NUTRITION AND HEALTH AMONG LOW-INCOME CHILDREN: ESTIMATING THE ASSOCIATION WITH SNAP USING A QUASI-EXPERIMENTAL APPROACH

by

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A dissertation submitted to the faculty of
The University of North Carolina at Charlotte
in partial fulfillment of the requirements
for the degree of Doctor of Philosophy in
Public Policy

Charlotte

2019

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ABSTRACT

KATELIN M. HUDAK. NUTRITION AND HEALTH AMONG LOW-INCOME CHILDREN: ESTIMATING THE ASSOCIATION WITH SNAP USING A QUASI-EXPERIMENTAL APPROACH. (Under the direction of DR. ELIZABETH F. RACINE AND DR. ARTHUR ZILLANTE)

The Supplemental Nutrition Assistance Program (SNAP) is the nation's largest federal food assistance program. The goal of the program is to help low-income families afford a healthy diet. However, several studies have found that participation in SNAP is associated with lower diet quality and an increased probability of being overweight among adults. Poor diet quality and being overweight contribute to the metabolic syndrome, which is a cluster of risk factors that increases the risk of heart disease, diabetes, and stroke. Poor diet and diet-related health in children is particularly harmful because of their vulnerable lifestage. This project uses two research designs that take advantage of policy variation to better identify the relationship between SNAP participation and child nutritional health: difference-in-differences and regression discontinuity. The difference-in-difference design uses the increase in SNAP benefit amounts from the American Recovery and Reinvestment Act to understand the link between an increase in SNAP benefits and child nutritional health. The regression discontinuity design uses the SNAP income-eligibility criteria to understand how the diet-related health of SNAP-eligible youth differ from those just over the eligibility threshold. Within these designs, I also examine how food security status and age modify the connection between SNAP and child nutritional health.

Chapter Two examines the relationship between SNAP and diet quality. I find that an increase in SNAP benefits is associated with lower diet quality in youth across

levels of food insecurity, and in two age groups: toddlers aged 2-3 years and children aged 6-11 years. However, youth who experience very low food security consume less sugar-sweetened beverages and more fiber when compared to those just over the SNAP income eligibility threshold. Chapter Three analyzes the link between SNAP and weight outcomes. I find that an increase in SNAP benefits is associated with healthier weight outcomes in youth who experience marginal food security, in children younger than 6 years, and in adolescents aged 12 to 18 years. Chapter Four studies the connection between SNAP and risk factors for the metabolic syndrome. I find that SNAP-eligible youth have significantly healthier outcomes, but this relationship varies by food security status and age. Developing a better understanding of the relationship between SNAP participation and diet-related health outcomes in children can lead to refined federal nutrition policy. This is a critical policy question that has far-reaching implications for the health and well-being of the low-income children and families that rely on SNAP to help meet basic needs.

DEDICATION

To my parents John and Kathy, my sister Melissa, and my niece Cali Grace, for their unconditional love and support always.

ACKNOWLEDGEMENTS

Because your love is better than life,
    my lips will glorify you.
I will praise you as long as I live,
    and in your name I will lift up my hands.
        Psalm 63: 3-4

Above all, I thank the Lord, who is the giver of life, and of every good gift, including the opportunity to be in the Public Policy program, and to complete this dissertation. Truly truly, praise the Lord!

I am deeply grateful to my dissertation committee members. Dr. Elizabeth Racine, my advisor, has expertly guided me throughout this process. Her patience, insight and willingness to provide incredibly helpful feedback have been invaluable. I constantly learned from, and thoroughly enjoyed, our many exchanges. Dr. Arthur Zillante, my co-advisor, has wisely guided me, and made sure my ideas and writing were clear. I am extremely appreciative of his influence and sense of humor throughout this process. Dr. Lisa Schulkind, my unofficial co-advisor, also has been essential since the beginning, starting with the initial discussions of my ideas and mapping out the research designs. Her guidance in making the designs and methods as strong as possible has been vital. From discussing what would be the best falsification tests to supremely helpful Stata tips, I constantly learned an immeasurable amount from her expertise. Dr. Beth Elise Whitaker has also been indispensable throughout my time in the program. Her wise advice and support on many fronts has been extremely valuable. It has been a joy and a blessing to work with all of my committee members, and I look forward to continuing to learn from them!

Next, I would like to take this opportunity to thank the many people in the Public Policy program who have taught and supported me throughout my time here. That includes the professors who taught courses that inspired my fascination with program evaluation designs (Drs. Jacqueline Chattopadhyay and Stephen Billings), the Public Policy program directors (Drs. Beth Rubin, Martha Kropf, and Cherie Maestas), and my fellow students, especially Sam Grubbs, Jennie Wienke, JoEllen Pope, Ping Mao, and Peter and [honorarily] Miriam Thompson). They have helped make my time in the program truly enjoyable and rewarding.

Finally, I am extremely grateful to my family: my parents (John and Kathy Hudak), who are some of the smartest and hardest working people I have ever known; my sister Melissa, and her precious Cali Grace; as well as Barbara Kraner, Kim Bleakney, Maryann Hudak, and Denise Biasucci, all of whom have been an incredible support and joy. Also, the love and support of my Hickory Grove church family have been essential. Sharon and Robert Locklear, Diana Soudy, Amber Barrett, and Christa Phipps have been a blessing beyond words. Last but not least, I am very thankful for the Steinbauer "Scholarship Fund" and family: Troy, Theresa, and Olivia. I have supremely enjoyed our conversations and laughs!

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CHAPTER 1: INTRODUCTION

The Supplemental Nutrition Assistance Program (SNAP) is the largest federal nutrition program.[1] Nearly one in five households received benefits in 2015,[a] and approximately 50 percent of participants are children.[2] The program provides financial assistance in the form of an electronic benefit transfer (EBT) card, which participants can use much the same as a debit card to purchase groceries. The goal of the program is to help low-income Americans afford a healthy diet.[3] Achieving this objective is essential for a healthy population; diet quality—especially in children—affects a range of outcomes, from cognitive development and functioning, to physiological factors like body weight and cholesterol levels.[4]

Policy makers and scholars debate the impact that SNAP has on diet and diet-related health outcomes. If SNAP enables families to spend more on groceries and obtain a healthier diet, then SNAP should be associated with higher diet quality and other related outcomes, such as healthy weight. Multiple studies have tested this relationship, with some confirming this association, and others finding the opposite effect. It is critical to understand the relationship between SNAP and diet-related health outcomes. The U.S. government spends billions of dollars each year on this program, and it is crucial to know if the program is meeting its goal. Furthermore, this question has significant implications for the health and well-being of the millions of families that rely on SNAP.

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[a] There were 22,388,684 households participating in SNAP in 2015, and 116,926,305 total households in the U.S. on average annually between 2011 and 2015.[192]

Understanding the effect of SNAP participation and diet-related health outcomes can help policy makers refine the program so as to capture the positive benefits, and ameliorate any potential negative impacts. This study examines the relationship between SNAP participation and nutrition-related outcomes in children.

Obtaining evidence on the impact of SNAP participation on diet-related health outcomes is difficult. Low socio-economic status (SES) is associated with increased rates of heart disease, diabetes, cancer, and obesity, and with poor diet quality.[5,6] Households of low SES are also those that may be eligible to participate in SNAP. Thus, the association between SNAP participation and worse health outcomes may be due to the relationship that exists between low SES and these outcomes. Numerous previous studies use income-eligible nonparticipants as a comparison group for SNAP participants to account for these associations. However, SNAP is a means-tested program for which potential participants must apply. Systematic and unobserved differences between those who choose to apply and participate and those who do not leads to bias from selection and unobserved determinants of diet quality and nutrition-related health.[7] In this dissertation, I use difference-in-differences (DD) and regression discontinuity (RD), two designs that the Institute of Medicine, epidemiologists, and economists have recognized as some of the strongest designs able to mitigate bias from selection and unobserved variables.[8–11] Because SNAP has the potential to impact the well-being of millions of children and their families each year, it is critical to understand how the program may be affecting health outcomes of the low-income families that rely on SNAP. Using DD and RD can better identify the relationship between SNAP participation and diet-related health outcomes.

Noncommunicable disease is the main cause of death and disability in the United States. Metabolic risk factors like high body mass index and elevated blood pressure and cholesterol are leading risk factors for noncommunicable diseases (NCD) such as cardiovascular disease and type 2 diabetes mellitus.[12,13] The clustering of these risk factors is known as the metabolic syndrome (MetS).[14] Populations of low SES have higher rates of these risk factors.[6] Low SES is associated with higher rates of overweight[b] and obesity,[15,16] lower diet quality,[17] and lower health outcomes overall.[5,18] Low SES and poor diet as a child can negatively impact a child's development, and directly affects health as an adult, including increasing the presence of metabolic risk factors.[18,19,20] Childhood overweight and obesity lead to immediate and long-term negative consequences on physical and emotional health, including cardiovascular disease and diabetes mellitus.[21,22,23] The food assistance program SNAP is meant to improve access to a healthy diet and address the health inequalities of those of low SES.[24]

However, findings about the relationship between SNAP and diet quality and diet-related health outcomes are inconsistent. Several studies showing that child SNAP participants have higher rates of obesity and poorer diet quality[17] have been publicized in popular media outlets[25] and have fueled debate regarding SNAP. Some scholars and journalists argue that certain foods of low nutritional value, such as sugar-sweetened beverages (SSBs) or processed snack foods, should be ineligible for purchase with SNAP benefits.[26–28] Other scholars argue that this unethically restricts the freedom of SNAP participants and can lead to further stigmatization for low-income groups,[29] which may

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[b] The literature frequently uses the term overweight as a noun, much the same as obesity. I will use the term similarly.

discourage participation in the program. The official position of the United States Department of Agriculture (USDA), which directs SNAP, is that restricting specific foods from SNAP purchases would unduly increase the cost and complexity of the program, without clear evidence that this would change the diet quality of participants.[30]

A recent USDA report compares shopping habits of households that participate in SNAP with those of non-SNAP households using transaction data from a large national grocery store.[c] The analysis showed that the types of foods purchased by SNAP households did not differ widely from the foods purchased by non-SNAP households. Meat/poultry/seafood, vegetables, SSBs, and high-fat dairy/cheese were in the top ten categories for both groups of households, with the order differing slightly. The report concluded that purchases of SSBs, salty snacks, and prepared desserts were common in both SNAP and non-SNAP households, although SNAP households purchased slightly more SSBs and frozen prepared foods.[31] This leads to the question of how these foods are affecting health outcomes and diet-related diseases. Are these diet patterns showing up in clinical markers that could provide early indication of higher risk of disease?

A recent study[d] from Tufts University found that adult SNAP participants were twice as likely to die from cardiovascular disease, and three times as likely to die from diabetes, than non-SNAP participants.[32] Mixed results in other studies that assess diet-related health outcomes in SNAP participants lead to concern that SNAP is not achieving

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[c] The data did not distinguish between foods purchased with SNAP benefits or with other sources, only that the transaction included the use of a SNAP benefit card.

[d] This study used data from the National Health Interview Survey and Public-Use Linked Mortality Files. These data may be the best available, but it is important to note that limitations to data and research studies—whether the study from Tufts, this dissertation, or more generally—may not paint the entire picture.

its goal of improving the diet and health of low-income Americans, or worse, that it is contributing to negative health outcomes.

This dissertation uses the 2005-2014 waves of the National Health and Nutrition Examination Survey (NHANES), which is a repeated cross-sectional, nationally representative dataset that includes questionnaires, laboratory tests, and body measurement components. The target population is low-income children between the ages of two and eighteen who participate in SNAP.

The aim of this project is to use both DD and RD to better identify the relationship that SNAP has with three groups of health and nutrition outcomes in children: diet quality, weight status, and risk factors for metabolic syndrome (MetS). Specifically, this project analyzes the association of SNAP with diet quality by assessing six dietary outcomes: consumption of sugar-sweetened beverages (SSBs), sodium, fiber, fruit and vegetables, as well as an indicator of overall diet quality, the Healthy Eating Index-2010. The second set of outcomes in this project is weight classification, e.g. whether the child is overweight or obese. The third set of outcomes includes four metabolic risk factors: blood pressure, high-density lipoprotein (HDL) cholesterol, triglycerides, and fasting glucose.

To be eligible to participate in SNAP, households must have a gross monthly income less than or equal to 130 percent of the federal poverty line (FPL).[33] The DD design takes advantage of a quasi-natural experiment resulting from an increase in SNAP benefits as part of the American Recovery and Reinvestment Act (ARRA) of 2009. Comparing diet and diet-related outcomes in participants and a comparison group of nonparticipants in the pre-ARRA and the post-ARRA periods can better identify the relationship between SNAP and child health outcomes. The benefit increase is exogenous to participant characteristics, and can better identify the relationship between SNAP and child health outcomes. Following Nord and Prell, this design analyzes differences between SNAP-eligible (less than or equal to 130 percent of the FPL) and households with income below the national average but above the SNAP eligibility criteria (between 150 to 250 percent of the FPL).[34] The DD approach removes the effects of year-to-year changes and other confounding factors that can impact the groups similarly.

The RD design uses the ratio of family income to the federal poverty line to distinguish those eligible for SNAP participation from those just over the eligibility threshold. The income-eligibility criteria mimics random assignment; it is almost a matter of chance whether households have income that is at 129 percent or 131 percent of the FPL. This is exogenous to child weight, and provides the source of identification for this analysis. This cutoff criterion helps to mitigate selection bias; those above the cutoff may not select into the program, thus providing a better comparison group. Households just below the cutoff are virtually the same as those just over the cutoff. They should be very similar on observable and unobservable characteristics, with the exception of meeting this SNAP eligibility criterion. This decreases the potential for endogeneity from omitted variables.

The dissertation proceeds as follows: Chapter 2 is the first paper and focuses on diet quality outcomes; Chapter 3 is the second paper and analyzes body weight and weight status; Chapter 4 is the third paper and examines the relationship between SNAP and cardiometabolic risk factors; Chapter 5 is the fourth essay and explores what happened to child nutritional health after the ARRA benefit increase was terminated; Chapter 6 concludes with a discussion of findings and a summary of policy implications.

CHAPTER 2: DIET QUALITY AMONG LOW-INCOME CHILDREN: ESTIMATING THE ASSOCIATION WITH SNAP

2.1 Introduction

A healthy diet is necessary for leading an active life and for proper cognitive functioning.[35,36] It is a leading protective factor against a multitude of diseases.[36] A nutritious diet is even more critical for children and adolescents due to the increased nutritional demands of their physical and mental development.[37] Yet nationally representative data demonstrates that most Americans do not eat a proper diet.[35] Children and adolescents follow this unhealthy pattern. The World Health Organization (WHO) identifies an unhealthy diet as having consumption levels low in fruits and vegetables, high in salt, and high in energy-dense, processed foods.[36] People of low socioeconomic status (SES) are more likely than higher-income individuals to have an unhealthy diet.[16,17] The Supplemental Nutrition Assistance Program (SNAP) is the largest federal food assistance program in the United States.[1] In 2016, over forty-four million people participated in SNAP,[38] and approximately half were children.[2] The goal of SNAP is to "alleviate hunger and malnutrition" and enable low-income households to obtain "a more nutritious diet."[3] However, it is unclear how well SNAP meets its goal of improving diet quality in children.

In this paper, I examine how an increase in SNAP benefits is linked with child diet quality. I evaluate the policy change that increased benefits as part of the American Recovery and Reinvestment Act of 2009 (ARRA) using a difference-in-differences design. Second, I examine how the diet quality of youth just under the SNAP income eligibility threshold differs from the diet quality of youth just over the threshold using a regression discontinuity design. These designs help clarify the relationship between SNAP and child diet quality.

Specific nutrients or food groups are particularly important to overall health. First, diets high in sodium are one of the top ten contributors to the burden of disease.[13] Children's and adolescents' sodium consumption levels have increased significantly since 1999.[39] Second, high dietary fiber intake is associated with a decreased risk of cardiovascular disease (CVD) and type 2 diabetes.[40] Average fiber intake in children and adolescents is 13 grams per day,[41] which is below adequate intake levels. Third, fruit and vegetables are a good source of fiber and provide many essential nutrients, including potassium, magnesium, vitamin A and vitamin C. Fruit and vegetable consumption is associated with reduced risk of CVD.[35] When compared to other age ranges, children and adolescents are the least likely to consume recommended amounts of vegetables.[35] Less than one in three adolescents eats the recommended amount of vegetables.[42] Finally, sugar-sweetened beverages (SSBs), snacks, and desserts are the main sources of added sugars in American diets.[35] SSBs are one of the top beverages consumed, and the U.S. Department of Health and Human Services and U.S. Department of Agriculture (USDA) identify them as a public health concern because of the added sugars and calories they contribute to the diet.[35]

Although certain foods or nutrients may be particularly important, both the 2015-2020 Dietary Guidelines for Americans (DGA)[35] and the Academy of Nutrition and Dietetics[43] emphasize that the overall pattern of food consumption is more significant than any one component. There are several tools to measure overall eating patterns. The Healthy Eating Index (HEI) assesses how well a diet conforms to the DGA. It is published by the USDA and the Center for Nutrition Policy and Promotion (CNPP) and is regularly updated.[44] The HEI-2010[e] is a recent version, and is a valid and reliable measure of diet quality, including in children.[45] Furthermore, it strongly predicts chronic disease risk and mortality.[46]

Low SES is associated with lower diet quality.[16,17] Having a poor diet is especially detrimental to children and adolescents because of their vulnerable life stage. Low SES, poor diet and overweight/obesity as a child can negatively impact a child's development, and directly affects health as an adult, including increasing the presence of cardiometabolic risk factors.[18–20] For these reasons, it is important to understand whether or not the largest nutrition assistance program successfully achieves its goal of enabling low-income families and children to afford a higher-quality diet. If it does, do we see higher diet quality in SNAP-eligible youth, compared to slightly higher-income, but ineligible, youth?

SNAP has the potential to improve diet quality of low-income populations by increasing the household food budget, which can help families afford higher quality, nutritious foods, which tend to cost more than nutritionally poor foods.[47] A recent review on the association between SNAP participation and diet quality noted that there is a paucity of evidence on outcomes in children.[48] Overall, the diet quality of child SNAP participants is similar to income-eligible nonparticipants.[17,39,49] However, SNAP children consume fewer fruits, vegetables, nuts, and legumes,[17,49] and more soda,[17,49] high-fat

[e] The CNPP recently published the HEI-2015. For the present study, I chose to use the HEI-2010 for three reasons. First, to my knowledge, the HEI-2015 has not yet been validated in children. Second, my analysis uses data from 2007 to 2014; therefore, the HEI-2010 is more relevant for my study population. Third, there are few differences between the HEI-2010 and HEI-2015.[193]

milk,[17,49] and empty calories.[17] Diet quality also differs by age, gender, race/ethnicity[17,39,49] and food security status.[49]

SNAP may potentially improve diet quality in millions of children, affecting their health and well-being. Therefore, it is critical to understand the program's impact. However, unobserved differences between participants and nonparticipants lead to selection bias and create challenges in accurately assessing the relationship between SNAP and diet outcomes. A quasi-experimental research design can better control for selection bias and improve estimates of the relationship between SNAP participation and diet outcomes.

The objective of this study is to estimate the relationship between SNAP participation and six measures of diet quality in children: 1) sodium; 2) fiber; 3) fruit; 4) vegetables; 5) sugar-sweetened beverages; and 6) the Healthy Eating Index 2010. I use two quasi-experimental methods in order to account for the problem of selection bias: difference-in-differences and regression discontinuity.

Studies have found that food insecurity is associated with lower diet quality.[50,51] Furthermore, food security may modify the relationship between SNAP participation and child nutrition-related health outcomes.[52,53] Therefore, based on the literature, I decided a priori to stratify the sample by food security level in a secondary analysis. In addition, diet quality changes across ages, with younger children generally having better nutrient intake and higher overall diet quality.[54,55] Studies have also found differences across age groups when assessing the relationship between SNAP and childhood obesity,[56,57] an outcome related to diet. For these reasons, based on a priori knowledge, I stratify the sample by age group. Finally, biological and psychological differences between boys and girls are likely to modify the relationship between SNAP participation and diet-related health outcomes. Studies assessing these relationships have found differences between boys and girls in diet quality[17] and in obesity, [52,56–58] another measure of nutritional health. Thus, I also stratify the sample by gender. As previous research has identified food security,[52,53] age, [56,57] and gender[52,56–58] as potential effect modifiers, failing to examine these groups separately may hide important differences in the relationship between SNAP and diet quality.

2.2 Methods

Study Population

This study uses the National Health and Nutrition Examination Survey (NHANES), an ongoing cross-sectional dataset that is nationally representative of the noninstitutionalized U.S. population. The Centers for Disease Control and Prevention's National Center for Health Statistics conducts NHANES using a complex, multistage probability design sampling plan. NHANES includes an in-home interview that collects data on individual demographic, health and nutrition information, as well as data regarding the household.[59] A 24-hour dietary recall interview and physical exams are conducted in a mobile examination center. A second dietary recall interview is conducted by phone three to ten days later. Proxy interviews are conducted for children less than six years old. Children between the ages of 6 and 11 answer the dietary interview questions themselves, with the assistance of an adult household member. Children aged 12 and older answer for themselves.[60–63]

The target population for the current study is children ages 2 to 18 years old who live in households that are eligible to participate in SNAP. Children living in households with similar, but slightly higher, income levels are the comparison group for this analysis. The study population is restricted to participants in the 2005-2014 waves of the NHANES survey who were between the ages of 2 and 18 years during data collection.

Dietary Intake Outcome Measures

Following Condon, et al.[17] and Hoy, et al.[64], I use dietary data from Day 1 of the dietary recall. I examine nutrients and foods that are important for child growth, health as an adult, and reduced risk of cardiometabolic diseases. The analysis assesses two nutrients: 1) sodium[13,39] and 2) fiber;[40,41] three food categories: 3) fruit, [35] 4) vegetables,[35,42] and 5) sugar-sweetened beverages (SSBs); [35] and one measure of overall diet quality: 6) the Healthy Eating Index 2010 (HEI).[35,43,44] I obtain nutrient intakes from the NHANES nutrient files and exclude contributions from dietary supplements. Intake levels are compared to national dietary recommendations for chronic disease prevention (table available upon request). Nutrients are examined both as continuous measures and coded as binary to indicate whether the child meets national dietary guidelines.

I use the USDA Food Patterns Equivalents Database (FPED) to create fruit and vegetable categories, and the HEI-2010. The FPED convert NHANES data into a form representing food groups and food patterns associated with recommendations in the U.S. Dietary Guidelines in equivalent amounts.[65] Fruit and vegetables are in cup equivalents and are examined as a continuous measure. Fruit consumption uses the FPED-defined Total Fruit category. Vegetable consumption is based on the FPED-defined Total Vegetables category but excludes white potatoes. Consistent with a commonly-used definition in the literature,[66,67] SSBs include soda, sport drinks, fruit drinks, and punches (non-carbonated beverages with added sugar), low-calorie SSBs (includes fruit drinks and teas identified as low-calorie), and sweetened tea. I examine SSBs as the total grams consumed and the total calories consumed.

The HEI-2010 is a scoring metric that measures how well diet quality meets the Dietary Guidelines for Americans. The HEI-2010 has 12 components: nine assess adequacy (Total Fruit, Whole Fruit, Total Vegetables, Greens and Beans, Whole Grains, Dairy, Total Protein Foods, Seafood and Plant Proteins and Fatty Acids) and three assess moderation (Refined Grains, Sodium, Empty Calories) (Table available upon request). Scores on each of these components are summed to create the total HEI score, which ranges from 0 to 100, with higher scores indicating higher diet quality.[44] This analysis focuses on the total HEI score. Previous research found the HEI-2010 to be a valid and reliable measure of diet quality, including in children.[45]

Covariates

Covariates include the child's age, gender, race/ethnicity, and food security level, the household reference person's (HR) educational attainment and marital status, the household size and poverty-income-ratio, and whether or not the day of the intake was during the weekend.[17,39,50,68–71] The analysis also controls for other food assistance programs: child participation in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) and school meals programs, including the National School Lunch Program (NSLP) and School Breakfast Program (SBP).

Previous research has found that food security may modulate the relationship between SNAP participation and child nutrition-related health outcomes.[52,53] Therefore, I stratify the sample by food security level in a secondary analysis. NHANES collects data on food security using questions from the U.S. Food Security Survey Module (FSSM).

Eight questions pertaining specifically to youth ages 18 and younger are used to create a categorical variable of child food security: 1) Full food security; 2) Marginal food security; 3) Low food security; and 4) Very low food security. The full sample of youth ages 2 to 18 are stratified by these categories.

Studies have found that age modifies the relationship between SNAP and child obesity,[56,57] another indicator of nutritional health. For these reasons, based on a priori knowledge, I stratify the sample by age group. Researchers have grouped youth into two age groups: children age 5 to 11, and adolescents age 12 and older.[56–58] Additionally, transitioning from home and/or childcare settings into preschool and kindergarten can affect child diet.[72,73] Following previous studies that separate adolescents age 12 and older from younger children, and to account for transitions in environment, this analysis stratifies the sample into four age groups: toddlers ages 2 and 3, preschoolers ages 4 and 5, children ages 6 to 11, and adolescents ages 12 to 18.

Finally, previous research has found that gender alters the relationship between SNAP and diet-related health in children and adolescents.[17,52,56–58] Therefore, I conduct an analysis in which I stratify the sample by gender.

2.3 Analysis

To test for differences in the study population, I run bivariate regression. Next, I use two analytic techniques: difference-in-differences (DD) and regression discontinuity (RD). As part of the overall goal of helping those most affected by the Great Recession, the American Recovery and Reinvestment Act of 2009 (ARRA) increased SNAP benefit levels for all participants by an average of 19 percent.[74] Using a DD, I exploit the ARRA benefit increase to identify the effect of an increase in SNAP benefits. The benefit increase became effective in April 2009 and ended on October 31, 2013.[75] The design uses the benefit increase to differentiate a pre- and post-period, which creates a comparison group: SNAP participants before the ARRA benefit increase and SNAP participants after the ARRA benefit increase.[f] SNAP nonparticipants who are low-income but above the SNAP-eligibility criteria serve as a second comparison group. The comparison group of nearly SNAP-eligible used in the DD includes children living in households with income between 150 and 200 percent of the federal poverty line (FPL). The DD design utilizes NHANES data from the 2007-2008 to the 2011-2012 waves. The framework of the DD to estimate the impact of SNAP can be understood as:

$$y_i = \alpha_0 + \alpha_1 T_i + \alpha_2 A_i + \alpha_3 (T_i * A_i) + u_i, \qquad (1)$$

where y_i is the child diet outcome; T_i equals 1 if in the treatment group; A_i equals 1 if in the post-ARRA period; $(T_i * A_i)$ is an interaction term between them; and u_i is the error term. α_3 gives the difference-in-differences estimate of the increase in SNAP benefits.

Second, RD is used because it most closely mimics random assignment.[8,9,11,76] The RD analysis utilizes the income eligibility criteria of SNAP to categorize the sample as SNAP-eligible (household income at or below 130 percent of the FPL) or ineligible (household income above 130 percent of the FPL).[g] The comparison group used in the RD includes all children living in families with household income above a 1.30 poverty-income ratio (PIR) and equal to or below 1.85. The RD design uses NHANES data from

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[f] Because the ARRA began in April 2009, including January through March 2009 would weaken the design. NHANES data is released in two-year waves and the exact year of a given observation is unknown. The six-month period from November 1 to April 30 of the 2009-2010 wave is excluded in the DD analysis.

[g] Hoynes and Schanzenbach note that RD may not be suitable for analyzing SNAP because the amount of benefits received falls as income rises and the discontinuity is not sharp.[125] However, during the period of the ARRA, benefits increased by a constant dollar amount for each household size, regardless of income.[75] The difference in benefits received even in SNAP households that are close to the cutoff is therefore more pronounced between 2009 and 2013 during the ARRA.

the 2005-2006 to 2013-2014 waves. The framework of the RD to estimate the impact of SNAP can be understood as:

$$y_i = \alpha_1 + \tau T_i + b_1(X_i\text{-}c) + b_2(X_i\text{+}c) + u_i \qquad (2)$$

where y_i is the child's health outcome; T_i indicates whether or not the child lives in a SNAP-eligible household, i.e. PIR below 1.30; X_i is the household's PIR for child *i*, which is the value on the assignment score; *c* is the SNAP-eligibility cutoff (equal to 1.30 PIR); and u_i is the error term. τ represents the intent-to-treat estimate of the SNAP program. The coefficient on *(X-c)* takes into account the distance between the cutoff and the household's score on the assignment variable PIR for child *i*. The term $(X_i\text{-}c)$ is linear trend for those with a PIR equal to or less than 1.30, and thus eligible for SNAP; $(X_i - c)$ is the linear trend for those living above this ratio and are ineligible.[h]

The sample is restricted to children with reliable dietary data. The DD analytical sample includes 4,780 children. The RD analytical sample includes 5,017 children. I first compare descriptive statistics between SNAP-eligible children and SNAP-ineligible children. I next use linear regression and linear probability models to estimate the relationship between SNAP participation and child dietary outcomes, first in a DD model, and then in an RD design. I estimate models separately by subgroups of age, food security status, and gender. Dietary survey weights are used to account for the complex survey design and response rates. All analysis is conducted using Stata 14.0.[77]

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[h] I also test various functional forms of equation (2) (Table S.3). However, because the graphs depicting the relationship between PIR and the diet outcomes did not suggest a nonlinear relationship, I use a linear form.

2.4 Results

Table 2.1 displays descriptive statistics of the individual and household characteristics. Table 2.2 displays descriptive statistics of nutrition-related measures. Statistics are weighted, and clustered by NHANES primary sampling units. When I test for significant differences, I find that in the pre-ARRA sample, SNAP-eligible children are significantly more likely to be black or Hispanic, participate in WIC and the SBP, and to live in households with significantly lower household income compared to nearly SNAP-eligible children. They also have significantly lower levels of food security and consume significantly less fruit (table of nutrition intake guidelines available upon request). The HR people of SNAP-eligible children have significantly less education and are less likely to be married.

Approximately one third of SNAP-eligible children experience some form of food insecurity. Although the comparison group lives in households with slightly higher income, fifteen percent also experience food insecurity. Prior to ARRA, roughly half of SNAP-eligible youth received free or reduced-price school lunch. After the Great Recession began, and during ARRA, the percentage of SNAP-eligible youth receiving free or reduced-price school lunch increased to 92 percent.

Furthermore, both groups of SNAP-eligible and nearly eligible children have diets that do not meet recommended standards. Average fiber intake is low in both SNAP-eligible and nearly eligible youth. Recommended intake ranges from 19 g/day for 2- to 3-year-olds, to 38 g/day for boys aged 14 to 18 years. In the pre-ARRA period, SNAP-eligible youth consumed approximately 12.5 g/day. Nearly eligible youth consumed 12.0 g/day on average. The tolerable upper limit for sodium is for 1,500 to 2,300 mg/day for older children. Both SNAP-eligible and nearly eligible youth are far above the recommended limit. Although SNAP-eligible youth consume significantly more fruit than nearly eligible youth, both groups are well below the recommended five cups of fruits and vegetables per day. Total HEI-2010 scores are far below the maximum score of 100, and below the 2007-2008 national average of 53.5.[78]

Table 2.1 Demographics: Dietary sample

	Pre-ARRA		Post-ARRA	
	SNAP-Eligible (*n*=2,696)	Nearly SNAP-Eligible (*n*=691)	SNAP-Eligible (*n*=3,920)	Nearly SNAP-Eligible (*n*=860)
	Mean/share	Mean/share	Mean/share	Mean/share
Age	9.79	9.47	9.65	9.64
	(0.17)	(0.31)	(0.13)	(0.29)
Female	0.52	0.48	0.51	0.48
	(0.01)	(0.03)	(0.01)	(0.02)
Race				
White	0.42	0.55*	0.40	0.51
	(0.05)	(0.05)	(0.04)	(0.05)
Black	0.23	0.17*	0.20	0.16
	(0.04)	(0.03)	(0.03)	(0.02)
Hispanic	0.29	0.22*	0.33	0.22
	(0.04)	(0.03)	(0.03)	(0.03)
Other	0.06	0.06*	0.06	0.10
	(0.01)	(0.02)	(0.01)	(0.03)
PIR	0.75	1.74**	0.74	1.72
	(0.01)	(0.01)	(0.01)	(0.01)
HR education				
>12 years	0.41	0.22*	0.41	0.19
	(0.02)	(0.04)	(0.02)	(0.03)
High school	0.30	0.35*	0.28	0.25
	(0.03)	(0.05)	(0.02)	(0.03)
Some college	0.22	0.36*	0.24	0.37
	(0.02)	(0.04)	(0.01)	(0.03)
College grad +	0.07	0.07*	0.07	0.18
	(0.02)	(0.02)	(0.01)	(0.03)
HR Married	0.47	0.65*	0.47	0.66
	(0.03)	(0.04)	(0.02)	(0.04)
HH size	4.69	4.29	4.80	4.39
	(0.07)	(0.09)	(0.05)	(0.10)

Standard errors in parentheses
** p<0.01, * p<0.05

Notes: Pre-ARRA statistics were computed from data from 2005-2008. Post-ARRA statistics were computed using data from 2007-2012, the analytic sample for the difference-in-differences analysis. SNAP-eligible participants include children living in households with income less than or equal to 130 percent of the FPL. SNAP-ineligible participants include children living in households with income between 150 and 200 percent of the FPL. Standard errors reported in parentheses. All means and proportions are weighted. The analysis accounts for the complex NHANES survey design. Asterisks indicate that the characteristic in the SNAP-eligible group is significantly different from the higher income group in the pre-ARRA sample.

Abbreviations:
HH: household
HR: household reference person
PIR: poverty-income ratio

Table 2.2 Nutrition-related Outcomes

	Pre-ARRA		Post-ARRA	
	SNAP-Eligible (*n*=2,696)	Nearly SNAP-Eligible (*n*=691)	SNAP-Eligible (*n*=3,920)	Nearly SNAP-Eligible (*n*=860)
	Mean/share	Mean/share	Mean/share	Mean/share
Child food security				
Full	0.63	0.85**	0.69	0.82
	(0.02)	(0.01)	(0.02)	(0.03)
Marginal	0.13	0.05**	0.09	0.06
	(0.01)	(0.01)	(0.01)	(0.02)
Low	0.21	0.10**	0.19	0.11
	(0.02)	(0.01)	(0.02)	(0.02)
Very low	0.03	>0.01**	0.03	>0.01
	(0.01)	(0.00)	(0.01)	(0.00)
Child WIC benefit	0.17	0.09**	0.17	0.10
	(0.01)	(0.01)	(0.01)	(0.01)
NSLP	0.56	0.33	0.92	0.70
	(0.02)	(0.03)	(0.01)	(0.04)
SBP	0.40	0.21**	0.43	0.27
	(0.02)	(0.03)	(0.02)	(0.03)
Diet outcomes				
Fiber (gm/day)	12.42	12.00	13.35	13.25
	(0.41)	(0.35)	(0.29)	(0.43)
Meet fiber guidelines	0.05	0.03	0.05	0.03
	(0.01)	(0.01)	(0.01)	(0.01)
Sodium (mg/day)	2,916.31	3,057.25	2,970.07	2,967.90
	(50.42)	(103.85)	(37.65)	(101.77)
Meet sodium guidelines	0.23	0.20	0.21	0.22
	(0.01)	(0.02)	(0.01)	(0.02)
Fruit servings/day	1.17	0.86**	1.10	0.97
	(0.07)	(0.07)	(0.04)	(0.08)
Vegetable servings/day	0.64	0.63	0.60	0.58
	(0.03)	(0.05)	(0.02)	(0.04)
SSBs gm/day	126.93	116.76	130.09	131.14
	(6.96)	(10.89)	(7.10)	(21.41)
SSBs kcal/day	787.01	847.26	811.61	809.74
	(32.29)	(69.55)	(31.61)	(72.28)
HEI-2010	46.59	44.39	47.00	46.39
	(0.64)	(0.88)	(0.47)	(0.99)

Standard errors in parentheses
** p<0.01, * p<0.05

Notes: Pre-ARRA statistics were computed from data from 2005-2008. Post-ARRA statistics were computed using data from 2007-2012, the analytic sample for the difference-in-differences analysis. SNAP-eligible participants include children living in households with income less than or equal to 130 percent of the FPL. SNAP-ineligible participants include children living in households with income between 150 and 200 percent of the FPL. Estimates for nutrition assistance programs (WIC, NSLP, SBP) indicate the share of the sample that are in the relevant age range and participate in the program. Standard errors reported in parentheses. All means and proportions are weighted. The analysis accounts for the complex NHANES survey design. Asterisks indicate that the characteristic in the SNAP-eligible group is significantly different from the higher income group in the pre-ARRA sample.

Abbreviations:
HEI-2010: Healthy Eating Index 2010
NSLP: National School Lunch Program
SBP: School Breakfast Program
SSB's: sugar-sweetened beverages
WIC: The Special Supplemental Nutrition Program for Women, Infants, and Children

Difference-in-Differences

A primary assumption of the DD design is the assumption of parallel trends, which states that outcome trends will be the same in both SNAP-eligible and nearly SNAP-eligible children in the absence of the ARRA. A graphical analysis of outcomes across time allows us to evaluate the parallel trends assumption, and to assess a potential change following the ARRA benefit increase (figures available upon request). Several outcomes suggest uneven trends between SNAP-eligible youth and nearly eligible youth. However, the limited number of time points prior to the ARRA prevents us from more fully assessing the assumption; the uneven trends may be due to a broader pattern of fluctuating trends. For this reason, I present regression results for all outcomes, although it is important to note that it is unclear whether the parallel trends assumption is met.

Table 3 displays the DD estimator that gives the impact of the increase in SNAP benefits. Results are presented in the pooled sample of youth aged 2 to 18 years, and across levels of food security status. I do not find that the increase in SNAP benefits significantly affects the diet of youth in the pooled sample. However, estimates change across food security levels. After the increase in SNAP benefits, I find evidence that marginally food secure, SNAP-eligible youth have lower sodium intake and are less likely to meet fiber guidelines than marginally food secure, ineligible youth. Compared to their ineligible counterparts, SNAP-eligible youth with low food security have a lower HEI-2010 score, and those with very low food security have lower fruit intake. However, the magnitude of several of these estimates reduces their credulity. The small sample size, particularly in youth with marginal and very low food security, may create inconsistent estimates.[i]

[i] I also collapsed food security into a binary measure in order to improve the sample size. (Results for an analysis examining fiber are not shown, but are available upon request). I did not identify any significant relationships. Moreover, the USDA four-category indicator for food security provides a more complete picture of a child's food security status.

Table 2.3 Estimated relationship between the ARRA increase in SNAP benefits and diet quality indicators in children and adolescents between the ages of 2 and 18 years: Differences across food security level (FS)

Child Health Outcome	(Model 1) Pooled sample	(Model 2) Full FS	(Model 3) Marginal FS	(Model 4) Low FS	(Model 5) Very Low FS
	(*n*=3,498)	(*n*=2,442)	(*n*=356)	(*n*=614)	(*n*=86)
Sodium (mg/d)	340.88 (256.61)	450.29 (285.11)	-1,012.98* (438.84)	172.33 (398.59)	1,115.63 (1,003.52)
Meets sodium guidelines[a]	-0.11 (0.06)	-0.10 (0.07)	-0.06 (0.11)	-0.20 (0.13)	-0.30 (0.38)
Fiber (g/d)	0.00 (0.89)	0.12 (1.06)	-0.17 (2.59)	-2.00 (2.36)	3.13 (4.70)
Meets fiber guidelines	-0.02 (0.02)	-0.01 (0.02)	-0.11**[b] (0.04)	-0.06 (0.06)	-0.21 (0.13)
Fruit (cups/d)	-0.17 (0.16)	-0.19 (0.18)	-0.49 (0.45)	-0.46 (0.48)	-2.09** (0.68)
Vegetables (cups/d)	-0.02 (0.09)	0.04 (0.10)	-0.20 (0.14)	-0.17 (0.31)	-0.12 (0.56)
SSBs (kcal/d)	114.70 (136.00)	140.98 (145.70)	310.64 (470.51)	-175.12 (425.55)	830.62 (583.60)
SSBs (gm/d)	-7.76 (36.84)	-16.50 (38.17)	88.59 (70.68)	69.52 (113.61)	236.10 (130.05)
HEI-2010	-4.20 (2.08)	-4.25 (2.43)	-3.90 (3.55)	-7.44* (3.64)	1.60 (8.55)

Standard errors in parentheses
** $p<0.01$, * $p<0.05$

Notes: Table 2.3 presents the difference-in-differences estimator (α_3) for youth aged 2 to 18 years. Column 1 displays estimates for the pooled sample (i.e. all levels of food security). Columns 2 through 5 display estimates by food security level. All models control for youth-specific characteristics (age, sex, race, participation in nutrition assistance programs) and household-level controls (HR education, HR marital status, HH

size). Model 1 also controls for child food security. All models account for the complex survey design.
[a] Models in which "meets sodium guidelines" have a slightly lower *n* than other models. This variable was coded to indicate children who have high sodium. 8.20 percent of the sample are below the minimum recommended sodium intake levels. These children were coded as missing for the sodium binary variable. For the pooled sample, *n*=3,235. For youth with full food security, *n*=2,274. For youth with marginal food security, *n*=328. For youth with low food security, *n*=557. For youth with very low food security, *n*=76.
[b] I ran logistic models to check the estimate for the probability that a child meets fiber guidelines. However, the model would not converge, even when trying an unconditional model that included only the treatment (SNAP), time period (ARRA), and the interaction between them.

Differences across Ages

As presented in Table 2.4, the relationship between the SNAP benefit increase and diet varies according to age. In very young children ages two to three, an increase in SNAP benefits leads to a predicted 3.56 g/day decrease in fiber intake ($p<0.01$), a 12 percent decrease in the probability of meeting recommended fiber guidelines ($p<0.01$), and a predicted 0.85 cups/day decrease in fruit consumption ($p<0.05$). In children aged 6 to 11 years, an increase in SNAP benefits is associated with a 986.91 mg/day increase in sodium consumption ($p<0.05$) and a 5.41 lower HEI score ($p<0.05$).

Table 2.4 Estimated relationship between the ARRA increase in SNAP benefits and diet quality indicators in children and adolescents: Differences across ages

Child Health Outcome	(Model 1) Toddlers 2-3	(Model 2) Preschoolers 4-5	(Model 3) Children 6-11	(Model 4) Adolescents 12-18
	(*n*=589)	(*n*=505)	(*n*=1,363)	(*n*=1,041)
Sodium (mg/d)	-287.85	74.92	986.91*	105.41
	(221.86)	(266.69)	(469.19)	(339.65)
Meets sodium guidelines[a]	0.01	-0.18	-0.14	-0.07
	(0.07)	(0.14)	(0.09)	(0.11)
Fiber (g/d)	-3.56**	1.71	2.71	-2.04
	(1.15)	(1.38)	(1.46)	(1.66)
Meets fiber guidelines	-0.12**	-0.04	0.04	-0.03
	(0.04)	(0.03)	(0.03)	(0.04)
Fruit (cups/d)	-0.85*	0.14	-0.01	-0.28
	(0.37)	(0.27)	(0.21)	(0.25)
Vegetables (cups/d)	0.04	0.29	-0.08	-0.11
	(0.13)	(0.15)	(0.15)	(0.14)
SSBs (kcal/d)	89.32	-10.36	409.81	-123.99
	(252.46)	(252.85)	(310.83)	(266.33)
SSBs (gm/d)	10.56	-21.04	5.59	-28.89
	(39.13)	(46.24)	(41.07)	(67.21)
HEI-2010	-3.39	-3.48	-5.41*	-4.10
	(3.62)	(4.21)	(2.67)	(2.50)

Standard errors in parentheses
** p<0.01, * p<0.05

Notes: Table 2.4 presents the difference-in-differences estimator (α_3) for youth across age ranges. Column 1 displays estimates for the pooled sample (i.e. all levels of food security). All models control for youth-specific characteristics (age, sex, race, child food security, and participation in other nutrition assistance programs [WIC, NSLP, and SBP, depending on the age of the subpopulation]) and household-level controls (HR education, HR marital status, HH size). All models account for the complex survey design.

[a] Models in which "meets sodium guidelines" have a slightly lower *n* than other models. This variable was coded to indicate children who have high sodium. 8.20 percent of the sample are below the minimum recommended sodium intake levels. These children were coded as missing for the sodium binary variable. For toddlers aged 2-3: *n*= 543. For

preschoolers aged 4-5: *n*= 483. For children aged 6-11, *n*=1,291. For adolescents aged 12-18: *n*=918.

The increase in SNAP benefits has a different relationship with diet outcomes across gender. Table 2.5 suggests that an increase in SNAP benefits is associated with an 18 percent lower likelihood of meeting sodium guidelines ($p<0.05$) and a 5.38 lower HEI score ($p<0.05$) in girls but is not significantly associated with diet outcomes in boys.

Table 2.5 Estimated relationship between the ARRA increase in SNAP benefits and diet quality indicators in children and adolescents between the ages of 2 and 18 years: Differences across gender

Child Health Outcome	(Model 1) Girls	(Model 2) Boys
	(*n*=1,725)	(*n*=1,803)
Sodium (mg/d)	172.10 (291.02)	519.32 (374.68)
Meets sodium guidelines[a]	-0.18* (0.08)	-0.05 (0.08)
Fiber (g/d)	-0.25 (1.21)	0.75 (1.14)
Meets fiber guidelines	-0.04 (0.03)	0.01 (0.02)
Fruit (cups/d)	-0.14 (0.18)	-0.20 (0.19)
Vegetables (cups/d)	-0.02 (0.10)	-0.02 (0.12)
SSBs (kcal/d)	-139.49 (223.50)	337.03 (236.10)
SSBs (gm/d)	-51.27 (56.71)	28.45 (35.99)
HEI-2010	-5.38* (2.61)	-3.34 (2.19)

Standard errors in parentheses
** p<0.01, * p<0.05

Notes: Table 2.5 presents the difference-in-differences estimator (α_3) for youth aged 2 to 18 years for girls and boys. All models control for youth-specific characteristics (age, sex, race, food security, participation in nutrition assistance programs) and household-level controls (HR education, HR marital status, HH size). All models account for the complex survey design.

[a] Models in which “meets sodium guidelines” have a slightly lower *n* than other models. This variable was coded to indicate children who have high sodium. 8.20 percent of the sample are below the minimum recommended sodium intake levels. These children were coded as missing for the sodium binary variable. For girls, *n*=1,570. For boys, *n*=1,690.

The main analysis estimates the intent-to-treat of SNAP, and includes all children living in households with incomes at or below 1.30 of the FPL as the “treatment” group. The comparison group in the DD includes children with household income with a PIR between 1.5 and 2.0. Alternate treatment and comparison groups were assessed, including a broader higher-income comparison group (PIR 1.5-2.5; see Nord and Prell, 2009[34]), and groups based on self-reported SNAP participation. Results are sensitive to the treatment and comparison group used, illustrating the importance of controlling for self-selection and misreport of participation (results not shown, but are available upon request). I did not find that an increase in SNAP benefits significantly affected diet outcomes across groups.

Regression Discontinuity

Next, I examine the influence of SNAP eligibility on youth diet outcomes in a regression discontinuity design. Graphing the outcomes of interest across levels of the PIR demonstrates if the outcomes exhibit a “jump” across the SNAP income eligibility threshold. If SNAP-eligible youth have higher diet quality than those just over the threshold, then we would expect to see higher average outcomes, and a drop-off in average outcomes in youth with PIR above 1.3. However, the graphical analysis does not show a discontinuity across the income threshold for the majority of outcomes (figures available upon request). However, sodium intake, fruit consumption and vegetable consumption suggest that there is a jump across the threshold of 1.3. Figures 2.1-2.3 plot the weighted, mean outcome for each level of PIR across 2005-2014. The red line shows the cut-point 1.3 in the poverty-income ratio, which is the main SNAP eligibility criteria. Figures 2.1-2.3 suggest that children just under the SNAP-eligibility threshold have lower sodium intake, and lower consumption of fruit and vegetables than those just over the threshold.

Figure 2.1 Sodium (mg/day) across PIR

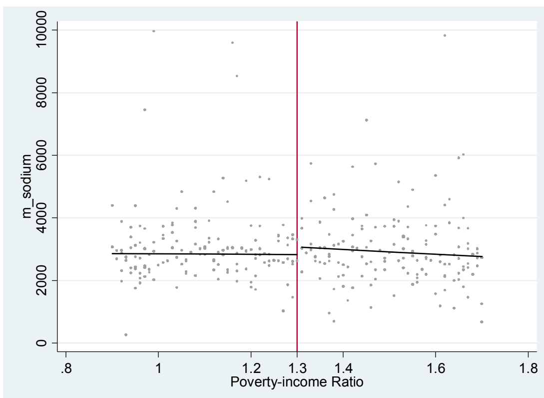


Figure 2.2 Fruit (c/day) across PIR

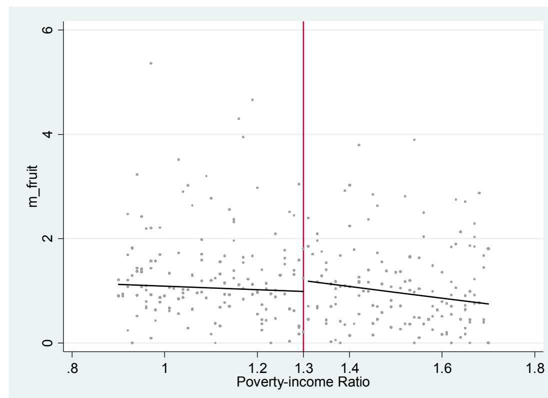
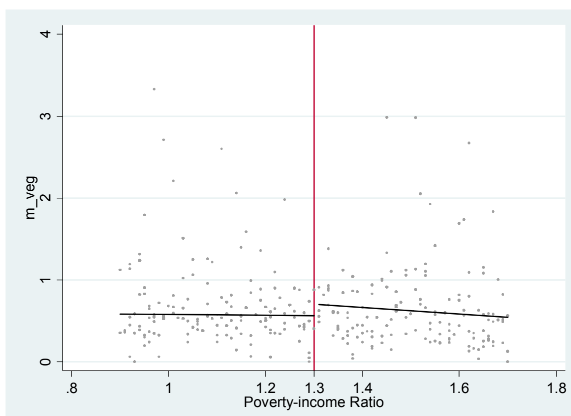


Figure 2.3 Vegetables (c/day) across PIR



Notes: Figures 2.1-2.3 present the graphical analyses of sodium, fruit, and vegetables for the regression discontinuity design. These graphs plot the weighted, mean outcome for each level of PIR across 2005-2014. The red line shows the cut-point 1.3 in the poverty-income ratio, which is the main SNAP eligibility criteria.

Whether or not there is a discontinuity in diet outcomes across the 1.3 cut-off is assessed formally using equation (2). Table 2.6 presents the intent-to-treat estimate of the SNAP program (τ) for youth aged 2 to 18 years, in the pooled sample, and across levels of food security. I use an unconditional model and linear fit, while still allowing for the relationship between SNAP eligibility and each diet outcome to vary on either side of the cut-off. Although Figures 2.1-2.3 suggest that there is a jump in sodium intake, fruit consumption, and vegetable consumption, these results are not statistically significant in the pooled sample, or in the majority of subpopulations. I do find that SNAP-eligible youth with very low food security consume 5.51 more grams/day ($p<0.05$) of fiber, and 252.14 less grams/day of SSBs, compared to those just over the income-eligibility threshold. However, very low food-secure youth are also 41 percent less likely to meet recommended sodium guidelines ($p<0.05$) than those just over the threshold.[j]

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[j] I tested the sensitivity of results to model specification across functional forms and choice of bandwidth (results available upon request). I find that results fluctuate across functional forms, but that estimates are generally robust to using a more narrow bandwidth. I examined the relationship between SNAP eligibility and diet outcomes separately for girls and boys (results available upon request). I did not find a different relationship between girls and boys. I examined the relationship between SNAP eligibility and diet outcomes across age groups (results available upon request). I largely did not find a different relationship across age groups.

Table 2.6 Estimated effect of SNAP-eligibility on diet quality indicators in children and adolescents compared to those just over the eligibility threshold: Differences across food security

Child Health Outcome	(Model 1) Pooled sample	(Model 2) Full	(Model 3) Marginal	(Model 4) Low	(Model 5) Very Low
	(*n*=8,553)	(*n*=5,693)	(*n*=942)	(*n*=1,478)	(*n*=233)
Sodium (mg/d)	-128.47 (145.14)	-163.48 (165.41)	470.55 (268.98)	-488.82 (456.35)	-938.03 (717.50)
Meets sodium guidelines[a]	0.04 (0.03)	0.06 (0.03)	0.09 (0.09)	0.00 (0.08)	-0.41* [b] (0.18)
Fiber (g/d)	0.67 (0.71)	0.52 (0.86)	1.52 (1.17)	-0.47 (1.95)	5.51* (2.65)
Meets fiber guidelines	0.01 (0.02)	0.01 (0.02)	-0.00 (0.02)	-0.01 (0.04)	0.02 (0.02)
Fruit (cups/d)	-0.00 (0.12)	0.10 (0.13)	-0.67 (0.36)	-0.26 (0.38)	0.73 (0.41)
Vegetables (cups/d)	-0.12 (0.07)	-0.11 (0.09)	-0.10 (0.10)	-0.26 (0.19)	-0.11 (0.23)
SSBs (kcal/d)	7.12 (110.23)	-0.24 (130.48)	-0.40 (262.26)	124.90 (244.19)	-1,157.28 (668.95)
SSBs (gm/d)	9.48 (23.02)	12.32 (29.88)	4.99 (41.66)	29.45 (38.94)	-252.14** (81.85)
HEI-2010	1.30 (1.44)	2.38 (1.64)	-5.21 (3.13)	0.08 (3.30)	7.37 (4.81)

Standard errors in parentheses

** $p<0.01$, * $p<0.05$

Notes: Table 2.6 presents the intent-to-treat estimate of the SNAP program (τ, from equation (2) for youth aged 2 to 18 years. Column 1 displays the RD estimates for the pooled sample (i.e. all levels of food security). Columns 2 through 5 display estimates by food security level. All models are unconditional, linear fits that center PIR on the 1.30 cutoff, and allow for a different relationship between SNAP eligibility and each diet

outcome on either side of the cutoff. All models account for the complex survey design. I also checked various specifications for each outcome to assess different functional forms (results not shown, but are available upon request). I focus on a linear fit because the graphs do not suggest a quadratic or cubic relationship.
[a] Models in which "meets sodium guidelines" have a slightly lower *n* than other models. This variable was coded to indicate children who have high sodium. 8.20 percent of the sample are below the minimum recommended sodium intake levels. These children were coded as missing for the sodium binary variable. For the pooled sample, *n*=7,793. For youth with full food security, *n*=5224. For youth with marginal food security, *n*=855. For youth with low food security, *n*=1,330. For youth with very low food security, *n*=199.
[b] Using logistic regression, the odds ratio of meeting recommended sodium guidelines was 0.16, with a p-value of 0.026, and thus remained significant.

2.5 Falsification tests

A regression discontinuity design is appropriate only if children just below and just above the cut-off do not differ systematically. To assess the probability of this assumption, first, I plot several observable characteristics against PIR (figures available upon request). Three socio-demographic characteristics (age, gender, and household size) are distributed continuously around the cut-off value of 1.3 PIR, and do not exhibit a discontinuity, suggesting that youth just under and just over the eligibility cut-off have similar observable characteristics. Second, if either potential SNAP participants or program administrators manipulate household income, then it will not be a matter of chance whether or not households fall just under or just over the 1.3 PIR eligibility criteria. To examine the possibility of manipulation at the cut-off, I plot the density of PIR. A greater number of cases around the cut-off would indicate that manipulation of household income is occurring. If this were true, it is likely that households just under the cut-off differed systematically on unobservable characteristics, when compared to households just over the cut-off. Graphs do not suggest that manipulation of income is occurring (figures not shown, but are available upon request).

If SNAP is the driving force behind differences in diet outcomes, then we would expect to see a discontinuity across the 1.30 SNAP eligibility cut-off, but not across other values of PIR. To examine this, I plot the dietary outcome across PIR and look for a discontinuity across the PIR value of 1.85 (graphs not shown, but are available upon request). I do not find evidence of a jump across other values of PIR, with the exception of the probability of meeting sodium recommendations. As I did not find a significant jump in the probability of meeting sodium recommendations across the SNAP eligibility criteria, the results of this falsification test do not alter the conclusions regarding fiber and vegetables.

2.6 Discussion

This study analyzed the relationship between participation in SNAP and multiple measures of diet quality in children and youth, using two quasi-experimental designs. In the DD, I find that an increase in SNAP benefits is associated with lower fiber intake, a lower probability of meeting recommended fiber guidelines, and lower fruit consumption in toddlers aged 2 to 3 years. In children aged 6 to 11 years, an increase in SNAP benefits is associated with higher sodium intake and a lower HEI score.

I also find that increased SNAP benefits are linked with lower diet quality in youth across levels of food security. Marginally food-secure youth are less likely to meet fiber guidelines. Low food-secure youth have a lower average HEI score, and very low food-secure youth consume less fruit. However, when compared with youth just over the eligibility threshold in the RD, I find evidence that SNAP contributes to higher diet quality in SNAP-eligible youth with very low food security.

Food insecurity is associated with lower diet quality.[50,51] A recent review found that food-insecure adults consumed fewer vegetables, fruit, and dairy, when compared to food-secure adults, but that the relationship between diet quality and food insecurity was weaker in children.[51] There is substantial evidence that SNAP improves food security.[79–82] If SNAP improves food security, then we would expect food-insecure, SNAP-eligible youth to have higher diet quality, when compared to food-insecure, nearly SNAP-eligible youth. The present study provides evidence supporting this idea.

If families use SNAP benefits to purchase high-quality, nutritious foods, then we would expect the increase in SNAP benefits during the ARRA to improve diet quality. However, the benefit increase has a negative relationship with fiber and fruit consumption in toddlers, and a lower HEI score in children aged 6 to 11. The reason that these relationships exist only for certain age ranges is unclear. Other studies have found that compared to non-participating children, youth living in SNAP-participating households consume less fruits, vegetables, nuts, legumes, and whole grains,[17,49] which are good sources of fiber.[35] Additionally, studies using data from the Feeding Infants and Toddlers Study found that approximately 30 percent of children ages two to three did not consume a distinct vegetable, and that French fries and other fried potatoes were the most commonly consumed vegetable.[83,84] If children in the two to three year age range do not eat many vegetables, which are a good source of fiber,[35] then an increase in SNAP benefits may not lead to an increase in fiber intake. However, it is unclear why an increase in SNAP benefits would be associated with a *decrease* in fiber intake, fruit consumption, and overall HEI score. The ARRA was implemented during the Great Recession. The national unemployment rate doubled from 2007 to 2009,[85] and many households reported higher levels of stress symptoms, including depression and sleeplessness.[86] A recent review finds that high levels of stress, poor sleep, and job insecurity are closely linked with poor diet quality.[87] If the stress and financial instability during this time affected what foods families purchased—such as buying more processed, convenient foods, or highly palatable items—then deteriorating diet quality could be expected.

Policy Implications

If SNAP has a significant relationship with dietary outcomes in youth who experience the most severe form of food insecurity, then policy makers may consider targeting benefits to those who fall into this category. This may include increasing benefit levels to the most food-insecure families. Single mother or father-headed households, non-Hispanic Black households, households located in rural areas, and households with incomes below 185 percent of the FPL are those most likely to experience very low food security.[88] However, the low prevalence of very low food security, even in those with higher risk, may make efforts at targeted interventions inefficient. At a minimum, community health workers and social service staff should screen youth for food insecurity and refer families to the SNAP program.

A recent study found that among children and adolescents, diet quality significantly declined in older age groups.[54] The present analysis suggests that this relationship may be different in children living in SNAP-eligible households. If future research corroborates these findings, then nutrition education efforts may be targeted towards families with very small children. SNAP nutrition education programs (SNAP –Ed) are the nutrition promotion element of SNAP.[89] SNAP –Ed has been effective at increasing fruit and vegetable consumption and use of low-fat dairy among young children.[90,91] However, SNAP –Ed is implemented through partnerships with community organizations, and is not available in all locations. An increase in funding and other resources to community partners in order to expand the reach of SNAP –Ed has the potential to improve dietary choices in SNAP-eligible households and youth.

Limitations

This study has several key limitations. First, although difference-in-differences and regression discontinuity are recognized as strong research designs, endogeneity from self-selection and/or omitted variables is still a threat. Second, DD and RD place high demands on the data, which limits the ability to identify a statistically significant relationship. Furthermore, strict assumptions must be met for these designs to be appropriate. Finally, the complex institutional rules of SNAP, e.g. assets tests, eligible deductions, and state flexibility in determining eligibility, make misclassification between the SNAP-eligible and comparison groups probable.

2.7 Conclusions

This study used difference-in-differences and regression discontinuity to examine the relationship that SNAP has with six dietary outcomes in children and adolescents. The results indicate that food insecure youth living in SNAP-eligible households consume more fiber and more fruit than food insecure youth who are just over the SNAP-eligibility cutoff. In addition, the relationship between SNAP and diet quality varies across age ranges. The SNAP benefit increase during the ARRA is associated with lower fiber intake, lower fruit consumption, higher sodium intake, and a lower HEI score in certain age ranges. Targeting SNAP benefits to youth who experience very low food security and directing nutrition education programs to SNAP-eligible households with very young children have the potential to improve the diets of low-income children and youth.

CHAPTER 3: WEIGHT OUTCOMES AMONG LOW-INCOME CHILDREN: ESTIMATING THE ASSOCIATION WITH SNAP

3.1 Introduction

There is substantial evidence of a sizeable correlation between income and health, including in children and adolescents. Obesity rates are highest in low-income youth [92]. There is less evidence regarding the role that policies and programs may have in this relationship. The degree to which policies can improve health and potentially decrease obesity rates is of great interest, both to policy-makers and to public health professionals. There is a growing body of literature that attempts to understand the connections between poverty, poor nutritional health, and policy initiatives. Fewer studies focus on health outcomes in children and adolescents. In this paper, I evaluate how the Supplemental Nutrition Assistance Program (SNAP) may play into these linkages. The American Recovery Reinvestment Act (ARRA) increased the amount of SNAP benefits families received. The benefit increase occurred as a constant dollar amount for households of a given size. Therefore, I use this benefit increase as an identification strategy to understand how additional benefits relate to youth obesity. In addition, there is a federal, income-based eligibility criterion that households must meet in order to participate in SNAP. I use the income cut-off as a second identification strategy and evaluate weight and obesity measures in youth under the eligibility threshold, compared with those just over the threshold.

The present analysis makes three important contributions to the literature that examines the connection between SNAP and obesity in children and adolescents. First, I use two quasi-experimental designs that help control for selection bias and misreporting program participation, two challenges that are inherent when evaluating SNAP and similar programs. Second, I use researcher-measured height and weight, which is significantly more reliable than self- or parent-reported measures. Third, I examine differences by food security level, age group, and gender, which previous research suggests modify the connection between SNAP and obesity.

The prevalence of obesity among youth ages 2 to 19 was 18.5% in 2015 to 2016, up from 17.0% in 2011 to 2014 [93,94]. Moreover, the gap in obesity rates has also increased. Recently, obesity rates in children living in households of higher socioeconomic status (SES) have decreased, while obesity rates in children living in households of lower SES have increased [15]. A primary contributing factor to this trend is the differential access that low-income households have to a healthy diet. Healthy, nutrient-dense diets cost more than lower-quality diets [47]. Research suggests that low SES populations have greater access to energy-dense, nutrient-poor diets, compared to higher-quality diets, largely due to budget constraints.

Food assistance programs can help low-income families to address their food needs and afford a higher-quality diet. The Supplemental Nutrition Assistance Program (SNAP) is the largest federal nutrition program. It provides aid in the form of an electronic benefits transfer (EBT) card to eligible households [1]. However, the relationship between SNAP and child obesity is unclear. Findings from previous studies examining the connection that SNAP has with child weight are inconsistent, which is partially due to methodological challenges when studying a program like SNAP. Eligible households must choose to apply and participate, which leads to unobserved differences between those who participate and those who do not. For example, children living in households with income well above the SNAP eligibility criteria likely have greater access to resources that can affect weight, such as healthier food or options to participate in sports or other physical activities [95]. A second layer of selection occurs when low-income households are eligible to participate in SNAP but choose not to apply and participate. For example, income-eligible, non-participating households may have lower caloric needs. This could occur if members of low-income, non-participating households are more likely to be a healthy weight than members of SNAP-participating households. Bitler explored selection of participants into SNAP, and found that participants are more likely to be obese, have poorer diets, and have overall lower child and adult health than either income-eligible non-participants or higher income non-participants [7].

Studies have used instrumental variables [57,58,96,97], difference-in-differences propensity score matching [98], panel data methods [56–58,99], and partial identification bounding methods [100] in order to address the selection bias inherent when studying SNAP and child obesity. This paper builds on these studies by using two different designs, difference-in-differences (DD) and regression discontinuity (RD), to help control for selection bias.

The objective of this study is to use D and RD to disentangle the relationship between SNAP and weight outcomes in children and adolescents ages 2 to 18. In this paper, I take advantage of the quasi-natural experiment provided by the temporary increase in SNAP benefits during the American Recovery and Reinvestment Act (ARRA) of 2009 in a DD design. Second, I use the income-eligibility criteria of SNAP in an RD design. I examine how SNAP may be differentially related with weight outcomes in boys and girls, and across age groups. I also investigate how food security status affects the association between SNAP and child weight.

Most prior studies in the economics literature[k] have relied on self- or parent-reported weight, which introduces error at the outcome level, as people are likely to misreport their own weight [101,102] and their child's weight [103,104]. This analysis uses data from the National Health and Nutrition Examination Survey (NHANES), which includes researcher-measured height and weight, and is more accurate than reported height and weight. I find that SNAP is associated with healthier weight outcomes in boys and in children within certain age groups.

3.2 Policy background and relevant literature

The Supplemental Nutrition Assistance Program (SNAP) is the largest federal food assistance program [1]. Total annual benefits costs were approximately $67 billion in fiscal year 2016 [105]. Forty-four million people participated in the average month, with children comprising nearly 50 percent [105]. In 2008, the name changed from the Food Stamp Program to the Supplemental Nutrition Assistance Program, and emphasis was placed on nutrition. Since then, the goal of SNAP has been to "alleviate hunger and malnutrition" and enable low-income households to obtain "a more nutritious diet"(Food and Nutrition Act of 2008). SNAP aims to meet its goals by providing financial assistance in the form of an EBT for eligible individuals and families to purchase food for home consumption. The benefit amount households receive is based on the Thrifty Food Plan (TFP), and also accounts for household size, income, and assets [24]. In 2009, the ARRA was created in response to the Great Recession. The ARRA made two major changes in SNAP: it increased benefit levels for all participants and it relaxed eligibility requirements for

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[k] I specify economics literature because studies using designs such as difference-in-differences, instrumental variables, or other designs that attempt to control for selection bias are typically in economics journals and literature.

unemployed adults without children. The benefit increase became effective in April 2009 and ended on October 31, 2013 [75].

The first identification approach of this study takes advantage of the benefit increase to differentiate a pre- and post-period in a difference-in-differences design.

The ARRA increased the TFP by 13.6 percent on average, which then increased the maximum monthly benefit levels. The benefit increase occurred as a constant dollar amount for a given household size. Therefore, households with no net income received a benefit increase of 13.6 percent on average during the ARRA, and households with income received a greater percentage increase. For example, before the ARRA, a four-person household was eligible to receive a maximum of $668 per month. The ARRA led to an $80 increase in SNAP benefits. For a household with no net income, this was a 13.6 percent increase in benefits. A household of four with $980 in net income also received an $80 increase in benefits, which was a 27.2 percent increase [74,79]. The average SNAP household received an additional $46 in benefits, which is a 19 percent increase [74].

The second estimation strategy utilizes the income-eligibility requirements of SNAP in a regression discontinuity design. To be eligible to participate in SNAP, gross household income must be under 130 percent of the federal poverty line (FPL). Households must also meet employment requirements and an assets test, meaning they must have no more than $2,250 in countable resources, e.g. a bank account [33]. These are the federal limits, though states have the option to expand eligibility requirements, making it easier for individuals to qualify [106]. The RD design uses the income-eligibility criteria as the cut-off to categorize children as SNAP-eligible or ineligible. The cut-off of 130 percent mimics random assignment; it is almost a matter of chance whether households have income that is at 129 percent or 131 percent of the FPL. This is exogenous to child weight and provides the source of identification.

SNAP may affect child weight through several potential mechanisms. Diet is a primary determinant of body weight [42,107] and SNAP benefits are designed to influence the diet of participants. First, SNAP benefits essentially increase the amount that households have to spend on food and on all other goods. SNAP benefits can only be used to purchase food for at-home consumption.[l] The substitution effect may encourage participants to substitute meals prepared in the home for meals eaten out [108]. Food at home tends to have fewer calories and a healthier nutritional profile than restaurant meals [109–111]. Using a design similar to the one used in this paper, Tuttle (2016) found that SNAP benefits increase the amount of food-at-home spending, but not food-away-from-home spending.

A second mechanism through which SNAP may affect weight is due to the in-kind transfer of SNAP benefits. Demand theory predicts that the majority of individuals[m] will treat SNAP benefits as cash [113]. However, several recent studies have found that the marginal propensity to consume food (MPCF) after receiving SNAP benefits is higher than the MPCF out of cash [112,114,115]. (For example, see *inter alia* Hastings and Shapiro (2017)). As families spend more money on food, two potential scenarios can occur. First, SNAP benefits may lead participants to substitute more expensive, higher-quality foods

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[l] An exception to this rule is sometimes made during times of disaster, when the USDA may grant SNAP participants living in affected areas the ability to purchase hot foods. For example, following Hurricane Florence in 2018, the USDA allowed SNAP participants living in North Carolina to purchase hot foods in authorized SNAP retail stores [194].
[m] This proposition holds for the households that spend more on food overall than what SNAP benefits provide (known as inframarginal households) [113]. SNAP is designed to supplement grocery spending made with other income [1], so the majority of participants fall into this category.

with greater nutrient content, e.g. fruits, vegetables, or fresh meats, for less-expensive, highly-processed foods with low nutritional value. Conversely, households may simply purchase a greater *quantity* of food, instead of higher *quality* foods. If food purchased and consumed includes a substantial amount of calorically-dense and/or nutrient-poor foods, then weight gain can result. A recent review found that adult SNAP participants had lower overall diet quality than either income-eligible or higher-income nonparticipants [48]. Child SNAP participants had diets that were similar to income-eligible nonparticipants, but of lower quality than higher-income nonparticipants [48]. These findings indicate that the second scenario is more likely to occur.

SNAP may influence weight through a third mechanism known as quasi-hyperbolic discounting. Quasi-hyperbolic discounting is a behavioral tendency that can lead people to place greater value on immediate rewards as compared to future rewards.[116] Discounting, in combination with the monthly distribution cycle of SNAP benefits, can lead to the "food stamp cycle," in which families use the majority of their benefits towards the beginning of the month, followed by a period of forced restriction. This pattern of eating can lead to weight gain over time [117,118]. Recent work by Todd (2015), Kharmats et al. (2014), and Hastings and Washington (2010) provides evidence to support the "food stamp cycle" hypothesis. For example, Todd (2015) found that daily caloric intake of adult SNAP participants declined 25 percent at the end of the benefit month.

There is a considerable body of work examining the relationship between SNAP and weight outcomes in adults. Fewer studies asses this relationship among children and adolescents. However, the majority of youth-focused studies do not mitigate selection bias. Among those that do, findings are mixed. When examining the relationship between SNAP and child weight outcomes, studies have found no significant association [97,98,100], a negative association [57,96], and a positive association, but only in girls [56–58,99]. Results can vary by age and gender [56–58,99] and length of SNAP participation [56,99]. I build on this body of work by examining differences among children in different age groups and gender, and with different levels of food security, using two quasi-experimental designs.

To my knowledge, this is the first paper to use the natural experiment provided by the ARRA benefit increase and a difference-in-differences design to study the relationship between SNAP and child weight. Other studies have used the ARRA and a DD design to estimate SNAP's influence on diet quality of adults [71,121], food security [79], and expenditure response [79,114].

This is also the first paper to use SNAP's income-eligibility criteria in a regression discontinuity design. Schanzenbach (2009) and Peckham and Kropp (2012) estimated the impact of the National School Lunch Program (NSLP) on childhood obesity, using the income-eligibility criteria as the cut-off. Gundersen, Kreider, and Pepper (2012) used a monotone instrumental variable approach, similar to an RD design, to likewise evaluate the effect of the NSLP on child health. Hoynes and Schanzenbach [125] note that RD may not be suitable for analyzing SNAP because the amount of benefits received fall as income rises. Therefore, the discontinuity between receiving benefits and not receiving any benefits is not as sharp a discontinuity as programs like the NSLP. However, during the period of the ARRA, benefits increased by a constant dollar amount for each household size, regardless of income [75]. The difference in benefits received even in SNAP households that are close to the cutoff is therefore more pronounced between 2009 and 2013 during the ARRA.

3.3 Methodology

Analytical Framework

Self-selection into SNAP leads to unobserved, systematic differences between participants and nonparticipants. In addition, people mis-report participation in SNAP [126–129]. Estimates of misreporting errors range from 12 to 50 percent [126,129]. Misreporting further biases estimates when using self-reported participation information to conduct analyses.

Finally, the ARRA benefit increase that began in April 2009 may have led to changes in the types of people participating in SNAP (For a more detailed discussion, see Nord and Prell (2011)). The benefit increase may have motivated people who had previously not participated in SNAP to participate. The under- or unemployment resulting from the Great Recession during this time may also have led to new households deciding to participate or becoming eligible to participate. Both groups of new participants would likely be systematically different from the pre-ARRA SNAP participants and nonparticipants. Self-selection, misreporting, and changes in the composition of SNAP participants would bias the estimated relationship between SNAP participation and health outcomes.

To decrease these biases, I use an Intent-to-Treat (ITT) framework to estimate outcomes in the SNAP *eligible* population, rather than using self-reported SNAP participation. The treatment group includes youth living in households with gross income at or below 130 percent of the federal poverty line (FPL). The comparison group in the

DD includes youth in low-income households with income 150 to 200 percent of the FPL, similar to Nord and Prell's (2011) "nearly SNAP eligible" group.[n] Furthermore, flexible state options in determining household eligibility and complex institutional rules can make households with income slightly over 130 percent of the FPL to be eligible.[o] To partially mitigate this potential misclassification error, I exclude youth living in households with incomes between 131 and 149 percent of the FPL.

The SNAP benefit increase became effective from April 2009 to October 31, 2013 [75]. I leverage the benefit increase to create a second comparison group. Youth living in SNAP-eligible and nearly SNAP-eligible households are further split into pre-ARRA and post-ARRA.[p]

The framework of the RD is based on the assumption that those with income just under the eligibility criteria and those with income just over the criteria are nearly the same; it is almost a matter of chance of having income at 129 percent of the FPL, or of having income at 131 percent of the FPL. Individuals close to the cut-off criteria (e.g. having income at 130 percent of less of the FPL) should be virtually identical. The comparison group in the RD design differs from the DD comparison group and includes individuals with incomes just over the income-eligibility criteria: between 131 percent of the FPL and less than or equal to 185 percent of the FPL. However, measurement error is

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[n] Nord and Prell used 150 to 250 percent of the FPL to designate a ""nearly SNAP eligible" comparison group. However, the income level for a family of four at 250 percent of the 2014 FPL is nearly twice as much as the income level at 130 percent. Therefore, I use a narrower income range for the comparison group

[o] Similarly, households with incomes slightly *under* 130 percent of the FPL may be ineligible. For example, if a household has a large savings account or multiple vehicles (varies by state), they may be ineligible to participate in SNAP [33].

[p] Because the ARRA began in April 2009, including January through March 2009 would weaken the design. NHANES has a variable to identify the six-month period in which the exam took place. I use this variable to exclude observations from November 1 to April 30.

introduced because the income level is not the only eligibility criteria for SNAP, making it more difficult to detect an effect.

I conduct a secondary analysis using those reporting SNAP participation as the treatment group. I compare them to two comparison groups: income-eligible nonparticipants (children with household income less than or equal to 130 percent of the FPL) and higher-income nonparticipants (children with household income between 150 and 200 percent of the FPL).

Data

I use data from the National Health and Nutrition Examination Survey (NHANES) for the analysis. NHANES is a repeated cross-sectional survey that is nationally representative of the civilian, noninstitutionalized U.S. population. The Centers for Disease Control and Prevention's National Center for Health Statistics conducts NHANES using a complex, multistage probability design. NHANES includes data on approximately 5,000 individuals each year [130], and the data is released in two-year waves. NHANES oversamples non-Hispanic blacks, Hispanics, low-income whites, and the elderly (80 years old and over) in order to increase the precision and reliability of estimates for these populations [59]. Because the present study focuses on a low-income population, the NHANES sampling design is important because it oversamples low-income groups, allowing for more precise estimates for this population. NHANES is unique in that it includes detailed health examination data, in addition to information from questionnaires. For the purposes of the present analysis, the key advantage of this survey is that height and weight are measured. Self- and parent-reported height and weight can introduce substantial measurement error [101–104]. However, there is a notable imitation to NHANES. Due to the limited geographical area sampled each year, and the sensitive nature of the data collected, stringent steps are taken to protect the identities of survey participants. As such, information on geographic location, specific year of data collection, and detailed financial information is not available on public use data. The DD design uses the 2007-2014 waves of the NHANES datasets. The RD design uses the 2005-2014 waves.

Population

The analysis focuses on children and adolescents who were ages 2 to 18 during data collection. The majority of studies that examine SNAP and child weight status include only children and adolescents between the ages of 5 and 18 (e. g. Gibson, 2001; Robinson & Zheng, 2011; Schmeiser, 2012). However, nearly one in ten children between the age of two and five years were obese in the period 2011 to 2014 [93], making it important to understand what influences weight outcomes in this age range.

Variables

Weight Outcome Measures

I use two standardized measures of body mass index (BMI) in youth: 1) BMI-for-age Z-scores and 2) age-and gender-specific BMI percentile. Z-scores indicate the number of standard deviations away from the mean that a given observation falls.[q] I use the 2000 CDC Growth Charts as the reference for both Z-scores and percentiles [132].

[q] That is, a negative Z-score indicates that a child is below the mean, though not necessarily underweight. A positive Z-score indicates that a child's weight is above the mean, though the child may not necessarily be overweight. A positive (or negative) coefficient when using BMI Z-score as the outcome measure suggests that the independent variable in question is associated with having weight above (or below) the mean.

I also examine three binary variables of child weight in order to identify if the youth falls into the category of overweight, obese, or underweight. According to the CDC definition, I categorize a child as overweight if their BMI-for-age percentile is at the 85th to less than the 95th percentile, obese if their BMI-for-age percentile is equal to or greater than the 95th percentile [133], and as underweight if their BMI-for-age percentile is less than the 5th percentile.

Assignment and Control Variables

I control for income in the DD and RD analyses, and use income as the assignment variable in the RD. The baseline federal income eligibility criteria for SNAP is set at 130 percent of the FPL, which is equivalent to a poverty-income ratio (PIR) of 1.30. States have flexibility in broadening this criteria, and as of 2018, 15 states had raised their cut-off to 200 percent [134]. There are also assets tests and eligible deductions (e.g. for childcare expenses) [33]. A major drawback of the NHANES dataset is that it does not provide the state in which the child resides, or detailed financial information in public-use data. Besides introducing measurement error, this is a limitation of this study's RD design.

The relationship between SNAP and obesity may differ according to food security status [52], age [56–58], and gender [56,57]. For this reason, I first analyze the relationship between SNAP and weight in the full sample of youth, and then stratify by food security level, age, and gender. The age ranges I examine are toddlers ages 2 to 3, preschoolers ages 4 to 5, children ages 6 to 11, and adolescents ages 12 to 18.

Following previous studies, all analyses control for the child's age, gender, race/ethnicity, participation in other nutrition assistance programs, and the household reference person's (HR) educational attainment, marital status, and household size [17,39,50,68–71].

Table 3.1 presents the summary statistics of the sample used in the DD. Several important differences exist between the SNAP-eligible and nearly-eligible youth prior to the ARRA. Race is significantly different between groups. SNAP-eligible youth are less likely to be white and are more likely to be black or Hispanic than nearly-eligible youth. The household reference person's (HR) level of education is lower in SNAP-eligible households. Youth living in SNAP-eligible households have significantly lower food security and are more likely to participate in WIC or the school breakfast program. SNAP-eligible youth have significantly higher BMI percentile and BMI Z-score than do nearly-eligible youth. A threat to the DD design exits if body weight outcomes would be different between SNAP-eligible and nearly SNAP-eligible youth, even in the absence of the ARRA. I visually assess this assumption in Indirect Tests of Identifying Assumptions.

Table 3.1 Sample characteristics: Weight outcomes sample

	Pre-ARRA		Post-ARRA	
	SNAP-Eligible (*n*=2,846)	Nearly SNAP-Eligible (*n*=721)	SNAP-Eligible (*n*=4,110)	Nearly SNAP-Eligible (*n*=895)
	Mean/share	Mean/share	Mean/share	Mean/share
Age	9.73	9.45	9.59	9.59
	(0.14)	(0.28)	(0.11)	(0.25)
Female	0.51	0.47	0.50	0.47
	(0.01)	(0.03)	(0.01)	(0.02)
Race				
White	0.42	0.57	0.39	0.53
	(0.04)	(0.04)	(0.04)	(0.04)
Black	0.21	0.16	0.21	0.16
	(0.03)	(0.02)	(0.02)	(0.02)
Hispanic	0.31	0.22	0.34	0.22
	(0.04)	(0.03)	(0.03)	(0.03)
Other	0.06	0.05	0.06	0.09
	(0.01)	(0.01)	(0.01)	(0.02)
PIR	0.75	1.75	0.74	1.73
	(0.02)	(0.01)	(0.01)	(0.01)
HR education				
< 12 years	0.42	0.21	0.42	0.18
	(0.02)	(0.03)	(0.02)	(0.02)
High school	0.29	0.36	0.28	0.29
	(0.02)	(0.04)	(0.02)	(0.03)
Some college	0.22	0.34	0.23	0.36
	(0.01)	(0.03)	(0.01)	(0.03)
College grad +	0.06	0.09	0.067	0.17
	(0.01)	(0.02)	(0.01)	(0.03)
HR Married	0.49	0.66	0.48	0.66
	(0.03)	(0.03)	(0.02)	(0.03)
HH size	4.77	4.35	4.84	4.40
	(0.06)	(0.08)	(0.05)	(0.08)

Notes: Pre-ARRA characteristics were computed using data from 2005-2008. Post-ARRA uses data from 2007-2012, the analytic sample for the difference-in-differences analysis. SNAP-eligible participants include children living in households with income less than or equal to 130 percent of the FPL. SNAP-ineligible participants include children living in households with income between 150 and 200 percent of the FPL. Standard errors reported in parentheses. The analysis accounts for the complex NHANES survey design.

Abbreviations:
HH: household
HR: household reference person
PIR: poverty-income ratio

Table 3.2 Nutritional health outcomes

	Pre-ARRA		Post-ARRA	
	SNAP-Eligible (*n*=2,846)	Nearly SNAP-Eligible (*n*=721)	SNAP-Eligible (*n*=4,110)	Nearly SNAP-Eligible (*n*=895)
	Mean/share	Mean/share	Mean/share	Mean/share
Child food security				
Full	0.64	0.84	0.69	0.84
	(0.02)	(0.02)	(0.02)	(0.02)
Marginal	0.12	0.04	0.11	0.06
	(0.01)	(0.01)	(0.01)	(0.02)
Low	0.21	0.11	0.18	0.09
	(0.02)	(0.02)	(0.01)	(0.01)
Very low	0.03	>0.01	0.03	>0.01
	(0.01)	(0.00)	(0.00)	(0.00)
Child WIC benefit	0.16	0.09	0.18	0.10
	(0.01)	(0.01)	(0.01)	(0.01)
NSLP	0.60	0.33	0.62	0.41
	(0.02)	(0.02)	(0.01)	(0.02)
SBP	0.41	0.20	0.43	0.24
	(0.02)	(0.02)	(0.01)	(0.02)
Weight outcomes				
BMI percentile	64.71	62.15	64.95	63.67
	(0.99)	(1.13)	(0.59)	(1.35)
BMI Z-score	0.57	0.47	0.59	0.50
	(0.04)	(0.04)	(0.02)	(0.5)
Overweight	0.15	0.14	0.15	0.16
	(0.01)	(0.02)	(0.01)	(0.01)
Obese	0.21	0.17	0.21	0.18
	(0.01)	(0.02)	(0.01)	(0.02)
Overweight or obese	0.35	0.31	0.36	0.34
	(0.01)	(0.02)	(0.01)	(0.02)
Underweight	0.03	0.03	0.03	0.04
	(0.00)	(0.01)	(0.00)	(0.01)

Notes: Pre-ARRA statistics were computed from data from 2005-2008. Post-ARRA statistics were computed using data from 2007-2012, the analytic sample for the difference-in-differences analysis. SNAP-eligible participants include children living in households with income less than or equal to 130 percent of the FPL. SNAP-ineligible participants include children living in households with income between 150 and 200 percent of the FPL. Estimates for nutrition assistance programs (WIC, NSLP, SBP) indicate the share of the sample that are in the relevant age range and participate in the

program. Standard errors reported in parentheses. All means and proportions are weighted. The analysis accounts for the complex NHANES survey design.
Abbreviations:
BMI: Body mass index
NSLP: National School Lunch Program
SBP: School Breakfast Program
WIC: The Special Supplemental Nutrition Program for Women, Infants, and Children

3.4 Estimation strategies

Difference-in-Differences

In order to estimate the influence of SNAP benefits on youth body weight, I estimate the following equation for the DD design:

$$y_i = \alpha_0 + \alpha_1 T_i + \alpha_2 A_i + \alpha_3 (T_i * A_i) + u_i, \quad (1)$$

where y_i is the outcome; T_i equals 1 if in the treatment group; A_i equals 1 if in the post-ARRA period; $(T_i * A_i)$ is an interaction term between them; and u_i is the error term. α_3 gives the difference-in-differences estimate of SNAP. I estimate this first for the full sample, and then separately for youth of different age groups and levels of food security.

Regression Discontinuity

Next, I utilize a global (parametric) strategy for the RD, in which I attempt to fit the model to all the data available, while still focusing on low-income youth. I first visually assess for a jump in youth weight outcomes across the 1.30 PIR cut-off. I then formally estimate this relationship using the following equation:

$$y_i = \alpha_1 + \tau T_i + f_1(r_i - c) + T_i[f_r(r_i - c) - f_l(r_i - c)] + u_i \quad (2)$$

where y_i is the child's health outcome; T_i indicates whether or not the child lives in a SNAP-eligible household, i.e. below 130% of the FPL; r_i is the household's PIR for child i, which is the value on the assignment score; c is the SNAP-eligibility cutoff (equal to 1.30 PIR); and u_i is the error term. τ represents the ITT of the SNAP program. The term

$(r\text{-}c)$ takes into account the distance between the cutoff and the household's score on the assignment variable PIR for child i. The term $f_l(r_i\text{-}c)$ is the functional form for those with a PIR equal to or less than 1.30, and thus eligible for SNAP; $f_r(r_i - c)$ is the functional form for those living above this ratio and are ineligible. The term $T_i[f_r(r - c) - f_l(r\text{-}c)]$ is an interaction term, which allows for a different relationship with the weight outcome for households on either side of the cutoff. I estimate this first for the full sample, and then separately for youth of different age groups and levels of food security.

Covariates for all regressions include child-specific controls (age, sex, race), household-level controls (HR education, HR marital status, HH size, PIR), child food security, and participation in other food assistance programs (WIC, NSLP, SBP). I account for the complex survey design of NHANES.[r]

Indirect Tests of Identifying Assumptions

Difference-in-differences and regression discontinuity are recognized as two of the strongest designs to address selection bias and other biases [8,10,11]. However, there are several potential threats to their validity. Because the results depend on multiple components related to model specifications and assumptions, I conduct multiple robustness checks and validity tests.

Difference-in-Differences

First, if body weight outcomes would be different between SNAP-eligible and nearly SNAP-eligible youth, even in the absence of the ARRA, then model estimates will

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[r] I do this by clustering the standard errors by the primary sampling units (usually counties, or sometimes groups of contiguous counties). I also account for the strata of the multistage, probability sampling design of NHANES, and use Taylor linearization for variance estimation. Finally, I use survey weights to account for the unequal probability of selection and nonresponse rates. Accounting for the complex survey design of NHANES produces unbiased, national estimates of the civilian, non-institutionalized US population [195].

be biased because they capture these differences. I visually test this assumption of parallel trends by examining youth weight outcomes using NHANES data from two waves prior to the ARRA: 2005 to 2006, and 2007 to 2008. Ideally, weight outcomes in the treatment and comparison groups mirror each other before implementation of the ARRA.

Figures 3.1-3.5: Parallel Trends Results

Figure 3.1 BMI Z-Score across years

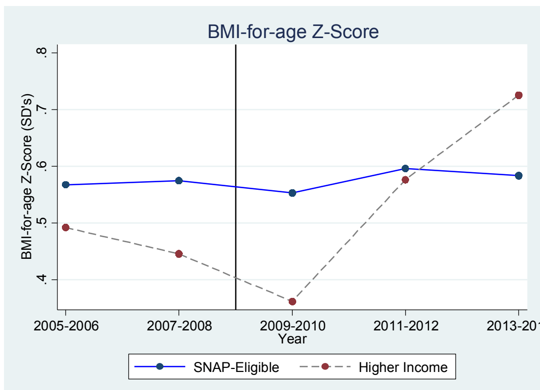


Figure 3.2 BMI Percentile across years

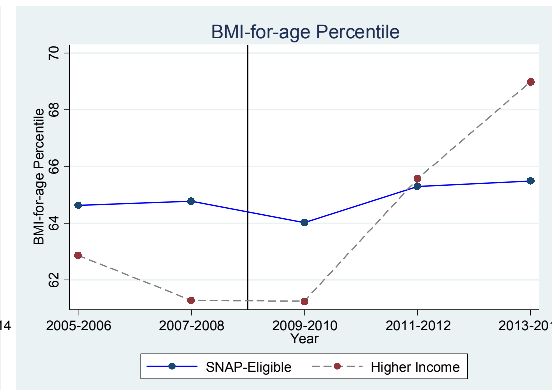


Figure 3.3 Probability of being overweight

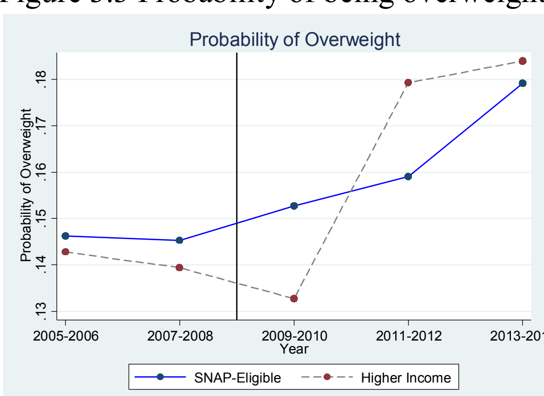
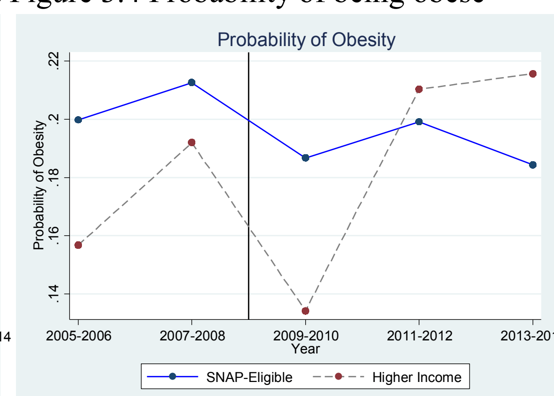


Figure 3.4 Probability of being obese

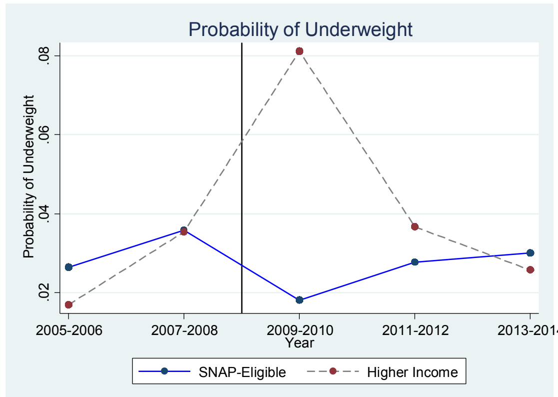


Notes: Graphs plot the weighted, mean outcome in each survey wave. The vertical line indicates the implementation of the ARRA in 2009. The ARRA was implemented in April 2009 and ended October 31, 2013. The pre-ARRA period includes the 2005-2006 and 2007-2008 waves, and the post-ARRA period includes the 2009-2010 through the 2013-2014 waves.[s] Solid blue lines indicate that the child's household meets the SNAP

[s] The benefit increase became effective in April 2009 and ended on October 31, 2013 [75]. For the majority of outcomes, the parallel trends assumption is more problematic during the 2005-2006 wave. For this reason, the pre-period used in the regression analysis includes only 2007-2008. In addition, because the ARRA began in April 2009, including January through March 2009 would weaken the design. Observations from

income-eligibility criteria (poverty income ratio is less than or equal to 1.30). Dotted gray lines indicate nearly SNAP-eligible children (poverty income ratio is between 1.5 - 2.0). The unit for BMI Z-score is standard deviations (SD's).

Figure 3.5 Probability of underweight across years



Notes: Graphs plot the weighted, mean outcome in each survey wave. The vertical line indicates the implementation of the ARRA in 2009. The ARRA was implemented in April 2009 and ended October 31, 2013. The pre-ARRA period includes the 2005-2006 and 2007-2008 waves, and the post-ARRA period includes the 2009-2010 through the 2013-2014 waves.[t] Solid blue lines indicate that the child's household meets the SNAP income-eligibility criteria (poverty income ratio is less than or equal to 1.30). Dotted gray lines indicate nearly SNAP-eligible children (poverty income ratio is between 1.5 - 2.0). The unit for BMI Z-score is standard deviations (SD's).

Figures 3.1 and 3.3 indicate that the parallel trends assumption is more plausible for BMI Z-Score and the probability of being overweight. However, this assumption may be violated for BMI percentile, the probability of being obese, and the probability of being underweight. However, given the limited number of time points prior to the ARRA, the uneven trends may be a result of a broader pattern of fluctuating trends. A wider

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the six-month period from November 1 to April 30 are excluded because I cannot be sure the observation occurred after the implementation of the ARRA.

[t] The benefit increase became effective in April 2009 and ended on October 31, 2013 [75]. For the majority of outcomes, the parallel trends assumption is more problematic during the 2005-2006 wave. For this reason, the pre-period used in the regression analysis includes only 2007-2008. In addition, because the ARRA began in April 2009, including January through March 2009 would weaken the design. Observations from the six-month period from November 1 to April 30 are excluded because I cannot be sure the observation occurred after the implementation of the ARRA.

examination of these trends with additional time points prior to the ARRA and a less narrowly focused y-axis would more clearly demonstrate whether or not the parallel trends assumption is met. For this reason, the analysis presents results for all outcomes examined, with the caveat that it is not clear whether or not the parallel trends assumption is met.

Second, if other changes occurred during the time period analyzed that affect the treatment and comparison groups differentially, then the estimates of the ARRA benefit increase may capture the influence of the outside event, resulting in a biased estimator. There is no way to formally test this assumption. However, two important changes were implemented. The WIC food package changed to include more fruits, vegetables, low-fat dairy and whole grains. Compliance was required by August 5, 2009 [135]. Similarly, nutrition standards of the NSLP and SBP changed to include more fruits, vegetables, and low-fat milk, and reduced the amount of sodium and saturated fat in school meals. Schools were required to comply by July 1, 2012 [136]. Because these changes occurred near the time that the ARRA was implemented, the estimated effects of the ARRA may capture the influence of changes to WIC and the NSLP/SBP. The change in school meals standards presents less of a threat because national compliance did not happen until three years after the ARRA took effect. However, changes in the WIC package occurred in the same year that the ARRA was implemented. There is no way to completely control for this change, and the DD estimates for children in the WIC-eligible range must be viewed with this caveat. Low-income children ages five and under may be eligible to participate in WIC. Even so, participation rates decrease drastically after a child's first birthday. Eighty-three percent of eligible infants participate in WIC, whereas only 54 percent of eligible children participate [137]. Nonetheless, it is important to consider the possibility of bias when examining the DD estimates for children between the ages of two to five.

Regression Discontinuity

Regression discontinuity is recognized as one of the strongest designs to identify the impact of a program or intervention because it most closely mimics random assignment.[u] However, there are several potential threats to the internal validity of this approach. First, because I use a global strategy and include all youth with PIR less than 1.30,[v] a nonlinear relationship between PIR and child weight may be mistaken for a jump across the threshold. A misspecification of form may lead to a biased estimate of SNAP. Thus, as suggested by Jacob et al. [138], I test a variety of functional forms that include polynomials of the assignment variable (centered on the cut-point), and interaction terms with the indicator for SNAP participation. To simplify notation, let $f(r_i)$ represent $f(X_i\text{-}c)$. Including a cubic interaction term makes the full model to be estimated:

$$y_i = \alpha_1 + \tau T + b_1 r_i + b_2 r^2_i + b_3 r^3_i + b_4 r_i T_i + b_5 r^2_i T_i + b_6 r^3_i T_i + u_i \qquad (3)$$

[u] Hoynes and Schanzenbach note that RD may not be suitable for analyzing SNAP because the amount of benefits received falls as income rises and the discontinuity is not sharp [125]. However, during the period of the ARRA, benefits increased by a constant dollar amount for each household size, regardless of income [75]. The difference in benefits received even in SNAP households that are close to the cutoff is therefore more pronounced between 2009 and 2013 during the ARRA. Another possible limitation in using an RD in the present analysis is the current trend in child obesity rates, which may be associated with trends in diet quality and cardiometabolic risk factors. Although in general the rate of childhood obesity decreases as income increases, in recent years children just under the federal poverty line (FPL) have slightly lower rates than those with incomes just above the FPL [42]. Because income level to be eligible for SNAP is at 130 rather than 100 percent of the FPL, this may not be an issue.

[v] That is, youth who are relatively far below the income-eligibility criteria. I do this because I would like to understand the relationship between SNAP and youth weight even for youth who live in very low-income households, and to increase the number of observations available for the analysis.

I present results for the unconditional, linear model. I test various specifications of higher order polynomials (results not shown, but are available upon request).

Second, if families or program administrators manipulate household income in order to qualify for SNAP, then families just under the cut-off likely will be systematically different from families just over the cut-off. I examine this by assessing the density of the assignment variable around the cutoff. The presence of bunching of cases around the cut-off would indicate that manipulation is occurring. Manipulation does not appear to be a problem in the current study (graphs not shown, but are available upon request).

Next, I run multiple falsification tests to assess if external factors may be driving any perceived influence of SNAP. I evaluate this first by visually examining if there are other discontinuities in child weight at other values of PIR, e.g. 1.85, which is the eligibility criteria to participate in WIC nationally, and in Medicaid/Children's Health Insurance Program(CHIP) programs in some states [139,140]. I next visually assess if there are discontinuities in other covariates, which are not expected to be impacted by SNAP. If weight outcomes exhibit a jump across other values of PIR, or if child characteristics unrelated to SNAP display a jump across the 1.30 cut-off, then other factors may be behind any detected influence of SNAP.

3.5 Results

Difference-in-Differences

In addition to allowing us to evaluate the parallel trends assumption, Figures 3.1 through 3.5 also visually illustrate the unconditional relationship between SNAP and youth weight across 2005 through 2014. Figure 3.3 suggests that the probability of being overweight increased in SNAP-eligible youth following the ARRA, but at a lower rate than slightly higher income, nearly SNAP-eligible youth. The other figures do not indicate a clear change in weight following the ARRA benefit increase. I formally estimate the relationship between SNAP and child weight with equation (1).

Table 3.3 displays the estimated association of SNAP and each outcome of interest (e.g. the difference-in-difference estimator α_3 from equation 1). In the full sample of youth ages 2 to 18, SNAP is not significantly related to youth weight. (full regression results not shown, but are available upon request)

Table 3.3 Estimated relationship between the ARRA increase in SNAP benefits and weight outcomes in children and adolescents between the ages of 2 and 18 years

	(Model 1) BMI percentile	(Model 2) BMI Z-score	(Model 3) p(overweight)	(Model 4) p(obese)	(Model 5) p(underweight)
ARRA*SNAP	0.10	0.02	0.02	-0.02	-0.03
	(3.35)	(0.12)	(0.03)	(0.04)	(0.02)
n	4,031	4,031	4,031	4,031	4,031

Standard errors in parentheses
** p<0.01, * p<0.05, + p<0.1

Notes: Estimates presented are from the preferred model (Results for building models from the unconditional are not shown, but are available upon request). The preferred models include the indicator that a child lives in a SNAP-eligible household, the indicator that the observation falls before or after the ARRA, and the interaction term between them. Models also control for youth-specific controls (age, age^2, sex, race), household-level controls (HR education, HR marital status, HH size), child food security, and participation in other nutrition assistance programs (WIC, NSLP, and SBP). All models account for complex survey design features.

I also examined if/how the relationship between SNAP and weight outcomes changes across different food security levels, ages, and gender (parallel trend graphs by stratification are not shown, but are available upon request). Table 3.4 presents the difference-in-differences estimator for each outcome across full, marginal, low, and very low food security (full regression results available upon request). Column 2 indicates that the ARRA benefit increase significantly decreased BMI percentile and BMI Z-score ($p<0.05$). I also find suggestive evidence that the benefit increase reduced the probability of underweight in youth with full food security, though this estimate is only marginally significant ($p<0.10$).

Table 3.4 Estimated relationship between the ARRA increase in SNAP benefits and weight outcomes in children and adolescents between the ages of 2 and 18 years: Differences across food security level

Weight outcome	(Model 1) Full	(Model 2) Marginal	(Model 3) Low	(Model 4) Very Low
BMI percentile	1.54	-35.30*	1.72	12.30
	(3.72)	(13.76)	(7.05)	(18.73)
BMI Z-score	0.07	-1.30*	0.05	0.55
	(0.14)	(0.60)	(0.28)	(0.70)
Overweight	0.02	-0.14	0.08	0.33
	(0.04)	(0.18)	(0.11)	(0.26)
Obese	-0.02	-0.00	-0.08	0.25
	(0.05)	(0.11)	(0.12)	(0.30)
Underweight	-0.04+	0.23	-0.04	___
	(0.02)	(0.20)	(0.05)	
n	2,575	378	641	87

Standard errors in parentheses
** p<0.01, * p<0.05, + p<0.1

Notes: This table presents the difference-in-differences estimator, and displays the estimated association of SNAP with the weight outcome of interest across levels of food security. Models control for youth-specific controls (age, age², sex, race), household-level controls (HR education, HR marital status, HH size, poverty-income ratio), child food security, and participation in other nutrition assistance programs (WIC, NSLP, SBP). All models account for the complex survey design. Due to the low prevalence of underweight, and the small number of observations within the category of very low food security, the model is unable to be estimated.

I examined how the relationship between SNAP and weight differs across age ranges (parallel trend graphs not shown, but are available upon request). Column 1 indicates that the ARRA SNAP benefit increase led to a decrease in BMI percentile and a lower probability of being overweight in toddlers ages 2 to 3, although the results for

BMI percentile are only significant at the 10% level. All else being equal, the benefit increase is associated with a 21% decrease in the probability that a SNAP-eligible toddler is overweight ($p<0.05$). Column 2 indicates that the increase in SNAP benefits significantly reduced the probability of being underweight by 8% for preschoolers ages 4 to 5 ($p<0.01$). Column 4 indicates that all else equal, the benefit increase reduced the probability of adolescents ages 12 to 18 being obese by 13% ($p<0.05$). Taken together, Table 3.5 suggests that the increase in SNAP benefits following the ARRA led to healthier weight outcomes.

Table 3.5 Estimated relationship between the ARRA increase in SNAP benefits and diet quality indicators in children and adolescents between the ages of 2 and 18 years: Differences across age ranges

Weight outcome	(Model 1) Ages 2-3	(Model 2) Ages 4-5	(Model 3) Ages 6-11	(Model 4) Ages 12-18
BMI percentile	-12.07+	-1.12	8.83	-6.68
	(7.07)	(7.72)	(6.07)	(4.12)
BMI Z-score	-0.38	-0.08	0.37	-0.25
	(0.24)	(0.26)	(0.23)	(0.17)
Overweight	-0.21*	-0.02	0.09	0.01
	(0.08)	(0.05)	(0.06)	(0.08)
Obese	0.03	-0.10	0.08	-0.13*
	(0.04)	(0.08)	(0.07)	(0.06)
Underweight	0.04	-0.08**	-0.04	-0.01
	(0.04)	(0.03)	(0.04)	(0.03)
n	592	553	1,467	1,066

Standard errors in parentheses

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

Notes: This table presents the difference-in-differences estimator, and displays the estimated association of SNAP with the weight outcome of interest across levels of food security. Models control for youth-specific controls (age, age^2, sex, race), household-level controls (HR education, HR marital status, HH size, poverty-income ratio), child food security, and participation in other nutrition assistance programs (WIC, NSLP, SBP). All models account for the complex survey design. Table 4 displays estimates of a linear probability model for binary outcomes. Using a logistic regression produced comparable estimates (results not shown).

Next, I examined differences across gender. Table 3.6 does not indicate that the benefit increase is significantly associated with weight in youth ages 2 to 18 when the sample is stratified by gender.

Table 3.6 Estimated relationship between the ARRA increase in SNAP benefits and weight outcomes in children and adolescents between the ages of 2 and 18 years: across genders

Weight outcome	(Model 1) Girls	(Model 2) Boys
BMI percentile	-0.62	0.82
	(4.87)	(4.19)
BMI Z-score	-0.04	0.07
	(0.19)	(0.16)
Overweight	0.03	0.02
	(0.05)	(0.04)
Obese	-0.04	-0.01
	(0.06)	(0.05)
Underweight	-0.01	-0.05
	(0.03)	(0.03)
n	1,783	1,895

Standard errors in parentheses
** p<0.01, * p<0.05, + p<0.1

Notes: This table presents the estimated association of SNAP with the weight outcome of interest across gender. Models control for youth-specific controls (age, age^2, race), household-level controls (HR education, HR marital status, HH size), child food security, and participation in other food assistance programs (WIC, NSLP, and SBP). All models account for the complex survey design of NHANES.

Regression Discontinuity

In the second part of the analysis, I use the 1.30 PIR SNAP eligibility criteria as the cut point in a RD design (Figures 6-10). First, I visually assess if there is a discontinuity in weight across the 1.30 PIR cut point. Figure 3.9 suggests that the probability of obesity is higher in youth just over the 1.30 threshold. The other figures do not provide evidence of a jump.

Figure 3.6 BMI percentile across PIR

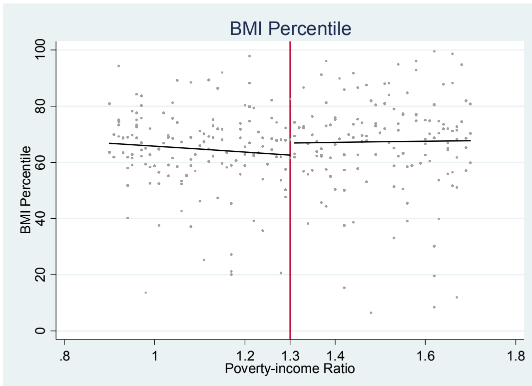


Figure 3.7 BMI Z-score across PIR

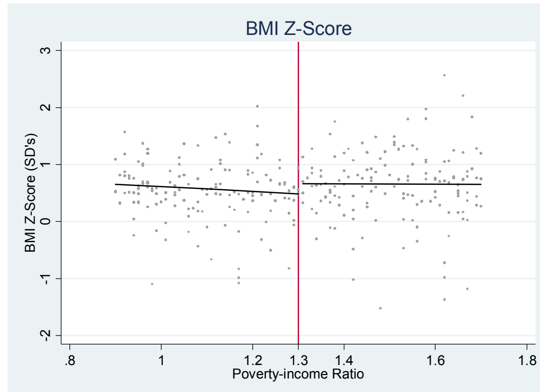


Figure 3.8 Probability of overweight

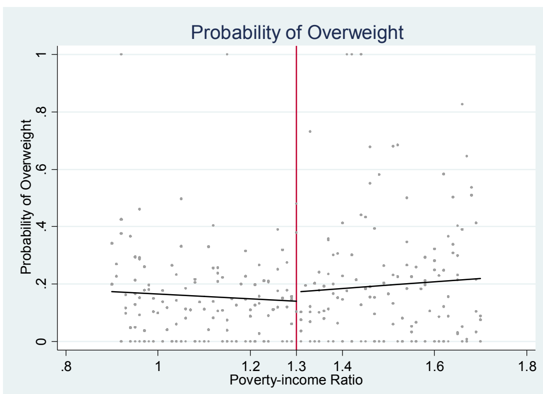


Figure 3.9 Probability of obesity

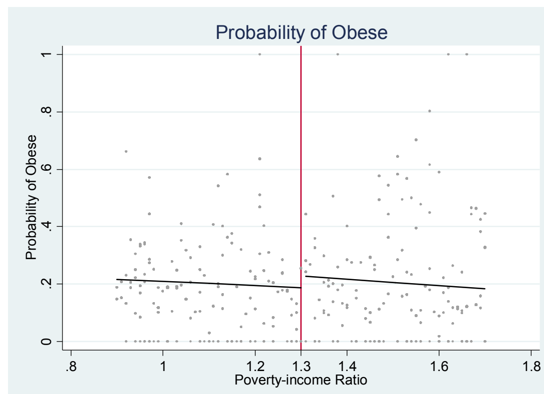
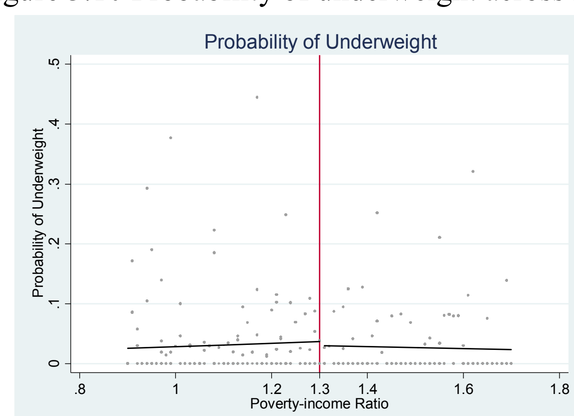


Figure 3.10 Probability of underweight across PIR



Notes: Figures 3.6 through 3.10 display the weighted, mean outcome across the poverty-income ratio. The sample includes youth ages 2 to 18. The RD uses data from 2005 to 2014. The unit for BMI Z-score is standard deviations (SD's).

I formally estimate the relationship between SNAP and weight using equation 2. Table 3.7 presents the unconditional, linear estimates for each outcome. The models do not suggest a significant discontinuity across PIR. I assess the relationship with higher order polynomials, using equation 3 (results not shown, but are available upon request). Using higher order polynomials results in estimates that are marginally significant, but the estimates are very sensitive to model specification.

Table 3.7 Estimated effect of SNAP-eligibility on weight outcomes in children and adolescents compared to those just over the eligibility threshold

	(Model 1) BMI percentile	(Model 2) BMI Z-score	(Model 3) p(overweight)	(Model 4) p(obese)	(Model 5) p(underweight)
SNAP	-1.09	-0.04	-0.03	0.01	0.00
	(1.81)	(0.07)	(0.02)	(0.02)	(0.01)
n=9,889					

Standard errors in parentheses
** p<0.01, * p<0.05, + p<0.1

Notes: This table presents the intent-to-treat estimate of the SNAP program (τ, from equation (2) for youth aged 2 to 18 years. All models are unconditional, linear fits that center PIR on the 1.30 cutoff. All models account for the complex survey design. I also checked various specifications for each outcome to assess different functional forms (results not shown, but are available upon request). I focus on a linear fit because the graphs do not suggest a quadratic or cubic relationship.

I examine if/how the relationship changes across levels of food security (Table 3.8). I find SNAP only marginally significantly related to BMI Z-score and the probability of overweight (results across specifications not shown, but are available upon request) Using higher order polynomials, estimates across food security levels are precisely estimated zeros.

Table 3.8 Estimated effect of SNAP-eligibility on weight outcomes in children and adolescents compared to those just over the eligibility threshold: across food security

Weight outcome	(Model 1) Full	(Model 2) Marginal	(Model 3) Low	(Model 4) Very Low
BMI percentile	-0.66	-3.59	-1.99	-18.23
	(2.17)	(4.39)	(4.36)	(11.44)
BMI Z-score	-0.03	-0.09	-0.04	-0.72+
	(0.08)	(0.17)	(0.18)	(0.43)
Overweight	-0.02	-0.02	-0.08+	-0.11
	(0.02)	(0.07)	(0.04)	(0.11)
Obese	0.01	0.04	0.01	-0.06
	(0.02)	(0.06)	(0.06)	(0.12)
Underweight	0.01	0.04	-0.03	0.05
	(0.01)	(0.02)	(0.02)	(0.03)
n	6,175	1,008	1,581	240

Standard errors in parentheses
** p<0.01, * p<0.05, + p<0.1

Notes: This table presents the estimated association of SNAP with the weight outcome of interest across levels of food security. Models presented here are simple linear, unconditional models. All models account for the complex survey design.

I examine the relationship between SNAP and youth weight across ages. Again, Table 3.9 does not provide evidence of a significant association, besides marginally. I also examine outcomes across higher order polynomials. The estimates do not suggest a significant relationship between SNAP and weight (results not shown, but are available upon request). Moreover, for the majority of age ranges, I find consistently estimated zeros.

Table 3.9 Estimated effect of SNAP-eligibility on weight outcomes in children and adolescents compared to those just over the eligibility threshold: across ages

Weight outcome	(Model 1) Ages 2-3	(Model 2) Ages 4-5	(Model 3) Ages 6-11	(Model 4) Ages 12-18
BMI percentile	0.25	-3.81	-0.17	-1.28
	(3.38)	(3.78)	(2.70)	(2.30)
BMI Z-score	0.03	-0.16	-0.02	-0.02
	(0.12)	(0.13)	(0.10)	(0.09)
Overweight	0.04	-0.00	-0.02	-0.06+
	(0.05)	(0.04)	(0.03)	(0.03)
Obese	0.02	-0.05	0.02	0.02
	(0.03)	(0.05)	(0.03)	(0.03)
Underweight	0.02	0.02	0.00	-0.00
	(0.02)	(0.02)	(0.02)	(0.01)
n	1,405	1,240	3,357	3,213

Standard errors in parentheses
** p<0.01, * p<0.05, + p<0.1

Notes: This table presents the estimated association of SNAP with the weight outcome of interest across ages. Models presented here are simple linear, unconditional models. All models account for the complex survey design.

Table 3.10 displays estimates across gender and suggests that SNAP-eligible boys have a lower probability of being overweight than boys just over the SNAP eligibility threshold (p<0.05). I examine outcomes across higher order polynomials (results not shown, but are available upon request). I find that estimates are consistent across specifications. Results suggest that SNAP is significantly associated with a lower BMI percentile, a lower BMI Z-score, and a lower probability of being overweight.

Table 3.10 Estimated effect of SNAP-eligibility on weight outcomes in children and adolescents compared to those just over the eligibility threshold: across gender

Weight outcome	(Model 1) Girls	(Model 2) Boys
BMI percentile	0.97	-3.12
	(2.61)	(2.08)
BMI Z-score	0.02	-0.09
	(0.10)	(0.08)
Overweight	0.00	-0.06*
	(0.03)	(0.03)
Obese	0.02	0.01
	(0.03)	(0.03)
Underweight	0.01	-0.00
	(0.01)	(0.01)
n	4,545	4,670

Standard errors in parentheses
** p<0.01, * p<0.05, + p<0.1

Notes: This table presents the estimated association of SNAP with the weight outcome of interest across gender, using the full sample of youth ages 2 to 18. Models presented here are simple linear, unconditional models. All models account for the complex survey design.

3.6 Robustness and validity checks

The results from both the DD and RD suggest that SNAP is associated with healthier weight outcomes. In order to assess the validity of the main results, I conduct a number of tests to assess the model assumptions, and the robustness of the estimates.

Difference-in-Differences

As discussed earlier, the parallel trends assumption indicates that trends in BMI Z-score and the probability of being overweight appear to be similar in SNAP-eligible youth and higher-income youth. However, because there only two time points in the data prior to the ARRA, it is uncertain if the uneven trends seen in the other outcome variables is due to a broader pattern of fluctuations. As such, it is not clear if the parallel trends assumption is met.

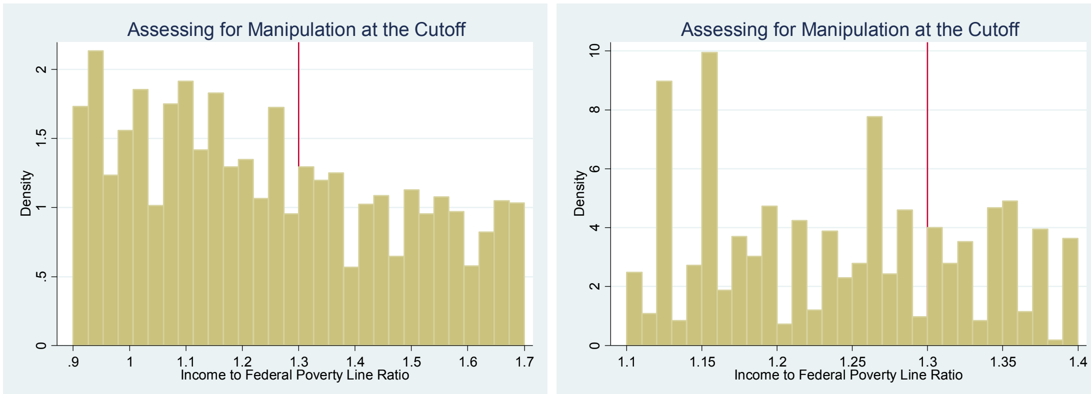
Regression Discontinuity

I test for manipulation of the income eligibility criteria. If the density of cases is greater just under or just over the 1.30 threshold, then income-eligible families may be systematically different from families just over the cut-off. Manipulation does not appear to be a problem in the current study (Figure 3.11). I examine if there are other discontinuities in child weight at other values of PIR e.g. 1.85, which is the eligibility criteria to participate in WIC nationally, and in Medicaid/CHIP programs in some states [139,140]. Figures 3.12-3.13 and 3.15-3.16 do not exhibit a jump in outcomes across the 1.85 threshold. However, Figure 3.14 indicates that there is a discontinuity in the probability of being overweight across the 1.85 threshold.

I next use graphs to test for discontinuities in other covariates, e.g. gender, household size, and age, which are not expected to be impacted by SNAP. Figures 3.17-3.19 suggest that these covariates are distributed evenly around the 1.30 threshold, providing support for the assumption that the treatment and comparison groups are not systematically different.

Figures 3.11-3.14 Regression Discontinuity Assumptions

Figure 3.11 Assessing for Manipulation at the Cutoff



Notes: Graphs plot the density of cases across levels of PIR in order to asses for manipulation at the 1.30 income eligibility threshold. Red lines identify 1.30 PIR.

Figure 3.12 BMI Z-Score

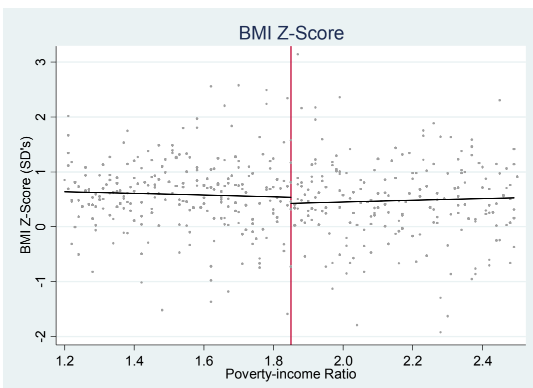


Figure 3.13 BMI Percentile

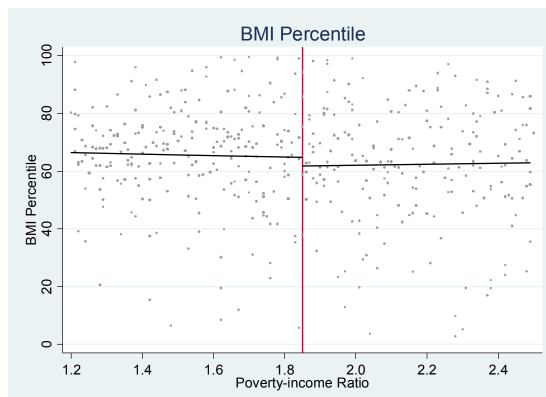


Figure 3.14 Probability of overweight

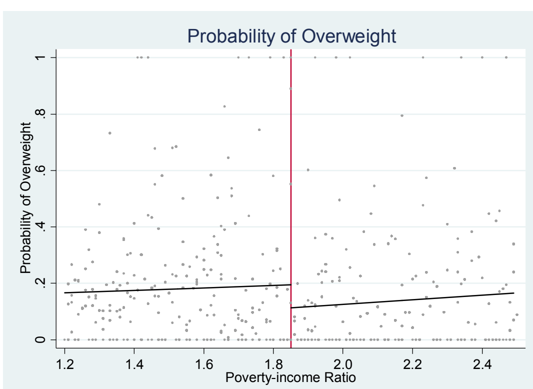
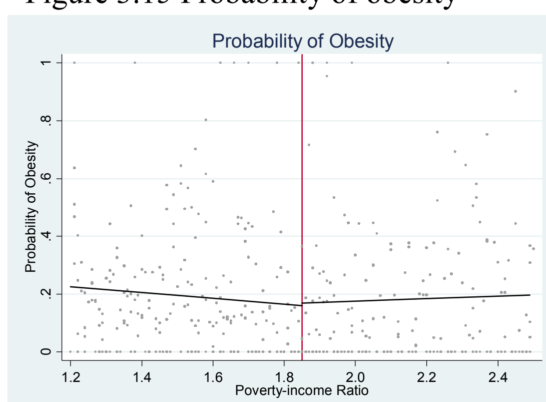
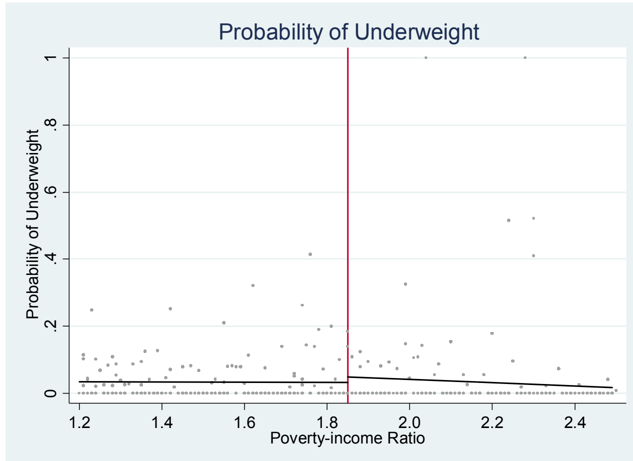


Figure 3.15 Probability of obesity



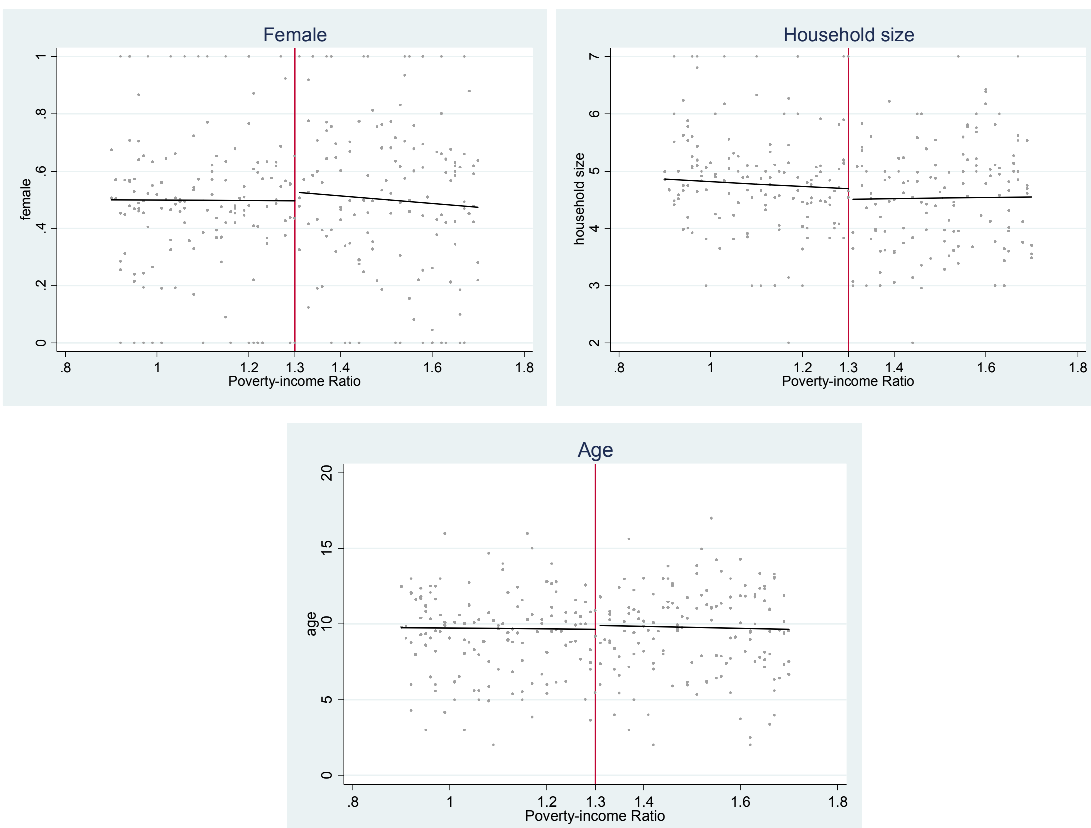
Notes: Figures 3.12 through 3.16 display the weighted, mean outcome across the poverty-income ratio. The sample includes youth ages 2 to 18. The RD uses data from 2005 to 2014. The unit for BMI Z-score is standard deviations (SD's).

Figure 3.16 Probability of underweight



Notes: Figures 3.12 through 3.16 display the weighted, mean outcome across the poverty-income ratio. The sample includes youth ages 2 to 18. The RD uses data from 2005 to 2014. The unit for BMI Z-score is standard deviations (SD's).

Figure 3.17-3.19 Examining Observable Characteristics around PIR



Notes: Figures 3.17 through 3.19 display the weighted, mean outcome of 3 observable characteristics across the poverty-income ratio. The sample includes youth ages 2 to 18. The RD uses data from 2005 to 2014.

3.7 Discussion

There is a rich body of literature on the association between SNAP participation and child weight, but it has produced contradictory findings. Moreover, a small proportion has used research designs that mitigate selection bias. Among those that have, few have examined how age, gender, and food security status modify the connection between SNAP and weight. To estimate the relationship between SNAP benefits and child weight, I exploit the 2009 SNAP benefit increase as an exogenous source of variation in a DD design. In addition, I leverage the SNAP income-eligibility criteria in an RD design. To my knowledge, this is the first study to investigate the relationship between SNAP benefits and child weight in either a DD or an RD design. Furthermore, I examine differences across food security status, age ranges, and gender. I do not find that SNAP is significantly associated with weight when examining the full sample of youth between the ages of two and 18. This is not surprising; research indicates that SNAP has a different relationship according to food security status, age, and gender. Examining a pooled sample may hide important relationships.

The RD does not reveal a significant association between SNAP and weight across different levels of food security. In the DD, I find that SNAP is associated with a 35.50 lower BMI percentile and 1.30 lower BMI Z-score in youth of marginal food security. In comparison, Kimbro and Rigby (2010) found that participating in any federal nutrition program (SNAP, WIC, child care meal programs, or school meals) led a 16.17 lower BMI percentile in cities with low food prices. Schmeiser (2012) found that an additional month of SNAP participation decreased BMI percentile by between 0.8 and 1.4. Although Schmeiser's results equate to BMI percentile reduced by as much as 16.8

over a year's period, the estimate of 35.5 lower BMI percentile is much greater than the magnitude found in previous studies. However, Schmeiser (2012) and Kimbro and Rigby (2010) examined youth pooled across all levels of food security. The magnitude of the estimates for BMI percentile and BMI Z-score may be due to the fact that I find this result only for youth who experience marginal food security. Few studies examined BMI Z-score as an outcome measure, making it difficult to identify a benchmark estimate. Even so, Leung et al. (2017) found that SNAP participating youth had 0.21 higher BMI Z-scores than nonparticipants.

Across age ranges, I find that the increase in SNAP benefits following the ARRA led to healthier weight outcomes. SNAP-eligible toddlers ages 2 to 3 and adolescents ages 12 to 18 have lower BMI percentiles, and lower probabilities of being overweight or obese. SNAP-eligible preschoolers ages 4 to 5 are less likely to be underweight.

Finally, I find differences in the relationship between SNAP and weight between boys and girls. The RD indicates that SNAP-eligible boys ages 2 to 18 have a lower probability of being overweight than boys just over the SNAP-eligibility threshold. A recent review of the literature (Hudak and Racine, *forthcoming*) found that SNAP benefits support healthier weight outcomes in boys but may contribute to a greater likelihood of being overweight or obese in girls. The results of the RD provide further evidence that SNAP may help boys maintain a healthy weight. The findings of the present analysis underscore the importance of examining specific subpopulations of youth. Studies pooling youth across ages and gender may mask important differences in the relationship between SNAP and child weight.

Policy Implications

The present analysis indicates that SNAP may be a protective factor against obesity in children. Even so, as SNAP reaches millions of low-income households, the program can do more to promote a healthy diet and body weight in low-income children and families. Currently, SNAP benefits can purchase any food item, with the exception of hot foods and alcohol [143]. A 2018 report by the Bipartisan Policy Center notes prioritizing nutrition in SNAP as a key way to leverage federal programs to improve national health [144]. Their recommendations include removing SSBs from SNAP-eligible items. Many other researchers and policy makers have made propositions to restrict SNAP benefits from purchasing nutritionally-poor foods such as SSBs and snack foods [28,145–148]. The USDA has consistently rejected these arguments [30].[w] Low-income children are more likely than high-income children to have heavy consumption of SSBs [149]. Furthermore, a recent review found that SSB consumption is linked to a higher risk of obesity in children [150]. French et al. conducted a randomized trial in which the researchers provided funds on debit cards to low-income households. Participants were randomized into four different groups, two of which included purchase restrictions on SSBs, sweet baked goods, or candies. The researchers found that SSB purchases significantly decreased in overall food purchases (i.e. by any tender) in the groups with purchase restrictions when compared to the control group [151]. Using forecasting models, Basu et al. found that restricting SSBs purchases using SNAP dollars would significantly decrease the prevalence of obesity and type 2 diabetes in SNAP participants [152]. A prevailing argument against purchase

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[w] See Schwartz, 2017 and Schanzenbach, 2017 for more detailed discussions of this issue.

restrictions is that it could further stigmatize SNAP participants and reduce their individual agency [29,153]. However, a recent survey of SNAP participants and food insufficient but not SNAP-enrolled individuals found that the majority of both participants and nonparticipants were in favor of a modified program that combined healthy purchase incentives with exclusions of SSBs [154]. Authorizing and evaluating pilot projects that restrict SSBs from SNAP purchases would allow researchers to test the feasibility and effectiveness of such restrictions.

The U.S. government funds SNAP under the farm bill. The farm bill recently proposed by the House (H.R. 2 The Agriculture Improvement Act of 2018 (115)) would have altered SNAP's eligibility policies related to countable resources and state categorical eligibility options. Under this proposed bill, nearly two million SNAP-participating households would no longer be eligible for the program, 23 percent of which include children [155]. Fortunately, the bill that President Trump signed into law in December 2018 did not change SNAP eligibility criteria (115th Congress, 2018). However, decreases in SNAP funding and/or restricting eligibility have been on the agenda during the past several farm bills. The present analysis indicates that SNAP benefits are associated with healthier weight outcomes in children across several age ranges, and in boys ages two to 18. If funding cuts or program eligibility restrictions lead to a substantial proportion of children losing SNAP benefits, the already-high U.S. child obesity rates may rise even higher.

Limitations

There are several limitations to the data and to the analysis. Although difference-in-differences and regression discontinuity are recognized as strong research designs [8,11], potential endogeneity, especially resulting from self-selection, may still bias the results. Second, because this analysis includes only two waves of data that occur prior to implementation of the ARRA, it is unclear if the parallel trends assumption of the DD design is met.

Third, complex institutional rules, such as the assets test and eligible deductions, in determining SNAP eligibility makes it probable that people are misclassified. The resulting measurement error decreases my ability to detect a significant relationship between SNAP and child weight. If this measurement error were due to sorting, then differences between the treatment and comparison groups would bias the results in a systematic way. However, the measurement error is due to institutional rules, making the results a lower-bound, conservative estimate. In addition, the overwhelming majority of SNAP-participating children live in households with incomes that are well below the eligibility threshold, making the proportion of children likely to be misclassified small. Over 80 percent of SNAP-participating households with children have incomes below the poverty line [157].

Finally, because I use cross-sectional data, I am only able to examine the relationship between SNAP eligibility and child weight at one point in time. In reality, factors such as SNAP participation and income have a cumulative effect over time.

3.8 Conclusions

This paper provides evidence that SNAP may be a protective factor against obesity and elevated weight in low-income boys ages 2 to 18, and in both boys and girls across certain age ranges. I find little evidence of a significant relationship between SNAP and weight among children of different levels of food security.

The effect that SNAP participation has on child weight is an indirect relationship, and one that manifests over time. Future studies should examine the mechanisms through which SNAP affects child weight. It would be particularly useful to investigate how and why SNAP is a significant factor in child weight in certain subpopulations but not others. If and when nationally representative longitudinal data that feature researcher-measured child height and weight become available, studies should incorporate the temporal relationship between SNAP and weight into the analysis. Continuing research in this area will provide insight into the connection between SNAP and child weight and can help inform policy makers and key stakeholders as program modifications are debated.

CHAPTER 4: METABOLIC RISK FACTORS IN LOW-INCOME CHILDREN: ESTIMATING THE ASSOCIATION WITH SNAP

4.1 Introduction

For the first time in recent U.S. history, younger generations may not live as long as their parents or grandparents.[158–160] Increases in mortality are largely due to rising rates of obesity and chronic disease, such as cancer and cardiovascular diseases.[158–161] Disparities in life expectancy are growing, particularly across income levels[159,160] and are often related to differences in health behaviors.[159] Behavioral risk factors like poor diet quality and low levels of physical activity lead to metabolic and physiological changes such as overweight and obesity, elevated blood pressure, high cholesterol, and high blood glucose.[36] The clustering of these risk factors is known as the metabolic syndrome (MetS).[14] Abdominal obesity, dyslipidemia, elevated blood pressure, glucose intolerance, and/or insulin resistance characterize MetS. These changes significantly increase the risk of chronic diseases, such as cardiovascular disease and type 2 diabetes.

MetS has mostly been associated with adults, but recent research indicates that MetS starts early in childhood.[162,163] Thirty percent of overweight children have MetS, and nine out of ten meet at least one of the criteria for MetS.[164] The American Academy of Pediatrics[165] recommends screening children and adolescents for cardiovascular risk factors.[12,13]

The link between low socio-economic status (SES) and poor health is well documented, but it is a matter of debate what initiatives may modulate this complex relationship. The Supplemental Nutrition Assistance Program (SNAP) has the potential to improve health, but it is unclear how SNAP affects cardiometabolic health. In this paper, I utilize the American Recovery and Reinvestment Act (ARRA) to understand how an increase in SNAP benefits influences child cardiometabolic health. This study also uses SNAP's income-eligibility criteria to illuminate how MetS factors differ in SNAP-eligible youth compared to those just over the eligibility cutoff.

Low-income populations are more likely to engage in the behavioral risk factors that lead to MetS[36] and have higher rates of the metabolic and physiological risk factors. Low SES is associated with lower diet quality,[16,17] higher rates of overweight and obesity,[15] and lower health outcomes.[5,18] Low SES and poor health are especially detrimental to children and adolescents because of their vulnerable lifestage. Low SES, poor diet, and overweight/obesity as a child can negatively impact a child's development, and directly affects health as an adult, including increasing the presence of cardiometabolic disease and its associated risk factors.[6,18–20] In addition to negatively impacting health as an adult, the presence of cardiometabolic risk factors during childhood places the child at risk of premature atherosclerosis, diabetes, organ damage, and developing insulin resistance.[166–168] Diet and elevated body weight are primary determinants of cardiometabolic health.[12,36] Improving diet quality in youth—especially low-income youth who are more likely to have poor diet quality and lower health outcomes[5,16–18] —can potentially serve as a preventive measure against developing cardiometabolic risk factors.

The Supplemental Nutrition Assistance Program (SNAP) is the largest federal nutrition program.[1] Nearly one in five households received benefits in 2015,[x] and approximately 50 percent of participants are children.[2] The program's stated goal is to

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[x] There were 22,388,684 households participating in SNAP in 2015, and 116,926,305[192] households in the U.S. on average annually between 2011 and 2015.

improve food security and access to a healthier diet for low-income Americans.[3] Therefore SNAP has the potential to protect against poor cardiometabolic health in low-income youth by improving diet quality.

However, research suggests that youth living in SNAP households are less likely to meet recommended dietary guidelines than either income-eligible or higher-income nonparticipants on several key food groups that are important for cardiometabolic health.[17,49] Multiple studies indicate that SNAP participation is also linked to higher weight outcomes in children and adolescents,[56,58,99,169] though the findings are inconsistent.[52,57,96]

A primary goal of SNAP is to improve food security and evidence suggests that it has been successful.[81,170,171] Two studies found that adults from households that experience food insecurity have increased odds of having poor cardiometabolic health.[172,173] By reducing food insecurity, SNAP has the potential to protect against poor cardiometabolic health.

To my knowledge, only two studies examined SNAP participation and cardiometabolic risk factors in youth, and they did not find a significant relationship when assessing individual risk factors.[142,174] However, when analyzing a composite score for overall cardiometabolic risk, Leung et al.[142] found that SNAP participants have a significantly higher risk score than either income-eligible or higher income nonparticipants. In summary, SNAP may help shield youth of low SES from developing cardiometabolic risk factors by potentially improving diet quality and reducing food insecurity. However, there is little empirical support that SNAP improves cardiometabolic health. Furthermore, there is some evidence that SNAP is associated with lower diet quality and higher weight, two primary risk factors for poor cardiometabolic health.

SNAP is targeted to low-income Americans, and household income must be at or below 130 percent[y] of the federal poverty line (FPL) to qualify.[33] Many of the same factors that influence a child's cardiometabolic health also affect a family's eligibility for SNAP and their decision to participate. This self-selection into the program leads to biased estimates when assessing the association between SNAP and child cardiometabolic health. No identified studies on SNAP and youth cardiometabolic health to date have used designs to control for this resulting selection bias. Understanding SNAP's relationship with cardiometabolic health has important implications for policy and for the health of the children that SNAP serves. This question becomes more salient as policy makers consider adding incentives or restrictions to the SNAP program.

To help inform this issue, the objective of this study is to assess the relationship between SNAP participation and cardiometabolic health in youth. I examine seven measures of cardiometabolic health: 1) waist circumference; 2) blood pressure; 3) high density lipoprotein (HDL) cholesterol; 4) triglycerides; 5) plasma fasting glucose; 6) an indicator of whether or not the child meets the criteria for MetS; and 7) a summary measure of overall cardiometabolic risk. The analysis uses two designs that help account for selection bias: difference-in-differences and regression discontinuity. The analysis also

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[y] These are the federal limits, though states have the option to expand eligibility requirements, making it easier for individuals to qualify.[106] Households must also meet employment requirements and an assets test.[33]

examines the potential role that age and food security may have in the relationship between SNAP participation and child cardiometabolic health.

4.2 Methods

Study Sample

National Health and Nutrition Examination Survey (NHANES), an ongoing nationally representative cross-sectional dataset, is the data source for this research. The Centers for Disease Control and Prevention's National Center for Health Statistics conducts NHANES using a complex, multistage probability design sampling plan. I use data from the 2005-2014 waves. NHANES includes an in-home interview that collects data on individual demographic, health and nutrition information, as well as data regarding the household.[59] Unique to this dataset is an exam and laboratory component, conducted by trained medical professionals in a mobile examination center (MEC). Trained physicians and medical technologists collect data such as physical measurements, as well as blood and urine samples.[59]

The study population includes SNAP-eligible children and adolescents between the ages of two and 18. Demographic data and waist circumference are available for all youth. However, data collection differs slightly across age ranges and survey components (see Table 4.1).

Table 4.1 Definitions of Abnormal Values for Risk-Factor Variables

Risk Factor	Age range	No. of participants evaluated	Definition of abnormal value
Waist circumference	2-18	4,855	≥ 90th percentile
HDL cholesterol	6-18	3,040	<40 mg/dL in boys <50 mg/dL in girls
Systolic blood pressure	8-18	2,635	≥ 130 mmHg
Triglycerides	12-18	647	≥150 mg/dL
Glucose	12-18	658	≥ 100 mg/dL
MetS	12-18	595	Elevated waist circumference and 2+ risk factors
MetS Z-score	12-18	586	Sum of risk factor Z-scores

Notes: International Diabetes Federation[175] criteria for risk-factor variables and metabolic syndrome in children and adolescents.[z] Table 4.1 also presents the age range for which each risk-factor is available in NHANES, and sample size used in the difference-in-differences analysis. Summary variables used in the analysis (MetS binary and MetS Z-score) were created using all risk factor variables, and are only available if the youth had reliable data for each specific indicator.

Measures of Cardiometabolic Health

I examined the five risk factors that the International Diabetes Federation (IDF) specifies in identifying metabolic syndrome: 1) waist circumference; 2) systolic blood pressure; 3) HDL cholesterol; 4) triglycerides; and 5) glucose. I examined them both as continuous measures and as binary variables according to whether or not they meet the IDF cut-off criteria. In addition, I used an indicator for whether or not the child meets the criteria of having the metabolic syndrome. I used the IDF definition of metabolic

[z] The IDF definition has minor differences between age ranges. For example, they propose that MetS should not be diagnosed in children between the ages of 6 and 10 due to lack of data to identify cut-offs. However, they do suggest that children meeting the waist circumference criteria be closely monitored. In addition, the cut-off for low HDL cholesterol is <40 mg/dL for both boys and girls between the ages of 10 and 16. After age 16, the cut-off for girls changes to <50 mg/dL, but remains <40 for boys. However, following Leung et al.,[142] I use the criteria identified above.

syndrome[175]: waist circumference ≥ 90th percentile and the presence of two or more risk factors; elevated systolic blood pressure (≥ 130 mmHg); low HDL cholesterol (<40 mg/dL in boys, <50 mg/dL in girls); elevated triglycerides (≥150 mg/dL); and elevated fasting glucose (≥ 100 mg/dL).[aa] Finally, I converted each individual risk factor to Z-scores[bb] within the analytic sample and summed them to create an overall cardiometabolic risk Z-score.[cc] Higher numbers in the cardiometabolic risk Z-score indicate higher overall cardiometabolic risk.

Covariates

Covariates include child's age, gender, race/ethnicity, child food security level, household reference person's (HR) educational attainment, HR marital status, household size, and household poverty-income-ratio (PIR).[68,142,172–174] NHANES reports income as PIR, and having a PIR equal to 1.30 is analogous to household income equal to 130 percent of the FPL. The analysis also controls for other food assistance programs: child participation in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) and school meals programs, the National School Lunch Program (NSLP) and School Breakfast Program (SBP). Studies have found that the relationship between SNAP participation and diet-related health outcomes in youth varies by age and food

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[aa] The IDF definition has minor differences between age ranges. For example, they propose that MetS should not be diagnosed in children between the ages of 6 and 10 due to lack of data to identify cut-offs. However, they do suggest that children meeting the waist circumference criteria be closely monitored. In addition, the cut-off for low HDL cholesterol is <40 mg/dL for both boys and girls between the ages of 10 and 16. After age 16, the cut-off for girls changes to <50 mg/dL, but remains <40 for boys. However, following Leung et al.,[142] I use the criteria identified above.

[bb] HDL cholesterol is a protective factor against cardiometabolic disease, where higher numbers indicate better health. To use this in the summary Z-score, I multiplied HDL by negative one, and then used this to create the HDL Z-score.

[cc] I examined each individual risk factor over the entire range of ages for which it is available. The two summary measures, one to indicate that a youth meets criteria for MetS, and the summary Z-score, are composites of all risk factors, and thus only includes youth ages 12 and older.

security status.[52,57] Therefore, I stratify the analysis by age and food security level. NHANES collects data on food security using questions from the U.S. Food Security Survey Module (FSSM). Eight questions[dd] pertaining specifically to youth ages 18 and younger were used to create a categorical variable of child food security: (1) Full food security; (2) Marginal food security; (3) Low food security; and (4) Very low food security. The sample of youth are stratified by these four categories.

Previous research on SNAP and child obesity has found distinct associations in younger children (aged 5 to 11 years) and older youth (aged 12 to 18 years).[56–58] In addition, substantial changes in body size and proportion occur with age, especially in toddlers and young children.[176,177] Changes in fat distribution, blood lipid levels, and blood pressure are also associated with developmental stages in youth.[176–179] For these reasons, I examine how an increase in SNAP benefits may differentially affect children and adolescents in different age ranges. I categorize youth into four categories: toddlers aged 2 to 3 years; preschoolers aged 4 to 5 years; children aged 6 to 11 years; and adolescents aged 12 to 18 years.

4.3 Analysis

I employed two strategies to correct for the selection problem associated with studying SNAP's relationship with child health. The first is a difference-in-differences (DD) strategy, and I use the American Recovery and Reinvestment Act of 2009 (ARRA) as a source of exogenous variation. The ARRA increased SNAP benefit levels for all participants, with the goal of helping low-income Americans to recover from the Great

[dd] Table listing specific questions used to create the child food security category is available upon request.

Recession. Beginning in April 2009, SNAP benefits increased by an average of 19 percent.[74] The DD analysis uses the benefit increase to mark a pre- and post-period. I compare SNAP participants before the ARRA to SNAP participants after the benefit increase. SNAP nonparticipants that are low-income but above the SNAP-eligibility criteria serve as a second comparison group. The nearly-SNAP eligible comparison group includes youth living in households with income between 150 and 200 percent of the FPL. The DD analysis uses NHANES data from the 2007-2012 waves. The framework of the DD to estimate the impact of SNAP can be understood as:

$$y_i = \alpha_0 + \alpha_1 T_i + \alpha_2 A_i + \alpha_3 (T_i * A_i) + u_i, \quad (1)$$

where y_i is the outcome; T_i equals 1 if in the treatment group; A_i equals 1 if in the post-ARRA period; $(T_i * A_i)$ is an interaction term between them; and u_i is the error term. α_3 gives the difference-in-differences estimate of SNAP.

Second, I leverage SNAP's income eligibility criteria in a regression discontinuity (RD) design. The income eligibility criteria serves as a cut-off to designate SNAP-eligible youth (household income at 130 percent or below of the FPL) from ineligible (household income above 130 percent of the FPL). The 130 percent cut-off in the RD mimics random assignment.[8,9,11,76] It is nearly a matter of chance if household income is just under or just below 130 percent. The comparison group used in the RD includes all children living in families with household income above 130 percent of the FPL and equal to or below 185 percent. The RD design uses NHANES data from the 2005 to the 2014 waves.

The framework of the RD to estimate the impact of SNAP can be understood as:

$$y_i = \alpha_1 + \tau T_i + f_1(X_i - c) + T_i[f_r(X_i - c) - f_l(X_i - c)] + u_i \quad (2)$$

where y_i is the child's health outcome; T_i indicates whether or not the child lives in a SNAP-eligible household, i.e. below 130 percent of the FPL; X_i is the household's PIR for child i, which is the value on the assignment score; c is the SNAP-eligibility cutoff (equal to 1.30 PIR); and u_i is the error term. τ represents the intent-to-treat estimate of the SNAP program. The term $(X\text{-}c)$ takes into account the distance between the cutoff and the household's score on the assignment variable PIR for child i. The term $f_1(X_i\text{-}c)$ is the functional form for those with a PIR equal to or less than 1.30, and thus eligible for SNAP; $f_r(X_i - c)$ is the functional form for those living above this ratio and are ineligible. This equation allows for a different relationship with the health outcome for households on either side of the cutoff. The term $T_i[f_r(X - c) - f_l(X\text{-}c)]$ is the interaction term that allows for this.

The sample includes youth who participated in the MEC exam and laboratory component. As noted above, the age ranges for which the outcome measure is available differ across outcomes: waist circumference: youth ages 2 to 18; HDL cholesterol youth ages 6 to 18; blood pressure youth ages 8 to 18; fasting triglycerides and fasting glucose: youth ages 12 to 18; indicator for having MetS and the cardiometabolic risk Z-score: youth ages 12 to 18. The analysis includes the entire age range for which each outcome measure is available.

Graphs of outcome trends and bivariate analyses of demographic variables are used to assess the similarity of SNAP-eligible youth and *nearly* SNAP-eligible (but slightly higher income) youth prior to the ARRA. Linear regression and linear probability models are used to estimate the relationship between SNAP participation and youth cardiometabolic outcomes. Models are estimated separately by age group and food security status. Exam or fasting survey weights are used to account for the complex survey design and response rates. All analysis is conducted using Stata 14.0.[77]

4.4 Results

SNAP-eligible youth have similar characteristics as nearly-eligible, but slightly higher income, youth, with a few exceptions (Table 4.2-4.3). Prior to the ARRA, SNAP-eligible youth are significantly more likely to be non-white (e.g. black, Hispanic, or another race), participate in WIC or SBP, and to experience some level of food insecurity. SNAP-eligible youth live in households with a significantly lower PIR and a larger household size. The HR of SNAP-eligible youth have less education and are less likely to be married, compared to the HR of nearly SNAP-eligible youth.

Table 4.2 Demographic characteristics: MetS sample

	Pre-ARRA		Post-ARRA	
	SNAP-Eligible (*n*=2,899)	Nearly SNAP-Eligible (*n*=732)	SNAP-Eligible (*n*=4,185)	Nearly SNAP-Eligible (*n*=909)
	Mean/share	Mean/share	Mean/share	Mean/share
Age	9.73	9.45	9.59	9.59
	(0.14)	(0.28)	(0.11)	(0.25)
Female	0.51	0.47	0.50	0.47
	(0.01)	(0.03)	(0.01)	(0.02)
Race				
White	0.42	0.57	0.39	0.53
	(0.04)	(0.04)	(0.04)	(0.04)
Black	0.21	0.16	0.21	0.16
	(0.03)	(0.02)	(0.02)	(0.02)
Hispanic	0.31	0.22	0.34	0.22
	(0.04)	(0.03)	(0.03)	(0.03)
Other	0.06	0.05	0.06	0.09
	(0.01)	(0.01)	(0.01)	(0.02)
PIR	0.75	1.75	0.74	1.73
	(0.01)	(0.01)	(0.01)	(0.01)
HR education				
>12 years	0.42	0.21	0.42	0.18
	(0.02)	(0.03)	(0.02)	(0.02)
High school	0.29	0.36	0.28	0.29
	(0.02)	(0.04)	(0.02)	(0.03)
Some college	0.22	0.35	0.23	0.36
	(0.01)	(0.03)	(0.01)	(0.03)
College grad +	0.06	0.09	0.06	0.17
	(0.01)	(0.02)	(0.01)	(0.03)
Married	0.49	0.66	0.48	0.66
	(0.03)	(0.03)	(0.02)	(0.03)
HH size	4.77	4.35	4.84	4.40
	(0.06)	(0.08)	(0.056)	(0.08)

Notes: Pre-ARRA statistics were computed from data from 2005-2008. Post-ARRA statistics were computed using data from 2007-2012, the analytic sample for the difference-in-differences analysis. SNAP-eligible participants include children living in households with income less than or equal to 130 percent of the FPL. SNAP-ineligible participants include children living in households with income between 150 and 200

percent of the FPL. Standard errors reported in parentheses. All means and proportions are weighted. The analysis accounts for the complex NHANES survey design.
HH: household; HR: household reference person; PIR: poverty-income ratio

Table 4.3 Nutrition-related health outcomes

	Pre-ARRA		Post-ARRA	
	SNAP-Eligible (*n*=2,899)	Nearly SNAP-Eligible (*n*=732)	SNAP-Eligible (*n*=4,185)	Nearly SNAP-Eligible (*n*=909)
	Mean/share	Mean/share	Mean/share	Mean/share
Child food security				
Full	0.64	0.84	0.9	0.84
	(0.02)	(0.02)	(0.02)	(0.02)
Marginal	0.12	0.04	0.11	0.06
	(0.01)	(0.01)	(0.01)	(0.02)
Low	0.21	0.11	0.18	0.09
	(0.02)	(0.02)	(0.01)	(0.01)
Very low	0.03	>0.01	0.03	>0.01
	(0.01)	(0.00)	(0.00)	(0.00)
Child WIC benefit	0.16	0.09	0.18	0.10
	(0.01)	(0.01)	(0.01)	(0.01)
NSLP	0.60	0.33	0.62	0.41
	(0.02)	(0.02)	(0.01)	(0.02)
SBP	0.41	0.20	0.43	0.24
	(0.02)	(0.02)	(0.01)	(0.02)
MetS outcomes				
Waist circumference (cm)	69.01	68.11	68.72	68.49
	(0.56)	(0.87)	(0.35)	(0.78)
Waist binary[a]	0.13	0.12	0.13	0.11
	(0.01)	(0.01)	(0.01)	(0.01)
BP (mmHg)	107.78	108.78	106.68	106.37
	(0.44)	(0.83)	(0.34)	(0.75)
BP binary	0.02	0.04	0.02	0.03
	(0.00)	(0.01)	(0.00)	(0.01)
HDL (mg/dL)	52.06	52.13	51.80	52.02
	(0.51)	(0.84)	(0.42)	(0.74)
HDL binary[a]	0.32	0.29	0.32	0.31
	(0.02)	(0.03)	(0.02)	(0.03)
Triglycerides (mg/dL)	92.62	94.51	83.92	75.06
	(3.00)	(4.50)	(2.36)	(2.91)
Triglycerides binary[a]	0.10	0.12	0.09	0.03
	(0.02)	(0.03)	(0.01)	(0.02)

Glucose (mg/dL)	96.56	96.22	96.46	93.81
	(1.52)	(1.29)	(1.08)	(1.06)
Glucose binary[a]	0.22	0.35	0.26	0.18
	(0.03)	(0.08)	(0.03)	(0.06)
Youth meets	0.06	0.09	0.03	0.04
MetS criteria	(0.02)	(0.05)	(0.01)	(0.03)
MetS Z-score	0.69	1.06	0.19	0.11
	(0.19)	(0.21)	(0.14)	(0.30)

Notes: Pre-ARRA statistics were computed from data from 2005-2008. Post-ARRA statistics were computed using data from 2007-2012, the analytic sample for the difference-in-differences analysis. SNAP-eligible participants include children living in households with income less than or equal to 130 percent of the FPL. SNAP-ineligible participants include children living in households with income between 150 and 200 percent of the FPL. Estimates for nutrition assistance programs (WIC, NSLP, SBP) indicate the share of the sample that are in the relevant age range and participate in the program. Standard errors reported in parentheses. All means and proportions are weighted. The analysis accounts for the complex
NHANES survey design.
BP: Blood pressure
HDL: High-density lipoprotein cholesterol
MetS: metabolic syndrome
NSLP: National School Lunch Program
SBP: School Breakfast Program
WIC: Special Supplemental Nutrition Program for Women, Infants, and Children
[a] Variable names are abbreviated. Variables denoted "binary" refer to the probability of meeting IDF criteria for metabolic syndrome for that specific component.

Difference-in-differences

Table 4.4 presents the difference-in-differences estimator for youth in the pooled sample, and across levels of food security. I do not find that the increase in SNAP benefits significantly affects cardiometabolic risk factors in the pooled sample. However, I do find evidence that an increase in benefits is significantly associated with higher triglycerides ($p<0.01$) in youth with low food security, and a higher risk of elevated waist circumference ($p<0.05$) and lower levels of HDL cholesterol ($p<0.01$) in youth with very low food security. Models for several of the outcomes are not able to be estimated due to a small number of observations. Therefore, although there are important differences in how each of the four levels of food security affects health,[180–182] I create a binary measure of food security to improve power. I combine full and marginal food security to indicate that a child is food secure, and I combine low and very low food security to indicate that a child is food insecure (results not shown, but are available upon request).[88] Although models are able to be estimated for all of the outcomes, combining categories attenuates the estimates.

Table 4.4 Estimated relationship between the ARRA increase in SNAP benefits and cardiometabolic risk factors in children and adolescents between the ages of 2 and 18 years: Differences across food security level

Risk factor	(1) Pooled sample (*n*=3,926)	(2) Full (*n*=2,503)	(3) Marginal (*n*=362)	(4) Low (*n*=622)	(5) Very Low (*n*=86)
Waist (cm)	1.27	1.71	1.40	-2.33	0.83
	(1.04)	(1.29)	(3.92)	(3.16)	(9.08)
Waist binary	0.04	0.03	0.20	-0.03	0.47*
	(0.03)	(0.04)	(0.14)	(0.07)	(0.23)
BP (mmHg)	0.65	0.54	5.94	-1.45	-2.40
	(1.60)	(1.68)	(4.50)	(4.48)	(12.95)
BP binary	0.01	0.00	0.03	0.03	-0.04
	(0.01)	(0.01)	(0.04)	(0.03)	(0.18)
HDL (mg/dL)	0.27	0.53	4.88	-2.17	-31.25**
	(1.68)	(1.81)	(5.39)	(4.27)	(10.42)
HDL binary	-0.05	-0.09	0.07	0.17	0.40
	(0.06)	(0.07)	(0.23)	(0.13)	(0.32)
Triglycerides	6.41	-2.28	---	127.31**	---
(mg/dL)	(11.68)	(12.92)		(32.71)	
Triglycerides	0.02	-0.02	---	0.34	---
binary	(0.06)	(0.07)		(0.21)	
Glucose (mg/dL)	-0.41	-0.84	---	-24.82	---
	(3.15)	(3.53)		(19.45)	
Glucose binary	0.13	0.16	---	-0.45	---
	(0.12)	(0.15)		(0.26)	
MetS binary	0.02	0.03	---	-0.09	---
	(0.03)	(0.03)		(0.10)	
MetS Z-score	0.73	1.00	---	1.93	---
	(0.53)	(0.57)		(1.75)	

Standard errors in parentheses
** p<0.01, * p<0.05

Notes: Table 4.4 presents the estimated relationship between the ARRA increase in SNAP benefits and cardiometabolic risk factors in children and adolescents between the ages of 2 and 18 years, or the age range for which the outcome is available. Model 1 displays estimates for the pooled sample (i.e. all levels of food security). Models 2 through 5 display estimates by food security level. All models control for youth-specific characteristics (age, sex, race, participation in nutrition assistance programs) and household-level controls (HR education, HR marital status, HH size). Model 1 also controls for child food security. All models account for the complex survey design. Due to a small number of observations for fasting and summary outcomes, models for youth

with marginal and very low food security were unable to be estimated.[ee]
BP: Blood pressure; HDL: High-density lipoprotein cholesterol; MetS: metabolic syndrome

Table 4.5 presents estimates of the relationship between the SNAP ARRA benefit increase and cardiometabolic risk factors across age ranges. As noted, different outcomes are only available once youth reach a certain age. Waist circumference, which is collected on children aged two years and older, is the only outcome that is available for all age ranges examined. I find that the increase in SNAP benefits is associated with significantly lower waist circumference in toddlers aged two to three years ($p<0.05$), but higher waist circumference in children aged 6 to 11 years ($p<0.05$).

[ee] I tried running the analysis using an unconditional model, and the difference-in-differences estimator was still unable to be estimated in many cases.

Table 4.5 Estimated relationship between the ARRA increase in SNAP benefits and cardiometabolic risk factors in children and adolescents: Differences across ages

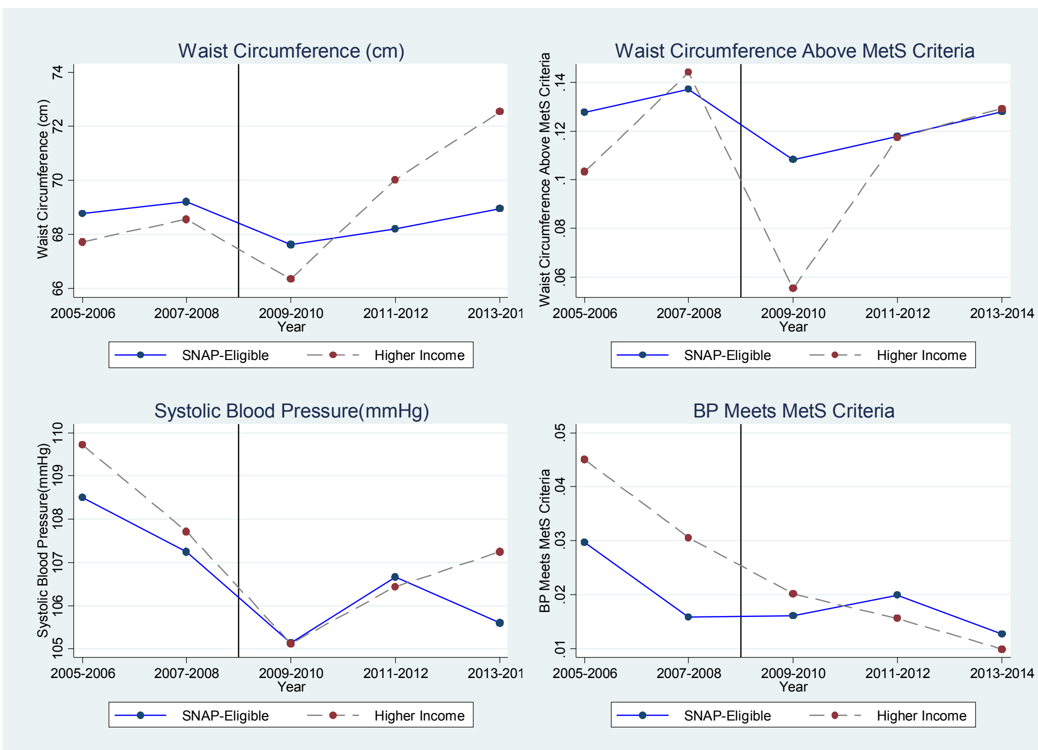
Risk factor	(Model 1) Toddlers aged 2-3 years (*n*=554)	(Model 2) Preschoolers aged 4-5 years (*n*=531)	(Model 3) Children aged 6-11 years (*n*=1,443)	(Model 4) Adolescents aged 12-18 years (*n*=1,045)
Waist (cm)	-1.85*	0.78	4.40*	-1.70
	(0.91)	(1.03)	(1.78)	(2.47)
Waist binary	-0.08	-0.05	0.05	0.09
	(0.09)	(0.06)	(0.04)	(0.06)
BP (mmHg)	---	---	1.89	-0.14
			(1.34)	(2.26)
BP binary	---	---	0.01	0.01
			(0.01)	(0.02)
HDL (mg/dL)	---	---	-0.15	0.40
			(2.32)	(2.21)
HDL binary	---	---	-0.03	-0.06
			(0.08)	(0.09)
Triglycerides (mg/dL)	---	---	---	6.41
				(11.68)
Triglycerides binary	---	---	---	0.02
				(0.06)
Glucose (mg/dL)	---	---	---	-0.41
				(3.15)
Glucose binary	---	---	---	0.13
				(0.12)
MetS binary	---	---	---	0.02
				(0.03)
MetS Z-score	---	---	---	0.73
				(0.53)

Standard errors in parentheses
** p<0.01, * p<0.05

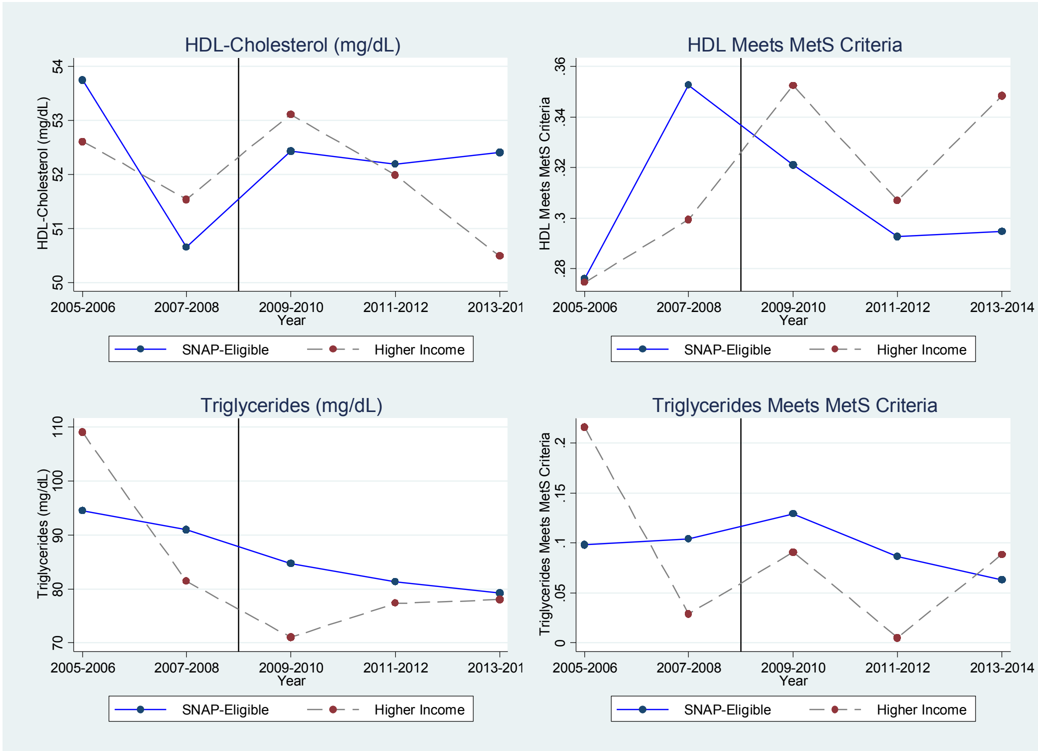
Notes: Table 4.5 presents the estimated relationship between the ARRA increase in SNAP benefits and cardiometabolic risk factors in children and adolescents across ages. All models control for youth-specific characteristics (age, sex, race, food security, participation in nutrition assistance programs) and household-level controls (HR education, HR marital status, HH size). All models account for the complex survey design.
BP: Blood pressure; HDL: High-density lipoprotein cholesterol; MetS: metabolic syndrome

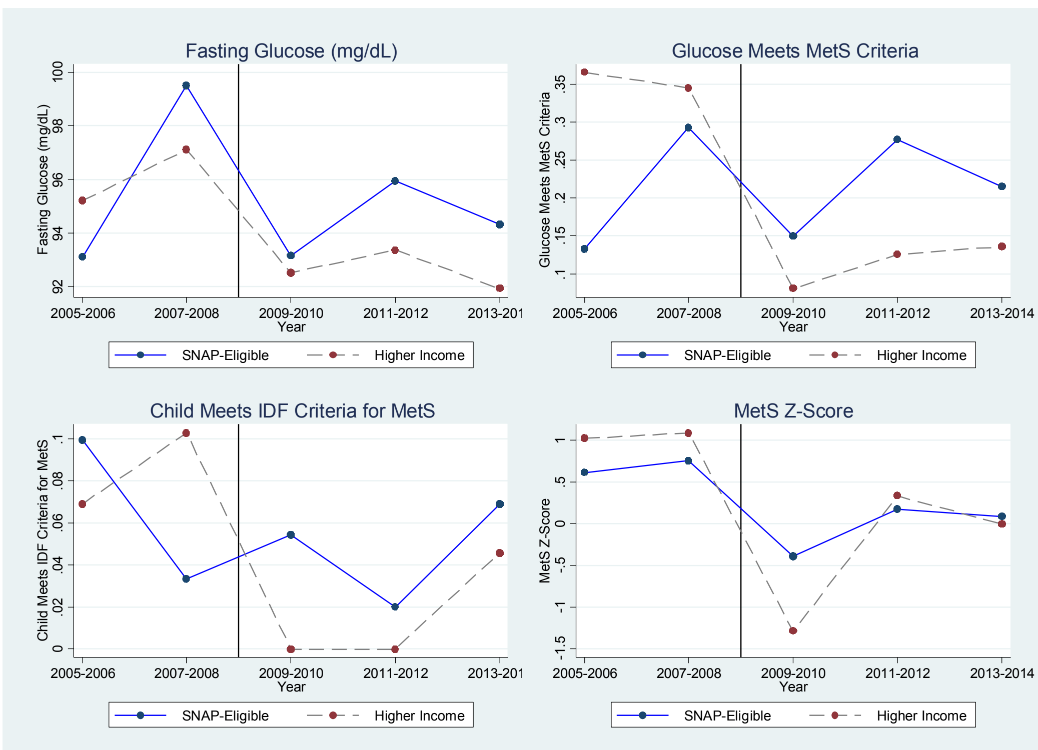
If cardiometabolic risk factors in SNAP-eligible youth would have been different than nearly eligible youth *even in the absence of the ARRA benefit increase*, then the results I find for triglycerides, waist circumference, and HDL would be spurious. I assess the pre-ARRA trends in outcome measures in order to examine if the trends were parallel, or very different. I visually examine the trends in the pooled sample of youth (Figure 4.1) and in each subgroup examined (figures available upon request). However, there are only two time periods of data that occur prior to ARRA, making it difficult to determine whether or not the parallel trends assumption is met. Any divergent trends may be part of a broader trend. When considering the results, it is important to keep in mind that it is unclear to what extent the parallel trends assumption is met.

Figure 4.1 MetS outcomes over time in SNAP-eligible and slightly higher income children and adolescents aged 2 to 18 years



Notes: Graphs plot the weighted mean of each outcome in each survey wave. The vertical line indicates the implementation of the ARRA in 2009. The ARRA was implemented in April 2009, and ended October 31, 2013. The pre-ARRA period includes the 2005-2006 and 2007-2008 waves, and the post-ARRA period includes the 2009-2010 through the 2013-2014 waves. Solid blue lines indicate that the child's household meets the SNAP income-eligibility criteria. Dotted gray lines indicate nearly SNAP-eligible children (poverty income ratio is between 1.5 and 2.0)





Notes: Graphs plot the weighted mean of each outcome in each survey wave. The vertical line indicates the implementation of the ARRA in 2009. The ARRA was implemented in April 2009, and ended October 31, 2013. The pre-ARRA period includes the 2005-2006 and 2007-2008 waves, and the post-ARRA period includes the 2009-2010 through the

2013-2014 waves. Solid blue lines indicate that the child's household meets the SNAP income-eligibility criteria. Dotted gray lines indicate nearly SNAP-eligible children (poverty income ratio is between 1.5 and 2.0)

The primary analysis estimates the intent-to-treat of SNAP, and examines as the "treatment" group all youth living in households with incomes at or below 1.30 PIR. The DD analysis compares the treatment group to youth living in households with a PIR between 1.5 and 2.0. I examine alternate treatment and comparison groups, including a broader higher-income group, with PIR between 1.5 and 2.5 (see Nord and Prell, 2009[34]), and groups based on self-reported SNAP participation. Results are sensitive to the treatment and comparison group used, primarily when comparing the intent-to-treat estimate with self-reported measures, which demonstrates the importance of controlling for self-selection bias, and misreporting SNAP participation. I do not find a significant relationship between an increase in SNAP benefits and youth cardiometabolic measures (results not shown, but are available upon request).

Regression discontinuity

I first visually assess if there is a discontinuity in cardiometabolic risk factors across the 1.30 PIR threshold (figures available upon request). I find evidence of a "jump" in several outcomes. Graphs suggest that SNAP-eligible youth have a significantly lower probability of meeting MetS criteria for HDL and triglycerides, but higher glucose levels, when compared to youth just above the SNAP eligibility threshold. Formal estimation of the relationship between SNAP-eligibility and MetS risk factors supports several of the results of the graphical analysis. I find that SNAP eligibility is associated with significantly lower triglycerides ($p<0.05$), a lower probability of having elevated triglycerides ($p<0.05$), and a lower overall MetS Z-score ($p<0.05$) (Table 4.6).

Furthermore, the effect of SNAP-eligibility on cardiometabolic risk factors in youth varies by food security status. I find that the significant relationship between MetS Z-score and SNAP-eligibility is driven by the subsample of fully food secure youth. In addition, SNAP-eligible youth who experience either low or very low food security have significantly lower waist circumference ($p<0.05$). While these results indicate that eligibility for SNAP benefits is associated with significantly healthier cardiometabolic risk factors, I find the opposite effect in youth who are marginally food secure. Marginally food secure youth have significantly lower HDL ($p<0.05$), and significantly higher probability of meeting MetS criteria for HDL ($p<0.05$).

Table 4.6 Estimated effect of SNAP-eligibility on cardiometabolic risk factors in children and adolescents compared to those just over the eligibility threshold: Differences across food security

Risk factor	(Model 1) Pooled sample (*n*=9,614)	(Model 2) Full (*n*=5,977)	(Model 3) Marginal (*n*=979)	(Model 4) Low (*n*=1,544)	(Model 5) Very Low (*n*=236)
Waist (cm)	-1.98	-1.21	2.13	-6.80*	-14.74*
	(1.54)	(1.76)	(3.67)	(2.75)	(7.15)
Waist binary	-0.01	0.00	-0.02	-0.11*	0.02
	(0.02)	(0.02)	(0.07)	(0.05)	(0.11)
BP (mmHg)	-1.56	-1.05	-1.78	-4.57	-3.17
	(0.96)	(1.20)	(3.08)	(2.44)	(3.95)
BP binary	-0.01	0.00	-0.04	-0.04	-0.09
	(0.01)	(0.01)	(0.04)	(0.04)	(0.09)
HDL (mg/dL)	0.98	1.71	-6.24*	1.83	4.75
	(1.19)	(1.30)	(2.62)	(3.28)	(6.08)
HDL binary	-0.04	-0.07	0.27*	0.02	-0.33
	(0.04)	(0.05)	(0.11)	(0.08)	(0.25)
Triglycerides	-17.31*	-15.09	-20.46	-16.61	6.27
(mg/dL)	(7.83)	(10.54)	(18.85)	(16.28)	(31.08)
Triglycerides	-0.12*	-0.08	-0.02	-0.18	-0.11
binary	(0.05)	(0.06)	(0.07)	(0.14)	(0.14)
Glucose (mg/dL)	3.22	3.22	6.75	3.06	2.97
	(1.89)	(2.46)	(5.77)	(6.42)	(2.86)
Glucose binary	-0.08	-0.12	0.15	-0.06	0.11
	(0.07)	(0.08)	(0.19)	(0.17)	(0.00)
MetS binary	-0.06	-0.11	0.02	---	-0.01
	(0.05)	(0.07)	(0.11)		(0.00)
MetS Z-score	-1.08*	-1.81**	0.08	0.54	0.84
	(0.48)	(0.59)	(1.34)	(1.65)	(1.84)

Standard errors in parentheses
** $p<0.01$, * $p<0.05$

Notes: Table 4.6 presents the estimated effect of living in a SNAP-eligible household on youth cardiometabolic risk factors (τ, from equation (2)). Model 1 displays the RD estimates for the pooled sample (i.e. all levels of food security). Models 2 through 5 display estimates by food security level. All models are unconditional, linear fits that center PIR on the 1.30 cutoff, and allow for a different relationship between SNAP eligibility and each risk factor on either side of the cutoff. All models account for the complex survey design. We also checked various specifications for each outcome to assess different functional forms (results not shown, but are available upon request). We focus on a linear fit because the graphs do not suggest a quadratic or cubic relationship. Variable names are abbreviated. Variables denoted "binary" refer to the probability of meeting IDF criteria for metabolic syndrome for that specific component. Model 4 is unable to be estimated for MetS binary due to a small n.
BP: Blood pressure; HDL: High-density lipoprotein cholesterol; MetS: metabolic

syndrome

I test different functional forms using the pooled sample (results not shown, but are available upon request). The results for triglycerides and MetS Z-score hold across multiple specifications. I also examine if/how the effect of SNAP-eligibility on cardiometabolic risk factors varies in different age groups and by gender (results not shown, but are available upon request). I do not generally find a significant relationship between SNAP-eligibility and risk factors when stratifying the analysis by age or gender.

4.5 Falsification tests

The strength of the regression discontinuity design is that by examining outcomes in youth who are under or just over the income-eligibility criteria, assignment to the "treatment" (SNAP-eligibility) or comparison group (youth just over the threshold) is nearly random. To assess the plausibility of this assumption, I use several methods to check for systematic differences between the treatment and comparison groups. First, I examine how several sociodemographic characteristics (age, gender, and household size) are distributed around the 1.30 PIR threshold (figures available upon request). These characteristics are distributed continuously around the threshold, which suggests that youth just under and just over the 1.30 cut-off have similar observable characteristics. Second, if either administrators of SNAP or potential SNAP participants manipulate household income, then assignment to treatment or control is no longer nearly random. I plot the density of PIR to assess if income manipulation may be occurring. If this were the case, then it is very likely that households just under and just over the cut-off differ systematically on unobservable characteristics. The graphs do not suggest that income manipulation is occurring.

Next, I examine the sensitivity of regression results to choice of bandwidth, i.e. choice of what levels of PIR to include in specifying who is in the treatment and comparison groups. The main RD analysis includes all youth who live in households with income at or below 1.85 PIR. The treatment group includes youth with household income at or below 1.30 PIR. The comparison group are youth with household income above 1.30 but at or below 1.85 PIR. I use a more narrow treatment group to test the sensitivity of results. The treatment group includes youth with household income above 0.80 PIR but equal to or below 1.30 PIR (results not shown, but are available upon request). Results are generally robust to choice of bandwidth, with a few exceptions. As in the main analysis, SNAP-eligible youth have significantly lower triglycerides and MetS Z-score. Interestingly, I also find that, when using a more narrow treatment group, SNAP-eligible youth have significantly *higher* glucose than those just over the eligibility threshold. These regression results corroborate the graphical analysis of the relationship between SNAP-eligibility and glucose.

Finally, if the intent-to-treat estimate of SNAP is driving the results, then we would not expect to see a similar discontinuity in outcomes across different levels of PIR. To evaluate this question, I visually check for a jump in outcomes across 1.85 PIR (figures available upon request), which is the eligibility criteria to participate in WIC nationally, and in Medicaid/CHIP programs in some states.[122] Graphs suggest that there is a discontinuity in several outcomes. There is evidence that those just under 1.85 PIR have a *lower* probability of meeting MetS criteria for HDL and glucose, and lower glucose levels. When using 1.30 PIR, graphs also suggest that SNAP-eligible youth have a significantly lower probability of meeting MetS criteria for HDL. Regression results of the relationship are not significant. Comparing the graphical analysis across 1.85 PIR to the main analysis using 1.30 PIR, I find the opposite relationship with glucose. This findings suggests that significantly higher glucose levels in SNAP-eligible youth are not driven by an outside factor.

4.6 Discussion and conclusions

This study uses two quasi-natural experiments to investigate the relationship between SNAP and cardiometabolic health of children and adolescents. I find that SNAP-eligible youth have significantly healthier outcomes (lower triglycerides, lower probability of triglycerides meeting MetS criteria, and lower overall MetS Z-score) compared to youth just over the eligibility threshold. In addition, the connection between SNAP and health outcomes varies by a youth's food security status. Results from the DD suggest that an increase in SNAP benefits is associated with *worse* outcomes (higher triglycerides, higher probability of having elevated waist circumference, and lower HDL levels) in youth with low or very low food security. However, the RD analysis indicates that SNAP eligibility is associated with *healthier* outcomes in youth who are fully food secure (lower MetS Z-score), or who experience low or very low food security (lower waist circumference).

The reason that the DD and the RD find opposite effects for youth with low or very low food security is unclear. One explanation may be that the main "treatment" group is the same in both analyses, but comparison groups differ. The DD uses youth living in households with income between 1.50 and 2.00, whereas the RD uses youth just over the SNAP eligibility threshold (1.31 and 1.85 PIR). Second, while the RD uses a similar but slightly broader time frame (2005-2014) than the DD (2007-2012), differences in findings may be due to the fact that the DD focuses on the period at the height of the Great Recession. The national unemployment rate was 5.0% in 2007, but by 2009,[ff] it had reached 10.0%.[85] Many households reduced spending at this time and reported higher levels of stress symptoms, such as sleeplessness and depression.[86] If families reduced spending on health-related goods (e.g. nutritious foods or fee-required physical activities), then youth may experience worse cardiometabolic risk factors. In addition, parental stress and/or depression is linked to poor health in children.[183–186] Increased parental stress and/or depression during the Great Recession may have adversely affected child health. To investigate the possibility that the slight difference in sample period is what is driving the differences in results, I restrict the RD to the years 2007 to 2012 (results not shown, but are available upon request). Although outcomes are no longer significant, the direction and effect size of the estimates are similar to the main RD analysis, indicating that the difference in sample years is not the reason for the contrasting findings for youth with low or very low food security. Therefore, the difference in the results remains unclear.

Furthermore, in the RD, I find that SNAP-eligibility is associated with a significantly *healthier* MetS Z-score in youth who are fully food secure and waist circumference in youth who experience low or very low food security. However, I find that marginally food secure youth have significantly lower (less healthy) HDL levels and a higher probability of having MetS. Similarly, Parker et al. found that adults with marginal or very low food security had increased odds of having MetS.[172] Tester et al. found that marginally food secure adolescents had increased odds of elevated

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[ff] The unemployment rate improved after 2010, and by the end of 2014, it was 5.6% (Cunningham, US BLS).

triglycerides and a less healthy blood lipid profile compared to fully food secure adolescents.[187] They did not find evidence of unhealthy lipid levels in youth with low or very low food security.

If SNAP-eligible youth have several significantly healthier MetS indicators across levels of food security except those who are marginally food secure, what is it about marginal food security that might contribute to this difference? I examined demographic characteristics by food security level (results available upon request) and used multinomial logistic regression to identify significant predictors of marginal food security. I find that being black, receiving free or reduced price school breakfast, living with a single parent or in a larger household, and household WIC participation increases the relative log odds of being marginally food secure versus fully food secure. Living in a household with a higher PIR increases the odds of marginal food security versus very low food security. Even so, it is unclear why marginally food secure youth may have lower HDL levels.

Finally, I find that the SNAP benefit increase during the ARRA is associated with a lower waist circumference in toddlers aged 2 to 3 years, but a higher waist circumference in children aged 6 to 11 years. This contrasting relationship may be due to differences in the amount of time spent in the home, and in the level of autonomy that children have. Toddlers are likely to spend more time at home, with very little choice in what foods they eat. If diet quality of food in the home environment improved with an increase in SNAP benefits, then waist circumference and adiposity may decrease. If school-age children spend less time at home and eat more meals outside of the home, such as relying on the school meals programs or purchasing snacks throughout the day, then an increase in SNAP benefits may not lead to a lower waist circumference.

Limitations

The present study has several strengths. To my knowledge, it is the first study to use a quasi-experimental design to investigate the relationship between SNAP and cardiometabolic risk factors in children and adolescents. In addition, I examine if/how food security and age modify the link between SNAP and youth risk factors. This paper also has limitations. Even though I use designs that address selection bias and attempt to control for both observable and unobservable characteristics, the data we use is observational. For that reason, I am limited in my ability to draw causal inferences. Second, due to complex institutional rules surrounding SNAP eligibility, it is likely I will misclassify youth as being in the SNAP-eligible group, or in the nearly, but not quite eligible group. Finally, Hoynes and Schanzenbach note that RD may not be suitable for analyzing SNAP because the amount of benefits received fall as income rises. Therefore, the discontinuity between receiving benefits and not receiving any benefits is not as sharp a discontinuity as programs like the NSLP.[125] However, during the period of the ARRA, benefits increased by a constant dollar amount for each household size regardless of income.[75] The difference in benefits received even in SNAP households that are close to the cutoff is therefore more pronounced between 2009 and 2013 during the ARRA.

Policy Implications and Future Research

Given the prevalence of cardiometabolic risk factors in increasing numbers of youth, it is essential to understand the role that the largest U.S. nutrition assistance program may play. However, the selection effect and misreporting program participation create special challenges in elucidating the connection between youth cardiometabolic health and SNAP. Multiple researchers have called for ethical, random-assignment designs in order to clarify this relationship.[188,189] Only one recent project identified has been successful in doing so.[170] Legislators may consider authorizing additional projects that use random-assignment research designs.

Second, I find that SNAP may be most beneficial for children and adolescents who experience either low or very low food security. If additional research corroborates these results, policy makers may examine the possibility of targeting additional SNAP benefits to segments of the population that are most likely to experience food insecurity. Additional research is needed to illuminate the relationship between SNAP and cardiometabolic health of children and adolescents. First, future studies should use research designs that address selection bias. In addition, researchers should use longitudinal data in order to study the dynamics of program participation, child health, and important factors such as food security, if/when data become available. Finally, studies should examine the causal mechanisms through which SNAP is linked with youth cardiometabolic health. The complexities of SNAP—and of the policy process—create significant challenges in studying the effects of SNAP, and in making changes to the program. However, continuing research in these areas will help clarify the relationship between SNAP and MetS risk factors in children and adolescents. Refining the largest nutrition assistance program has the potential to improve the cardiometabolic health of low-income youth.

CHAPTER 5: EPILOGUE: WHAT HAPPENS POST-ARRA?

The American Recovery and Reinvestment Act (ARRA) temporarily increased SNAP benefit amounts as a way of providing additional assistance to low-income families during the Great Recession. The ARRA benefit increase was effective from April 2009 to October 31, 2013. The present study finds that the ARRA benefit increase is associated with:

- Lower diet quality in toddlers aged 2-3 years and in children 6-11 compared to nearly SNAP-eligible but slightly higher income children;
- Healthier weight outcomes in toddlers aged 2-3, in preschoolers aged 4-5 years, and in adolescents aged 12-18 years;
- Lower waist circumference in toddlers aged 2-3 years;
- Higher waist circumference in children aged 6-11 years;
- Lower diet quality in youth who experience marginal, low, or very low food security;
- Healthier weight outcomes in marginally food-secure youth; and
- Less healthy levels of cardiometabolic risk factors in youth with low or very food security.

If the increase in SNAP benefits during the time of ARRA is associated with lower diet quality and less healthy levels of several cardiometabolic risk factors in some populations, but also healthier weight outcomes, what happens when ARRA ended?

This epilogue begins to investigate this question. Using the same analytical framework as the difference-in-differences design throughout this study, I extend the analysis to examine if and how nutrition and nutrition-related health changed after ARRA ended.

The framework and variables are the same with a few important differences. The analysis includes data from the 2009-2010 to the 2013-2014 waves of NHANES. Instead of an ARRA variable, I use a post-ARRA variable to identify the timing of an observation. Post-ARRA is equal to 0 if the observation occurred during the ARRA benefit increase (2009-2010 or 2011-2012), and equal to 1 if the observation occurred in 2013-2014.[gg] I use this post-ARRA variable to create a new interaction term with the treatment variable SNAP, which gives us the difference-in-differences estimator of the post-ARRA SNAP benefit levels.[hh]

5.1 Dietary

Differences across food security levels

Table 5.1 indicates that the end of the SNAP benefit increase is associated with a 13 percent higher probability of meeting sodium guidelines in the pooled sample ($p<0.05$). This improvement in sodium levels is primarily accounted for by the significant decrease in daily sodium consumption by youth with marginal food security (*b*= -1,124.03, $p<0.01$). In the pooled sample, youth are 5 percent more likely to meet fiber guidelines ($p<0.05$). However, youth with marginal food security have decreased fiber consumption of 4.22 g/day ($p<0.05$).[ii] Youth with low food security consume

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[gg] The ARRA was effective from April 2009 to October 31st, 2013. Public use NHANES data does not provide the exact year or timing of an observation, but it does have a variable to indicate if the observation occurred from November 1st to April 30th, or from May 1st to October 31st. Including months prior to April 2009 in the category of "=0" (during which time the benefit increase was effective) would weaken the design. For this reason, I exclude observations from the 2009-2010 wave if they occurred from November 1st to April 30th. Similarly, I exclude observations from May 1st to October 31st in the 2013-2014 wave. Taking these steps gives us more confidence that the observation actually occurred either during the ARRA benefit increase or after.

[hh] When assessing changes post-ARRA, I did not re-do the DD graphs. The original graphs (see chapters 2-4) include all waves of data (i.e. 2005-2006 through 2014-2014). Therefore the graphs would be the same, with the only change being the vertical reference line would now mark the 2013-2014 wave, as opposed to being between the 2007-2008 and 2009-2010 waves. As there are no data points after 2013-2014, the reference line to mark the end of the ARRA benefit increase simply marks the end of the graph. Therefore, the present epilogue section does not present a graphical analysis.

[ii] Model 3 indicates that daily fiber consumption *decreased* (*b*= -4.22 g/d, $p<0.05$), but that the likelihood of meeting fiber guidelines *increased*. I attribute this to misspecification of form. Logistic or probit models are

significantly less sugar-sweetened beverages (SSBs) after the SNAP benefit increase ended. Low food-secure youth consume 1,906.35 kcal ($p<0.01$) and 226.62 grams[jj] ($p<0.01$) less of SSBs daily.

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more appropriate when analyzing binary dependent variables. Throughout this project, I have checked the results of the linear probability model with logistic regression, and have largely found similar results across both models. However, in stratifying the sample by food security status in the present analysis, the logistic regression failed to converge, even with an unconditional model. Because the model is more appropriate for the dependent variable, I have higher confidence in the negative estimate for daily fiber consumption.

[jj] 226.2 grams is equal to 7.66 ounces, or almost one cup.

Table 5.1. Estimated relationship between the end of the ARRA increase in SNAP benefits and diet quality indicators in children and adolescents between the ages of 2 and 18 years: Differences across food security level

	(Model 1) Pooled sample	(Model 2) Full	(Model 3) Marginal	(Model 4) Low	(Model 5) Very Low
Sodium (mg/d)	164.96 (200.08)	286.73 (220.25)	-1,124.03** (326.25)	-467.39 (384.28)	—
Meets sodium guidelines[a]	0.13*[b] (0.05)	0.11+ (0.06)	0.18* (0.08)	0.15 (0.10)	—
Fiber (g/d)	1.18 (1.18)	1.04 (1.07)	-4.22* (1.92)	3.47 (2.79)	—
Meets fiber guidelines	0.05* [b] (0.02)	0.03 (0.02)	0.16* (0.07)	0.20 (0.12)	—
Fruit (cups/d)	0.01 (0.16)	0.09 (0.16)	0.50 (0.42)	-0.02 (0.33)	—
Vegetables (cups/d)	-0.31 (0.29)	-0.41 (0.30)	-0.11 (0.24)	0.48 (0.36)	—
SSBs (kcal/d)	-88.08 (180.64)	73.78 (211.85)	732.39+ (381.74)	-1,906.35** (391.34)	—
SSBs (gm/d)	-25.54 (52.42)	0.36 (59.00)	46.69 (37.08)	-226.62** (51.79)	—
HEI-2010	-1.89 (3.10)	-3.36 (3.14)	11.38* (4.93)	8.44* (3.68)	—
n	2,876	2,065	295	455	61

Standard errors in parentheses

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

Notes: Table 5.1 presents the estimated relationship between the end of the ARRA increase in SNAP benefits and diet quality indicators in children and adolescents aged 2 to 18 years. Model 1 displays estimates for the pooled sample (i.e. all levels of food security). Models 2 through 5 display estimates by food security level. All models control for youth-specific characteristics (age, sex, race, weekend, participation in nutrition assistance programs) and household-level controls (HR education, HR marital status, HH size). Model 1 also controls for child food security. All models account for the complex survey design.

[a] Models in which "meets sodium guidelines" have a slightly lower *n* than other models. This variable was coded to indicate children who have high sodium. 8.20 percent of the sample are below the minimum recommended sodium intake levels. These children were coded as missing for the sodium binary variable. For the pooled sample, *n*=2,661. For youth with full food security, *n*=1,919. For youth with marginal food security, *n*=275. For youth with low food security, *n*=411. For youth with very low food security, *n*=56.

[b] Estimates presented are from linear probability models. I also used logistic regression to check results for binary variables. The probability of meeting sodium guidelines remains significant ($p<0.05$) and positive (OR = 2.24). The probability of meeting fiber also remains significant ($p<0.01$) and positive (OR = 14.59). However, when stratified by food security level, the model failed to converge, even for unconditional models.

Differences across ages

Table 5.2 shows the estimated relationship between the end of the ARRA increase in SNAP benefits and diet quality indicators across ages. The end of the benefit increase is largely not significantly associated with diet quality when the sample is stratified by age. I do find that the decrease in SNAP benefits is associated with a 1.19 cup per day increase in fruit consumption ($p<0.05$) and an 8.51 increase in HEI score ($p<0.05$) in toddlers aged 2 to 3 years.

Table 5.2. Estimated relationship between the end of the ARRA increase in SNAP benefits and diet quality indicators across ages

	(Model 1) 2-3 Years	(Model 2) 4-5 Years	(Model 3) 6-11 Years	(Model 4) 12-18 Years
Sodium (mg/d)	97.00	337.83	63.39	647.21
	(276.74)	(578.83)	(265.89)	(400.37)
Meets sodium guidelines[a]	0.12	-0.15	0.10	0.08
	(0.13)	(0.19)	(0.07)	(0.09)
Fiber (g/d)	2.36+	-3.53+	0.87	2.87+
	(1.18)	(1.91)	(1.43)	(1.60)
Meets fiber guidelines	0.03	0.04	0.04	0.07+
	(0.04)	(0.03)	(0.03)	(0.04)
Fruit (cups/d)	1.19*	-1.02+	-0.08	0.04
	(0.58)	(0.53)	(0.30)	(0.20)
Vegetables (cups/d)	-0.12	-0.01	0.21	-0.61
	(0.13)	(0.15)	(0.19)	(0.41)
SSBs (kcal/d)	-201.02	-441.93	-174.84	79.28
	(307.54)	(512.79)	(270.56)	(322.76)
SSBs (gm/d)	-55.57	-46.66	1.57	-33.84
	(40.95)	(66.59)	(38.46)	(96.55)
HEI-2010	8.51*	-11.33	0.77	-3.37
	(3.64)	(7.05)	(3.41)	(4.24)
n	446	409	1,113	908

Standard errors in parentheses
** p<0.01, * p<0.05, + p<0.1

Notes: This table presents the estimated relationship between the end of the ARRA increase in SNAP benefits and diet quality indicators in youth across ages. Model 1 displays estimates for toddlers aged 2 to 3 years. Model 2 includes preschoolers aged 4 to 5 years. Model 3 includes children aged 6 to 11 years. Model 4 includes adolescents aged 12 to 18 years. All models control for youth-specific characteristics (age, sex, race, weekend, child food security, participation in nutrition assistance programs) and household-level controls (HR education, HR marital status, HH size). All models account

for the complex survey design.
[a] Models in which "meets sodium guidelines" have a slightly lower *n* than other models. This variable was coded to indicate children who have high sodium. 8.20 percent of the sample are below the minimum recommended sodium intake levels. These children were coded as missing for the sodium binary variable. For ages 2-3 years, *n*=417. For ages 4-5 years, *n*=386. For ages 6-11 years, *n*=1,047. For ages 12-18 years, *n*=811.

5.2 Weight outcomes

Differences across food security levels

Next, I examine how the reduction in SNAP benefits is linked with weight outcomes in children and adolescents. Table 5.3 presents estimates in the pooled sample of youth, and across food security levels. I find that the decrease in SNAP benefits is connected with significantly healthier weight outcomes in marginally food-secure youth. Reduced SNAP benefits are associated with 30.73 lower BMI percentile ($p<0.01$), 1.48 lower BMI Z-score ($p<0.01$), and a lower probability of obesity in SNAP-eligible youth with marginal food security.

Table 5.3. Estimated relationship between the end of the ARRA increase in SNAP benefits and weight outcomes: Differences across food security level

	(Model 1) Pooled	(Model 2) Full	(Model 3) Marginal	(Model 4) Low	(Model 5) Very Low
BMI percentile	-6.23	-5.36	-30.73**	22.25	1.32
	(5.85)	(5.50)	(7.59)	(23.43)	(27.81)
BMI Z-score	-0.30	-0.26	-1.48**	1.18	-0.72
	(0.26)	(0.24)	(0.36)	(0.98)	(1.14)
Overweight	-0.01	-0.02	0.07	-0.12	-0.12
	(0.07)	(0.06)	(0.09)	(0.34)	(0.23)
Obese	-0.10	-0.06	-0.83**[a]	0.19+	-0.52
	(0.10)	(0.10)	(0.12)	(0.10)	(0.45)
Underweight	0.01	0.02	0.03	-0.37	-0.11
	(0.04)	(0.03)	(0.05)	(0.26)	(0.08)
n	3,514	2,280	326	488	63

Standard errors in parentheses
** p<0.01, * p<0.05, + p<0.1

Notes: This table presents the estimated relationship between the end of the ARRA increase in SNAP benefits and weight outcome of interest in children and adolescents aged 2 to 18 years. Model 1 displays estimates for the pooled sample (i.e. all levels of food security). Models 2 through 5 display estimates by food security level. All models control for youth-specific characteristics (age, age², sex, race, participation in nutrition assistance programs) and household-level controls (HR education, HR marital status, HH size). Model 1 also controls for child food security. All models account for the complex survey design.
[a] The estimate presented is from a linear probability model. I attempted to check this with a logistic model. However, the model failed to converge. The magnitude of this estimate is very high, and may be a result of a misspecification of form. Even so, estimates for BMI percentile and BMI Z-score support the finding of significantly lower weight. For these reasons, I mention the result for the probability of obesity, but do not discuss it in detail.

Differences across ages

Table 5.4 displays results of the association between the reduction in SNAP benefits and weight outcomes across ages. I do not find a significant relationship between the decrease in SNAP benefits in weight outcomes when the sample is stratified by age.

Table 5.4. Estimated relationship between the end of the ARRA increase in SNAP benefits and weight outcomes across ages

	(Model 1) 2-3 Years	(Model 2) 4-5 Years	(Model 3) 6-11 Years	(Model 4) 12-18 Years
BMI percentile	10.13	1.58	-15.00+	-4.47
	(8.55)	(10.25)	(7.76)	(6.59)
BMI Z-score	0.27	-0.35	-0.63+	-0.16
	(0.29)	(0.54)	(0.33)	(0.28)
Overweight	0.26*[a]	0.09	0.10	-0.20+
	(0.10)	(0.15)	(0.06)	(0.12)
Obese	-0.02	-0.14	-0.22+	-0.02
	(0.06)	(0.20)	(0.12)	(0.14)
Underweight	0.00	0.04	0.04	-0.03
	(0.06)	(0.03)	(0.05)	(0.05)
n	491	467	1,246	953

Standard errors in parentheses
** p<0.01, * p<0.05, + p<0.1

Notes: This table presents the estimated relationship between the end of the ARRA increase in SNAP benefits and weight outcome of interest in children and adolescents.

Model 1 displays estimates for toddlers aged 2 to 3 years. Model 2 includes preschoolers aged 4 to 5 years. Model 3 includes children aged 6 to 11 years. Model 4 includes adolescents aged 12 to 18 years. All models control for youth-specific characteristics (age, age^2, sex, race, child food security, participation in nutrition assistance programs) and household-level controls (HR education, HR marital status, HH size). All models account for the complex survey design.
[a] Table 4 presents estimates from linear regression or linear probability models. I checked the estimate for the probability of overweight with a logistic model. The odds ratio indicated an increased probability of overweight, but was no longer significant (OR: 14.89, p=0.067).

5.3 Metabolic syndrome risk factors

Differences across food security levels

Next, I estimate the relationship between the reduction in SNAP benefits and risk factors for cardiometabolic syndrome. Table 5.5 presents results for the pooled sample, and across levels of food security. I find that the decrease in SNAP benefits is associated with a 14.68 cm lower waist circumference ($p<0.01$), a lower probability of having elevated waist circumference, and 11.72 mg/dL higher HDL ($p<0.01$) in marginally food-secure youth. The decrease in SNAP benefits is associated with 116.80 mg/dL lower triglycerides ($p<0.05$), but also a lower probability of meeting recommended guidelines for HDL in youth with low food security, and 17.53 mmHg lower blood pressure ($p<0.05$) in youth with very low food security.

Table 5.5. Estimated relationship between the end of the ARRA increase in SNAP benefits and metabolic syndrome risk factors in children and adolescents: Differences across food security level

	(Model 1) Pooled sample	(Model 2) Full	(Model 3) Marginal	(Model 4) Low	(Model 5) Very Low
Waist (cm)	-3.29	-2.59	-14.68**	6.67	-19.71
	(2.84)	(2.76)	(5.30)	(3.33)	(11.91)
Waist binary	-0.07	-0.03	-0.88** [a]	0.11	-1.03** [a]
	(0.08)	(0.08)	(0.11)	(0.08)	(0.29)
BP (mmHg)	-0.72	-1.59	7.37+	4.52	-17.53*
	(1.96)	(1.79)	(3.68)	(7.90)	(6.92)
BP binary	-0.03	-0.03	-0.09+	0.07+	0.05
	(0.02)	(0.02)	(0.05)	(0.04)	(0.08)
HDL (mg/dL)	1.99	0.65	11.72**	3.80	15.93
	(2.81)	(2.96)	(4.30)	(5.39)	(9.45)
HDL binary	-0.05	0.00	-0.05	-0.44** [a]	-0.56
	(0.09)	(0.09)	(0.16)	(0.16)	(0.49)
Triglycerides	6.42	10.19	___	-116.80*	___
(mg/dL)	(13.49)	(13.47)		(45.85)	
Triglycerides	-0.02	-0.02	___	-0.28	___
binary	(0.07)	(0.07)		(0.29)	
Glucose (mg/dL)	-2.58	-1.43	___	7.60	___
	(2.45)	(2.00)		(6.62)	
Glucose binary	-0.13	-0.09	___	0.43	___
	(0.10)	(0.10)		(0.28)	
MetS binary	-0.00	-0.03	___	0.17+	___
	(0.03)	(0.03)		(0.09)	
MetS Z-score	0.28	0.52	___	0.61	___
	(1.08)	(1.22)		(1.96)	
n	3,396	2,195	312	472	60

Standard errors in parentheses

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

Notes: This table presents the estimated relationship between the end of the ARRA increase in SNAP benefits and weight outcome of interest in children and adolescents aged 2 to 18 years, or the entire range of which the outcome is available. Model 1 displays estimates for the pooled sample (i.e. all levels of food security). Models 2 through 5 display estimates by food security level. All models control for youth-specific characteristics (age, age^2, sex, race, participation in nutrition assistance programs) and household-level controls (HR education, HR marital status, HH size). Model 1 also controls for child food security. All models account for the complex survey design. Variable names are abbreviated. Variables denoted "binary" refer to the probability of meeting IDF criteria for metabolic syndrome for that specific component (see Table 4.1 in Chapter 4).

Data for MetS outcomes are collected for different age ranges. The age ranges for each outcome follow: waist circumference: full sample aged 2 years and older; HDL cholesterol: aged 6 years and older; blood pressure (BP): aged 8 and older; fasting-related variables (triglycerides, LDL, glucose): aged 12 and older. Therefore, the number of observations is slightly different across outcomes. The number of observations presented above represents youth aged 2 to 18 years, as in models with waist circumference as the outcome.

[a] The estimates presented are from a linear probability model. I attempted to check these results with logistic regression. The models examining waist binary failed to estimate. However, the logistic model with HDL binary resulted in similar findings as the linear probability model, and remained significant (OR=0.093, p=0.024).

Differences across ages

Finally, I examine how the reduction in SNAP benefits is associated with MetS risk factors across ages (Table 5.6). I find that a decrease in benefits is associated with a 2.31 cm higher waist circumference (p<0.05) and a 14 percent greater probability of having elevated waist circumference (p<0.05) in toddlers aged 2 to 3 years.

Table 5.6. Estimated relationship between the end of the ARRA increase in SNAP benefits and metabolic syndrome risk factors across ages

	(Model 1) 2-3 Years	(Model 2) 4-5 Years	(Model 3) 6-11 Years	(Model 4) 12-18 Years
Waist (cm)	2.31*	-5.52	-5.15+	-1.69
	(1.01)	(4.35)	(3.03)	(3.92)
Waist binary	0.14*	-0.22	-0.14	-0.03
	(0.06)	(0.19)	(0.12)	(0.08)
BP (mmHg)	___	___	1.09	-1.55
			(1.91)	(2.24)
BP binary	___	___	-0.00	-0.04
			(0.01)	(0.03)
HDL (mg/dL)	___	___	2.19	0.20
			(2.14)	(4.23)
HDL binary	___	___	-0.02	-0.03
			(0.09)	(0.15)
Triglycerides (mg/dL)	___	___	___	6.42
				(13.49)
Triglycerides binary	___	___	___	-0.02
				(0.07)
Glucose (mg/dL)	___	___	___	-2.58
				(2.45)
Glucose binary	___	___	___	-0.13
				(0.10)
MetS binary	___	___	___	-0.00
				(0.03)
MetS Z-score	___	___	___	0.28
				(1.08)
n	450	443	1,218	928

Standard errors in parentheses
** p<0.01, * p<0.05, + p<0.1

Notes: This table presents the estimated relationship between the end of the ARRA increase in SNAP benefits and weight outcome of interest in children and adolescents across age ranges. Model 1 displays estimates for the pooled sample (i.e. all levels of food security). Models 2 through 5 display estimates by food security level. All models control for youth-specific characteristics (age, age², sex, race, participation in nutrition assistance programs) and household-level controls (HR education, HR marital status, HH size). Model 1 also controls for child food security. All models account for the complex survey design.

Variable names are abbreviated. Variables denoted “binary” refer to the probability of meeting IDF criteria for metabolic syndrome for that specific component (see Table 1 in Chapter 4).

BP: Blood pressure; HDL: High-density lipoprotein cholesterol; MetS: metabolic syndrome

Data for MetS outcomes are collected for different age ranges. The age ranges for each outcome follow: waist circumference: full sample aged 2 years and older; HDL cholesterol: aged 6 years and older; blood pressure (BP): aged 8 and older; fasting-related variables (triglycerides, LDL, glucose): aged 12 and older. Therefore, the number of observations is slightly different across outcomes. The number of observations presented above represents youth aged 2 to 18 years, as in models with waist circumference as the outcome.

5.4 Discussion and conclusion

I find that the reduction in SNAP benefits following the end of ARRA is associated with:

- Higher probability of meeting recommended guidelines for sodium and fiber in the pooled sample;
- Lower consumption of sodium but also a lower consumption of fiber in marginally food-secure youth;
- Lower consumption of SSBs by nearly one cup in youth with low-food security;
- Significantly lower weight outcomes in marginally food-secure youth;
- Generally healthier cardiometabolic risk factors in youth who experience marginal, low, or very low food security;
- Higher waist circumference in toddlers aged 2 to 3 years.

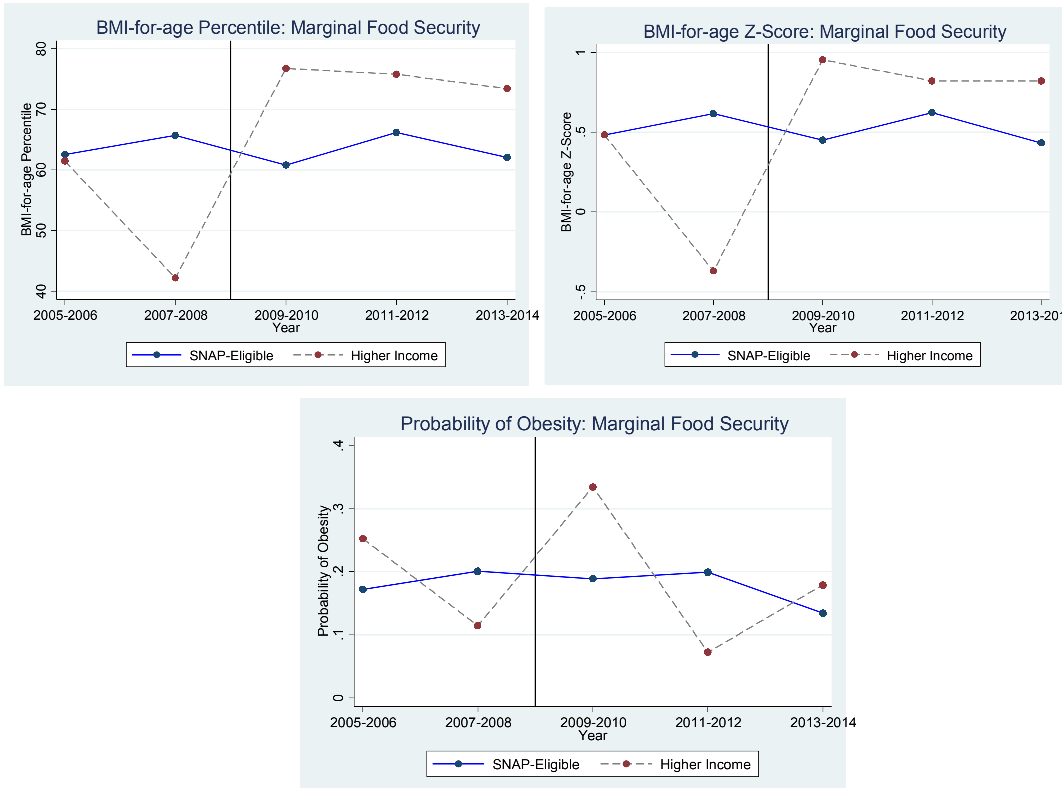
With a few exceptions, I find that the decrease in SNAP benefits after ARRA ended is associated with improved diet quality, lower weight outcomes, and generally healthier MetS risk factors. These results are seen primarily in youth who experience marginal, low, or very low food security. Of particular note is the significant decrease in SSB consumption among youth with low food security. If families do not have consistent, reliable access to food, then it is plausible that once SNAP benefit levels were cut, households cut back on less-necessary items, such as SSBs. However, it is uncertain why this relationship occurs in youth with low food security, but not other levels of food insecurity.

A second notable finding is the significant decrease in BMI percentile, BMI Z-score, and probability of obesity in marginally food-secure youth. In the analysis in Chapter 4, I find that the *increase* in SNAP benefits from ARRA is associated with 35.30

lower BMI percentile and 1.30 lower BMI Z-score in marginally food-secure youth. How can it be that both the ARRA benefit increase and the post-ARRA reduction in SNAP benefits are associated with lower weight outcomes in marginally food-secure youth?

I returned to the graphical analysis in order to look further into the issue. Figure 5.1 shows that weight outcomes in SNAP-eligible, marginally food-secure youth did not fluctuate to a large extent either when ARRA was implemented in 2009 or once the benefit increase ended in 2013. Rather, weight outcomes of the slightly higher-income comparison group shows increases in BMI percentile, BMI Z-score, and the probability of obesity. This suggests that at both time points (i.e. during the Great Recession, when ARRA was implemented, and afterwards, when SNAP benefits decreased), SNAP plays a protective role against elevated weight outcomes in youth who experience marginal food security. However, it is unclear why this relationship exists for marginally food-secure youth, but not for youth who experience more severe forms of food insecurity. Additional research is needed to a) quantitatively investigate the significant predictors of different levels of food security (rather than a binary measure of food-secure vs. –insecure) and b) qualitatively explore the experiences of children and families across the four levels of food security. Such research could shed light on the differences across a range of food security levels, illuminate mechanisms behind them, and point to policy options to improve food security.

Figure 5.1 Investigating weight outcomes in marginally food-secure youth



Notes: Graphs present the weighted, mean outcome in each survey wave. The vertical line indicates the SNAP ARRA benefit increase in 2009. Solid blue lines indicate that the child's household meets the SNAP income-eligibility criteria (poverty income ratio is less than or equal to 1.30). Dotted gray lines indicate nearly SNAP-eligible children (poverty income ratio is between 1.5 and 2.0).

CHAPTER 6: CONCLUSION

What is the relationship between the Supplemental Nutrition Assistance Program (SNAP) and nutrition-related health of low-income children and adolescents? This question is of great interest to policy makers and to public health professions, particularly as changes to the program are considered. In this dissertation, I examined three sets of outcomes: 1) measures of diet quality; 2) weight outcomes; and 3) indicators for metabolic syndrome (MetS). I use two quasi-experimental designs—difference-in-differences and regression discontinuity—to address self-selection into the program, a challenge inherent when evaluating SNAP and similar programs.

In the pooled sample of youth, I find a significant relationship only between SNAP and MetS factors. SNAP eligibility is associated with generally healthier cardiometabolic risk factors in the pooled sample of youth when compared to those just over the income-eligibility criteria. Specifically, SNAP-eligible youth have lower triglycerides, a lower probability of having elevated triglycerides, and a lower overall MetS Z-score (RD). Furthermore, the connection that SNAP has with nutritional health differs according to a child's food security status. Fully food-secure, SNAP-eligible youth have a significantly lower MetS Z-score than those just over the income threshold (RD). This result appears to be largely driving the estimate found for the pooled sample.

In contrast, an increase in SNAP benefits is associated with lower diet quality in youth who experience either marginal, low, or very low food security (DD). However, lower diet quality in these subgroups does not necessarily translate into less healthy weight or cardiometabolic risk factors. Children and adolescents in the "treatment" (SNAP) group and are marginally food secure have *healthier* weight (DD: lower BMI percentile and lower BMI Z-score), but *less healthy* MetS outcomes (RD: lower HDL and a higher probability of meeting criteria for the metabolic syndrome). SNAP-eligible youth who experience low food security have higher triglycerides (DD), but a lower waist circumference and a lower risk of elevated waist circumference (RD). I find more consistently negative health outcomes in youth with very low food security. SNAP-eligible youth who experience very low food security have a higher risk of elevated waist circumference and lower HDL (a protective factor) (DD).[kk]

The relationship between SNAP and nutritional health also differs across age groups. Toddlers aged 2 to 3 years have lower diet quality (lower daily fiber, probability of meeting fiber guidelines, less daily fruit consumption) (DD), but a lower probability of being overweight (DD), and a lower waist circumference (DD). Preschoolers aged 4 to 5 years also have a healthier weight. Interesting, with an increase in SNAP benefits, preschoolers are less likely to be underweight (DD). However, children aged 6 to 11 years have lower diet quality (higher daily sodium and lower HEI) (DD) and a higher waist circumference (DD).

The differential connection that an increase in SNAP benefits has with diet-related health across ages may be reflective of the transition between environments. It

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[kk] In instances where findings differ in the regression discontinuity (RD) and the difference-in-difference (DD) designs, I highlight the results of the DD. The possibility of misclassifying youth into the treatment and comparison groups is a limitation of both designs. However, because of the complex institutional rules (such as state flexibility in raising the income eligibility criteria, among other things) and the nature of the RD (i.e. comparing those just under and those just over the income eligibility criteria), I believe misclassification error is a greater threat in the RD. Thus, I highlight results of the DD in the case of conflicting findings. Specifically, in the DD, I find that youth with very low food security have less daily fruit consumption, whereas in the RD I find higher daily fiber intake in this subgroup. I find that SNAP-eligible youth with very low food security have a higher risk of having an elevated waist circumference in the DD, whereas in the RD I find that they have a lower waist circumference and a lower risk of elevated waist circumference.

may be that SNAP benefits are more closely linked to nutritional health during younger ages, when the child likely spends more time at home. Moving into a more structured environment, such as what entering preschool or kindergarten would entail, may be a health-promotion program in and of itself. Some homes may already provide a structured environment, including around meals and snacks. However, other homes may be less structured. For children in the latter scenario, entering childcare or school would mean that children are not free to eat whenever and whatever they want. In a childcare or school setting, children would be served meals and snacks that meet minimum nutritional standards, on a predictable schedule, may have a physical activity component built into their days. The difference in environments plausibly explains the different relationships I find between increased SNAP benefits and diet-related health.

Finally, I find evidence that an increase in SNAP benefits is associated with a lower probability of meeting recommended sodium guidelines and a lower average total HEI score in girls (DD). In addition, SNAP-eligible boys are less likely to be overweight compared to boys just over the income-eligibility threshold (RD).

Taken together, the findings of this dissertation have several policy implications. I discuss the policy implications in greater detail in the individual papers, but I summarize them here. First, it is important to note that the relationship between SNAP and the nutritional health of children and adolescents varies by subgroup, particularly across food security level and age range. Any changes to the program are likely to affect groups differently.

1. Target additional benefits to those in greatest need/those most likely to be food insecure

First, I find that an increase in SNAP benefits is associated with generally *worse* health outcomes in youth who experience some form of food insecurity. Previous research found that the ARRA benefit increase significantly improved food security.[79] Another study evaluating an increase in food assistance benefits during a randomized controlled trial improved child diet quality across several measures.[190] In the evaluation by Collins and Klerman, [190] the additional nutritional assistance was equal to an approximate 25 percent increase in SNAP. In the present dissertation, I find that the average 19 percent increase in benefits during the ARRA is associated with worse nutritional health outcomes. Given this evidence, it may be that the increase in benefits during the ARRA was not enough to buffer against the job losses and insecurity that occurred during the Great Recession. Therefore, although targeting additional benefits to those who are most likely to experience the most severe forms of food insecurity has the potential to improve nutritional health, additional research is needed. Future studies should also evaluate what level of benefit increase could improve health.

2. Target SNAP-Ed to families with young children

Second, I find that an increase in SNAP benefits is associated with lower dietary quality, but a lower probability of being overweight and a lower waist circumference, in toddlers aged 2 to 3 years. SNAP nutrition educations programs (SNAP-Ed) have been found to improve diet quality in young children.[90,91] Policy-makers should consider targeting nutrition education programs to families with young children, especially if lower diet quality in toddlers is due to a lack of structure and routines around healthy meals and snacks. Increased funding and resources to SNAP-Ed programs may be successful in improving the diets of low-income children.

3. Authorize and evaluate pilot projects that alter the structure of SNAP, such as restricting SSBs from eligible purchases

Finally, many researchers and policy-makers have proposed removing certain nutritionally-poor items, such as SSBs, from SNAP-eligible items.[144] [28,145–148] Several studies have found that restricting items from SNAP purchases led to healthier overall food purchases[151] and healthier diet-related health.[152] Although further stigmatizing vulnerable households is a major argument against purchase restrictions,[29,153] a recent survey of SNAP participants and food insecure, non-SNAP participants finds that the majority of respondents were in favor of a restructured program that combined an incentive for healthy purchases with restrictions of SSBs.[154] Authorizing and evaluating pilot projects that alter the structure of SNAP, such as restricting SSBs from eligible purchases, would allow researchers to test the impact of program modifications on nutritional health and the perceptions of participants.

However, SNAP is only one piece of the very complex puzzle of improving nutritional health of low-income populations. There is a large body of evidence that environmental factors—e.g. accessibility of full-service grocery stores and healthy foods, and availability of safe places to engage in physical activity—can negatively affect diet quality and nutrition-related health in low-income populations. In addition, new research is shedding light on previously overlooked mechanisms that affect the diet and diet-related health of low-income groups.

A recent review by Laraia et al. highlights the complex factors that affect food choice and nutritional health of low-income populations.[87] Food insecurity, housing instability, stress, and poor sleep are some of the elements that influence not only what food choices individuals make, but also biological processes related to diet. Changes in metabolism and in brain chemistry, such as how the body reacts to stressors, are affected by the array of uncertainties that people living in poverty face daily. Therefore, it is not only the individual choices and immediate physical environment that shape nutritional health, but a host of other factors.

Thus, it is not a single policy that is the cause or solution of poor diet quality, high rates of obesity, or an unfavorable cardiometabolic risk profile. Rather, living in poverty—and all that it entails—is the critical underlying factor behind poor health in low-income populations. In 2015, 9.6 million children (13.0%) lived in households with incomes below the poverty line. Approximately 2.1 million (2.9%) lived in deep poverty, i.e. in households with incomes less than half of the poverty line.[191]

There is much debate as to how effectively modifications to SNAP may help improve diet quality and curb rising rates of obesity. However, if we want to improve the health of low-income populations, then we need to tackle the problem at the root: poverty and systemic inequalities. And what is the role that SNAP may play? Regardless of what proportion of SNAP participants purchase lower-quality food items (compared to the large proportion of the general American population that does the same), a recent report from the National Academies finds that SNAP is the number three program in reducing child poverty, second only to the Federal Earned Income Tax Credit (EITC) and the Child Tax Credit (CTC).[191] Moreover, the EITC and CTC operate as refundable tax credits based on income. While this income-based structure is effective at encouraging work, it also means that these programs do not reach families in deep poverty who have very low levels of earned income. The report found that, in this regard, SNAP is the most effective program at reducing deep poverty.[191] Because of its poverty-reducing effects, although some program modifications may nudge families to make healthier food choices, , SNAP is a critical program for the health and well-being of low-income children and adolescents.

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