percent of Type that Participated | Percent of those who Participated |
|---|---|---|---|---|
| **A** | 70.0 | 66.6 | 3.0 | 48.8 |
| **B** | 14.7 | 16.3 | 4.1 | 16.4 |
| **C** | 15.3 | 17.1 | 8.2 | 34.8 |

**Results**

All six dependent variables (F&V expenditure, fruit expenditure, vegetable expenditure, F&V expenditure share, F&V variety and the F&V purchase decision) are run for the three program effects based on time across all SNAP customers, yielding 18 regressions. Then the 18 regressions were run again separately for each consumer type to see how DUFB affected the three types of F&V shoppers separately, thereby providing a total of 72 regressions. Table 3.3 offers a summary of the DUFB effects on the six F&V purchase behaviors over time and over consumer types. The complete regression results on the six purchase behaviors for all the customer types together are shown in Appendix C; Table C.1 for the initial incentive effects (before versus during DUFB); Table C.2 for the after incentive effects (during versus after DUFB); and Table C.3 for the persistence of program effects (before versus after DUFB). These regressions were originally estimated using a linear regression with fixed effects to provide a linear approximation of program effects. This allows the unobserved heterogeneity to be controlled for through fixed effects, while offering a clear interpretation of the results across the different effects (Wooldridge, 2010). However, as a robustness check each regression was re-estimated with an appropriate nonlinear

model.[14] For the expenditure and expenditure share regressions Tobit models were estimated (due to a high prevalence of no F&V purchases in the dataset). For the F&V variety model a Poisson regression was estimated (because the variety variable is a count variable) and for the F&V purchase decision a probit regression was estimated (because the decision to purchase F&V is a binary variable). A summary of the results from the nonlinear regressions, over all customer types, are shown in Table C.4 in Appendix C. The linear and non-linear models have similar results in terms of signs and significance but have slightly different magnitudes due to estimation procedures; therefore, only the linear models will be discussed.

DUFB Program Effects

An increase of $0.40 in the SNAP customers' monthly F&V expenditures is attributable to the DUFB program being implemented, which is approximately a 5.8% increase. This implies that over the four months that DUFB was implemented, SNAP customers spent a total of $1.60 more on F&V compared to what they would have spent had the DUFB program not been implemented. However, most of that significant increase in expenditure is from increased expenditures on vegetables, which increased by $0.33 a month due to DUFB, while the fruits expenditure did not significantly increase due to DUFB. Examining changes in these expenditures across the different types of consumers reveals that DUFB increased SNAP Consumer Type B's the most and statistically increased both their fruit expenditures and vegetable expenditures. DUFB statistically increased the F&V expenditure share by 0.7% on average but this significant increase was not present among type A consumers. The number of F&V varieties purchased increased by 0.11 F&V

[14] Correlated Random Effects are estimated in these nonlinear regressions (time averages of the time varying customer specific explanatory variables included as additional explanatory variables) to avoid the incidental parameters problem present in fixed effects nonlinear models (Wooldridge, 2010).

due to DUFB, driven mostly by the type B consumers. DUFB did not have any influence on the decision to purchase F&V.

The loss of the DUFB financial incentive is responsible for a $0.27 (roughly 3.6%) decline in the monthly F&V expenditure of the SNAP participants. Examining the F&V expenditure effects separately reveals that the program decreased monthly vegetable expenditures by $0.19, but had no significant impact on fruit expenditures. These SNAP consumers spend less money on fruits than vegetables, on average, and their fruit expenditure is not affected by the implementation nor conclusion of the DUFB program while their vegetable expenditure is statistically affected by both. None of these expenditures significantly changed for the individual consumer types except vegetable expenditures significantly decreased for the type C consumers. The F&V expenditure shares and the variety of F&V significantly decreased after the DUFB ended by 0.5% and 0.16 F&V, respectively. F&V purchase decisions were unaffected by the start and end of DUFB. None of consumer type B's F&V purchasing behaviors significantly changed due to the DUFB program ending.

The DUFB program has positive effects on the F&V purchase behaviors and the conclusion of DUFB has negative effects; however, this raises the question as to whether the program has any lasting impact on the purchasing habits of customers. This is investigated by comparing the F&V expenditures before and after DUFB implementation. There are no statistically significant differences in fruit or vegetable expenditures, F&V expenditure shares, F&V variety and the probability of purchasing F&V before or after DUFB was implemented. Hence, DUFB does not have a lasting effect on any of these dimensions of consumer F&V purchasing behavior at this store and all F&V purchasing behaviors return to where they were before DUFB was implemented. This is also true for the consumer types A and C, with the exception in decreased F&V variety for

**Table 3.3: Summary of DUFB Effects over Time and Consumer Types**

| | All Consumers | Consumer A | Consumer B | Consumer C |
|---|---|---|---|---|
| Before versus During | | | | |
| **F&V Expenditure** | \$0.40*** (0.143) | \$0.30** (0.131) | \$0.98*** (0.244) | \$0.43 (0.381) |
| **Fruit Expenditure** | \$0.08 (0.083) | \$0.04 (0.075) | \$0.52*** (0.148) | -\$0.03 (0.228) |
| **Veg Expenditure** | \$0.33*** (0.096) | \$0.26*** (0.090) | \$0.46*** (0.164) | \$0.47* (0.255) |
| **F&V Exp Share** | 0.70%*** (0.216) | 0.26% (0.229) | 1.74%*** (0.394) | 1.12%*** (0.389) |
| **F&V Variety** | 0.11** (0.049) | 0.08 (0.048) | 0.24*** (0.090) | -0.05 (0.119) |
| **F&V Purchase Decision** | 0.01 (0.010) | -0.00 (0.011) | 0.02 (0.016) | 0.02 (0.015) |
| During versus After | | | | |
| **F&V Expenditure** | -\$0.27* (0.161) | -\$0.20 (0.168) | -\$0.41 (0.309) | -\$0.45 (0.433) |
| **Fruit Expenditure** | -\$0.08 (0.091) | -\$0.03 (0.094) | -\$0.10 (0.180) | \$0.07 (0.245) |
| **Veg Expenditure** | -\$0.19* (0.110) | -\$0.16 (0.118) | -\$0.31 (0.208) | -\$0.53* (0.289) |
| **F&V Exp Share** | -0.53%** (0.238) | -0.53%* (0.276) | -0.38% (0.428) | -1.21%*** (0.448) |
| **F&V Variety** | -0.16*** (0.055) | -0.13** (0.061) | -0.13 (0.112) | -0.29** (0.134) |
| **F&V Purchase Decision** | -0.01 (0.011) | -0.01 (0.013) | 0.01 (0.020) | 0.00 (0.019) |
| Before versus After | | | | |
| **F&V Expenditure** | \$0.07 (0.191) | -\$0.04 (0.172) | \$0.50 (0.312) | -\$0.02 (0.508) |
| **Fruit Expenditure** | \$0.06 (0.110) | -\$0.08 (0.097) | \$0.36* (0.157) | \$0.24 (0.296) |
| **Veg Expenditure** | \$0.01 (0.128) | -\$0.04 (0.119) | \$0.14 (0.201) | -\$0.26 (0.343) |
| **F&V Exp Share** | -0.10% (0.279) | -0.39% (2.99) | 1.06%** (0.466) | -0.08% (.531) |
| **F&V Variety** | -0.077 (0.066) | -0.06 (0.064) | 0.09 (0.118) | -0.38** (0.155) |
| **F&V Purchase Decision** | -0.015 (0.013) | -0.02 (0.014) | 0.04* (0.021) | -0.00 (0.019) |

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

type C. However, the type B consumers do have persistent significant increases in fruit expenditure, F&V expenditure shares and the decision to purchase F&V after DUFB.

### Other Factors

There are three main factors, other than the DUFB program, that influenced the F&V purchasing behaviors: seasonality, frequency of store visits, and non-F&V store expenditures. Most of the month dummy variables are significant, meaning that seasonality affects customers' F&V expenditure shares, variety of F&V purchased and their decision to purchase. Fruit expenditure is higher in the warmer months of the year, similar to national data (Cox et al., 2000). The number of store visits the consumer makes in a month and the F&V purchasing behaviors are significant and positive for all the program times. The more frequently a customer shops at the store the greater their F&V expenditures, the higher their F&V expenditure share, the more varieties of F&V purchased and the more likely they are to purchase F&V. Consumers who spend more money throughout the rest of the store spend more money on both fruits and vegetables, purchase more varieties of F&V and are more likely to purchase F&V. However, as the non-F&V expenditure increases, the F&V expenditure share decreases. These relationships are consistent across the program time comparisons.

## Conclusion

To incentivize SNAP participants to consume more F&V, the DUFB program gave $10 gift cards for Michigan grown F&V to SNAP customers that spent $10 on F&V. The DUFB program increases SNAP customers' vegetable expenditures, F&V expenditure shares and the variety of F&V purchased during implementation; however, persistent program effects on

purchasing behaviors are lacking and may require longer interventions, as shown in other studies (Song et al., 2009). The DUFB effects were relatively modest compared to what other financial incentive programs in supermarkets have generated (Klerman et al., 2014, Herman et al., 2008, Young, 2013). The Healthy Incentives Pilot program, subsidy intervention, gave SNAP customers 30% off on targeted F&V purchases and increased F&V expenditures by 20% (Klerman et al., 2014), which was larger than the 5.8% F&V expenditure increase found for DUFB. An intervention implemented in Pennsylvania which gave low-income customers a 50% rebate on fresh and frozen F&V (for eight weeks), and then a 25% rebate during a tapering phase (for four weeks) before ending was also found to be more impactful. Similar to DUFB, this program significantly increased the treated households' weekly F&V purchases, vegetables more so than fruits, and when the incentive was discontinued, households returned to their baseline F&V purchases (Phipps et al., 2015). Herman et al. (2008) found that WIC participants in Los Angeles, California increased their consumption of F&V due to a F&V subsidy intervention and maintained the increase six months after the intervention ended (Herman et al., 2008).

Examining how the program affects the different types of consumers based on their initial F&V expenditures shows that the DUFB program is more effective for the consumers who spent a moderate amount of money on F&V before DUFB started than those who spent very little or a lot on F&V before the program.

## Program Implications

The lack of participation and persistence of program effects are concerning for the DUFB program. DUFB participation was extremely low, evident by only 535 DUFB transactions out of the 28,609 total potential SNAP transactions during DUFB implementation at this store. This low

participation rate, especially compared to subsidy type financial incentive programs, could be an indication that the $10 F&V purchase hurdle discourages participation rather than encouraging spending more. This purchase hurdle requirement prior to any benefits being received in the DUFB program mirrors the early purchase requirements of the U.S. food stamps program which required low-income households to meet food purchase requirements in order to receive food stamps (Stucker and Boehm, 1978). The large hurdle failed for DUFB as it did for SNAP in the past; hence, one suggestion to increase the participation rate is to make this purchase hurdle lower.

Another aspect of the program that could be influencing the participation rate is the fact that the DUFB gift card is not available until after the initial transaction is complete. For the customers who shop less frequently a program which gives immediate benefit would be more effective (Prell and Smallwood, 2017). The literature suggests addressing the concern of limited program effect persistence through implementing the programs for longer periods of time (Song et al., 2009, An, 2013). By doing this, higher program costs are unavoidable; hence, the benefit and costs of extending the program duration should be evaluated by the program implementers.

Prell & Smallwood (2017) use neoclassical economics to show that the effectiveness of the subsidy versus rebate program types depend on the proportion of SNAP consumers who fall into the different consumer types (Prell and Smallwood, 2017). In this community, the majority of consumers purchase little to no F&V (less than $5 worth a month). Consumers who initially purchase no F&V's are less responsive to initiatives that require them to pay something to participate (Prell and Smallwood, 2017). The results from this analysis agree with this, in that the program is more effective at improving F&V purchase behaviors among those that already were purchasing from a moderate amount to a lot F&V per month. However, programs need to target those consumers who purchase little to no F&V because they will gain the most health benefits

from additional F&V consumption, due to diminishing returns (Prell and Smallwood, 2017). A more economically efficient type of incentive program for this community would be a subsidy type program, for example giving a discount on all Michigan produce purchased. Another potential program option is every dollar a customer spends on F&V be matched in their next transaction. The results indicate that the program has no significant effects on the F&V purchase decision so the store should cross-merchandize and have signage and displays more throughout the rest of the store (outside of the produce department) to target those customers who may not typically enter the produce department.

Consumer preferences are important factors to consider in evaluating the effectiveness of consumer behavior based programs. Analyzing the most frequently purchased F&V at this store reveals that the grown in Michigan requirement should be dropped in order to encourage increased F&V consumption. Michigan grown F&V are apples, asparagus, blackberries, blueberries, cabbage, carrots, celery, cherries, corn, cucumbers, onions, peaches, pears, plums, raspberries, strawberries, and tomatoes (MDARD, 2016). Only two of these (apples and peaches) make the list of the top ten sold fruits and five of these (cabbage, carrots, cucumbers, onions and tomatoes) make the list of the top ten sold vegetables at this store. This divergence between preferences and gift card eligibility could be driving the low program participation and the lack of DUFB effect on fruit expenditures.

Though the DUFB program had a modest impact on F&V purchases, it also invoked relatively small costs for the store. The costs the store faced due to DUFB implementation were: signage and displays to promote DUFB; employee training on what DUFB is, how to give and accept the gift cards as well as how to inform customers about it; programming the POS system; and any switching costs affiliated with having to provide more in-season Michigan produce.

## Limitations and Future Research

Limitations of this study associated with external validity are present, as with most nutrition program evaluations. This study focuses on a subset of the population which limits the generalizability of the results beyond this community. With respect to internal validity, one possible confounding issue is if there were any changes to federal or state level SNAP policy. There are no other store receipt data available, implying the assumption that these consumers only purchase their food from this supermarket. This assumption is not as restrictive as it may seem given that there are no other nearby supermarkets with similar assortment and quality. Finally, it should be noted that one limitation of expenditure analysis is that it does not capture changes in F&V choices and the differences in relative prices, which could be partially driving the expenditure changes. Future research should collect information about consumer demographics to be able to compare how the DUFB affects consumers differently across different demographics.

# APPENDICES

## APPENDIX A: Supplementary Material For Chapter 1

*Proof of Lemma 3*

The Derivation of $\underline{\Phi}$ and $\overline{\Phi}$ values.

The $\underline{\Phi}$ value is the $\Phi$ that makes even having duopoly profit with the high costs profitable in the food desert. Hence $\underline{\Phi}$ is the maximum value such that

$$0 \leq \mathrm{E}\left[\pi_{i2}^{D}\left(\overline{c},\overline{c}\right)\right] - \Phi \quad \text{which is when} \quad 0 = \mathrm{E}\left[\pi_{i2}^{D}\left(\overline{c},\overline{c}\right)\right] - \Phi.$$

Hence,

$$\mathrm{E}\left[\pi_{i2}^{D}\left(\overline{c},\overline{c}\right)\right] = \mathrm{E}\left[\left(\frac{\theta-\overline{c}}{3}\right)^{2}\right] = \Phi$$

which implies

$$\underline{\Phi} = \frac{1}{27}\left(1 - 3\overline{c} + 3\overline{c}^{2}\right).$$

The $\overline{\Phi}$ value is the $\Phi$ that makes having monopoly power with the high costs unprofitable in the food desert. Hence $\overline{\Phi}$ is the minimum value such that

$$0 \geq \mathrm{E}\left[\pi_{i2}^{M}\left(\overline{c}\right)\right] - \Phi \quad \text{which is when} \quad 0 = \mathrm{E}\left[\pi_{i2}^{M}\left(\overline{c}\right)\right] - \Phi.$$

Hence,

$$\mathrm{E}\left[\pi_{i2}^{M}\left(\overline{c}\right)\right] = \mathrm{E}\left[\left(\frac{\theta-\overline{c}}{2}\right)^{2}\right] = \Phi$$

which implies

$$\overline{\Phi} = \frac{1}{12}\left(1 - 3\overline{c} + 3\overline{c}^{2}\right).$$

*Proof of Proposition*

The derivation of the r, $\underline{\Delta c(\Phi)}$ and $\overline{\Delta c(\Phi)}$ values.

The probability r is the probability associated with the MSNE of the first period game. It is the probability that makes a supermarket indifferent between entering and not entering in the first period given that the other supermarket will also enter with probability r.

The probability r is the solution to the following:

$$\begin{aligned} &r\,E(\text{simultaneous entry in period 1}) + (1-r)E(\text{leader profit}) \\ &\quad = r\,E(\text{follower profit}) + (1-r)(s^2 * (\text{simultaneous profit in period 2}) \\ &\quad + \big(s(1-s)\big)(\text{monopoly profit in period 2}) \end{aligned}$$

which is equivalent to

$$r\ \left(E\left[\pi_{i1}^{D}\left(\overline{c},\overline{c}\right) + \pi_{i2}^{D}\left(\underline{c},\underline{c}\right)\right] - \Phi\right) +$$

$$(1-r)\left(E\left[\pi_{i1}^{M}\left(\overline{c}\right)\right] + E\left[\pi_{i2}^{D}\left(\underline{c},\overline{c}\right) \mid \theta > \hat{\theta}\right](1-\hat{\theta}) + E\left[\pi_{i2}^{M}\left(\underline{c}\right) \mid \theta \leq \hat{\theta}\right]\hat{\theta} - \Phi\right) =$$

$$r\left(E\left[\pi_{i2}^{D}\left(\overline{c},\underline{c}\right) - \Phi \mid \theta > \hat{\theta}\right]\left(1-\hat{\theta}\right)\right) +$$

$$(1-r)\left(s^2 * \left(E\left[\pi_{i2}^{D}\left(\overline{c},\overline{c}\right)\right] - \Phi\right) + s(1-s)\left(E\left[\pi_{i2}^{M}\left(\overline{c}\right)\right] - \Phi\right)\right).$$

The function for the probability r is not displayed due to its complexity, but it is a function of $\Phi$ and $\Delta c$, i. e. $r = r(\Phi, \Delta c)$. To get the $\underline{\Delta c(\Phi)}$ value, solve the implicit function $0 = r(\Phi, \Delta c)$ for $\Delta c$ and to get the $\overline{\Delta c(\Phi)}$ value, solve the implicit function $1 = r(\Phi, \Delta c)$ for $\Delta c$.

*Graphical Analysis Redone for the Cost Advantage on the Fixed Investment Costs*

*(rather than the Marginal Costs)*

Whichever supermarket(s) enter the food desert in period 1 will face low investment costs, $\underline{\Phi}$.

Whichever supermarket(s) enter the food desert in period 2 will face high investment costs, $\overline{\Phi}$.

Both supermarkets face the same marginal costs, c, no matter which period they enter.

**Figure A.1: Period 1 Investment Decisions with a Fixed Investment Cost Advantage**

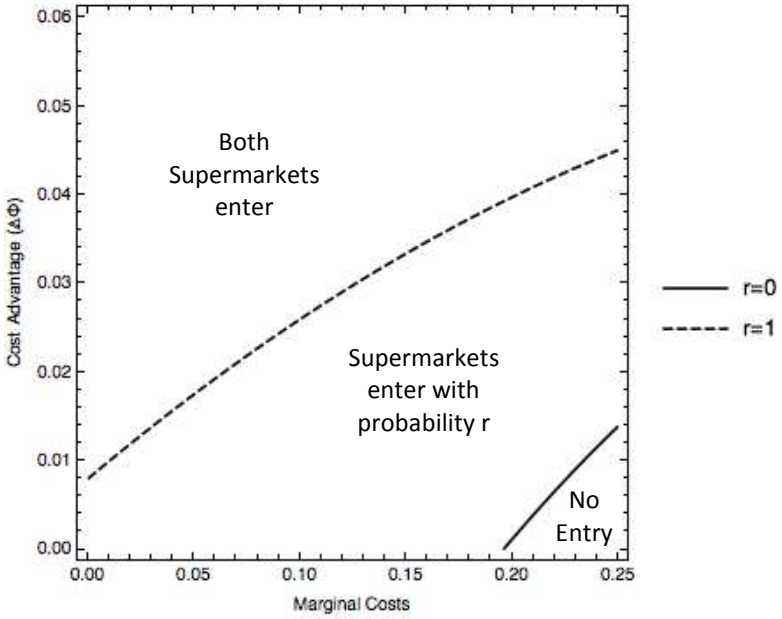


**Figure A.2: Follower Investment Decision with a Fixed Investment Cost Advantage**

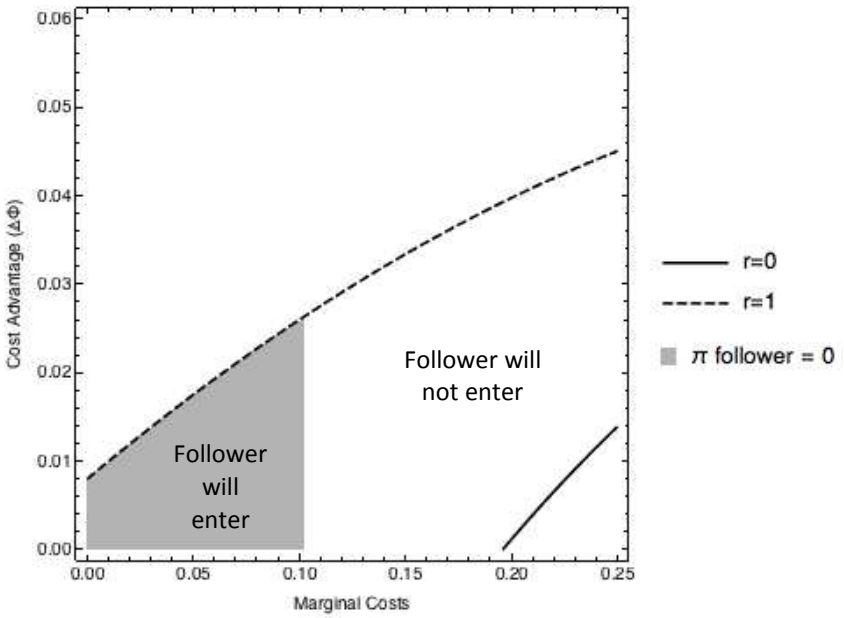
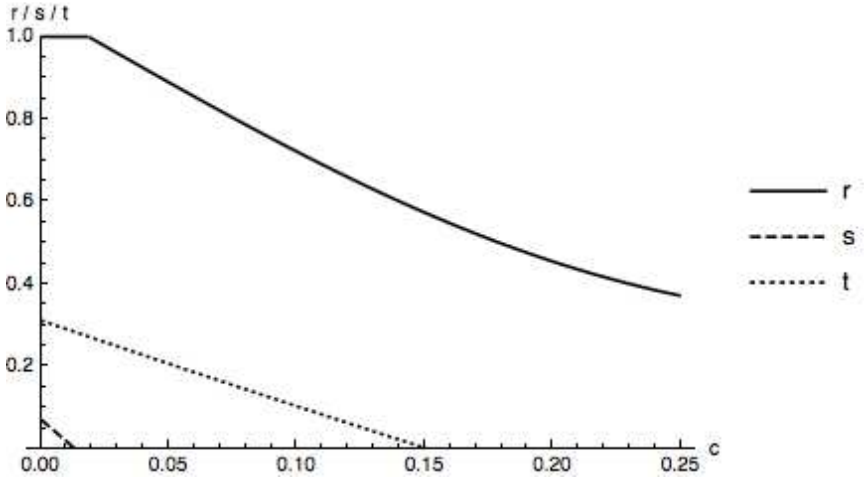
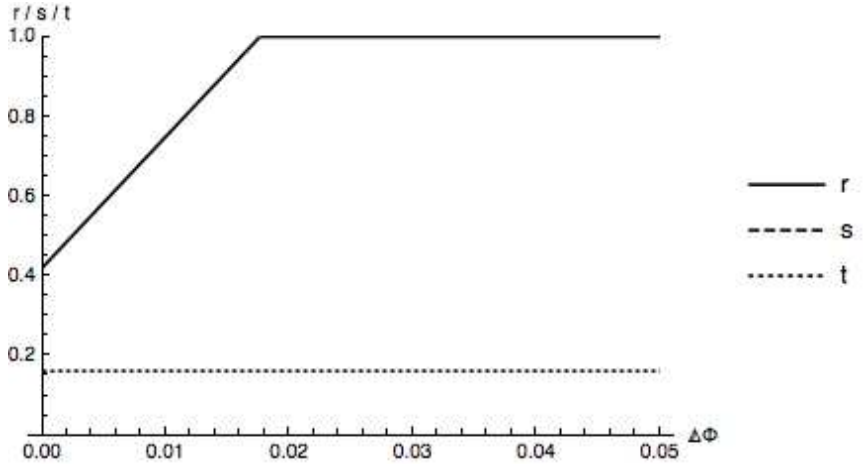



**Figure A.3: Marginal Cost Effect on the Entry Probabilities with a Fixed Investment Cost Advantage**




Note: r is the first period entry, s is the second period initial entry, and t is the sequential entry after leader.

**Figure A.4: Investment Cost Advantage from Early Investment Effect on the Entry Probabilities**




Note: r is the first period entry, s = 0 is the second period initial entry, and t is the sequential entry after leader.

## APPENDIX B: Supplementary Material For Chapter 2

### Table B.1: Compensated Price Elasticities

| | Green Fruit | White Fruit | Red / Blue / Purple Fruit | Yellow / Orange Fruit | Green Veg | White Veg | Red / Blue / Purple Veg | Yellow / Orange Veg |
|---|---|---|---|---|---|---|---|---|
| **Green Fruit** | **-0.916*** (0.125)** | 0.017 (0.063) | 0.056 (0.050) | -0.046 (0.053) | 0.154** (0.076) | 0.218*** (0.078) | 0.237*** (0.050) | 0.280*** (0.048) |
| **White Fruit** | 0.018 (0.066) | **-0.984*** (0.071)** | 0.154*** (0.041) | 0.241*** (0.041) | 0.099 (0.063) | 0.200*** (0.052) | 0.209*** (0.041) | 0.063* (0.033) |
| **Red / Blue / Purple Fruit** | 0.064 (0.056) | 0.166*** (0.045) | **-0.873*** (0.045)** | 0.064** (0.032) | 0.133*** (0.048) | 0.144*** (0.040) | 0.144*** (0.029) | 0.158*** (0.029) |
| **Yellow / Orange Fruit** | -0.052 (0.060) | 0.261*** (0.044) | 0.064 (0.044) | **-1.058*** (0.053)** | 0.128** (0.051) | 0.235*** (0.046) | 0.201*** (0.032) | 0.222*** (0.032) |
| **Green Veg** | 0.145** (0.071) | 0.088 (0.057) | 0.110* (0.057) | 0.106** (0.042) | **-0.952*** (0.090)** | 0.082 (0.054) | 0.244*** (0.045) | 0.177*** (0.042) |
| **White Veg** | 0.219*** (0.079) | 0.192*** (0.050) | 0.128** (0.050) | 0.208*** (0.041) | 0.088 (0.058) | **-0.874*** (0.071)** | 0.052 (0.041) | -0.014 (0.036) |
| **Red / Blue / Purple Veg** | 0.239*** (0.050) | 0.201*** (0.039) | 0.129*** (0.039) | 0.178*** (0.029) | 0.262*** (0.048) | 0.052 (0.041) | **-1.009*** (0.047)** | -0.053** (0.026) |
| **Yellow / Orange Veg** | 0.321*** (0.056) | 0.069* (0.037) | 0.160*** (0.037) | 0.225*** (0.033) | 0.216*** (0.051) | -0.016 (0.041) | -0.060** (0.029) | **-0.915*** (0.039)** |

Row names represent Quantities and Column names represent Prices.
Standard errors (delta method) are in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

**Table B.2: Partially Unavailable Individual F&V and the Number of two-week Periods Unavailable**

| Fruit or Vegetable Name | Number of Two-week Periods Unavailable |
|---|---|
| apricots | 7 |
| blueberries | 9 |
| Brussel sprouts | 2 |
| cherries | 7 |
| honeydew | 3 |
| jicama | 3 |
| plums | 5 |
| pumpkin | 13 |
| radishes | 9 |
| strawberries | 5 |
| turnip roots | 2 |

## APPENDIX C: Supplementary Material For Chapter 3

*Parallel Trend Assumption*

The parallel trend assumption is what alleviates the endogeneity of the treatment concern for the DD estimators. It requires that in the absence of treatment, the average change in the F&V expenditure would have been the same for both the treatment and comparison groups. To assess this assumption the unconditional F&V expenditure patterns in SNAP versus non-SNAP before DUFB were compared. Figure C.1 shows the lines of best fit for SNAP and non-SNAP F&V purchases before the DUFB program. It shows that the SNAP F&V purchases over time were moving roughly together with the non-SNAP F&V purchases, which provides confidence that the parallel trend assumption is satisfied. Hence, the non-SNAP consumers' transactions over time were used as the comparison group for analysis.

**Figure C.1: SNAP versus Non-SNAP Customers F&V Purchases Before DUFB**

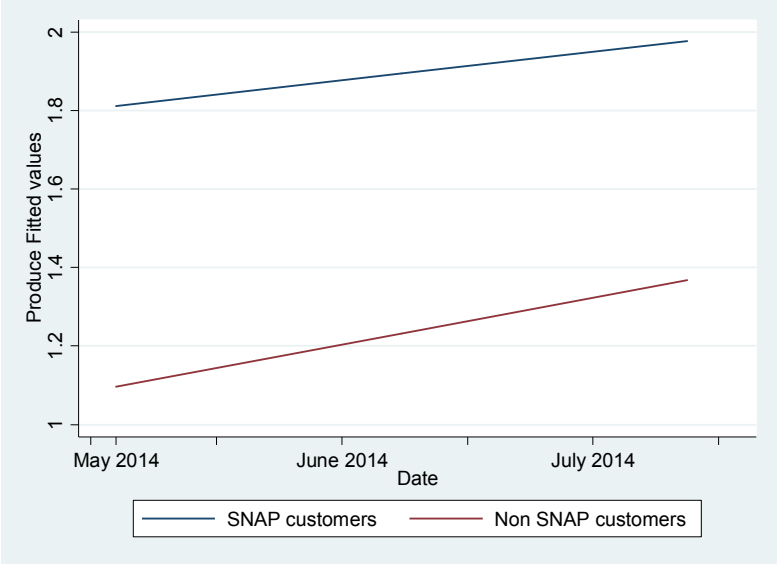


**Table C.1: Before versus During DUFB Implementation Regression Results**

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Variables | **F&V Exp** | **Fruit Exp** | **Veg Exp** | **F&V Exp Share** | **F&V Variety** | **F&V Purchase Decision** |
| | | | | | | |
| DUFB Effect | 0.40*** | 0.08 | 0.33*** | 0.01*** | 0.11** | 0.01 |
| | (0.143) | (0.083) | (0.096) | (0.002) | (0.049) | (0.010) |
| SNAP | -0.34*** | -0.17** | -0.18** | -0.00 | 0.04 | 0.07*** |
| | (0.132) | (0.077) | (0.088) | (0.002) | (0.049) | (0.010) |
| May 2014 | -0.49*** | 0.18** | -0.67*** | -0.01*** | -0.19*** | -0.02** |
| | (0.136) | (0.077) | (0.096) | (0.002) | (0.040) | (0.008) |
| June 2014 | 0.32** | 0.66*** | -0.33*** | -0.00 | -0.14*** | -0.02*** |
| | (0.145) | (0.084) | (0.099) | (0.002) | (0.041) | (0.008) |
| July 2014 | -0.01 | 0.54*** | -0.53*** | -0.01*** | -0.23*** | -0.04*** |
| | (0.142) | (0.082) | (0.098) | (0.002) | (0.048) | (0.010) |
| August 2014 | -0.39*** | 0.47*** | -0.86*** | -0.01*** | -0.17*** | -0.04*** |
| | (0.127) | (0.073) | (0.090) | (0.002) | (0.048) | (0.010) |
| September 2014 | -0.32*** | 0.29*** | -0.61*** | -0.01*** | -0.23*** | -0.05*** |
| | (0.197) | (0.068) | (0.084) | (0.002) | (0.049) | (0.010) |
| October 2014 | -0.20* | 0.31*** | -0.51*** | -0.01*** | -0.21*** | -0.04*** |
| | (0.118) | (0.068) | (0.081) | (0.002) | (0.048) | (0.010) |
| Other Dept Exp | 0.04*** | 0.02*** | 0.03*** | -0.00*** | 0.02*** | 0.00*** |
| | (0.002) | (0.001) | (0.001) | (0.000) | (0.000) | (0.000) |
| Number of Visits | 0.49*** | 0.23*** | 0.25*** | 0.00*** | 0.19*** | 0.03*** |
| | (0.040) | (0.023) | (0.024) | (0.000) | (0.013) | (0.002) |
| Constant | 0.41*** | -0.22*** | 0.62*** | 0.07*** | 0.59*** | 0.39*** |
| | (0.132) | (0.079) | (0.085) | (0.002) | (0.045) | (0.008) |
| | | | | | | |
| Observations | 43,600 | 43,600 | 43,600 | 43,600 | 43,600 | 43,600 |
| R-squared | 0.353 | 0.235 | 0.306 | 0.008 | 0.267 | 0.087 |
| Number of ID | 12,046 | 12,046 | 12,046 | 12,046 | 12,046 | 12,046 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

**Table C.2: During versus After DUFB Implementation Regression Results**

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Variables | **F&V Exp** | **Fruit Exp** | **Veg Exp** | **F&V Exp Share** | **F&V Variety** | **F&V Purchase Decision** |
| | | | | | | |
| DUFB Ending Effect | -0.27* | -0.08 | -0.19* | -0.01** | -0.16*** | -0.01 |
| | (0.161) | (0.091) | (0.110) | (0.002) | (0.055) | (0.011) |
| SNAP | -0.14 | -0.19** | 0.05 | 0.00 | 0.11** | 0.08*** |
| | (0.149) | (0.083) | (0.091) | (0.002) | (0.049) | (0.010) |
| August 2014 | -0.15 | 0.29*** | -0.44*** | -0.00 | 0.04 | 0.00 |
| | (0.152) | (0.089) | (0.102) | (0.002) | (0.042) | (0.008) |
| September 2014 | -0.11 | 0.09 | -0.20** | 0.00 | -0.01 | -0.00 |
| | (0.147) | (0.085) | (0.096) | (0.002) | (0.042) | (0.008) |
| October 2014 | 0.02 | 0.10 | -0.09 | 0.00 | -0.02 | 0.00 |
| | (0.145) | (0.084) | (0.095) | (0.002) | (0.043) | (0.008) |
| November 2014 | 0.13 | -0.26*** | 0.39*** | 0.00 | -0.01 | 0.00 |
| | (0.145) | (0.082) | (0.099) | (0.002) | (0.050) | (0.010) |
| December 2014 | -0.01 | -0.16** | 0.15* | 0.00 | 0.11** | 0.02 |
| | (0.120) | (0.067) | (0.083) | (0.002) | (0.052) | (0.010) |
| Other Dept Exp | 0.05*** | 0.02*** | 0.03*** | -0.00*** | 0.02*** | 0.00*** |
| | (0.002) | (0.001) | (0.001) | (0.000) | (0.000) | (0.000) |
| Number of Visits | 0.49*** | 0.22*** | 0.27*** | 0.00*** | 0.18*** | 0.02*** |
| | (0.045) | (0.026) | (0.027) | (0.000) | (0.013) | (0.002) |
| Constant | 0.23 | 0.05 | 0.18* | 0.06*** | 0.41*** | 0.36*** |
| | (0.163) | (0.094) | (0.099) | (0.002) | (0.047) | (0.008) |
| | | | | | | |
| Observations | 37,077 | 37,077 | 37,077 | 37,077 | 37,077 | 37,077 |
| R-squared | 0.355 | 0.241 | 0.307 | 0.007 | 0.270 | 0.090 |
| Number of ID | 11,570 | 11,570 | 11,570 | 11,570 | 11,570 | 11,570 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

**Table C.3: Before versus After DUFB Implementation Regression Results**

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Variables | **F&V Exp** | **Fruit Exp** | **Veg Exp** | **F&V Exp Share** | **F&V Variety** | **F&V Purchase Decision** |
| | | | | | | |
| DUFB After Effect | 0.07 | 0.06 | 0.01 | -0.00 | -0.08 | -0.02 |
| | (0.191) | (0.110) | (0.128) | (0.003) | (0.066) | (0.013) |
| SNAP | -0.27* | -0.19** | -0.08 | -0.00 | 0.08 | 0.08*** |
| | (0.152) | (0.089) | (0.101) | (0.003) | (0.056) | (0.012) |
| May 2014 | -0.46*** | -0.08 | -0.39** | -0.00 | -0.17*** | -0.00 |
| | (0.158) | (0.092) | (0.105) | (0.003) | (0.055) | (0.011) |
| June 2014 | 0.43*** | 0.44*** | -0.01 | 0.01* | 0.05 | 0.02 |
| | (0.164) | (0.096) | (0.109) | (0.003) | (0.055) | (0.011) |
| July 2014 | 0.07 | 0.31*** | -0.24** | 0.00 | -0.11* | -0.01 |
| | (0.161) | (0.095) | (0.107) | (0.003) | (0.056) | (0.011) |
| December 2014 | -0.02 | -0.19*** | 0.16* | -0.00 | -0.13*** | -0.01 |
| | (0.122) | (0.068) | (0.085) | (0.002) | (0.043) | (0.008) |
| Other Dept Exp | 0.04*** | 0.02*** | 0.03*** | -0.00*** | 0.02*** | 0.00*** |
| | (0.002) | (0.001) | (0.001) | (0.000) | (0.000) | (0.000) |
| Number of Visits | 0.45*** | 0.22*** | 0.24*** | 0.00*** | 0.18*** | 0.03*** |
| | (0.041) | (0.023) | (0.026) | (0.000) | (0.013) | (0.002) |
| Constant | 0.39*** | 0.12 | 0.27*** | 0.07*** | 0.57*** | 0.38*** |
| | (0.151) | (0.087) | (0.096) | (0.002) | (0.051) | (0.009) |
| | | | | | | |
| Observations | 31,121 | 31,121 | 31,121 | 31,121 | 31,121 | 31,121 |
| R-squared | 0.350 | 0.236 | 0.298 | 0.008 | 0.267 | 0.090 |
| Number of ID | 11,458 | 11,458 | 11,458 | 11,458 | 11,458 | 11,458 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

**Table C.4: Summary of DUFB Effects over the Three Time Periods (Nonlinear Models)**

| | Before versus During | During versus After | Before versus After |
|---|---|---|---|
| F&V Expenditure (Tobit) | \$0.36*** (0.123) | -\$0.29** (0.142) | \$0.04 (0.148) |
| Fruit Expenditure (Tobit) | \$0.08 (0.266) | -\$0.11 (0.082) | -\$0.01 (0.086) |
| Veg Expenditure (Tobit) | \$0.27*** (0.081) | -\$0.18* (0.095) | \$0.05 (0.097) |
| F&V Exp Share (Tobit) | 0.70%*** (0.196) | -0.60%*** (0.218) | 0.09% (0.234) |
| F&V Variety (Poisson) | 0.04** (0.015) | -0.09*** (0.016) | -0.06 (0.018) |
| F&V Purchase Decision (Probit) | 0.03 (0.028) | -0.03 (0.032) | -0.01 (0.033) |

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

# REFERENCES

## REFERENCES


AN, R. 2013. Effectiveness of subsidies in promoting healthy food purchases and consumption: a review of field experiments. *Public health nutrition,* 16**,** 1215-1228.

ANDRÉS-BELLO, A., BARRETO-PALACIOS, V., GARCÍA-SEGOVIA, P., MIR-BEL, J. & MARTÍNEZ-MONZÓ, J. 2013. Effect of pH on color and texture of food products. *Food Engineering Reviews,* 5**,** 158-170.

ANDREYEVA, T., LONG, M. W. & BROWNELL, K. D. 2010. The impact of food prices on consumption: a systematic review of research on the price elasticity of demand for food. *American journal of public health,* 100**,** 216-222.

ANDREYEVA, T., LUEDICKE, J., MIDDLETON, A. E., LONG, M. & SCHWARTZ, M. 2011a. Changes in access to healthy foods after implementation of the WIC food package revisions. *Rudd Center for Food Policy and Obesity, Yale University*.

ANDREYEVA, T., MIDDLETON, A. E., LONG, M. W., LUEDICKE, J. & SCHWARTZ, M. B. 2011b. Food retailer practices, attitudes and beliefs about the supply of healthy foods. *Public health nutrition,* 14**,** 1024-1031.

ARES, G. & DELIZA, R. 2010. Studying the influence of package shape and colour on consumer expectations of milk desserts using word association and conjoint analysis. *Food Quality and Preference,* 21**,** 930-937.

ASSOCIATEDPRESS. 2017. *Big grocery chains leave U.S. "food deserts" parched* [Online]. Available: http://www.cbsnews.com/news/big-grocery-chains-leave-u-s-food-deserts-parched/ [Accessed].

BALIÉ, J., MAGRINI, E. & MORALES OPAZO, C. 2016. Cereal price shocks and volatility in Sub-Saharan Africa: What does really matter for farmers' welfare? : Diskussionspapiere, Department für Agrarökonomie und Rurale Entwicklung.

BALL, K., TIMPERIO, A. & CRAWFORD, D. 2009. Neighbourhood socioeconomic inequalities in food access and affordability. *Health & place,* 15**,** 578-585.

BANKS, J., BLUNDELL, R. & LEWBEL, A. 1997. Quadratic Engel curves and consumer demand. *Review of Economics and statistics,* 79**,** 527-539.

BAQUERO, B., LINNAN, L., LARAIA, B. A. & AYALA, G. X. 2014. Process evaluation of a food marketing and environmental change intervention in tiendas that serve Latino immigrants in North Carolina. *Health promotion practice,* 15**,** 839-848.

BARONBERG, S., DUNN, L., NONAS, C., DANNEFER, R. & SACKS, R. 2013. Peer Reviewed: The Impact of New York City's Health Bucks Program on Electronic Benefit Transfer Spending at Farmers Markets, 2006–2009. *Preventing chronic disease,* 10.

BASSFORD, N., GALLOWAY-GILLIAM, L. & FLYNN, G. 2010. *Food Desert to Food Oasis: Promoting Grocery Store Development in South Los Angeles* [Online]. Available: http://suprmarkt.la/wp-content/uploads/2017/09/Food-Desert-to-Food-Oasis.-Promoting-Grocery-Store-Development-in-South-Los-Angeles.pdf [Accessed July 26, 2017].

BITLER, M. & HAIDER, S. J. 2011. An economic view of food deserts in the United States. *Journal of Policy Analysis and Management,* 30**,** 153-176.

BIX, L., SEO, W. & SUNDAR, R. P. 2013. The Effect of Colour Contrast on Consumers' Attentive Behaviours and Perception of Fresh Produce. *Packag. Technol. Sci,* 26**,** 96-104.

BLANCHARD, T. C. & MATTHEWS, T. L. 2007. 10. Retail Concentration, Food Deserts, and Food-Disadvantaged Communities in Rural America. *Remaking the North American Food System: Strategiesfor Sustainability*.

BLANCIFORTI, L. & GREEN, R. 1983. An almost ideal demand system incorporating habits: an analysis of expenditures on food and aggregate commodity groups. *The Review of Economics and Statistics***,** 511-515.

BONANNO, A. 2012. Food deserts: Demand, supply, and economic theory. *Choices,* 27.

BROWN, A. 2016. *Taste A Rainbow . . . Of Fruits and Veggies* [Online]. Available: http://www.fruitsandveggiesmorematters.org/taste-a-rainbow-of-fruits-and-veggies [Accessed 2016].

CASON, K., NIETO-MONTENEGRO, S. & CHAVEZ-MARTINEZ, A. 2006. Food choices, food sufficiency practices, and nutrition education needs of Hispanic migrant workers in Pennsylvania. *Topics in Clinical Nutrition,* 21**,** 145-158.

CDFI. 2017. *New Markets Tax Credit Program* [Online]. Available: https://www.cdfifund.gov/programs-training/Programs/new-markets-tax-credit/Pages/default.aspx?utm_source=HUD+Exchange+Mailing+List&utm_campaign=b64b94e191-Promise_Zones_Update_10_27_2015&utm_medium=email&utm_term=0_f32b935a5f-b64b94e191-19340809 [Accessed].

CHRISTENSEN, L. R., JORGENSON, D. W. & LAU, L. J. 1975. Transcendental logarithmic utility functions. *The American Economic Review,* 65**,** 367-383.

CLARKSON, K. W. 1975. Food Stamps and Nutrition.

CLARKSON, R. M., CLARKE-HILL, C. M. & ROBINSON, T. 1996. UK supermarket location assessment. *International Journal of Retail & Distribution Management,* 24**,** 22-33.

COLAPINTO, C. K. & MALAVIARACHCHI, D. 2009. Paint your plate: effectiveness of a point-of-purchase display. *Canadian Journal of Dietetic Practice and Research,* 70**,** 66-71.

COLBY, S. L. & ORTMAN, J. M. 2015. Projections of the size and composition of the US population: 2014 to 2060. *Current Population Reports*.

COLEMAN, M., WEATHERSPOON, D. D., WEATHERSPOON, L. & OEHMKE, J. F. 2011. Food retailing in an urban food desert: strategies for success in fresh fruits and vegetables.

COX, B. D., WHICHELOW, M. J. & PREVOST, A. T. 2000. Seasonal consumption of salad vegetables and fresh fruit in relation to the development of cardiovascular disease and cancer. *Public health nutrition,* 3**,** 19-29.

DAVIS, C. & SALTOS, E. 1999. Dietary recommendations and how they have changed over time In: America's Eating Habits: Changes and Consequences (Frazao, E., ed.). *Economic Research Service, US Department of Agriculture, AIB-750*.

DEATON, A. & MUELLBAUER, J. 1980. *Economics and consumer behavior*, Cambridge university press.

DESALVO, K. B., OLSON, R. & CASAVALE, K. O. 2016. Dietary guidelines for Americans. *Jama,* 315**,** 457-458.

DILLING, A. 2014. Supermarkets don't go to 'food deserts'. *Market Place Business*

DUBOWITZ, T., NCUBE, C., LEUSCHNER, K. & THARP-GILLIAM, S. 2015. A natural experiment opportunity in two low-income urban food desert communities: Research design, community engagement methods, and baseline results. *Health Education & Behavior,* 42**,** 87S-96S.

DURHAM, C. & EALES, J. 2010. Demand elasticities for fresh fruit at the retail level. *Applied Economics,* 42**,** 1345-1354.

DUTKO, P., VER PLOEG, M. & FARRIGAN, T. L. 2012. *Characteristics and influential factors of food deserts*, US Department of Agriculture, Economic Research Service.

ELLICKSON, P. B. 2007. Does Sutton apply to supermarkets? *The RAND Journal of Economics,* 38**,** 43-59.

ELLICKSON, P. B. 2013. Supermarkets as a natural oligopoly. *Economic Inquiry,* 51**,** 1142-1154.

FFN. 2014. *Double Up Food Bucks* [Online]. Available: http://www.doubleupfoodbucks.org/ [Accessed].

FFN. 2016. *Double Up National Network* [Online]. Available: http://www.doubleupfoodbucks.org/national-network/ [Accessed].

FMI. 2016. *Supermarket Facts* [Online]. Available: http://www.fmi.org/research-resources/supermarket-facts [Accessed May 15 2016].

FNS. 2014. *USDA Announces up to $31 Million to Empower People to Make Healthy Eating Choices* [Online]. Available: http://www.fns.usda.gov/pressrelease/2014/021514 [Accessed].

FNS. 2016a. *Eat A Rainbow* [Online]. Available: http://www.fns.usda.gov/sites/default/files/colorchart.pdf [Accessed].

FNS. 2016b. *Food Desert Locator* [Online]. Available: https://www.fns.usda.gov/tags/food-desert-locator [Accessed].

FOLTA, T. B., JOHNSON, D. R. & O'BRIEN, J. 2006. Uncertainty, irreversibility, and the likelihood of entry: An empirical assessment of the option to defer. *Journal of Economic Behavior & Organization,* 61**,** 432-452.

FOLTA, T. B. & O'BRIEN, J. P. 2004. Entry in the presence of dueling options. *Strategic Management Journal,* 25**,** 121-138.

GARDEN-ROBINSON, J. 2009. What Color is Your Food? Taste a rainbow of fruits and vegetables for better heallth.

GELIEBTER, A., ANG, I. Y. H., BERNALES-KORINS, M., HERNANDEZ, D., OCHNER, C. N., UNGREDDA, T., MILLER, R. & KOLBE, L. 2013. Supermarket discounts of low-energy density foods: Effects on purchasing, food intake, and body weight. *Obesity,* 21**,** E542-E548.

GITTELSOHN, J., SONG, H.-J., SURATKAR, S., KUMAR, M. B., HENRY, E. G., SHARMA, S., MATTINGLY, M. & ANLIKER, J. A. 2009. An urban food store intervention positively affects food-related psychosocial variables and food behaviors. *Health Education & Behavior*.

GLANZ, K. & YAROCH, A. L. 2004. Strategies for increasing fruit and vegetable intake in grocery stores and communities: policy, pricing, and environmental change. *Preventive Medicine,* 39**,** 75-80.

GRAY, V. B., COSSMAN, J. S., DODSON, W. L. & BYRD, S. H. 2005. Dietary acculturation of Hispanic immigrants in Mississippi. *Salud pública de méxico,* 47**,** 351-360.

GREEN, R. D. 1999. Demand for California Agricultural Commodities. *Outlook,* 99**,** 11.

GRIEP, L. M. O., VERSCHUREN, W. M., KROMHOUT, D., OCKÉ, M. C. & GELEIJNSE, J. M. 2011. Colors of fruit and vegetables and 10-year incidence of stroke. *Stroke,* 42**,** 3190-3195.

GUITART, D. A., PICKERING, C. M. & BYRNE, J. A. 2014. Color me healthy: Food diversity in school community gardens in two rapidly urbanising Australian cities. *Health & place,* 26**,** 110-117.

HAGAN, E. & RUBIN, V. 2013. Economic and community development outcomes of healthy food retail. *Oakland, CA: Policy Link.*

HEBER, D. 2004. Vegetables, fruits and phytoestrogens in the prevention of diseases. *Journal of postgraduate medicine,* 50**,** 145.

HEIEN, D. & WESSELLS, C. R. 1990. Demand systems estimation with microdata: a censored regression approach. *Journal of Business & Economic Statistics,* 8**,** 365-371.

HERMAN, D. R., HARRISON, G. G., AFIFI, A. A. & JENKS, E. 2008. Effect of a targeted subsidy on intake of fruits and vegetables among low-income women in the Special Supplemental Nutrition Program for Women, Infants, and Children. *American Journal of Public Health,* 98**,** 98-105.

HOTELLING, H. 1990. Stability in competition. *The Collected Economics Articles of Harold Hotelling.* Springer.

HOWLETT, E., DAVIS, C. & BURTON, S. 2015. From Food Desert to Food Oasis: The Potential Influence of Food Retailers on Childhood Obesity Rates. *Journal of Business Ethics***,** 1-10.

HUANG, K. S. & LIN, B.-H. 2000. *Estimation of food demand and nutrient elasticities from household survey data*, US Department of Agriculture, Economic Research Service.

IMBENS, G. M. & WOOLDRIDGE, J. M. 2008. Recent developments in the econometrics of program evaluation. National Bureau of Economic Research.

IRZ, X., LEROY, P., RÉQUILLART, V. & SOLER, L.-G. 2015. Economic assessment of nutritional recommendations. *Journal of health economics,* 39**,** 188-210.

JOSEPH, J. A., NADEAU, D. & UNDERWOOD, A. 2002. *The color code: a revolutionary eating plan for optimum health*, Hyperion New York.

KARPYN, A., MANON, M., TREUHAFT, S., GIANG, T., HARRIES, C. & MCCOUBREY, K. 2010. Policy solutions to the 'grocery gap'. *Health Affairs,* 29**,** 473-480.

KHANDKER, S. R., KOOLWAL, G. B. & SAMAD, H. A. 2010. *Handbook on impact evaluation: quantitative methods and practices*, World Bank Publications.

KLERMAN, J. A., BARTLETT, S., WILDE, P. & OLSHO, L. 2014. The short-run impact of the Healthy Incentives Pilot Program on fruit and vegetable intake. *American Journal of Agricultural Economics,* 96**,** 1372-1382.

KULATILAKA, N. & PEROTTI, E. C. 1998. Strategic growth options. *Management Science,* 44**,** 1021-1031.

LAKKAKULA, P., SCHMITZ, A. & RIPPLINGER, D. 2016. US Sweetener Demand Analysis: A QUAIDS Model Application. *Journal of Agricultural and Resource Economics,* 41**,** 533-548.

LAMBERT, R., LARUE, B., YÉLOU, C. & CRINER, G. 2006. Fish and meat demand in Canada: Regional differences and weak separability. *Agribusiness,* 22**,** 175-199.

LANGTREE, I. 2005. *Color Wheel of Fruits and Vegetables* [Online]. Disabled World. Available: http://www.disabled-world.com/artman/publish/fruits-vegetables.shtml [Accessed].

LECLAIR, M. S. & AKSAN, A.-M. 2014. Redefining the food desert: combining GIS with direct observation to measure food Access. *Agriculture and Human Values,* 31**,** 537-547.

LEE, J., SHIN, A., OH, J. H. & KIM, J. 2017. Colors of vegetables and fruits and the risks of colorectal cancer. *World journal of gastroenterology,* 23**,** 2527.

LEE, R. M., ROTHSTEIN, J. D., GERGEN, J., ZACHARY, D. A., SMITH, J. C., PALMER, A. M., GITTELSOHN, J. & SURKAN, P. J. 2015. Process Evaluation of a Comprehensive Supermarket Intervention in a Low-Income Baltimore Community. *Health promotion practice,* 16**,** 849-858.

LIN, B.-H., YEN, S. T., DONG, D. & SMALLWOOD, D. M. 2010. Economic incentives for dietary improvement among food stamp recipients. *Contemporary Economic Policy,* 28**,** 524-536.

LOPEZ, J. A. & PECKHAM, J. A. 2015. An Analysis of Fresh Vegetables in the Dallas-Fort Worth Metropolitan Area.

LOPEZ, J. A. & PECKHAM, J. A. An Analysis of Fresh Vegetables in the Dallas-Fort Worth Metropolitan Area. 2016 Annual Meeting, February 6-9, 2016, San Antonio, Texas, 2016. Southern Agricultural Economics Association.

MDARD. 2016. *Michigan Specialty Crops* [Online]. Available: https://www.michigan.gov/documents/mda/MDA_Crops_Brochure_low-resolution_324586_7.pdf [Accessed].

MHURCHU, C. N., EYLES, H., SCHILLING, C., YANG, Q., KAYE-BLAKE, W., GENÇ, M. & BLAKELY, T. 2013. Food prices and consumer demand: differences across income levels and ethnic groups. *PloS one,* 8**,** e75934.

MORTON, L. W. & BLANCHARD, T. C. 2007. Starved for access: life in rural America's food deserts. *Rural Realities,* 1**,** 1-10.

MOSCHINI, G., MORO, D. & GREEN, R. D. 1994. Maintaining and testing separability in demand systems. *American Journal of Agricultural Economics,* 76**,** 61-73.

MOSS, A., SMITH, S., NULL, D., LONG ROTH, S. & TRAGOUDAS, U. 2013. Farm to school and nutrition education: Positively affecting elementary school-aged children's nutrition knowledge and consumption behavior. *Childhood Obesity,* 9**,** 51-56.

MUI, Y., LEE, B. Y., ADAM, A., KHARMATS, A. Y., BUDD, N., NAU, C. & GITTELSOHN, J. 2015. Healthy versus unhealthy suppliers in food desert neighborhoods: A network analysis of corner stores' food supplier networks. *International journal of environmental research and public health,* 12**,** 15058-15074.

MURRAY, J. & DELAHUNTY, C. 2000. Mapping consumer preference for the sensory and packaging attributes of Cheddar cheese. *Food quality and preference,* 11**,** 419-435.

NAANWAAB, C. & YEBOAH, O. 2012. Demand for Fresh Vegetables in the United States: 1970–2010. *Economics Research International,* 2012.

NZAKU, K., HOUSTON, J. E. & GREG FONSAH, E. 2010. Analysis of US Demand for fresh fruit and vegetable imports. *Journal of Agribusiness,* 28**,** 163.

OFFICE OF SOCIAL AND ECONOMIC DATA ANALYSIS , U. O. M. O. E. 2010a. *MCDC Demographic Profile 3, Census, Census Tract 5256 , Wayne County, MI* [Online]. Available: http://mcdc2.missouri.edu/cgi-bin/broker?_PROGRAM=websas.dp3_2k.sas&_SERVICE=sasapp&st=26&co=163&tr=5256.00 [Accessed].

OFFICE OF SOCIAL AND ECONOMIC DATA ANALYSIS , U. O. M. O. E. 2010b. *MCDC Demographic Profile 3, Census, Census Tract 5256 , Wayne County, MI* [Online]. Available: http://mcdc2.missouri.edu/cgi-bin/broker?_PROGRAM=websas.dp3_2k.sas&_SERVICE=sasapp&st=26&co=163&tr=5256.00 [Accessed].

OGAWA, Y., TANABE, N., HONDA, A., AZUMA, T., SEKI, N., SUZUKI, T. & SUZUKI, H. 2011. Point-of-purchase health information encourages customers to purchase vegetables:

objective analysis by using a point-of-sales system. *Environmental health and preventive medicine,* 16**,** 239-246.

OLSTAD, D. L., BALL, K., ABBOTT, G., MCNAUGHTON, S. A., LE, H. N., MHURCHU, C. N., POLLARD, C. & CRAWFORD, D. A. 2016. A process evaluation of the Supermarket Healthy Eating for Life (SHELf) randomized controlled trial. *International Journal of Behavioral Nutrition and Physical Activity,* 13**,** 1.

PARK, J. L., HOLCOMB, R. B., RAPER, K. C. & CAPPS, O. 1996. A demand systems analysis of food commodities by US households segmented by income. *American Journal of Agricultural Economics,* 78**,** 290-300.

PBHFOUNDATION. 2015. *State of the Plate. 2015 Study on America's Consumption of Fruits and Vegetables* [Online]. Available: http://www.pbhfoundation.org/pdfs/about/res/pbh_res/State_of_the_Plate_2015_WEB_Bookmarked.pdf [Accessed].

PBHFOUNDATION. 2016a. *Fruits and Veggies More Matters: Fruit and Veggie Color List* [Online]. Available: http://www.fruitsandveggiesmorematters.org/fruit-and-veggie-color-list [Accessed].

PBHFOUNDATION. 2016b. *What are Phytochemicals?* [Online]. Available: http://www.fruitsandveggiesmorematters.org/what-are-phytochemicals [Accessed].

PENNINGTON, J. A. & FISHER, R. A. 2009. Classification of fruits and vegetables. *Journal of Food Composition and Analysis,* 22**,** S23-S31.

PENNINGTON, J. A. & FISHER, R. A. 2010. Food component profiles for fruit and vegetable subgroups. *Journal of Food Composition and Analysis,* 23**,** 411-418.

PHIPPS, E. J., BRAITMAN, L. E., STITES, S. D., SINGLETARY, S. B., WALLACE, S. L., HUNT, L., AXELROD, S., GLANZ, K. & UPLINGER, N. 2015. Impact of a rewards-based incentive program on promoting fruit and vegetable purchases. *American journal of public health,* 105**,** 166-172.

PITTS, S. B. J., MCGUIRT, J. T., WU, Q., RUSHING, J., USLAN, D., STANLEY, K. K., BULLOCK, S. L., WARD, R. K., RAFFERTY, A. P. & AMMERMAN, A. S. 2016. Assessing Preliminary Impact of the North Carolina Community Transformation Grant Project Farmers' Market Initiatives Among Rural Residents. *Journal of nutrition education and behavior,* 48**,** 343-349. e1.

POI, B. 2002. Dairy policy and consumer welfare. *Three Essays in Applied Econometrics*.

POI, B. P. 2012. Easy demand-system estimation with quaids. *Stata Journal,* 12**,** 433.

POLICYLINK. 2017. *The Healthy Food Financing Initiative: an innovative public-private partnership sparking economic development and improving health* [Online]. Available: http://www.healthyfoodaccess.org/sites/default/files/HFFI 2017 Brochure Final_April 2017.pdf [Accessed].

POTHUKUCHI, K. 2005. Attracting supermarkets to inner-city neighborhoods: economic development outside the box. *Economic Development Quarterly,* 19**,** 232-244.

PRELL, M. & SMALLWOOD, D. 2017. Comparing Alternative Economic Mechanisms To Increase Fruit and Vegetable Purchases.

RAY, R. 1983. Measuring the costs of children: an alternative approach. *Journal of Public Economics,* 22**,** 89-102.

REED, A. J. & LEVEDAHL, J. W. 2010. Food stamps and the market demand for food. *American Journal of Agricultural Economics***,** aaq069.

ROB, R. 1991. Learning and capacity expansion under demand uncertainty. *The Review of Economic Studies,* 58**,** 655-675.

ROSE, D. & RICHARDS, R. 2004. Food store access and household fruit and vegetable use among participants in the US Food Stamp Program. *Public health nutrition,* 7**,** 1081-1088.

SEALE, J. L., ZHANG, L. & TRABOULSI, M. R. 2013. US import demand and supply response for fresh tomatoes, cantaloupes, onions, oranges, and spinach. *Journal of Agricultural and Applied Economics,* 45**,** 435-452.

SELLEN, D. & GODDARD, E. 1997. Weak separability in coffee demand systems. *European Review of Agricultural Economics,* 24.

SHADISH, W. R., COOK, T. D. & CAMPBELL, D. T. 2002. *Experimental and quasi-experimental designs for generalized causal inference*, Wadsworth Cengage learning.

SHONKWILER, J. S. & YEN, S. T. 1999. Two-step estimation of a censored system of equations. *American Journal of Agricultural Economics,* 81**,** 972-982.

SILAYOI, P. & SPEECE, M. 2007. The importance of packaging attributes: a conjoint analysis approach. *European Journal of Marketing,* 41**,** 1495-1517.

SINGH, M. 2015. *Why A Philadelphia Grocery Chain Is Thriving In Food Deserts* [Online]. NPR. Available: http://www.npr.org/sections/thesalt/2015/05/14/406476968/why-one-grocery-chain-is-thriving-in-philadelphias-food-deserts [Accessed].

SIRMON, D. G., HITT, M. A. & IRELAND, R. D. 2007. Managing firm resources in dynamic environments to create value: Looking inside the black box. *Academy of management review,* 32**,** 273-292.

SMIT, H. T. & ANKUM, L. 1993. A real options and game-theoretic approach to corporate investment strategy under competition. *Financial Management***,** 241-250.

SMITH, C., PARNELL, W. R., BROWN, R. C. & GRAY, A. R. 2013. Providing additional money to food-insecure households and its effect on food expenditure: a randomized controlled trial. *Public health nutrition,* 16**,** 1507-1515.

SONG, H.-J., GITTELSOHN, J., KIM, M., SURATKAR, S., SHARMA, S. & ANLIKER, J. 2009. A corner store intervention in a low-income urban community is associated with increased availability and sales of some healthy foods. *Public health nutrition,* 12**,** 2060-2067.

STATISTA. 2017. *Which Form of Payment do you usa most often when at the supermarket?* [Online]. Available: https://www.statista.com/statistics/294075/payment-preference-supermarket-us/ [Accessed].

STEWART, H., BLISARD, N., BHUYAN, S. & NAYGA, R. 2004. The demand for food away from home: Full-service or fast food? *USDA Economic Research Service: Report*.

STOREY, M. & ANDERSON, P. 2014. Income and race/ethnicity influence dietary fiber intake and vegetable consumption. *Nutrition Research,* 34**,** 844-850.

STUCKER, T. A. & BOEHM, W. T. 1978. *A Guide to Understanding the 1977 Food and Agricultural Legislation*, US Department of Agriculture, Economics, Statistics, and Cooperatives Service.

STURM, R., AN, R., SEGAL, D. & PATEL, D. 2013. A cash-back rebate program for healthy food purchases in South Africa: results from scanner data. *American journal of preventive medicine,* 44**,** 567-572.

SUGRUE, T. J. 2014. *The origins of the urban crisis: Race and inequality in postwar Detroit*, Princeton University Press.

TAFERE, K., TAFFESSE, A. S., TAMIRU, S., TEFERA, N. & PAULOS, Z. 2010. Food demand elasticities in Ethiopia: Estimates using household income consumption expenditure (HICE) survey data. *Ethiopia Strategy Support Program II Working paper*.

THEIL, H. 1965. The information approach to demand analysis. *Econometrica: Journal of the Econometric Society***,** 67-87.

TREUHAFT, S. & KARPYN, A. 2010. *The grocery gap: Who has access to healthy food and why it matters*, PolicyLink.

USDA. 2015a. *Food and Nutrition Service, Office of Policy Support. PROFILE OF SNAP HOUSEHOLDS. Michigan Congressional District 13* [Online]. Available: http://www.fns.usda.gov/sites/default/files/ops/Michigan_13.pdf [Accessed].

USDA. 2015b. *Food Insecurity Nutrition Incentive (FINI) Grant Program* [Online]. Available: https://nifa.usda.gov/sites/default/files/rfa/FY 16 FINI_to POST.pdf [Accessed].

VAUGHAN, J. & GEISSLER, C. 2009. *The new Oxford book of food plants*, OUP Oxford.

VER PLOEG, M., BRENEMAN, V., FARRIGAN, T., HAMRICK, K., HOPKINS, D., KAUFMAN, P., LIN, B., NORD, M., SMITH, T. & WILLIAMS, R. 2009. Access to Affordable and Nutritious Food–Measuring and Understanding Food Deserts and Their Consequences: Report to Congress. Publication No.(AP-036), USDAERS, 160 pages.

WALKER, R. E., KEANE, C. R. & BURKE, J. G. 2010. Disparities and access to healthy food in the United States: A review of food deserts literature. *Health & place,* 16**,** 876-884.

WANG, Z. & WOLMAN, A. L. 2016. Payment choice and currency use: Insights from two billion retail transactions. *Journal of Monetary Economics,* 84**,** 94-115.

WEATHERSPOON, D., OEHMKE, J., DEMBÉLÉ, A., COLEMAN, M., SATIMANON, T. & WEATHERSPOON, L. 2013. Price and expenditure elasticities for fresh fruits in an urban food desert. *Urban Studies,* 50**,** 88-106.

WEATHERSPOON, D., OEHMKE, J., DEMBELE, A. & WEATHERSPOON, L. 2014. Fresh vegetable demand behaviour in an urban food desert. *Urban Studies***,** 0042098014529340.

WEATHERSPOON, D., OEHMKE, J., DEMBELE, A. & WEATHERSPOON, L. 2015. Fresh vegetable demand behaviour in an urban food desert. *Urban Studies,* 52**,** 960-979.

WILDE, P. E. & RANNEY, C. K. 2000. The Monthly Food Stamp Cycle: Shooping Frequency and Food Intake Decisions in an Endogenous Switching Regression Framework. *American Journal of Agricultural Economics,* 82**,** 200-213.

WITT, K. E. & DUNN, C. 2012. Increasing fruit and vegetable consumption among preschoolers: evaluation of Color Me Healthy. *Journal of nutrition education and behavior,* 44**,** 107-113.

WOOD, S. 2013. Revisiting the US food retail consolidation wave: regulation, market power and spatial outcomes. *Journal of Economic Geography***,** lbs047.

WOOLDRIDGE, J. M. 2010. *Econometric analysis of cross section and panel data*, MIT press.

WOOLDRIDGE, J. M. 2015. *Introductory econometrics: A modern approach*, Nelson Education.

YOU, Z., EPPERSON, J. E. & HUANG, C. L. 1996. A composite system demand analysis for fresh fruits and vegetables in the United States. *Journal of Food Distribution Research,* 27**,** 11-22.

YOUNG, C. R. 2013. Improving fruit and vegetable consumption among low-income customers at farmers markets: Philly Food Bucks, Philadelphia, Pennsylvania, 2011. *Preventing chronic disease,* 10.

ZHU, K. & WEYANT, J. P. 2003. Strategic decisions of new technology adoption under asymmetric information: a game-theoretic model. *Decision sciences,* 34**,** 643-675.