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Three Essays on Grocery Sales Taxes

Lingxiao Wang
University of Kentucky, lexi.lxwang@gmail.com
Author ORCID Identifier:
https://orcid.org/0000-0003-1032-6429
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Lingxiao Wang, Student

Dr. Yuqing Zheng, Major Professor

Dr. Tyler Mark, Director of Graduate Studies

Three Essays on Grocery Sales Taxes

DISSERTATION

A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in the
College of Agriculture, Food and Environment
at the University of Kentucky

By

Lingxiao Wang

Lexington, Kentucky

Co- Directors: Dr. Yuqing Zheng, Associate Professor of Agricultural Economics

and Dr. Steven Buck, Assistant Professor of Agricultural Economics

Lexington, Kentucky

2021

https://orcid.org/0000-0003-1032-6429

ABSTRACT OF DISSERTATION

THREE ESSAYS ON GROCERY SALES TAXES

Grocery sales taxes represent a stable tax revenue stream for state and municipal government, but there is rare empirical evidence suggesting grocery taxes may adversely affect health. In addition, the how governments set grocery sales taxes is still unclear. Therefore, based on a novel national dataset of annual county and state-level grocery taxes from 2009 through 2016, the following three essays in the dissertation investigate the health impacts of grocery sales taxes and the causes of grocery sales taxes in a framework of tax competition.

In the first essay, we document the spatial and temporal variation in grocery taxes and empirically examine the statistical relationship between county-level grocery taxes and obesity and diabetes. We link the tax data to three-year, county-level estimates based on data from the Centers for Disease Control and Prevention on rates of obesity and diabetes and provide a nation-wide spatial characterization of grocery taxes and these two health outcomes. Using a county-level fixed effects estimator, we estimate the effect of grocery taxes on obesity and diabetes rates, also controlling for a subset of potential confounders that vary over time. We find a one percentage point increase in grocery taxes is associated with 0.588 and 0.215 percentage point increases in the county-level obesity and diabetes rates. In conclusion, Counties with grocery taxes have increased prevalence of obesity and diabetes. We estimate the economic burden of increased obesity and diabetes rates resulting from grocery taxes to be $5.9 billion. Based on this estimate, the benefit-cost ratio of removing grocery taxes is 1.90 across the United States if we only consider the effects on obesity and diabetes rates.

In the second essay, we aim to examine whether grocery sales taxes make significant impacts on individual's body weight outcome. We merged the county-level grocery tax data with the individual longitudinal data from Panel Study Income Dynamics (PSID) and explore a fixed effect model to estimate the causal impact of grocery sales taxes on family food expenditures and individual BMI (Body Mass Index). After that, we conduct the analysis of heterogeneous effects by income category and obesity level to identify the policy impacts on different individuals and families. We find that a ten point-percentage increase in grocery sales rate leads to a rise of BMI by 0.61 (which roughly translates to a body weight gain of 1.68kg). The results are more significant for the overweight population whose BMI is greater than 25 but smaller than 30. We do not find significant results towards different income population.

In the third essay, we study the state-county tax policy interaction patterns and explore the causes of grocery sales tax changes considering spatial externalities under a Stackelberg tax competition model with three propositions. Derivatized from the model, county grocery tax rates are affected by states' grocery tax rates (vertical effects), neighboring counties' grocery tax rates (horizontal effects) and neighboring states' grocery tax rates (diagonal effects). By employing the twelve-year data of state and county grocery taxes, we also empirically examine the three propositions in a spatial autoregressive model. The empirical results are consistent with the three theoretical proportions. The average county grocery sales tax rate is less than the average state grocery sales tax rate, and we find the county grocery tax rate changes negatively with its domestic state grocery sales tax rate. Neighboring counties play a large role in determining the local county grocery tax rates. For example, a county will increase its grocery tax rates by 0.780-point percentages if its neighboring county increases one percentage point tax rate on average. Neighboring state tax rates can also positively affect a county's grocery tax rate. A county is expected to increase its grocery tax rate by 0.110 percentage point when its neighboring states increase state grocery tax rate by one percentage point on average.

KEYWORDS: Grocery Tax, Obesity, Diabetes, Tax Competition

Lingxiao Wang

(Name of Student)

07/27/2021

Date

THREE ESSAYS ON GROCERY SALES TAXES

By
Lingxiao Wang

Yuqing Zheng

Co-Director of Dissertation

Steven Buck

Co-Director of Dissertation

Tyler Mark

Director of Graduate Studies

07/27/2021

Date

DEDICATION

To anyone who did not realize the existence of grocery sales taxes.

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CHAPTER 1. INTRODUCTION

Grocery sales taxes were first levied over the Great Depression, yet during the past two decades, seven states have consecutively exempted grocery sales taxes, which provoked an intense discussion on the impacts of grocery sales taxes and repeals of the taxes. Some researchers argued that "the persistence for the grocery tax is strange" because most local governments have already given up taxing groceries (Tate, 2018). Indeed, only thirteen states persist on the taxes, five of which levy the taxes at limited rates, and three of which provide different levels of tax refund credits. However, policymakers in the with-tax states are unwilling to cut the grocery sales taxes because the taxes contribute considerably to the local government finances.

In most states and counties, grocery sales tax rates are different from general sales tax rates. Since the Great Depression when general sales states were created, some states and governments have decided to exempt groceries from the sales taxes. This is where the tax division come from. More divisions come up when some states and counties levy grocery taxes at limited rates, while some levy at the same rates as general sales taxes (full rates). The dissertation focusses on the grocery sales tax policy instead of the general sales taxes.

This dissertation is a collection of three essays that explore the impacts and causes of the grocery tax changes and discuss repealing the tax. Although a few studies have investigated the impacts of grocery sales taxes on food related outcomes, there are also topics that remain unexplored. First, there is no empirical research investigating the impacts of grocery taxes on health outcomes such as obesity and diabetes. Second, most of the research fails to track the causal influence due to the limit of micro panel data. Third, there is limited academic analysis on the causes of grocery sales tax changes in the framework of tax competition, even though over 100 counties changed grocery sales tax rates more than 300 times during the past decade, according to the tax data we collected and used in this dissertation. Therefore, in the dissertation, the three essays emphasizing on the above blank aspects target to enrich the investigation of grocery sales taxes.

The first essay examines the impact of grocery taxes on health outcomes, including obesity and diabetes. The income effects and substitution effects of grocery taxes change consumers' food choices, finally influencing people's weights and blood sugar levels. By exploiting U.S. county-level data from 2009 to 2016, and controlling for other socio-economic factors, results from the multiple linear regression show that higher grocery sales taxes are associated with higher obesity.

The second essay follows the association found in the first essay, aiming to identify the causal impacts of grocery taxes on body weight outcome using individual longitudinal data. The county grocery taxes are merged with the family and individual level data from PSID. By employing the fixed-effect model, the reduction impacts of grocery sales taxes on body weight are found. In our preferred model, one point percentage decrease in grocery tax rate leads to 0.061 BMI decrease translating to 0.168 kg reduction in body weight on average.

The last essay explores the causes of grocery sales tax changes considering both spatial externalities and vertical externalities. Based on a spatial econometric model, the grocery tax rate of a county is positively affected by its neighbor counties and states, showing the evidence of spatial autocorrelation of grocery tax among counties. Vertical interaction also plays a significant role, and we find evidence that county-level tax rates increase as state-level tax rates decrease given that the average county-level tax rate is smaller than the state-level tax rate.

Taxing groceries is a pivotal decision for local governments, and the grocery tax rates are also important food policies that influence every citizen's life. Although there are passionate debates on tax exemption for groceries in the society amongst policy makers, the impacts and motivations of cutting the taxes have not been thoroughly examined. Through this dissertation research, I hope to provide a rigorous evaluation of these important issues.

CHAPTER 2. GROCERY FOOD TAXES AND U.S. COUNTY OBESITY AND DIABETES RATES

2.1 Introduction

Grocery sales taxes (hereafter referred as grocery taxes) are sales taxes imposed on grocery foods and exist in the form of a state tax, a county tax, or both in sixteen U.S. states. Taxing groceries is an attractive revenue source for state and municipal governments because grocery sales are relatively stable; thus, protecting facilitates budgeting planning even during times of economic downturn. Of course, grocery taxes make grocery foods more expensive, which society may feel most during times of economic downturn as lower income households become even more food insecure. For example, coronavirus disease 2019 (COVID-19) pandemic began in early 2020 and food insecurity sky-rocketed in the United States—in April 2020, food insecurity increased to 23%.[i] Not surprisingly, food insecurity is associated with social problems (particularly for children) such as health (Cook et al., 2004; Dunifon & Kowaleski-Jones, 2003; Weinreb et al., 2002), psychological (Alaimo, Olson, & Frongillo, 2001), and behavioral problems (Slack & Yoo, 2005; Whitaker, Phillips, & Orzol, 2006); therefore, policies thought to impact food insecurity and health have been extensively studied. Notably, there are studies that have analyzed the impacts of specific food taxes, such as soda taxes, on consumption and health. Recent examples include studies showing that at-risk subpopulations such as obese children coming from low-income families are more sensitive to soda taxes (J. M. Fletcher, D. E. Frisvold, & N. Tefft, 2010c; Sturm, Powell, Chriqui, & Chaloupka, 2010).

In contrast, the relationship between grocery taxes and health outcomes has received little attention. This is somewhat surprising given that relative to soda taxes, grocery taxes are far more common, a significantly larger percentage tax on average, and they apply to all grocery foods so represent a considerably larger share of household income. The current lack of research on the impacts of grocery taxes is unfortunate since it is during times of economic hardship, such as a COVID-19 (Coronavirus Disease 2019) induced recession, that policies such as grocery taxes receive greater consideration as a source of stable tax revenue for state and local governments.

2.2 Literature Review

Grocery taxes can affect the odds of eating at home versus dining out through changing the relative effective prices (tax included price) of grocery and restaurant foods. Compared with states such as New York where restaurant foods are taxed while grocery foods are tax exempt, taxing both grocery and restaurant foods in states like Alabama creates more of a disincentive to eat at home (French, 2003). For the poorest segment of the population, fast food restaurants become their primary option as a substitute for grocery foods because fast food restaurants are both more accessible (Powell, Chaloupka, & Bao, 2007; Rydell et al., 2008) and cheaper (Khan, Powell, & Wada, 2012). In particular, two recent empirical studies show that grocery taxes reduced U.S. consumers' grocery food expenditures and increased restaurant food expenditure, and restaurant food sales taxes increased U.S. consumers' grocery food expenditures (Dong, Zheng, & Stewart, 2020; Zheng, Dong, Burney, & Kaiser, 2019b). Therefore, the substitution from grocery food to fast food in response to taxing groceries may increase the odds of unhealthy outcomes since there is evidence that consumption of fast food affects a person's risk of becoming both obese (Chou, Grossman, & Saffer, 2004) and diabetic (Pereira et al., 2005).

Unlike soda or fat taxes, grocery taxes apply to thousands of grocery items and may effectively change consumers' grocery food choices. Though not all grocery foods are healthy, reduced consumption of fruits and vegetables may induce obesity (Darmon & Drewnowski, 2015) and diabetes (Popkin, 2015), and food-at-home is widely considered healthier than food-away-from-home. Therefore, we hypothesize that health outcomes are negatively correlated with grocery taxes. We choose two health outcome measures for this study: obesity and diabetes rates within a county, because food consumption is closely related to obesity and diabetes.

It is well known that individuals gain weight whenever consumed calories exceeds expended calories (Finkelstein, Ruhm, & Kosa, 2005). Yet, rates of obesity vary significantly from person to person according to the individual's social economic status (McLaren, 2007) like education (Cohen, Rai, Rehkopf, & Abrams, 2013), income (Pickett, Kelly, Brunner, Lobstein, & Wilkinson, 2005), gender (Kanter & Caballero, 2012), age, and race (Wolf et al., 1993). In addition, individual body mass index (BMI) is also highly related with individual risky behavior such as smoking (Courtemanche, Tchernis, & Ukert, 2018) and alcohol consumption (Sayon-Orea, Martinez-Gonzalez, & Bes-Rastrollo, 2011). However, these individual-level reasons do not explain fully the increasing prevalence of obesity across the entire society over time.

Researchers from multiple disciplines have identified various underlying causes of obesity epidemic from different perspectives, such as decreasing price per calorie (Darmon & Drewnowski, 2015), high availability of fast food, high cost of healthy food (Wiggins et al., 2015), difficulty to access healthy food especially for lower-income households (Jetter & Cassady, 2006), and the high amount of marketing of unhealthy food and beverages especially among younger children (Harris, Pomeranz, Lobstein, & Brownell, 2009). While the evidence is mixed, some studies have identified physical inactivity as a cause for obesity, attributed to urban sprawl (Vandegrift & Yoked, 2004), labor-saving devices such as dish washers (Ng & Popkin, 2012), and increasingly sedentary occupations (Thorp, Owen, Neuhaus, & Dunstan, 2011). Similar to findings in the obesity literature, the rising rates of diabetes has been attributed in part to environmental factors, such as the abundance of food supply and sedentary lifestyles (Barnett, Eff, Leslie, & Pyke, 1981; Marx, 2002; Zimmet, 1982). In fact, 60% of diabetes cases can be attributed to being obese or overweight (Ezzati, Lopez, Rodgers, & Murray, 2004).

In terms of magnitude, the quantitative significance for obesity and diabetes risk factors also varies widely. For instance, quitting smoking has been found to reduce body mass index (BMI) by 1.8-1.9 units with a BMI above 30 defining obesity (Courtemanche et al., 2018). As a separate example, a one percent increase in soda taxes has been associated with a 0.013 decrease in average BMI (Sturm et al., 2010). Overall, there is not clear consensus on the aggregate effects of different risk factors on either obesity or diabetes rates, especially among individual studies that examine specific sub-populations.

In summary, the public health literature has identified a multitude of causes for the rising obesity and diabetes epidemic in the United States, including prices, food availability and accessibility, and marketing. The aim of this study is to examine another potential factor which has not been investigated previously: the relationship between grocery food taxes and health outcomes. Despite the fact that groceries are taxed in one third of U.S. states as well as on-going debates on whether to impose significant grocery taxes (e.g., New Mexico and West Virginia) to our knowledge there is, no comprehensive dataset on state and county-level grocery taxes. Therefore, one contribution of our work is the development of a comprehensive dataset on state and county-level grocery taxes from 2009 through 2016, which we then link to county-level estimates of obesity and diabetes rates. The main empirical contribution of our work is to estimate the effect of grocery taxes on these two important health outcomes using our novel county-level panel data and a county fixed effects estimator that also includes time-varying variables to control for socioeconomic factors, risky behaviors, and food access and affordability environment. A third contribution is policy-focused, we calculate benefit-cost ratios of eliminating grocery taxes as a way to assess the quantitative significance of grocery taxes in determining obesity and diabetes rates.

2.3 Methods

2.3.1 Data Organization and Structure

We organize county-level panel data consisting of six time periods on obesity and diabetes rates, food taxes, socioeconomic characteristics, and risky health behaviors. Each of the six periods is three years in length; thus, the unit of observation in the statistical analysis is the county-three-year period. Each of the six periods in the study has a one-year overlap with the subsequent period or the preceding period or both—Figure 1 depicts this somewhat unique structure of our county-level panel data and empirical design. We develop this data structure because the outcome variables of obesity and diabetes rates are only precisely estimated and reported based on the average of a three year-sample window. Concordance on the timing of measurements between the health outcome variables and the explanatory variables requires that the food tax, socioeconomic, and risky health behavior variables also be measured as three-year averages. A separate justification for measuring each variable as a three-year average is that the adjustment of diets due to a tax change, and any subsequent transition to or from obesity is not likely immediate.

2.3.2 Data Sources

We assemble a large set of data on state- and county-level grocery tax rates in the U.S. from 2009 to 2016. The key independent variable of interest in this study is the total grocery sales tax, measured as a percentage. The total tax is the sum of the state-level and county-level grocery sales taxes. We also collect data on restaurant sales taxes, which we use to calculate the ratio of the grocery to restaurant sales tax as an alternative explanatory variable. The tax data are obtained from Bridging the Gap for state tax rates, Tax-Rates.org for 2016 county rates, and state Departments of Revenue for the rest (by online searching by two research assistants over an extended period of time).

Comparing with the panel data source of sales tax rates assembled by other researchers (Agrawal, 2014, 2015), our dataset does not include municipal tax rates. However, it is the first panel dataset that focuses on grocery tax rates, instead of general sales tax rates. In addition, it contains national grocery tax data of state and county level for as long as twelve years.

We assess two dependent variables in our analyses: 1) three-year county-level obesity prevalence; and 2) three-year county-level diabetes prevalence. County-level rates of diagnosed obesity and diabetes are obtained from the Centers for Disease Control and Prevention (CDC) county data indicators (Centers for Disease Control Prevention, 2016), which are three-year average rates calculated by CDC using annual surveys from the Behavioral Risk Factor Surveillance System (BRFSS) (Centers for Disease Control and

Prevention, 2018) and are based on a three-year average to improve precision. For both obesity and diabetes outcomes we use age-adjusted rates to measure the health outcomes.

We collect data for control variables in the regression analysis from multiple sources on a wide range of socioeconomic data measured at the annual level. To conform the explanatory variables with the dependent variable, we use the annual socioeconomic data to construct three-year county level averages for use as control variables in the regression analysis. The first set includes food environment/access/affordability including the numbers of grocery stores, fast food restaurants, and full-service restaurants, and the average cost per meal. The former three variables are from the Census Bureau's County Business Patterns (U.S. Census Bureau, 2018) and the latter is from Feeding America (Feeding America, 2018). Socioeconomic measures on population, race, gender income, employment and education are based on data from the Census Bureau's Population Estimates Program (U.S. Census Bureau, 2018.). The per capita income and employment rate are from the Regional Economic Information System (REIS) (U.S. Bureau of Economic Analysis, 2017).

Additional control variables include data on risky health behaviors, which are also at the annual level and used for constructing three-year county-level averages. The county-level prevalence estimates of smoking and alcohol use are obtained from BRFSS. Smoking is measured as the percentage of adults in a county who both report that they currently smoke every day or most days and have smoked at least 100 cigarettes in their lifetime. Excessive alcohol use is the percentage of adults that report excessive alcohol consumption in the past 30 days in each county. Data on drug-possession and driving under the influence (DUI) arrests are obtained from the County Level Detailed Arrest and Offense Data supported by the Uniform Crime Reporting (UCR) Program (U.S. Bureau of Justice Statistics, 2018). We divide the arrests by county population from REIS to obtain per capita possessing-drug and DUI arrests.

In total we have tax data for 3,101 U.S. counties. We only keep 2,446 counties in the dataset due to our study design. Moreover, 408 counties are lost when merging in socioeconomic variables. After eliminating the 180 singleton counties, we are left with 1,858 counties including both urban and rural counties in the dataset. Of these counties, 87 experienced a grocery tax change in the year 2012, 2013 or 2014. The other 1,771 counties experienced no grocery tax change during the study window (2009 – 2016); 1,250 of these counties never have a grocery tax, while 521 have a constant grocery tax during the study window. In terms of our entire panel of county-period observations, we only keep observations for which the grocery tax is constant within the three-year period. As a consequence, counties with grocery tax changes appear in exactly two periods each, which correspond to either 1) the three-year periods before and after 2012, 2) the three-year periods before and after 2013, or 3) the three-year periods before and after 2014. Counties with no tax grocery tax changes during our study window will appear in each of the six periods unless there is missing data for covariates in a county for some years. If our panel of counties with no tax changes is balanced, then we would have 11,148 observations (1,858 counties by 6). Of the 1,771 counties without tax changes, 1,319 of them appear in all six periods. In terms of total county-period observations, we have, 9,979 observations; 9,805 observations from our panel of counties that never experience a tax change and 174 observations from counties that do experience a tax change.

2.3.3 Statistical Analysis

We estimate the effects of grocery taxes on obesity and diabetes rates resulting from changes in county-level grocery taxes in the years 2012, 2013 and 2014. Our estimating procedure uses a county fixed effects linear regression model for county-level, age-adjusted health outcomes. The main explanatory variables of interest are 1) grocery taxes and 2) restaurant taxes. Our main parameter of interest describes how changes in the county-level total grocery sales tax relates to county-level health outcomes on average, after parsing out other observable variables and unobservable time-constant variables. Standard errors are clustered at the state level to account for arbitrary intra-cluster correlations between the error terms (Cameron & Miller, 2015). The regression model controls for county-level food access, demographics, socioeconomics, and risky health behaviors. The model also includes period fixed effects to control for period-specific time shocks common to all counties and county fixed effects to control for county-specific time-invariant factors.

In addition to the main analysis described above, we assess the robustness of our results to an alternative measure of food taxes—the ratio of the grocery tax to the restaurant tax. Because some counties have no restaurant tax, we add 0.01 to both the numerator and denominator. This adjustment has only a small influence on the ratio when then the restaurant tax is non-zero, which is the vast majority of observations. In all instances when the restaurant tax is zero, the grocery tax is also zero, which makes the ratio equal to one in such cases. To us this transformation is reasonable since it keeps intact the ratio when the denominator is non-zero and implies parity when the denominator is zero.

2.3.4 Calculation of Health Burden and Benefit-Cost Ratio

We calculate the aggregate U.S. health burden of grocery tax rates in the year 2016 based on direct costs of treating obesity and diabetes and the cost of mortalities. Direct costs are measured as the medical expenditures for treating people with obesity and for treating people with diabetes; the cost of mortalities is measured as the value of statistical life (VSL). Our calculated estimates of annual expenditures (direct costs only) for treating obesity and diabetes are $1,901 (American Diabetes Association, 2018) and $9,601 (Kim & Basu, 2016), respectively.

The first step to calculate these aggregate health burdens is to calculate the additional cases of people with obesity and diabetes at the county level. These counts are calculated based on multiplying the regression coefficients relating grocery taxes to obesity and diabetes by the grocery tax rate in a county, and then multiplying by the county population. These products deliver county-level estimates of the additional people with obesity and diabetes associated with an increase in the grocery tax rate. Next, we multiply these additional cases of people with obesity and diabetes by our estimates of annual medical expenditures on obesity/diabetes, which deliver estimates of health burdens aggregated at the county level. To recover a national aggregate estimate, we aggregate our county-level estimates across all counties with grocery taxes.

Next, we calculate benefit-cost ratios (BCRs) to summarize whether the health benefits associated with reducing the grocery tax by one percentage point are likely to exceed the cost of foregone tax revenues from the reduction. The numerator of the BCR captures the health benefits per person of reducing the grocery tax by one percentage point. This is calculated as the product of 1) the regression coefficient relating grocery taxes to a health outcome, 2) a one percentage point tax reduction, and 3) our calculated estimate for annual expenditures on treatment. The denominator is the cost per person, in terms of foregone tax revenue, of reducing grocery taxes by one percentage point. The average annual food at-home expenditure of U.S. households was $4,363 (USDA ERS, Food Expenditure Series), which translates to $1630.78 per person assuming average household size was 2.6 (U.S. Census Bureau 2016); thus, a one percentage point reduction implies $16.31 per person in foregone annual grocery tax revenue. If the benefit-cost ratio exceeds one, then the marginal benefit exceeds the marginal cost. We complete sensitivity analyses for both the health burden and benefit-cost ratio calculations using different estimates for the direct costs of treating obesity or diabetes for person with the condition.

We found variations among cost estimates; for example, a meta-analysis found that the annual medical expenditures attributable to treating obesity for a person with the condition varies from $1,239 to $2,582 (Kim & Basu, 2016). Therefore, in a sensitivity analysis we consider low and high estimates for these figures. These results are summarized in Table 2.4.

The health burden and BCR estimates do not take into account all of the potential adverse impacts of grocery taxes; for example, they do not consider the indirect costs of obesity or diabetes on quality of life or lost work productivity. We also note that obesity and diabetes are related; our estimates of health burden are based on the assumption that they are separate. It is possible that combining the health burden from obesity and diabetes produces an over-estimate. On the other hand, as we have already suggested, the grocery tax might be associated with other adverse effects for which we do not account (as another example, household food insecurity). Not accounting for these other mechanisms would lead to an under-estimate.

2.4 Results

2.4.1 A Map of Grocery Taxes

Figure 2 presents a map of the United States depicting county-level grocery taxes along with the top 12 most obese states identified in bold. This figure illustrates that grocery taxes are more prevalent in states with the highest obesity rates.

2.4.2 Health Outcomes by Taxing Status

Figure 3 plots the average rates of obesity and diabetes from 2009 through 2016 for both counties with and without a grocery tax (state, county, or both). Over this period, the national average obesity and diabetes rates increased significantly, especially after 2013. If we look at counties with and without grocery sales tax separately, the taxed counties are less healthy. Specifically, the average obesity and diabetes rates of counties with taxes are approximately 3 and 2.5 percentage points higher, respectively. Figure 3 clearly shows that counties with a grocery tax were consistently worse for both obesity and diabetes.

2.4.3 Regression Results on Obesity and Diabetes Rates

In Table 2.1 we present the summary statistics of the variables used in our analysis. The first three columns in Table 2.2 report the regression results of obesity rates on grocery sales tax rates under a base specification with year fixed effects, the base specification augmented with county fixed effects, and a third specification that also adds time-varying control variables. The results in columns 1, 2 and 3 are all similar with point estimates of 0.707, 0.606 and 0.588, respectively. Under all specifications, the grocery tax is positive and statistically significant at the 1% level. Our preferred specification reported in column 3, which includes the most comprehensive controls (county fixed effects plus a number of factors identified in the literature), suggests that a one-percentage point increase in the grocery tax rate is associated with a 0.588 percentage point increase in the obesity rate. In contrast, the coefficient on the restaurant tax is a negative value (-0.158), though it is statistically indistinguishable from zero.

The results in columns 4, 5 and 6 present the results for diabetes rates. The point estimates of the associations between grocery sales tax and the prevalence of diabetes are 0.400, 0.252 and 0.215, respectively. Under all specifications, the grocery tax is positive and statistically significant at the 5% level. Our preferred specification reported in column 6 suggests that a one-percentage point increase in the grocery tax rate is associated with a 0.215 percentage point increase in the diabetes rate. Again, the coefficient on the restaurant tax is negative (-0.127), though it is statistically indistinguishable from zero.

In Table 2.3 we assess the robustness of our results for both obesity and diabetes rates using an alternative food tax measure—the grocery tax to restaurant tax ratio is used as the main independent variable instead of the grocery tax. Results are consistent with those reported in Table 2.2 and are statistically significant at the 5% level for specifications including county fixed effects.

2.5 Discussion

We find evidence that grocery taxes have an adverse effect on both obesity and diabetes rates. Specifically, assuming our county fixed effects estimator is not biased by time-varying omitted variables, then a one percentage point increase in grocery taxes increases obesity and diabetes rates by 0.588 and 0.215 percentage points, respectively.

To put our results in context from a policy perspective, we calculate benefit-cost ratios (BCRs) to summarize whether the health benefits associated with reducing the grocery tax by one percentage point are likely to exceed the cost of foregone tax revenues from their reduction. Table 2.4 reports the ratios and Appendix 2 shows the detailed steps to obtain the ratios.

Our preferred estimates of annual expenditures (direct costs only) for treating obesity and diabetes are $1,901 (Association, 2018). We also considered variations among cost estimates; for example, a meta-analysis found that the annual medical expenditures attributable to treating obesity for a person with the condition varies from $1,239 to $2,582 (Kornfield, Huang, Vera, & Emery, 2015). Therefore, in a sensitivity analysis we consider low and high estimates for these figures, these results are also summarized in Table 2.4.

The top portion of Table 2.4 summarizes our estimates of health burdens associated with grocery taxes. The aggregate U.S. health burden of grocery taxes in the year 2016 due to medical expenditures on obesity and diabetes is calculated to be $5.86 billion (95% C.I. is $1.81 billion to $10.30 billion).

The bottom portion of Table 2.4 summarizes the BCRs. The calculated BCRs for obesity and diabetes using our preferred estimates of medical expenditures are 0.666 (95%

C.I. is 0.324 to 1.008) and 1.23 (95% C.I. is 0.163 to 2.329), respectively. The BCR of these two factors combined is 1.896. Similar to health burden analysis we also summarize the results of our sensitivity analysis for the BCR. Based on the sensitivity analysis and taking into account a range based on sampling variability of our regression output, our lowest estimate of the combined BCR is 1.289 and the highest is 2.601.

Many states and local municipalities have recently considered changing their grocery tax, such as West Virginia in 2017 (proposing an 8% new tax) and Utah in 2018 (proposing removing grocery taxes). States and counties that tax food need to understand that this policy is associated with adverse health outcomes. Our preliminary results suggest that officials in states that tax groceries should take a closer look at ways to lessen the potential burden of such taxes as a way to improve health outcomes for the community. Decreasing the grocery tax would reduce tax revenue, and government officials would need to look at alternative revenue generating options if it lowered grocery taxes. Another option to off-set the potential adverse effects of grocery taxes would be a tax credit, though it would have to be sufficiently large to off-set the tax. Further, it is not clear how a lump-sum tax credit would affect the marginal responses to taxes we estimate in our analysis.

Furthermore, we find that the ratio of the grocery tax to the restaurant sales tax is also positively associated with adverse health outcomes. In particular, a doubling of this tax ratio is found to increase obesity and obesity rates by an average of 0.773 and 0.21 percentage point, respectively. This has policy implications that should be considered especially by states and counties that are either considering levying a grocery tax or eliminating it. It is possible the adverse health outcomes could be lessened if this relative tax ratio were lowered in states with grocery taxes. For example, one option would be to consider a revenue neutral simultaneous decrease in the grocery tax and increase in the restaurant (particularly fast-food establishments) tax as a way to lessen adverse health outcomes.

2.6 Conclusion

Our county-level depiction of grocery taxes in the United States reflects the first comprehensive dataset on state and county-level grocery taxes and shows a clear spatial correlation between grocery taxes and nutrition-related health outcomes. The regression results, which are based on data county fixed effects estimator, shows a strong statistical relationship between grocery taxes and both obesity and diabetes. Several states and counties are actively considering the levying or removal of grocery taxes. Our study design is only one component of the costs (or benefits) of a grocery tax; nonetheless, the results are thought-provoking and suggest the possibility of a large health burden from grocery taxes and a benefit-cost ratio greater than one corresponding to reductions in the grocery tax. Based on our findings using a novel panel dataset combining comprehensive county-level grocery tax data with county-level health outcome measures, we recommend both researchers and policy makers give further consideration to the removal of grocery taxes a possible mechanism to improve health outcomes. Meanwhile, more evidence would be required to pin down a mechanism through which grocery taxes may affect health outcomes, for example, more evidence on the potential link through fruit and vegetable consumption choices.

Tables and Figures for Chapter 2

Table 2.1 Summary Statistics of the Variables Used

	Unit	Mean	S.D.	Min	Max
Health Outcomes					
Obesity rate (age-adjusted diagnosed)	%	30.419	4.84	10.7	47.6
Diabetes rate (age-adjusted diagnosed)	%	9.305	2.122	3.4	19.4
Tax Variables					
Total grocery sales tax rate	%	1.142	2.084	0.000	9.000
Total restaurant sales tax rate	%	6.036	1.686	0.000	9.933
(1+Grocery Tax)/(1+Restaurant Tax)		0.340	0.328	0.093	1.000
Socioeconomic Variables					
Grocery stores per capita	1/1000	0.221	0.14	0.017	1.701
Fast-food restaurants per capita	1/1000	0.616	0.198	0.044	1.964
Full-service restaurants per capita	1/1000	0.781	0.414	0.042	3.995
Cost per meal	$	2.775	0.306	1.956	5.113
White		0.857	0.145	0.093	0.991
Black		0.087	0.133	0.000	0.85
Female		0.502	0.016	0.366	0.553
Hispanic		0.085	0.12	0.004	0.957
Income per capita	1,000$	39.014	10.899	18.768	199.241
Employees' share of total population		0.527	0.144	0.219	3.213
Share of bachelor's degree or higher of the 25-year- and-over population	%	21.983	9.291	5.967	72.867
Smoking rate	%	20.599	5.096	3.167	42.160
Drinking rate	%	15.331	4.947	1.6	35.933
Drug arrest rate		0.005	0.04	0.000	1.893
DUI		0.006	0.034	0.000	1.886
Counties: 1,858; Obs.: 9,779					

Table 2.2 Regression Results of Health Outcomes on Respective Grocery and Restaurant Sales Taxes

	Dependent variable: Obesity Prevalence (unit: %, mean: 30.419, S.D.: 4.840) Diabetes Prevalence (unit: %, mean: 9.305, S.D.: 2.122)					
	Obesity			Diabetes		
	1	2	3	4	5	6
Total Grocery Sales Tax Rate (%)	0.707*** (0.203)	0.636*** (0.153)	0.588*** (0.154)	0.400*** (0.118)	0.252** (0.108)	0.215** (0.098)
Total Restaurant Sales Tax Rate (%)	0.369* (0.194)	-0.147 (0.139)	-0.158 (0.127)	0.290*** (0.096)	-0.134 (0.111)	-0.127 (0.101)
Observations	9,779	9,779	9,779	9,779	9,779	9,779
R-squared	0.129	0.909	0.910	0.227	0.927	0.928
Period FE (m_period = 6)	Y	Y	Y	Y	Y	Y
County FE (m_county = 1,858)			Y			Y
Controls		Y	Y		Y	Y

Note: The results are presented in six columns from one to six. Standard errors are in parentheses. *, **, and *** denote statistically significance at the 10%, 5%, and 1% levels, respectively.

Table 2.3 Regression Results of Health Outcomes on Grocery to Restaurant Sales Taxes Ratio

Dependent variable: Obesity Prevalence (unit: %, mean: 30.419, S.D.: 4.840)
Diabetes Prevalence (unit: %, mean: 9.305, S.D.: 2.122)

	Obesity			Diabetes		
	1	2	3	4	5	6
Tax Ratio	2.639 (1.721)	5.144*** (1.263)	4.760*** (1.169)	1.498 (1.026)	1.603*** (0.594)	1.296** (0.571)
Observations	9,779	9,779	9,779	9,779	9,779	9,779
R-squared	0.036	0.909	0.910	0.028	0.927	0.928
Period FE (m_period = 6)	Y	Y	Y	Y	Y	Y
County FE (m_county = 1,858)			Y			Y
Controls		Y	Y		Y	Y

Note: The results are presented in six columns from one to six. Standard errors are in parentheses. *, **, and *** denote statistically significance at the 10%, 5%, and 1% levels, respectively. We calculate Tax Ratio as:
(1+Grocery Tax) / (1+Restaurant Tax).

Table 2.4 Summary of Aggregate U.S. Health Burdens and Benefit-Cost Ratios with Sensitivity Analysis

	1	2	3
	Obesity	Diabetes	Total
Aggregate U.S. health burdens (billions of USD)			
Low estimate	1.34	2.64	3.98
	(0.65, 2.03)	(0.56, 5.00)	(1.21, 7.03)
Preferred estimate	2.06	3.8	5.86
	(1.00, 3.11)	(0.81, 7.19)	(1.81, 10.30)
High Estimate	2.79	5.24	8.03
	(1.36, 4.23)	(1.11, 9.92)	(2.47, 14.15)
Benefit-cost ratios (health benefits / cost of reduced tax revenue)			
Low estimate	0.434	0.855	1.289
	(0.211, 0.657)	(0.091, 1.619)	(0.302, 2.276)
Preferred estimate	0.666	1.23	1.896
	(0.324, 1.008)	(0.163, 2.329)	(0.487, 3.337)
High Estimate	0.905	1.696	2.601
	(0.440, 1.369)	(0.181, 3.212)	(0.621, 4.581)

Note: The results are presented in three columns from one to three. In parentheses we report the 95% confidence interval derived from the sampling variability of the regression coefficients reported in columns (3) and (6) of Table 2.2.

<table>
<tr><th>Year</th><th colspan="3">Period</th></tr>
<tr><td>2009</td><td rowspan="3">Period 1
Counties with a tax change: 36 Counties w/o tax change: 1,444</td><td></td><td rowspan="2"></td></tr>
<tr><td>2010</td><td rowspan="3">Period 2
Counties with a tax change: 43 Counties w/o tax change: 1,673</td></tr>
<tr><td>2011</td><td rowspan="3">Period 3
Counties with a tax change: 8 Counties w/o tax change: 1,695</td></tr>
<tr><td>2012</td><td rowspan="3">Period 4
Counties with a tax change: 36 Counties w/o tax change: 1,581</td></tr>
<tr><td>2013</td><td rowspan="3">Period 5
Counties with a tax change: 43 Counties w/o tax change: 1,599</td></tr>
<tr><td>2014</td><td rowspan="3">Period 6
Counties with a tax change: 8 Counties w/o tax change: 1,613</td></tr>
<tr><td>2015</td><td rowspan="2"></td></tr>
<tr><td>2016</td><td></td></tr>
</table>

Figure 2.1 Study Design

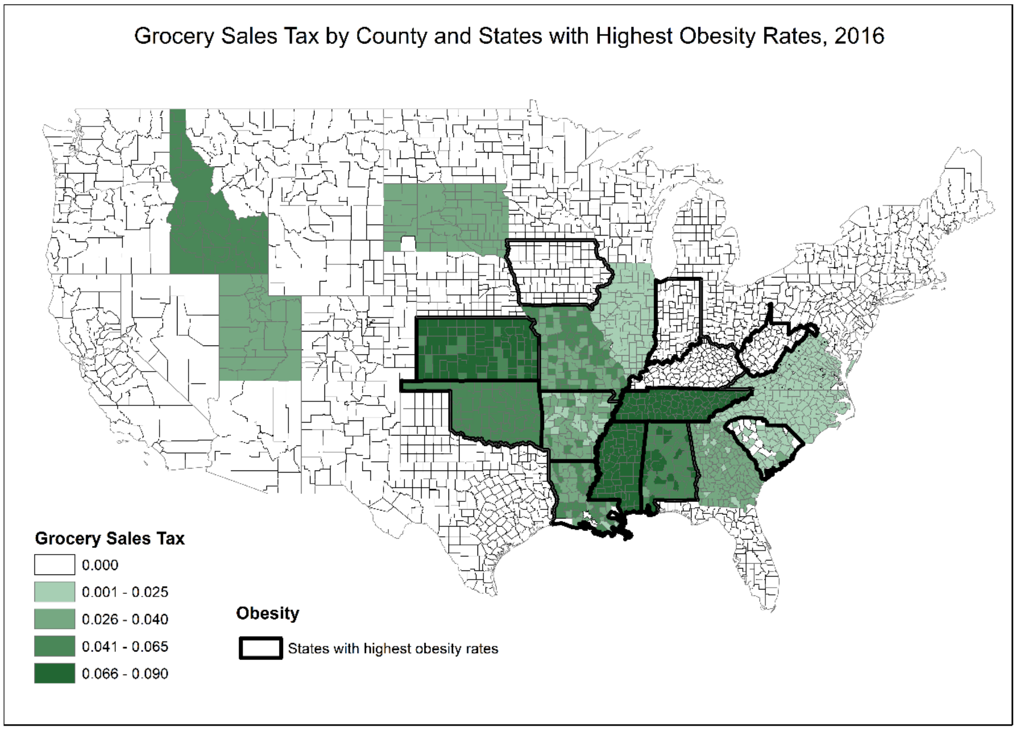


Figure 2.2 U.S. Grocery Sales Tax Distribution for the Year of 2016

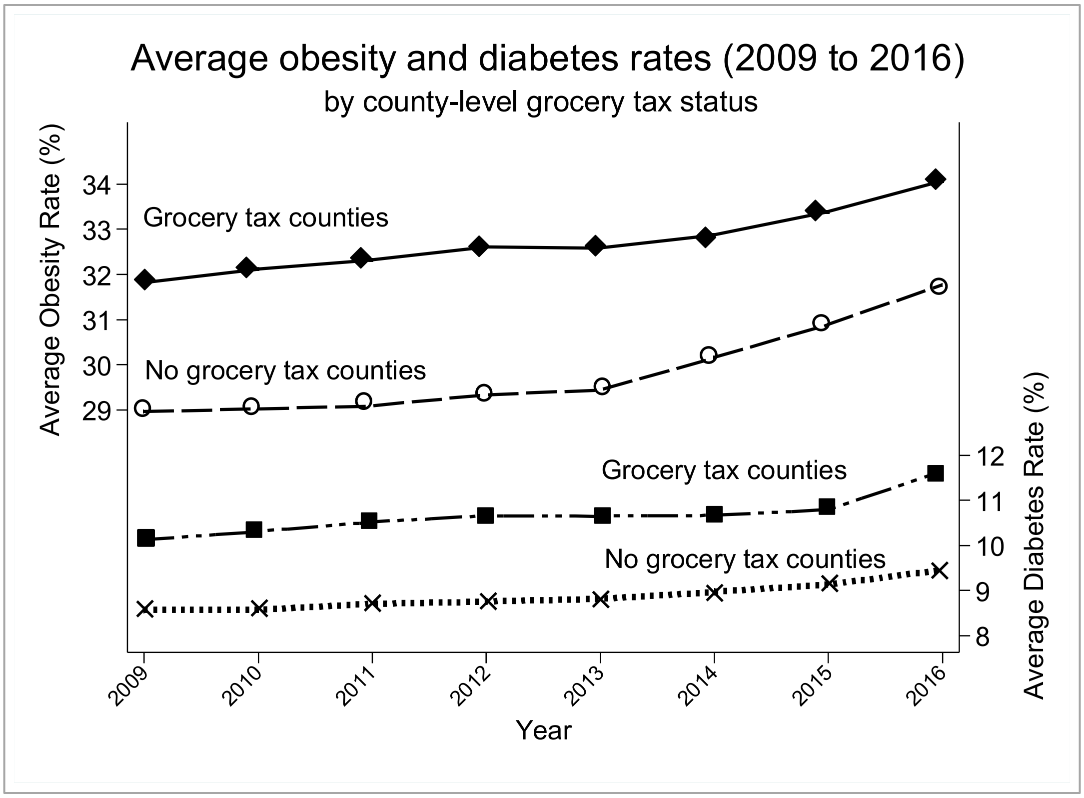


Figure 2.3 Average Obesity and Diabetes Rates by Grocery Sales Taxes
Sources: Centers for Disease Control and Prevention and authors' own data collection.

CHAPTER 3. CAUSAL IMPACT OF GROCERY SALES TAXES ON WEIGHT OUTCOME: EVIDENCE FROM THE PSID PANEL

3.1 Introduction

Grocery sales taxes exist in 16 states in the U.S., but their causal impacts on obesity remain unknown. Recently, there has been a trend of exempting or decreasing grocery sales tax rates in many states and counties to achieve more progressive tax systems. Although the major purpose of decreasing grocery sales taxes is not to prevent obesity, such food tax policy may unexpectedly affect people's food choice and subsequent body weight.

As a matter of fact, taxing food is not a novel policy instrument in local governments' tool kit to control the increasing food-related health risks. Like any other food and beverage taxes, grocery sales taxes affect obesity through guiding people's food consumption behaviour (Powell & Chriqui, 2011). If grocery sales tax rates decrease, the relative price of grocery food to restaurant food is lower. With people switching to grocery food due to this substitution effect, healthier diets likely follow, and the obesity issue is therefore mitigated. Unlike other food and beverage taxes which aims on limited specific types of items, grocery sales taxes have a larger tax base so that the decline of grocery taxes is expected to have a larger impact on reducing obesity. In other words, if the taxes increase, it can in turn aggravate prevalence of obesity and diabetes (L. Wang, Zheng, Buck, Dong, & Kaiser, 2021).

It seems that the reduction of grocery sales taxes can effectively tackle the obesity issue according to the economic intuition above. In reality, the health impact of the taxes may not be as noticeable as expected. First, food consumption may not be as sensitive as the price changes. As a review summarizes, price elasticities of most groceries are less than one: the price elasticities of fruits and vegetables are -0.70 and -0.59, which indicates that groceries are inelastic (Andreyeva, Long, & Brownell, 2010). Second, it is pointed out by some researchers that taxes are not salient to some consumers (Chetty, Looney, & Kroft, 2009; Zheng, McLaughlin, & Kaiser, 2012). If consumers are not able to realize tax changes, taxes then would not be effective in changing consumers' grocery consumption, let alone improving diets and affecting body weight outcomes. Third, it takes tax policies a long time to affect consumers' body weight (Goldman, Lakdawalla, & Zheng, 2009). If the study period is too short for consumers' health to be affected, significant health impacts of grocery sales taxes cannot be found. Last but not least, genetics, gender, race and income contributed to heterogeneous health impacts, and some researchers found black, female and low-income populations are more sensitive to food taxes (Goryakin, Monsivais, & Suhrcke, 2017; Yaniv, Rosin, & Tobol, 2009). As a result, if the impacts are estimated without considering those demographic and income variables, the estimated impacts may be insignificant.

Considering the heterogeneous effects, the lower-socioeconomic status (SES) population is expected to suffer the most from incretion of grocery taxes if no other food subsidies are implemented. The substitution effect is expected to be more significant for lower-SES population, leading to more severe obesity problem with the increase of grocery sales taxes. As grocery sales taxes become relatively expensive due to the tax addition, the primary option to shift to is fast restaurant food (French, 2003) because fast restaurant food is more easily accessible (Powell et al., 2007; Rydell et al., 2008) and affordable (Khan et al., 2012) than groceries and other restaurant food for the lower-SES population. But there are large health costs of consuming fast restaurant food from a long-term perspective. It can directly and indirectly cause obesity, diabetes, and other chronic cardiovascular diseases if fast food is regularly consumed (Chou et al., 2004). However, Supplemental Nutrition Assistance Program (SNAP) provides a protection shelter for its participants to offset the tax impact (Zheng et al., 2021) since the tax is exempted for the grocery consumption covered by SNAP. Therefore, the lower-SES population is likely to suffer the most from grocery taxes if without food subsidies. However, taking SNAP into consideration, we are not certain which income-category family suffer the most.

In this essay, therefore, we aim to demonstrate whether grocery sales taxes make significant impacts on body weight outcomes. Through merging the county-level grocery tax data with the individual longitudinal data from Panel Study Income Dynamics (PSID), we explore a fixed effect model to estimate the causal impact of grocery sales taxes on family food expenditures and individual BMI. Additionally, we conduct the analysis of heterogeneous effects by income category and obesity level to identify the policy impacts on different individuals and families. We find that a ten point-percentage increase in grocery sales rate leads to a rise of BMI by 0.61 (which roughly translates to a body weight gain of 1.68kg). The results are more significant for the overweight population whose BMI is greater than 25 but smaller than 30. We do not find significant results towards different income populations.

There are two main contributions of this essay. This is the first paper, to my knowledge, trying to estimate the causal impact of grocery sales taxes on people's body weight outcome. Second, based on the empirical evidence, we distinguish the policy differences between grocery sales taxes and sin taxes and provide policy suggestions to local governments.

The rest of the essay is arranged in the following way. In the second section, we review studies on all types of food and beverage taxes and summarize the impact of the taxes on corresponding food and beverage consumption and obesity. In the third section, we introduce the econometric model and the data. We then present the empirical results in the fourth section. In the last section, we conclude and discuss the policy implications of the study.

3.2 Literature Review

The development of how food and beverage taxes affect body weight outcome are shown in Figure 3.1. There are two major food and beverage taxes, grocery sales taxes and sin taxes. Sin taxes, including fat taxes and soda taxes, have been investigated in numerous studies, while the literature on grocery sales taxes is scarce. These two taxes affect body weight outcome through similar paths. Both taxes shift prices and affect consumption of food and beverages, ultimately affecting body weight (Powell & Chaloupka, 2009).

3.2.1 Grocery Sales Taxes

There is little literature on how grocery sales taxes affect food and beverage consumption and obesity, probably because of the lack of a ready dataset recording the county-level grocery taxes and tax changes. To our knowledge, there is only one study that directly reported how grocery tax changes in Kansas reshaped consumer grocery demand, and finally concluded that food sales are sensitive to grocery sales tax changes (Srithongrung, 2017). In this study, only one state is considered, and the time period of tax change being investigated was quite short, from 2012 to 2013. Recently, a few researchers have exploited nation-wide county-level grocery tax variations and published a series of results of grocery tax impacts. By employing newly collected grocery tax data, they found that grocery sales taxes can induce people to eat out (Zheng, Dong, Burney, & Kaiser, 2019a), aggravate food insecurity among the Non-SNAP lower-SES population (N. L. Wilson, Zheng, Burney, & Kaiser, 2016a), and promote obesity, which burdens public health costs (L. Wang et al., 2021). Nevertheless, these three studies either employ cross sectional individual survey data (N. L. Wilson, Zheng, Burney, & Kaiser, 2016b; Zheng et al., 2019a) or county-level aggregate data (L. Wang et al., 2021). There have been no studies that identify the causal impact of grocery sales taxes by employing individual panel data. Our interest using PSID data to tackle this issue stems partly from this observation.

3.2.2 Sin Taxes of Food and Beverages

Although there is not a federal food and beverage tax in the U.S., levels of local governments have levied food and beverage taxes to collect extra tax revenue since the end of the Great Depression (Creighton, 2010). Sin taxes are usually levied on addictive products, such as tobacco and alcohol, to overcome the health externalities. Nowadays, most food and beverage taxes, except grocery sales taxes, have been adopted as a type of "sin tax" by local governments (Allcott, Lockwood, & Taubinsky, 2019). The principle behind the "sin tax" is that some food and beverages, usually calorie-condensed, are unhealthy, and consuming such food becomes a sin. The purpose of the "sin taxes" is to control the consumption of unhealthy food and/or beverages, and therefore to prevent negative health outcomes, like obesity, and reduce overwhelming health costs. As "sin taxes" are levied in more and more places, increasing studies are promoted to examine the effects of food and beverage taxes on the food and beverage consumption, as well as weight outcomes.

One of the most well-known “sin taxes” is the “fat tax", which was first introduced by Denmark in 2011 but was quickly abandoned in 2012 (Bødker, Pisinger, Toft, & Jørgensen, 2015). The Demark “fax tax” policy is a systematic tax reform imposing taxes on food that contains more saturated fat. The tax largely increased the prices of food such as butter, butter blends, margarine and oil. As a result, the estimated consumption of fat sharply shrunk by an estimated 41.8g/week (Jensen & Smed, 2013). However, since the implemented period is short, no significant health impacts were found from the Danish “fat tax” policy.

Inspired by the Danish “fat tax”, researchers from other European Union countries estimated demand system models to calculate the price, consumption and health effects of a hypothesized “fat tax”. For example, employing Norway consumer expenditure surveys of statistics, researchers found people in Norway limited their purchases of the taxed items, resulting in a small body weight change (Gustavsen & Rickertsen, 2013). In contrast, through a simulation, French researchers concluded that the “fat taxes” have few impacts on building healthy diets for French households because of the inelasticity of fat intake in France (Allais, Bertail, & Nichèle, 2020). Since the taxed items are different from country to country, whether fat taxes are effective is debatable depending on different studies. To conclude, most researchers found that simulated “fat taxes” can reduce the consumption of the taxed food, but the health effect is expected to be small because of the inelasticity of food consumption (Abdus & Cawley, 2008; Tiffin & Arnoult, 2011). Researchers agreed that a carefully designed food tax, usually a “fat tax” can modify people’s eating habits. Also, those meaningful changes in food consumption can reduce cardiovascular disease and prevent deaths. However, the impacts are modest and some are even insignificant

(Mhurchu et al., 2015; Mytton, Gray, Rayner, & Rutter, 2007). So far, there has been no empirical evidence employing real survey data about the impact of fat taxes on improving health, including whether fat taxes can reduce obesity and how much the impact could be.

Another typical “sin tax” that is frequently adopted in the U.S. is the soda tax. There is more empirical evidence of this tax because soda taxes have been adopted in over two-thirds of all states and some cities. Some studies directly estimate how the soda tax affects body weight outcome in reduced-form equations using self-reported body weight data from national cross-sectional surveys. For example, by employing the Behavioral Risk Factor Surveillance System (BRFSS) survey data, a group of researchers found that state-level soda taxes have a significant but small impact on weight loss for adults (J. M. Fletcher, D. Frisvold, & N. Tefft, 2010a). The weight-reduction impact disappears when they apply similar methods investigating the samples of children and adolescents (J. M. Fletcher, D. Frisvold, & N. Tefft, 2010b) because those populations can easily substitute other high-calorie drinks (Fletcher et al., 2010c). Other researchers employed scanner data to estimate demand systems, and through calibrating the tax with the demand system, they estimated how soda taxes reduced soda price and consumption (Zheng & Kaiser, 2008). Based on the consumption reduction, they calculated the declined calorie intake and then predict the transmission into weight loss (Dharmasena & Capps Jr, 2012; Zhen, Finkelstein, Nonnemaker, Karns, & Todd, 2014). Most of these studies confirmed the price and consumption effect of soda taxes (Paarlberg, Mozaffarian, & Micha, 2017; Teng et al., 2019). The predicted weight-loss impact is usually larger than the direct estimation using reduced form, even when controlling the substitution to non-taxed beverages (Finkelstein et al., 2013).

After reviewing the literature, we find the causal impact of grocery taxes on health outcomes is still not clear with empirical evidence, and there has been no study investigating this impact. The goal of our research is to fill this gap.

3.3 Econometric Model

We use a fixed-effect model to estimate the causal impact of how grocery sales taxes affect individual body weight outcome (BMI) and family food expenditures. For the impact on individual BMI, the econometric identification can be expressed using the equation:

$$BMI_{ict} = \beta_0 + \beta_1 GroceryTax_{ct} + \beta_2 RestaurantTax_{ct} + \boldsymbol{\theta Z_{it}} + \sigma_c + \psi_t + \lambda_c t + e_{ict} \quad (3.8),$$

where BMI_{ict} is the body mass index of individual i residented at county c in year t. $GroceryTax_{ct}$ and $RestaurantTax_{ct}$ are the main independent variables representing total grocery sales tax rate and total restaurant sales rate of county c in year t. $\boldsymbol{Z_{it}}$ is a vector including individual-level demographic characteristics, namely age, gender, race, marital status, whether has kids, education years, types of working industry, family income, participation in SNAP, time spent in housework, cigarette smoking habit, alcohol drinking habit and frequency of physical activity. σ_c is the county-fixed effect controlling for the time-invariant unobserved county variables, while ψ_t is the year-fixed effect controlling for the annual time shock. $\lambda_c t$ represents a time trend at county-level, and e_{it} is an error term. In order to obtain correct and robust standard errors, standard errors are clustered at county-level.

Our main parameter, β_1, implies how changes of the county-level total grocery sales tax can affect individual BMI on average holding other variables constant. If β_1 is significantly positive, it shows that imposing grocery sales tax induces body-weight gain, while if the parameter is significantly negative, it shows that grocery sales taxes can improve obesity.

Although grocery sales tax is generally regarded exogenous to the local health status, we still add covariates, year-fixed effects, county-fixed effects and time trend by counties to identify a more accurate estimator. Aside from covariate individual demographics, there are unobserved factors that are associated with both grocery taxes and weight outcomes. Year-fixed effects are added to account for the shocks that take place in specific years. We also fix county effects in the regression to control for the variations across counties. By adding a year trend by county, we expect to avoid spurious regression because the average obesity is increasing during the nine years as shown in Chapter 2. In a nutshell, these selections on the observable and unobservable factors mitigate the potential omitted variable issues and unobserved endogeneity problems, providing a feasible way to identify unbiased health impacts of the grocery sales taxes on body weight outcomes.

We also clustered the standard error of the estimator at county level (which is at the policy implementation level) to obtain an accurate statistical inference (Cameron & Miller, 2015). There is a high possibility that the residuals are correlated within counties. For example, the unexplained part of the individual body weight is correlated with other individual's body weights in the same county for they may have similar environment and culture. Thus, we employ clustered standard error instead of classic standard error to avoid the overstated estimator precision.

3.4 Data

We obtain the individual-level data and family-level data from the Panel Study of Income Dynamics (PSID). The PSID is a longitudinal family survey conducted by University of Michigan. It mainly asks questions about income and expenditure of each family and family members. Further, the survey also contains food and health related questions and self-reported individual weight and height (Sastry, Fomby, & McGonagle, 2018). The entire PSID dataset contains more than 18,000 individuals in over 5,000 households. During our research period from 2006 to 2017, the survey is conducted six times, namely in 2007, 2009, 2011, 2013, 2015 and 2017, and we only include adult samples in our research. The weight outcome variables are separated according to head and wife from PSID Main Family Data. Then the weight outcome data is merged with the control variables which are obtained from the PSID Individual Data. At last, we merge the PSID data with the grocery sales tax data based on the county-level FIPS code. The FIPS codes of PSID families are obtained from the PSID restricted Geographic Information data. The grocery tax data is uniquely assembled, including state-level grocery taxes and county-level grocery taxes from 2006 to 2017. The state-level grocery data is obtained from Bridging the Gap, while the county-level grocery taxes are collected from state Departments of Revenue and Tax-Rates.org. Totally, 3,101 counties are covered in the tax dataset.

In our final merged dataset, there are 19,432 individuals from 13,949 families. In particular, there are 9,145 men and 10,287 women who are resident in 1,468 counties from 51 states. In total, the dataset includes 78,872 observations. To merge with our county-level grocery sales tax data, we only keep individuals and families who are residents in counties in the merged dataset and delete the individuals and families who are resident in cities. We also delete the observations who refuse to report/don't know their weights and heights. We calculate the BMI for each observation using the formular as:

$$BMI = \frac{Weight}{Height^2} \quad (3.9),$$

where the unit of the weight is kilogram, while the unit of the height is meter. Table 3.1 presents the summary statistics (mean) of main variables.

3.5 Results

3.5.1 Main Results

Table 3.2 reports the impacts of grocery sales taxes on body weight outcomes. Based on Equation (3.8), the result from column (1) is estimated without any controlled variables while column (2) result is estimated with individual-level covariates. The dependent variables change to body weight measured by kilogram is shown in the results from the last two columns. Column (3) is estimated without individual-level covariates, while column (4) is estimated with the same covariates as column (2). All the results are estimated with county-fixed effects, year-fixed effects, and county by year trend. Comparing the first two columns, the sign and magnitude of estimates are similar indicating that the impact of grocery sales taxes on BMI is relatively stable. Although the estimate from column (1) is not significant, the standard error is relatively small. With the individual demographic controlled, the estimate become significant at 10% significance level. The estimate of grocery tax on BMI is 0.061, implying that if the grocery sales tax increases by one percentage point, individual BMI on average increases by 0.061, holding other factors constant. If we use body weight to measure the weight gain caused by grocery taxes, a one percentage point increase in grocery taxes leads to a gain of 0.168 kg weight for an average individual. To sum up, the estimates of interest are consistent with what we anticipate, demonstrating that increased grocery sales taxes cause individual to gain weight.

3.5.2 Heterogeneous Impacts

We apply the same estimation method among the population with different income, but we do not find grocery sales taxes have significant heterogeneous impacts. However, we find the taxes have more significant impact on the overweight population. The overweight population contains individuals whose BMI is less than (<) 30 but greater than (>=) 25 (Flegal, Carroll, Kuczmarski, & Johnson, 1998). All the estimates of this sampled population are significant at 5% significance level which are stronger than the entire sampled population (Table 3.3), implicating that this population is more likely to be affected by the grocery tax changes. In addition, if we only select individuals from the taxed states and counties, the magnitude of the tax impact becomes larger (Table 3.4), but the significance does not change.

3.6 Conclusion and Discussion

In this article, we exam the causal impacts of grocery sales tax on body weight outcomes and find significant results. It is estimated that an additional ten percentage point increase in grocery sales rate leads to the rise of BMI by 0.61 in our preferred model. Using body weight measured by kilogram, this translates to a 1.68 kg increase in body weight on average. If we only focus on families and individuals from the taxed states and counties, the impacts are greater. The impact on BMI increased to 0.91 and that on body weight increased to 2.69 kg, and the estimates are more significant for the overweight population. Given the high medical costs of obesity, whether it is worthy to levy sales taxes on grocery became a challenging question for those states and counties with grocery sale taxes.

It is essential to compare grocery sales taxes and sin taxes. On one hand, both taxes are raised by local governments instead of federal governments, thus the two types of taxes have local and limited impact on the residents. Both taxes are food taxes, which affect obesity through changing the relative prices of food and/or beverage. However, the two taxes are different in root. Sin taxes are born to tackle the negative health outcomes by controlling certain food and/or beverage consumption; while grocery taxes are levied on all groceries, aiming to generate more tax revenue. Sin taxes are levied on unhealthy groceries like soda and sweets, while grocery sales taxes are levied on grocery food (food at home), which is considered healthier as compared to restaurant food (food away from home). Thus, if the government would like to employ tax instruments to offset the medical costs of obesity, it should impose sin taxes but exempt groceries. It is interesting to compare the impacts of levying soda taxes and exempting grocery sales taxes on the U.S. adult since the two food and beverage taxes have similar mechanism affecting obesity. According to the most optimistic estimation in literature, imposing a 20% soda tax reduces an average individual's body weight by 0.7-1.2 kg every year (Dharmasena & Capps Jr, 2012), while a similar amount of body weight reduction can also be achieved with decreasing grocery sales taxes by 4.2-7.1 point percentage.

Since our dataset does not include municipal tax rates, ignoring municipal other level grocery tax rates may cause our estimates biased due to the omitted variable bias (OVB). If increasing municipal tax rates can also cause obesity, and municipal tax rates are positively related with county grocery sales tax rates. Then our estimates are overestimated. Additionally, the investigation does not consider the tax rebates. However, there are only three states that allow refunding grocery sales taxes to low-income, disabled, old and pregnant populations. We are not able to obtain information about these populations. Omitting the refunding populations can also slightly biased our estimates.

While this is the first study, to the best of our knowledge, to empirically examine the causal impacts of grocery sales tax on body weight gain using individual longitudinal data, we recognize that it is only a first step towards full identification. To get a full picture of the health impacts of grocery sales tax, it is necessary to test the causal link on how grocery sales taxes affect food consumption patterns, followed by how the changes in food consumption patterns affect consumers' health. As such, scanner data that can track individual food consumption behavior and health outcomes could be helpful for fully identifying the impacts of grocery sales tax.

Tables and Figures for Chapter 3

Table 3.1 Summary Statistics (Mean)

Variable	Unit	All	Men	Women
BMI	NA	27.494	27.703	27.323
Weight	Kg	82.150	90.553	75.281
Grocery Tax	%	1.309	1.27	1.34
Restaurant Tax	%	6.466	6.433	6.493
Age	Years	45.238	45.307	45.181
White	%	0.502	0.563	0.452
Hispanic	%	0.027	0.029	0.247
Black	%	0.177	0.183	0.173
Married	%	0.673	0.758	0.604
Have Kid	%	0.445	0.413	0.471
Family Income	$	78042.63	83954.6	73216.3
Education Years	Years	15.151	15.208	15.104
SNAP	%	0.151	0.112	0.183
HouseWork	Hours per Week	11.885	8.183	14.92
Cigrettes Per Day	Number	3.788	5.028	2.77
Drinking Alcohol	%	0.614	0.685	0.555
Physical Activity	Hours per Week	2.149	2.43	1.92
Numbers of Observations		78,872	35,449	43,423
N		19,432	9,145	10,287

Table 3.2 Impacts of Grocery Sales Taxes on BMI and Body Weight

	(1)	(2)	(3)	(4)
VARIABLES	BMI	BMI	Weight	Weight
Grocery Tax	0.052	0.061*	0.189*	0.168*
	(0.033)	(0.032)	(0.102)	(0.095)
Restaurant Tax	-0.051	-0.076*	0.001	-0.157
	(0.044)	(0.043)	(0.136)	(0.130)
Controls	N	Y	N	Y
County FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Time Trend	Y	Y	Y	Y
Observations	78,786	77,769	78,786	77,769
R-squared	0.142	0.164	0.151	0.27

Note: The estimated results are shown in four columns from column (1) to column (4). Column (1) and (3) do not contain control variables. The dependent variable in column (1) and (2) are BMI, and the dependent variable in column (3) and (4) are Weight by kilogram. Standard errors are clustered at county-level in paratheses; * denotes 10% significance.

Table 3.3 Impacts of Grocery Sales Taxes on Weight Outcomes for the Over -Weight

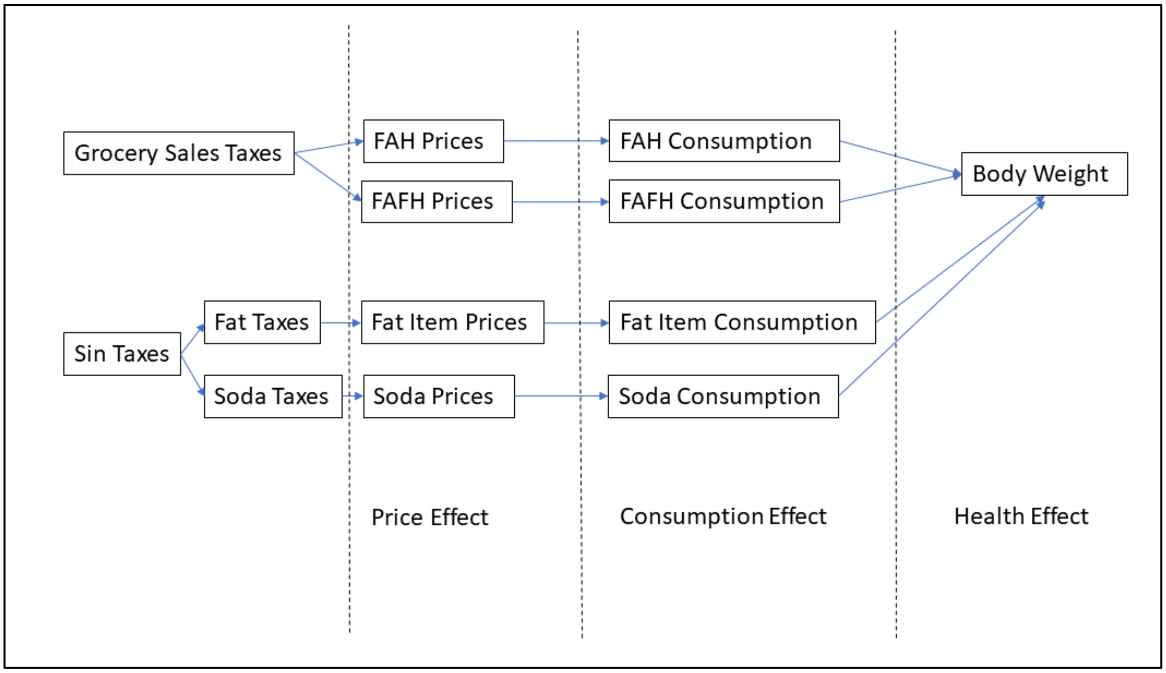
VARIABLES	(1) BMI	(2) BMI	(3) Weight	(4) Weight
Grocery Tax	0.048**	0.051**	0.143**	0.150**
	(0.021)	(0.021)	(0.067)	(0.067)
Restaurant Tax	-0.002	-0.004	-0.035	-0.04
	(0.026)	(0.026)	(0.079)	(0.078)
Controls	N	Y	N	Y
County FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Time Trend	Y	Y	Y	Y
Observations	26,598	26,230	26,598	26,230
R-squared	0.142	0.148	0.868	0.868

Note: The estimated results are shown in four columns from column (1) to column (4). Column (1) and (3) do not contain control variables. The dependent variable in column (1) and (2) are BMI, and the dependent variable in column (3) and (4) are Weight by kilogram. Standard errors are clustered at county-level in paratheses; ** denotes 5% significance.

Table 3.4 Impacts of Grocery Sales Taxes on Weight Outcomes (Taxed County Sample)

VARIABLES	(1) BMI	(2) BMI	(3) Weight	(4) Weight
Grocery Tax	0.079	0.091*	0.241*	0.269*
	(0.053)	(0.054)	(0.145)	(0.144)
Restaurant Tax	-0.075	-0.091	-0.192	-0.245
	(0.084)	(0.083)	(0.226)	(0.224)
Controls	N	Y	N	Y
County FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Time Trend	Y	Y	Y	Y
Observations	27,460	27,063	27,460	27,063
R-squared	0.166	0.184	0.319	0.334

Note: The estimated results are shown in four columns from column (1) to column (4). Column (1) and (3) do not contain control variables. The dependent variable in column (1) and (2) are BMI, and the dependent variable in column (3) and (4) are Weight by kilogram. Standard errors are clustered at county-level in paratheses; * denotes 10% significance.



Notes: FAH represents food at home, while FAFH represents food away from home.

Figure 3.1 Literature of How Food Taxes Affect Body Weight Outcomes

CHAPTER 4. THE DIVERSITY OF GROCERY SALES TAX RATES IN THE U.S.: EVIDENCE FROM MULTI-LEVEL GOVERNMENT INTERACTION

4.1 Introduction

Groceries are taxed at diverse rates across the U.S. In some places, grocery sales taxes are exempted at the state and/or county level, while in other places, the tax rate can be as high as 9%, including the state tax rate and county tax rate. The divergent tax rates lead to continual public discussions and political proposals on cutting and even repealing the grocery sales taxes in the 16 with-tax states every year. In this essay, we discuss the causes of diverse grocery tax rates in a framework of local tax competition by considering the horizontal, vertical and diagonal tax effects at the state and county level.

From a historical perspective, states followed a spatial pattern exempting state-level sales taxes on groceries, which occurred successively in three waves. The first wave of the tax exemption started in the Great Depression of the 1930s, when general sales taxes were firstly introduced, and grocery foods were excluded from being taxed. Those states in the first wave are California, Texas, and most northeastern states. The second wave of exempting grocery sales taxes was triggered by Iowa in the early 1970s, followed by other middle eastern states including Michigan, Washington D.C., Indiana, Kentucky and North Dakota over the 1980s. During the second wave, some western states, including Washington, Nevada, Arizona, Colorado, and Nebraska, exempted their taxes as well. The last wave of grocery sales tax exemptions happened at the start of the third millennium, when more and more southern states, such as Georgia, Louisiana, North and South Carolina, New Mexico and West Virginia, tarted to exempt grocery sales taxes (Figure 4.1).

More recently, from 2006 to 2017, the grocery tax rates at state level have been decreasing on average, according to the data we collected. Among the seven states that changed the tax during those twelve years, six states dropped the state grocery tax rates, while Kansas is the only one state that slightly increased its state grocery tax rates from 5.3% in 2006 to 6.5% in 2017 (Figure 4.1). In particular, Wyoming, South Carolina and West Virginia consecutively exempted the grocery taxes during the study period. County-level grocery tax rates also frequently change. More than 100 counties changed grocery sales tax rates over 300 times during the research period. However, contradictory to the decreasing state-level grocery tax rates, county-level grocery tax rates have been increasing. The average county-level grocery tax rate increased by 0.4-point percentage between 2006 and 2017. It is also noticeable that even in some states, such as Georgia, Louisiana and North Carolina, where state-level grocery taxes are exempted, there are still considerable amount of county-level grocery taxes.

The tax policy is so divergent from state to state, from county to county, and between states and counties that the cause of grocery tax rate changes becomes an intriguing phenomenon. In this article, in order to explore the causes of grocery sales tax changes, we consider spatial externalities of grocery tax rates and study the state-county and county-county tax policy interaction patterns under a Stackelberg tax competition model. Derivatized from the model, we obtain three propositions. County-level grocery tax rates are affected by their domestic states' grocery tax rates (the vertical-effect proposition), the neighboring counties' grocery tax rates (the horizontal-effect proposition) and the neighboring states' grocery tax rates (the diagonal-effect proposition) (Agrawal, 2016). In addition, by employing the newly assembled twelve-year data of state and county grocery tax rates, this essay also empirically examines the three propositions using a spatial autoregressive model.

Our study contributes to the tax and food inequality literature, as well as practical policy making in broad ways. First, it is the first study, to our knowledge, that explains patterns and reasons for the changes of county-level grocery sales tax rates. Second, we also expand state-county interaction on the grocery sales tax rate by allowing the diagonal interaction where counties' grocery tax rates are affected also by neighboring states' tax rates. There are theories about state-county federalism, but the empirical evidence is rare considering nation-wide counties and a more than ten-year study period. In this study, we investigate not only the horizontal competition, but also vertical and diagonal interaction between upper-tier governments (states) and lower-tier governments (counties) nationally from a decade-long perspective. Third, we first use a Stackelberg game model to mimic the tax competition between the two-level governments. In our model, since states are upper-tier governments, they are the tax leaders in the game, while counties, as the lower-tier governments, usually follow the state leaders setting their tax rates. Compared to the simultaneous gaming between the two-level governments, our model is more practical and closer to reality. Finally, it is well acknowledged that local governments compete for major tax categories such as property tax, income tax and general sales tax, but there is limited research examining whether governments also compete on other local specific tax categories, such as grocery sales taxes. As more and more local governments explore food and beverage taxes as policy instruments, our study fills this gap by providing evidence that local governments tend to interact with their upper-level governments and neighboring governments competing on grocery sales tax rates.

The rest of the essay is organized in the following way. The next section reviews previous research on grocery sales taxes and the tax competition. The third section presents a theoretical approach to how states and counties set optimal tax rates in a Stackelberg gaming model. The subsequent sections illustrate the data and classifications, followed by the empirical strategies and econometric method. Then, we present and analyze the results in the sixth section. Finally, we summarize and discuss the policy implication in the last section.

4.2 Literature Review

4.2.1 Grocery Sales Taxes

Grocery sales taxes have impacted people's lifestyle and even the society in multiple ways. On the one hand, the taxes imposing on food broadly influence consumer behaviors related to food. First, the substitution effect of the grocery sales taxes influenced public eating habits. Levying taxes on groceries makes grocery foods more expensive than restaurant food so that more people are likely to eat away from home. As a result, restaurant food expenditure grows while grocery food expenditure drops, and such substitution exists in families across all income levels (Zheng, Dong, Burney, & Kaiser, 2019). This effect is fully discussed in the previous two essays and can lead to severe problems on public health. Second, grocery sales taxes are extra expenses added on the original food prices, which ultimately raised food expenditures and aggravated food insecurity due to the shrinking food budget among the low-SEC families. Although the tax does not apply to purchases using SNAP, it largely increased the possibility of being insecure for the low-income but non-participating SNAP households (N. L. Wilson, Zheng, Burney, & Kaiser, 2017).

Third, grocery sales taxes directly increase cross-border grocery shopping. A cohort of studies reported that when 46 counties in West Virginia changed their county-level grocery sales taxes during 1979-1984, consumers travelled from places of higher grocery sales taxes to the close-by places of lower grocery sales taxes to shop for groceries (Walsh & Jones, 1988). The cross-border shopping boosted again in West Virginia when the state started to reduce and finally exempt its state-level grocery sales taxes gradually in the 1990s (Tosun & Skidmore, 2007).

On the other hand, the grocery sales taxes may introduce a profound influence on public health and other social outcomes. Since grocery sales taxes can change and guide consumers' eating behavior, the public health outcomes are subsequently affected by the tax (Cawley & Ruhm, 2011). Besides the evidence provided in the previous two essays of this dissertation, food and beverage taxes are frequently correlated with obesity issues (Cawley, 2015). Furthermore, grocery sales taxes can also lead to other social problems. Researchers found that grocery sales taxes cause unemployment in the food and beverage industries, especially among young and female workers (Greenhalgh-Stanley, Rohlin, & Thompson, 2018).

While the consequences of grocery sales taxes have been investigated by a range of researchers, the causes of grocery sales taxes have never been thoroughly discussed. There are limited academic discussions on why grocery sales tax changes, even though over 100 counties changed grocery sales tax rates more than 300 times during the past decade.

4.2.2 Tax Competition Theory

It is straight-forward to attribute the tax-exemption to a tax competition model, where governments compete with each other for a lower sales tax rate. This is supported by the spatial tax competition theory (Agrawal, Hoyt, & Wilson; J. D. Wilson, 1999). As is assumed in the theory, the consumers are mobile for tax arbitrage to maximize their utility (Mintz & Tulkens, 1986), so local governments from the same tier compete horizontally, choosing the optimal taxes in order to maximize their government revenue (Kanbur & Keen, 1993). In the Nash equilibrium of the horizontal competition, an increase of commodity tax in a high-tax region encourages its residents to cross the region border to shop in the nearby low-tax regions if the marginal revenue of the shopping trip exceed the marginal transportation costs (Ohsawa, 1999). As a result, the competing governments take turns offering as low as possible sales tax rates in the sales tax competition, not only to encourage their residential consumers to consume at their own region, but also to attract more consumers from other regions (Y.-Q. Wang, 1999). In a nutshell, the competition always leads to declining tax rates for all the competing regions (Haufler, 1998), although only the governments with lower sales tax rates are capable of enlarging their sales tax revenue (Braid, 2000).

The tax exemption for groceries become more complicated considering the vertical externalities where different levels of regional governments jointly compete for the same sales tax bases (Esteller-Moré & Solé-Ollé, 2001). In a non-cooperative equilibrium, the vertical externalities can adversely balance the excessively low tax rates caused by the horizontal competitions (M. Keen & Kotsogiannis, 2003; M. J. Keen & Kotsogiannis, 2004), and sometimes the vertical externalities can even dominate the competition, resulting in excessively high local tax rates (M. J. Keen & Kotsogiannis, 2002). Currently, counties adopting Home-Rule have more flexibility to impose local sales taxes within their regions in the U.S. (Veuger, Shoag, & Tuttle, 2019), which promotes the vertical interactions on sales tax rates (Burge & Rogers, 2011). However, the upper-level governments gain the advantage over the lower-level governments in the frame of federalism (Lucas, 2004), and thus, a state usually plays as a tax policy leader followed by its counties in the state-county sales tax interaction. This is especially true in the regions governed by Dillon Rule (Russell & Bostrom, 2016), where counties obtain the authority to levy taxes from their states, which leads those counties to keep the same policy pattern as their states. Furthermore, some recent literature also found that the sales taxation of a lower-tier region is also positively influenced by the tax rates of its neighboring upper-tier governments and the distances to the region border (Agrawal, 2016), mixing the vertical externalities with the horizontal externalities(Agrawal, 2015).

4.3 Theoretical Model

We expand the tax competition model (Devereux, Lockwood, & Redoano, 2007) to a sequential government game. States and counties act in a Stackelberg competition, where the upper-tier governments move first(Y.-Q. Wang, 1999). As the tax leaders in the Stackelberg model, states compete for the state tax rates first. Then, counties observe the state rates and compete for county tax rates. We also assume that governments at the same tier move simultaneously to find a Nash equilibrium. Similar to the two-level (Agrawal, 2016) and multi-level models (Agrawal, 2016; Janeba & Osterloh, 2013), our theoretical model focuses on the tax interaction among two-level local governments.

4.3.1 Model Framework

Assume there are two states (I and J) located on a line segment, and each state has one county (i and j). Sharing the same tax base, each level government can set their own commodity tax rate freely. The tax is levied based on the transaction location. Governments are revenue maximizers. States and counties follow a Stackelberg game taking turns setting tax rates. Since states are higher-level governments, in the first stage, states take the lead, setting the state-level tax rates (τ_I and τ_J) to maximize state revenue. The state-level tax rates are set simultaneously between states. Then, in the second stage, counties observe the state-level tax rates and simultaneously set the county-level tax rates (t_i and t_j) to maximize county revenue. We assume symmetry between same-level governments.

Assume the producer price of commodity (p) is the same in every county and is normalized into 1: $p_i = p_j = 1$. Then the consumer price of commodity in county i is $q_i = 1 + t_i + \tau_I$. The consumers maximize their utilities by consuming commodities, where their indirect utility $v(q) = \max_x\{u(x) - qx\}$ and the consumer demand $x(q) = argMax\{u(x) - qx\}$.

We also assume the population is normalized at unit, and the transportation price is fixed at c. Then, consumers living in i will cross-board shop in j only if $q_i > q_j$, and the distance constraints for cross-border shopping is $d < \frac{1}{c}(v(q_i) - v(q_j))$. Therefore, the tax base of county i allowing cross-border shopping to county j is $B(q_i, q_j) = \left[1 + \rho\left(v(q_i) - v(q_j)\right)\right] x(q_i)$, where $\rho = \frac{1}{c}$.

As a result, state I choses τ_I to maximize its state-level tax revenue R_I:$\max_{\tau_I} R_I = \tau_I B\big(1 + \ t_i + \tau_I, 1 + t_j + \tau_J\big)$. Simultaneously, state J chooses τ_J to maximize its state-level tax revenue R_J. Then, county i and j observe the state tax rates and choose their optimal tax rates. The tax revenue maximization for county i is $\max_{t_i} r_i = t_i B\big(1 + t_i + \tau_I, 1 + t_j + \tau_J\big)$.

4.3.2 Solving the Model

We use backward induction to solve the model. In Stage 2, counties take states' tax rates as given and set county-level tax rates simultaneously. Then the F.O.C. (First Order Condition) for county i is:

$$\frac{\partial r_i}{\partial t_i} = B + t_i \frac{\partial B}{\partial t_i} = 0 \tag{4.1}$$

If a symmetric Nash equilibrium exists with $t_i = t_j$, $q_i = q_j$, and Roy's identity that $x(q_i) = -\frac{\partial v(q_i)}{\partial q_i}$, we can solve the equilibrium t_i taking τ_I as given, and the equilibrium t_i is a function of τ_I :

$$t_i(\tau_I) = \frac{x(q_i)}{\rho x^2(q_i) - x'(q_i)} \tag{4.2}$$

Since $t_i \geq 0$, as a result, $\rho x^2(q_i) - x'(q_i) > 0$. Additionally, t_i solves the maximized r_i, so $\frac{\partial^2 r_i}{\partial {t_i}^2} < 0$.

Back to stage 1, states know the reactions of counties and set their optimal state level tax rates by solving the F.O.C. of the state maximization problem:

$$\frac{\partial R_i}{\partial \tau_I} = B + \tau_I \frac{\partial B}{\partial \tau_I} = 0 \tag{4.3}$$

$$\left[1 + \rho\left(v(q_i) - v(q_j)\right)\right] x(q_i) + \tau_I \frac{\partial B}{\partial q_i} * \frac{\partial q_i}{\partial \tau_I} = 0$$

If the symmetric Nash equilibrium exists, plugging $t_i(\tau_I)$ according to equation (4.2), and the equilibrium τ_I is solved as:

$$\tau_I = \frac{x(q_i)}{\rho x^2(q_i) - x'(q_i)} * \frac{1}{\frac{\partial t_i}{\partial \tau_I} + 1} = \frac{t_i}{\frac{\partial t_i}{\partial \tau_I} + 1} \tag{4.4}$$

Proposition 1. In the Stackelberg game of two-level governments where Stackelberg equilibrium exists between different-tier governments and symmetric Nash equilibrium exists among governments from same tiers, the slope of vertical reaction function is negative if the county tax rate is greater than (or equal to) its domestic state's state-level tax rate, while the slope of vertical reaction function is positive if the county tax rate is less than its domestic state's state-level tax rate.

From equation (4.4), we can solve that

$$\frac{\partial t_i}{\partial \tau_I} = \frac{t_i - \tau_I}{\tau_I}. \tag{4.5}$$

If $t_i \geq \tau_I$, then $\frac{\partial t_i}{\partial \tau_I} \geq 0$. A county's tax rate increases with the increase of its domestic state's state-level tax rate. However, when $t_i < \tau_I$, a county's tax rate decreases with the increase of its domestic state's state-level tax rate.

Proposition 2. In the Stackelberg game of two-level governments where Stackelberg equilibrium exists between different-tier governments and symmetric Nash equilibrium exists among governments from same tiers, the slope of horizontal reaction function is positive. It means a county's county-level tax rate is positively affected by the county-level tax rate of its neighbor county.

With the totally differentiation of equation (4.1) in a symmetric Nash equilibrium, the slope of the horizontal reaction function is:

$$\frac{\partial t_i}{\partial t_j} = \frac{\rho x^2(q_i) + t_i \rho x(q_i) x'(q_i)}{-\frac{\partial^2 r_i}{\partial {t_i}^2}} = \frac{\rho x^2(q_i)\left[1 + t_i \frac{x'(q_i)}{x(q_i)}\right]}{-\frac{\partial^2 r_i}{\partial {t_i}^2}} \tag{4.6}$$

If we plug equation (4.2) into (4.6), we can solve that:

$$\frac{\partial t_i}{\partial t_j} = \frac{\rho x^2(q_i)\left[1 + \frac{x(q_i)}{\rho x^2(q_i) - x'(q_i)} * \frac{x'(q_i)}{x(q_i)}\right]}{-\frac{\partial^2 r_i}{\partial {t_i}^2}} = \frac{\frac{[\rho x^2(q_i)]^2}{\rho x^2(q_i) - x'(q_i)}}{-\frac{\partial^2 r_i}{\partial {t_i}^2}} > 0$$

Proposition 3. In the Stackelberg game of two-level governments where Stackelberg equilibrium exists between different-tier governments and symmetric Nash equilibrium exists among governments from same tiers, the slope of diagonal reaction function (Agrawal, 2016) is positive. This means a county's county-level tax rate is positively affected by its neighbor states' state-level tax rates, but the magnitude is smaller than the neighboring counties' tax effect.

With the total differentiation of equation (4.1) in a symmetric Nash equilibrium, the slope of the horizontal reaction function is:

$$\frac{\partial t_i}{\partial \tau_J} = \frac{\rho x^2(q_i) + t_i \rho x(q_i) x'(q_i)}{-\frac{\partial^2 r_i}{\partial {t_i}^2}} = \frac{\rho x^2(q_i)\left[1 + t_i \frac{x'(q_i)}{x(q_i)}\right]}{-\frac{\partial^2 r_i}{\partial {t_i}^2}} \tag{4.7}$$

If we plug equation (4.2) into (4.7), we can solve that

$$\frac{\partial t_i}{\partial \tau_J} = \frac{\rho x^2(q_i)\left[1 + \frac{x(q_i)}{\rho x^2(q_i) - x'(q_i)} * \frac{x'(q_i)}{x(q_i)}\right]}{-\frac{\partial^2 r_i}{\partial t_i{}^2}} = \frac{\frac{[\rho x^2(q_i)]^2}{\rho x^2(q_i) - x'(q_i)}}{-\frac{\partial^2 r_i}{\partial t_i{}^2}} > 0$$

4.4 Data and Government Tax Strategies

We use a unique grocery tax panel that is hand-assembled from various data sources. The dataset contains annual state and county level grocery tax rates from 2006 to 2017. The state level grocery tax rates are obtained from Bridging the Gap, while the county level grocery tax rates are gathered from Tax-Rates.org and state Departments of Revenue. Our data covers all the counties in the mainland U.S., the four main areas in Alaska, and all the five counties of Hawaii. Comparing with the previous tax competition datasets of sales taxes (Agrawal, 2016), one shortcomings of our dataset are that it does not contain municipal tax rates. We are unable to know how municipal-level governments interact with upper-level governments and their neighboring jurisdictions.

The summary statistics of grocery tax rates are shown in Table 4.2. Overall, during our study period, among the 50 states, Washington D.C., and 3,101 counties, there have been 16 states and 1,036 counties that have implemented the grocery tax policy. For those with grocery taxes, the average state-level grocery tax rate is 3.644%, with 1% as the minimum and 7% as the maximum, while the average county-level grocery tax rate is 2.016%, ranging from 0.15% to 7%.

Sharing the same tax base, states and counties can implement their own tax strategies. States can choose to exempt taxes (state grocery tax rate = 0), tax at limited tax rates, or tax at full tax rates (state grocery tax rate = state general sales tax rate). Correspondingly, counties can also have similar tax strategies. However, some counties are not authorized to freely set their own county tax rates, but instead follow the state strategies by setting their county tax rate at a fixed and united number statewide.

The diverse vertical interaction between states and counties should theoretically form 64 (4*4*4) taxing strategies between the two-level government, but only seven types of the strategies existed among the U.S. state and county governments (Table 1). The most frequent tax strategy is double exempt, where states and counties choose to exempt both levels of grocery tax rates. The second popular strategy adopted by the eight states is the double full, where states and counties choose to tax both at full general sales tax rates. There are five states that choose to exempt the state-level tax rate, while their counties choose to tax. Similarly, there are also four states where states choose to tax a limited rate but counties tax fully; in these counties' their taxing strategies are more radical than states.

Our research also controls the county-level demographic variables such as race, gender, per capita income, and unemployment rates. The demographic data used are from the U.S. government census.

4.5 Empirical Strategies

We apply similar the empirical equation form as Agrawal (2014), but we also consider the sequential gaming between states and counties, where states are leaders. Therefore, the tax reaction function of county *i* within state *I* in year *y* considering vertical, horizontal, and diagonal tax effects is established as follows:

$$t_{iy} = \beta_0 + \beta_1\tau_{Iy-1} + \beta_2 W_{ij} t_{jy} + \beta_3 W_{iJ}\tau_{Jy-1} + \boldsymbol{\theta X_{iIy}} + \alpha_i + \alpha_y + \varepsilon_{iy} \quad (4.8),$$

where t_{iy} is the county-level tax rate of county *i* within state *I* in year *y*. τ_{Iy-1} is the state-level tax rate of state *I* in year $y - 1$. We use τ_{Iy-1} instead of τ_{Iy} to mimic the sequential gaming. Since states are leaders in setting tax rates, we assume counties start to set tax rates in year y one year after states set their tax rates. Similarly, t_{jy} is the county-level tax rate of county *j* within state J in year *y*. W_{ij} is a spatial weighting matrix based on the polygon contiguity between county *i* and county *j*, indicating whether county *i* and *j* are neighboring counties. τ_{Jy-1} is the state-level tax rate of state J in year $y - 1$. $W_{iJ}$is another spatial weighting matrix based on the polygon contiguity between county i and state J, indicating whether county *i* is near the state border. $\boldsymbol{X_{iIy}}$ is a vector containing time variant controls related to the economy, politics and socio-demographic variables that are correlated to the local grocery sales tax, such as per capital income, the unemployment rate, race and gender. The controlling vector also includes current state grocery sales taxes τ_{Iy} and $W_{iJ}\tau_{Jy}$. At last, α_i is the county-fixed effect controlling for the time-invariant unobserved variables, and α_y is the year fixed effect controlling for annual shocks. ε_{iy} denotes the error term.

w_{ij} is an element of the spatial contiguity matrix W_{ij},

$$w_{ij} = \begin{cases} 1 & \text{if } i \text{ and } j \text{ are contiguous} \\ 0 & \text{if } i \text{ and } j \text{ are not contiguous} \end{cases} \quad (4.9).$$

Similarly, w_{iJ} is an element of the spatial contiguity matrix W_{iJ}. The Queen criterion is used in the binary contiguity, where neighboring jurisdictions are defined as sharing either common border or vertex. Both matrixes are normalized in rows.

Under this identification, $\widehat{\beta_1}$, $\widehat{\beta_2}$, and $\widehat{\beta_3}$ are the estimated slopes of vertical, horizontal and diagonal reactions, accounting for the vertical, horizontal and diagonal tax effects. The parameters are estimated using the Maximum Likelihood Estimation (MLE) method. Since the counties could cluster in group, clustered standard errors at state level are considered to obtain accurate statistic inference (Cameron & Miller, 2015).

4.6 Results

Our estimates are presented in Table 4.3. Considering all the states and counties in our sample, the estimates of β_1 , β_2 , and β_3 are -0.102, 0.780, and 0.110, respectively, shown in column (2). However, not all the three estimates are statistically significant. The negative coefficient of the state grocery tax rate suggests that state grocery sales taxes negatively affected county grocery sales taxes. Although the estimate is not statistically significant, the clustered standard error is relatively small. This estimate result is consistent with proposition 1. Given the average state grocery sales tax rate (3.644%) is greater than the average county grocery sales tax rate (2.016%), a county grocery tax rate changes negatively with its domestic state grocery sales tax rate.

Neighboring counties play the largest role in determining the local county grocery tax rates. A county will increase its grocery tax rates by 0.78 percentage points if its neighboring county increases its tax rate by one percentage point tax rate on average. The estimate is statistically significant at 10% significance level. Neighboring state tax rates can also affect a county's grocery tax rate. A county is expected to increase its grocery tax rate by 0.11 percentage point when its neighboring states increase state grocery tax rate by one percentage point on average, holding other variables constant. This estimate is statistically significant at 1% significance level. To compare the diagonal tax effect with the horizontal tax effect, the estimated diagonal tax effect is smaller than the horizontal tax effect, suggesting that neighboring states have limited tax effect on counties. Furthermore, the Wald test result shows that the spatial parameter coefficients are significantly different from zero, indicating that county grocery tax rates are spatially correlated with the tax rates of neighboring counties and states.

Since there are 31 states and their corresponding counties that have adopted a double exempt strategy, the spatial correlations are overestimated by taking them into consideration. In column (3) and (4), we exclude Type 1 jurisdictions (Table 4.1) where double exempt strategies are adopted, and only include the remaining 20 states and their corresponding counties. The signals of the main estimates stay the same, but the magnitude of the three effects get smaller. The empirical results are consistent with the derived propositions in our theoretical model.

4.7 Conclusion and Discussion

During the past two decades, seven more states consecutively exempted groceries from sales taxes. Although there are still thirteen states remained holding the grocery sales taxes, five of them levy the taxes at limited rates, and three of them provide different levels of tax refund credits. At least at the state level, exemption, as well as reduction in grocery sales taxes has become a trend. Many governments exempted the tax in terms of equality since most jurisdictions have already exempted taxing groceries. Additionally, grocery taxes exaggerate inequality as the low-SES populations tend to spend a larger proportion of their income on groceries.

It is an important decision for all levels of local governments regarding whether to tax groceries. A growing number of researchers and policy makers have been exploring how food and beverage taxes can impact consumers' eating and drinking behavior (Fletcher et al., 2010c; Zhen et al., 2014). Grocery taxes gain the advantages as such a policy instrument since they are imposed on wider types of groceries than most single food and beverage taxes which only tax a specific type of groceries. The impacts of grocery sales taxes are more salient than the single base taxes such as fat taxes and sweetened beverage taxes.

Our study, in a framework of tax competition, investigates that the driven factors of county grocery sales tax rate changes come from three sources: its neighboring county's grocery tax rates have a positive horizontal effect, its mother state government has a negative vertical effect, and its neighboring state governments have a slightly positive diagonal effect. Our research confirms the tax competition theory in grocery sales taxes that multi-level local governments interacted in a game. Governments choose grocery tax rates to maximize government revenue considering cross-border shopping and federalism. Additionally, the findings help to explain the diversity of grocery sales tax rates. The diverse tax rates are not only due to horizontal competition but are also results of diverse interacted strategies between states and counties. Furthermore, as increasing numbers of states and counties consider changing their grocery tax policies, our study addresses the interaction among multi-level governments, helping policy makers to balance the costs and benefits of the tax changes.

Tables and Figures of Chapter 4

Table 4.1 Vertical Taxing Strategy Types, 2006-2017

			Type1	Type2	Type3	Type4	Type5	Type6	Type7
Vertical Interaction Strategies									
State	Exempt		Y	Y	Y	Y			
	Limited						Y	Y	
	Full								Y
County	Exempt		Y						
	Limited	Fixed		Y			Y		
		Changed			Y				
	Full					Y		Y	Y
Numbers of States			31	1	2	2	3	4	8
State Abbreviations				SC	LA, NC	AK, GA	UT, VA, IL	MO, AR, TN, WV	AL, HI, ID, KS, MS, OK, SD, WY

Notes: a. The table is generated using our state and county tax dataset.

b. The Type 1 states include AZ, CA, CO, CT, DE, DC, FL, IN, IA, KY, ME, MD, MA, MI, MN, MT, NE, NV, NH, NJ, NY, ND, OH, OR, PA, RI, TX, VT, WA, and WI.

c. In 2009 and 2013, Wyoming and West Virginia exempted grocery taxes at state and county levels.

d. Georgia exempted state-level grocery taxes in 2000, while Louisiana and North Carolina exempted state-level grocery taxes in 2002. But county-level grocery taxes are permitted in the three states.

Table 4.2 Grocery Sales Tax Rates at State and County Levels, 2006-2017

	State	County
Grocery Tax Rate (Mean)	3.644%	2.016%
Grocery Tax Rate (Min)	1.000%	0.150%
Grocery Tax Rate (Max)	7.000%	7.000%
Numbers of With-Tax Jurisdictions	16	1,036

Table 4.3 Vertical, Horizontal and Diagonal Tax Effect Results

	(1) All States	(2) All States	(3) Judications with Taxes
State Tax Rate (τ_I)	-0.102	-0.102	-0.084
	(0.08)	(0.08)	(0.06)
Average Neighboring County Tax Rate ($W_{ij}t_j$)	0.781***	0.780***	0.760***
	(0.11)	(0.11)	(0.10)
Average Neighboring State Tax Rate ($W_{IJ}\tau_J$)	0.109*	0.110*	0.091*
	(0.06)	(0.06)	(0.03)
Controlling Variables	N	Y	Y
County Fixed Effect	Y	Y	Y
Year Fixed Effect	Y	Y	Y
Counties	3,101	3,101	1,432
Observations	34,111	34,111	15,752

Notes: Standard errors are clustered at state level. *** p<0.01, ** p<0.05, * p<0.1

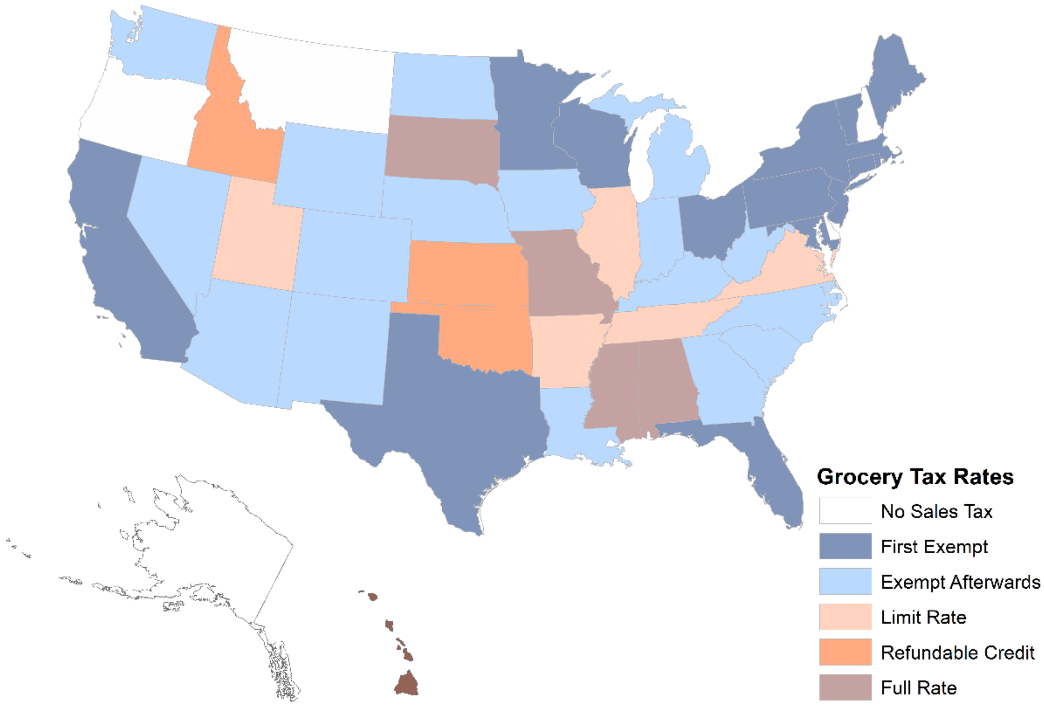


Figure 4.1 The Exemption and Distribution of State Grocery Tax Rates

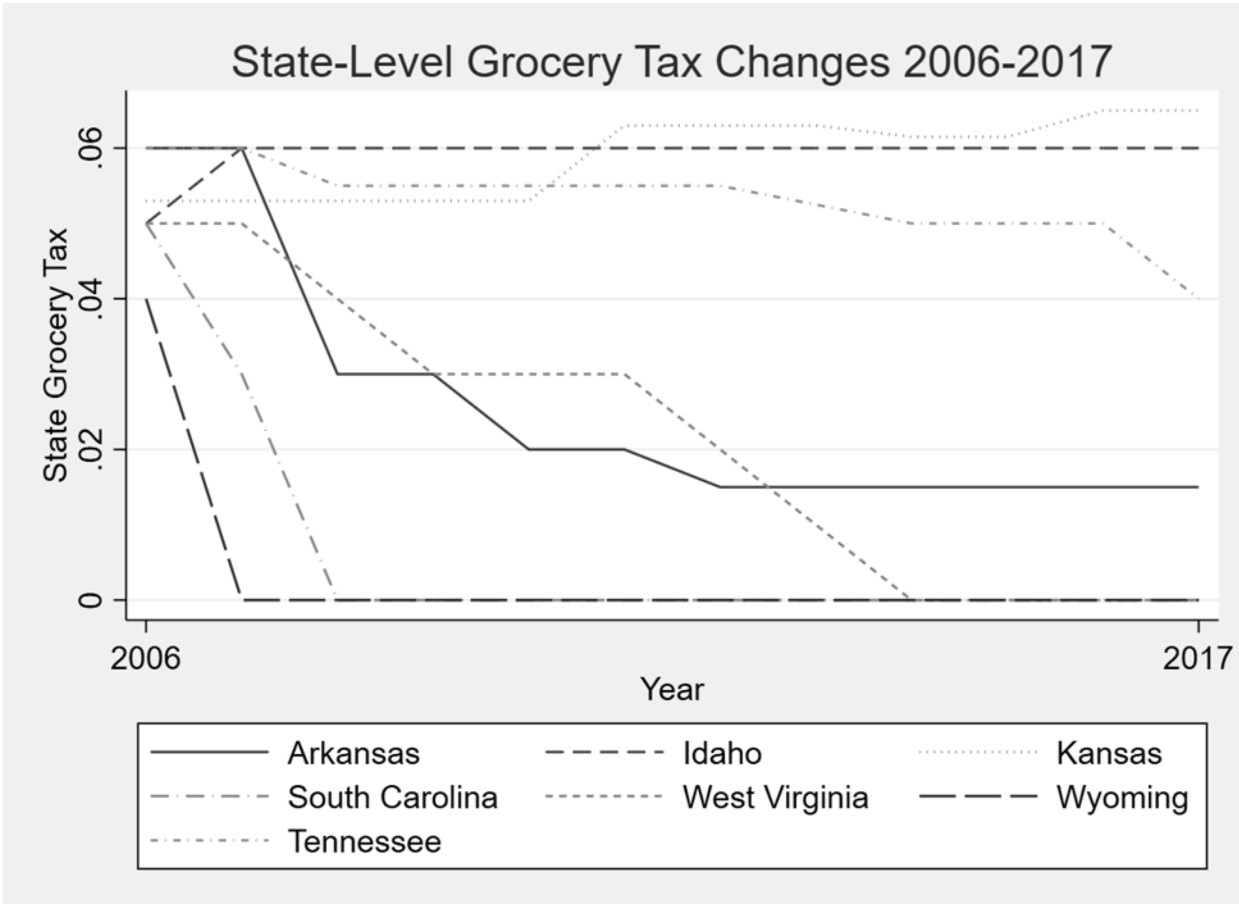


Figure 4.2 State-Level Grocery Tax Rates, 2006-2017

APPENDICES

APPENDIX 1. ABBREVIATIONS

COVID-19: coronavirus disease 2019

BMI: body mass index

CDC: Centers for Disease Control and Prevention

BRFSS: Behavioral Risk Factor Surveillance System

REIS: Regional Economic Information System

UCR: Uniform Crime Reporting

DUI: driving under the influence

BCR: benefit-cost ratio

SES: socioeconomic status

FAH: food at home

FAFH: food away from home

SNAP: Supplemental Nutrition Assistance Program

PSID: Panel Study of Income Dynamics

FE: Fixed Effect

OVB: omitted variable bias

F.O.C.: First Order Condition

APPENDIX 2. Full Regression Results Health Outcomes on Grocery and Restaurant Sales Taxes

VARIABLES	(1) obesity	(2) diabetes	(3) obesity	(4) diabetes
Total grocery sales tax rate	0.588***	0.215**		
	(0.154)	(0.098)		
Total restaurant sales tax rate	-0.158	-0.127		
	(0.127)	(0.101)		
(1+Grocery Tax)/(1+Restaurant Tax)			4.760***	1.296**
			(1.169)	(0.571)
Grocery stores	-0.244	-1.113***	-0.215	-1.101***
	(1.262)	(0.406)	(1.258)	(0.408)
Fastfood restaurants	-0.377	0.289	-0.377	0.292
	(0.569)	(0.228)	(0.570)	(0.228)
Full-service restaurants	0.080	-0.063	0.091	-0.062
	(0.517)	(0.181)	(0.518)	(0.183)
Cost per meal	-0.735*	-0.512***	-0.720*	-0.522***
	(0.386)	(0.182)	(0.385)	(0.184)
White	11.058	1.993	11.088	1.994
	(14.889)	(5.913)	(14.926)	(5.901)
Black	53.462**	23.179***	53.523**	22.997***
	(24.510)	(7.179)	(24.572)	(7.167)
Female	-15.464	-5.143	-15.609	-5.151
	(17.564)	(7.582)	(17.481)	(7.566)
Hispanic	-19.896*	-5.802	-19.886*	-5.607
	(10.077)	(5.561)	(10.054)	(5.523)
Income per capita	0.025*	0.010	0.026*	0.010
	(0.014)	(0.008)	(0.013)	(0.008)
Employees' share of total population	-7.258*	-1.045	-7.353*	-1.011
	(3.752)	(1.161)	(3.762)	(1.168)
Share of bachelor's degree or higher of the 25-year- and-over population	-0.032	-0.016	-0.032	-0.016
	(0.045)	(0.018)	(0.045)	(0.018)
Smoking rate	0.002	0.004	0.002	0.004
	(0.030)	(0.008)	(0.030)	(0.008)
Drinking rate	-0.020	-0.010	-0.020	-0.010
	(0.023)	(0.013)	(0.023)	(0.014)
Drug arrest rate	4.294***	-1.055***	4.290***	-1.054***
	(0.241)	(0.125)	(0.240)	(0.125)
DUI	-5.908***	1.619***	-5.903***	1.619***

	(0.384)	(0.176)	(0.384)	(0.178)
Constant	32.161*	11.305	30.258	10.356
	(18.835)	(7.253)	(18.697)	(7.262)
Observations	9,779	9,779	9,779	9,779
R-squared	0.910	0.928	0.910	0.928

Note: Standard errors are in parentheses. *, **, and *** denote statistically significance at the 10%, 5%, and 1% levels, respectively.

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VITA

Education

University of Kentucky — Lexington, KY
Advisors: Yuqing Zheng (Chair), Steve Buck (Co-chair) — Aug. 2021

Cornell University, Dyson School of Applied Economics — Ithaca, NY
Visiting Researcher, working with Dr. Harry M. Kaiser — Spring 2020

National University of Political Studies and Public Administration — Bucharest, Romania
Visiting Student — Spring 2016

Ocean University of China — Qingdao, China
Master of Science (Economics) — Jun. 2017

Central China Normal University — Wuhan, China
Bachelor of Arts (Major: Economics; Minor: Philosophy) — Jul. 2014

Journal Publications

Lingxiao Wang, Yuqing Zheng, and Steven C. Buck. "How Does the Affordable Care Act Affect Cigarette Consumption? –The Mechanism and Heterogeneity." Forthcoming in *Journal of Consumer Affairs*

Lingxiao Wang, Yuqing Zheng, Steven C. Buck, Diansheng Dong, Stewart Hayden, and Harry M. Kaiser. "Grocery Food Taxes and U.S. County Obesity and Diabetes Rates", *Health Economics Review*, 11(1) (February 2021), pp. 1-9

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Papers under Journal Review

Yuqing Zheng, **Lingxiao Wang**, Shuoli Zhao, and Wuyang Hu. "Corona Beer in Coronavirus Pandemic: Impact of Unintentional Negative Name Association"

Shuoli Zhao, **Lingxiao Wang**, Wuyang Hu, and Yuqing Zheng. "Meet the Meatless: Demand for New Generation Plant-Based Meat Alternatives"

Working Papers

- Dissertation Essay 2: Causal Effect of Grocery Sales Tax on Obesity
- Dissertation Essay 3: Spatial Grocery Tax Competition
- Impacts of "Non-Meat" Labeling on the Meat-alternative Sales

Teaching and Professional Experience

Independent Instructor	University of Kentucky 2019
Teaching Assistant	University of Kentucky 2018
Professional Services	University of Kentucky
Graduate Student Congress Representative of Agricultural Economics	August 2018-Present
Department Graduate Research Committee Representative	August 2019-Present
Journal Reviewer for *Value in Health*, *China Agricultural Economics Review* and *Marine Policy*	2019-Present

Grants

Richards Graduate Student Research Activity Grant. $750, 2020-2021

Fundamental Research Funds for the Central Universities Thesis. "Charging problems of Six Bridges and One Tunnel in Wuhan" PI: Lingxiao Wang, co-PIs: Wenkang Zhang, Yao Gong and Lin Zhong, ￥5,000, Jun 2012-Sep 2013

Honor and Awards

Graduate Research Assistantship of University of Kentucky, Department of Agricultural Economics	2017-2021
Academic First-Class Scholarship, Ocean University of China	2016
First Prize of 4th Postgraduate's Marine Forum of Beibu Gulf Rim	2015
First Prize of the 14th Challenge Cup National University Science and Technology Competition	2015