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**THE DETERMINANTS OF FOOD INSECURITY IN THE UNITED STATES:
A STATE LEVEL ANALYSIS**

A Master's Thesis

Presented to

The Graduate College of
Missouri State University

In Partial Fulfillment

Of the Requirements for the Degree
Master of Science, Agriculture

By

Zhuoya Li

August 2021

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THE DETERMINANTS OF FOOD INSECURITY IN THE UNITED STATES: A STATE LEVEL ANALYSIS

Agriculture

Missouri State University, August 2021

Master of Science

Zhuoya Li

ABSTRACT

The purpose of this study was to examine the determinants of food insecurity at the state level with the goal of providing policy guidance to reduce the prevalence of food insecurity in the United States. Data for the study was collected from various governmental and non-governmental sources. Linear regression models and sensitivity analyses were conducted. The study found that increase in household income is likely to significantly reduce the prevalence of food insecurity and very low food security. While poverty alleviation is more important than level of education for food insecure households, level of education is more important than poverty alleviation for very low food secure households. Therefore, investments on education could significantly reduce the prevalence of very low food security.

KEYWORDS: food insecurity, very low food security, state level, income, cost-of-living, education, poverty

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In the interest of academic freedom and the principle of free speech, approval of this thesis indicates the format is acceptable and meets the academic criteria for the discipline as determined by the faculty that constitute the thesis committee. The content and views expressed in this thesis are those of the student-scholar and are not endorsed by Missouri State University, its Graduate College, or its employees.

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INTRODUCTION

Problem Statement

Food insecurity which is defined as a household level condition of limited or uncertain access to adequate food caused by a lack of money or other resources, affects millions of households in the U.S (Coleman, Rabbit, Gregory & Anita, 2020). In 2012, 17.6 million of households were considered food insecure by the United States Department of Agriculture (USDA) (Pinotak & Schulman, 2014). Food insecurity has lasting effects on people both, physically, and emotionally, and effects the educational development of children. Policy makers are concerned about prevalence of food insecurity. Subsequently, many government programs are created to alleviate food insecurity. Unfortunately, food insecurity remains so high even though the federal government spent over \$100 billion on various federal food-assistance programs in 2012 (Gundersen & Ziliak, 2014). Severe downturn in economic situation such as great recession in 2008 or catastrophic health episode such as ongoing COVID-19 pandemic can exasperate the prevalence of food insecurity.

COVID-19 pandemic spread around the world including the United States beginning early 2020. Due to stay home strictions households needed their food consumption habits including majority of the meals either cooked at home or delivered from the food service sectors like restaurants. As a result, many stores and businesses closed. The downward economic effects on food demand and export prices started in January and accelerated, as countries closed businesses and kept people home. Many Bureau of Labor Statistics (BLS) food price indices rose as a result of the pandemic, causing the cost of living to rise (Mead, Ransom, Reed & Sager, 2020). Many countries' incomes were also severely impacted. In Kenya and Uganda, two-thirds

of the population has suffered income shock. During the COVID-19 pandemic, low-income households and those who rely on labor are more vulnerable to income shock (Kansiime et al., 2021). In U.S, lower income Americans, particularly women and non-whites, are more likely to lose their income in the first month of the pandemic than Americans in higher income brackets (Bachand, 2021). Prevalence of food insecurity is expected to get worse because of the pandemic.

Purpose of the Study

This study aims to 1) address the relationship between prevalence of household food insecurity/very low food security and predictor variables; and 2) to examine how these predictor variables collectively determine prevalence of food insecurity using a sensitivity analysis approach ; and 3) to identify predictor variables with significant impact on the prevalence of food insecurity in the Unites States. Studying these three questions can help identify critical factors affecting prevalence of food insecurity and make necessary policy adjustments.

LITERATURE REVIEW

Definition, Measurement and Relative Concept

Food security was defined by Anderson in 1990 (Bukonya, 2017, p.74):

Access by all people at all times to enough food for an active, healthy life and includes at a minimum: (a) the ready availability of nutritionally adequate and safe foods, and (b) the assured ability to acquire acceptable foods in socially acceptable ways.

There is a sense of food insecurity when food is not available or people's ability to obtain food is restricted. The three pillars on which the concept of food insecurity rests are availability, access and utilization (Barrett, 2010) which are also the basis of food insecurity measures used in this study.

In the 1996 Current Population Survey (CPS), a set of questions was designed to measure food insecurity. The Core Food Security Module consists of 18 questions that were officially used to measure food insecurity in the United States after some modifications (CFSM). These 18 questions are provided in Table 1. In this survey, the number of affirmatively responses was held to reflect the level of food hardship indication (Gundersen, Kreider & Pepper, 2011).

The food security status of each household lies somewhere along a continuum extending from high food security to very low food security. This continuum is divided into four ranges, which is defined as follows (USDA, 2020):

Food Security:

- High food security: no reported indications of food-access problems or limitations

- Marginal food security: one or two reported indications-typically of anxiety over food sufficiency or shortage of food in the house. Little or no indication of changes in diets or food intake.
Food Insecurity:
- Low food security: reports of reduced quality, variety, or desirability of diet. Little or no indication of reduced food intake
- Very low food security: reports of multiple indications of disrupted eating patterns and reduced food intake.

A relative concept, “marginal food insecure” is developed by researchers. The concept "marginal food insecure" was introduced because households identified as marginal food insecure are often more similar to food insecure households in terms of health outcomes and other characteristics (such as income) than food secure households further away from the margin. (Gundersen, Kreider & Pepper, 2011).

Trends on Measuring Food Insecurity

The “undernourishment” estimates generated by Food and Agriculture Organization of United Nations (FAO) became the most cited food insecurity figures (Barrett, 2010). An alternative measure is the simulation model generated by USDA, which is based on price, national accounts and production equations. This estimates often differ radically from FAO estimates. According to Barrett (2010), “such discrepancies make even macroscale geographic targeting difficult for policy-makers.” Food insecurity estimates based on household and individual data are consistently higher than those obtained from more aggregate data. Differences in intra- and interhousehold nutrient distribution, as well as the resulting estimates of nutrient availability, appear to be to blame. (Smith et al., 2006).

Table 1. Food insecurity questions in the Core Food Security Module

Number	Question
1	"We worried whether our food would run out before we got money to buy more." Was that often, sometimes, or never true for you in the last 12 months?
2	"The food that we bought just didn't last and we didn't have money to get more." Was that often, sometimes, or never true for you in the last 12 months?
3	"We couldn't afford to eat balanced meals." Was that often, sometimes, or never true for you in the last 12 months?
4	"We relied on only a few kinds of low-cost food to feed our children because we were running out of money to buy food." Was that often, sometimes, or never true for you in the last 12 months?
5	In the last 12 months, did you or other adults in the household ever cut the size of your meals or skip meals because there wasn't enough money for food? (Yes/ No)
6	"We couldn't feed our children a balanced meal, because we couldn't afford that." Was that often, sometimes, or never true for you in the last 12 months?
7	In the last 12 months, did you ever eat less than you felt you should because there wasn't enough money for food? (Yes/ No)
8	(If yes to Question 5) How often did this happen - almost every month, some months but not every month, or in only 1 or 2 months?
9	"The children were not eating enough because we just couldn't afford enough food." Was that often, sometimes, or never true for you in the last 12 months?
10	In the last 12 months, were you ever hungry, but didn't eat, because you couldn't afford enough food? (Yes/ No)
11	In the last 12 months, did you lose weight because you didn't have enough money for food? (Yes/ No)
12	In the last 12 months, did you ever cut the size of any of the children's meals because there wasn't enough money for food? (Yes/ No)
13	In the last 12 months did you or other adults in your household ever not eat for a whole day because there wasn't enough money for food? (Yes/ No)
14	In the last 12 months, were the children ever hungry but you just couldn't afford more food? (Yes/No)

Table 1 continued. Food insecurity questions in the Core Food Security Module

15	(If yes to Question 13) How often did this happen- almost every month, some months but not every month, or in only 1 or 2 months?
16	In the last 12 months, did any of the children ever skip a meal because there wasn't enough money for food? (Yes/ No)
17	(If yes to Question 16) How often did this happen- almost every month, some months but not every month, or in only 1 or 2 months?
18	In the last 12 months did any of the children ever not eat for a whole day because there wasn't enough money for food? (Yes/No)

Note: From Gundersen and Kreider, 2008

Food Insecurity in the U.S.

Food insecurity is a serious problem faced by millions of Americans. Figures 1 and 2 show the prevalence of food insecurity/very low food security trend in the United States. The data are from the CPS which represents the official data source for food insecurity rates of the United States. USDA Economic Research Service did the calculation and generate the figure. Figure 1 displays the prevalence of “food insecurity” and “very low food security” in the U.S. households from 2001-2019 (Coleman, Rabbit, Gregory & Anita, 2020). From 2002 to 2007, the percentage of food insecure household increased steadily. Between 2007 and 2008, percentage of food insecure and very low food secure households increased dramatically because of the Great Recession, which is the global economic slump that wreaked havoc on global financial markets, banking, and real estate sectors. Millions of people lost their life savings, jobs, and homes as a result of the crisis. At this point, the prevalence of food insecurity and very low food security reached a peak in 2009, and slightly fluctuated in the following years but did not decrease until 2015.

Figure 2 shows the trends in food insecurity in the United States households with children from 1998-2019 (Coleman, Rabbit, Gregory & Anita, 2020). As in Figure 1, the rate kept steady during 1998-2007 and significantly increased from 2007-2008 because of the Great Recession. The rate of food insecurity and very low food security among children reached a peak in 2008, food insecurity in households with children reached to the peak in 2009. The proportion of very low food security among children has remained under 1%. In following years these rates decreased gradually and reached the lowest percentage in 2019. Though the Great Recession ended in December 2009, the economy still needed some time to recover. The overall poverty rate in the United States was 2.5 percent higher than prerecession figures (Kaufman, 2014).

Comparing Figure 1 and Figure 2, the great recession has a greater impact on food insecurity households with children. From 2007 to 2008, the percentage of food insecurity households with children dramatically increased by 5.4%. Followed by percentage of food insecure household which increased 3.5%. These changes reveal the huge impact of food insecurity on the younger generation. Hence, reducing the prevalence of food insecurity is very important. Helping food insecurity households with children is a top priority in reducing the prevalence of food insecurity.

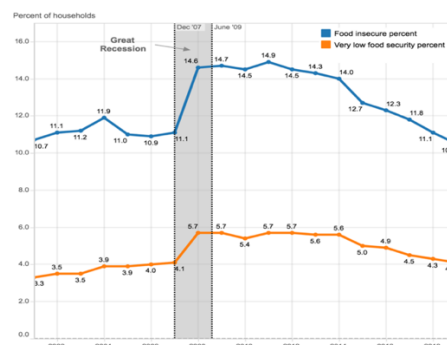


Figure 1. Trend in the prevalence of food insecurity and very low food security in U.S. households (2001-2019)

Note: Calculated by USDA, Economic Research Service, using Current Population Survey Food Security Supplement data.

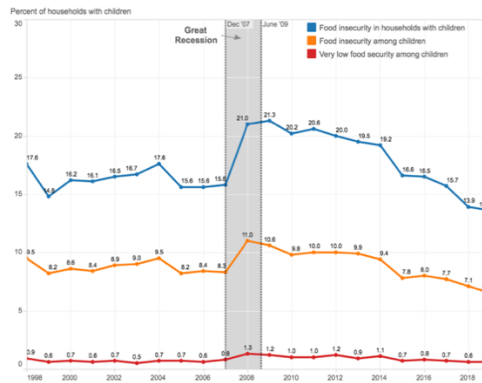


Figure 2. Trends in food insecurity in U.S. households with children (1998-2019)
 Note: Calculated by USDA, Economic Research Service, using Current Population Survey Food Security Supplement data.

Factors Influencing Food Insecurity

U.S residents experience food insecurity for numerous reasons, including economic conditions, lack of social and government programs. Recent studies have shown that income, poverty, price, geography, and rate of participation in food assistance programs including Supplemental Nutrition Assistance Program (SNAP) are important determinants of food insecurity. Other factors such as unemployment and household size are influencing food insecurity indirectly. Unemployment Rates in the United States is shown in Appendix A.

Income. Recent studies have shown income is a key factor affecting food insecurity. Rose, Gundersen and Oliveira (1998) indicated income was one of the strongest predictors of food insufficiency (a proxy measure for the most food-insecure households). This result corresponded with the study by Bukenya (2017) which demonstrated household income was a significant determinant of food insecurity in the Huntsville, Alabama, Metropolitan area.

Income and food insecurity have an inverse relationship (Gregory & Coleman, 2013). Households with lower incomes were more likely to experience food insecurity. A study by Alaimo, Briefel, Frongillo, and Olson (1998) compared the relationship between the household

poverty index ratio (the ratio of household income to the federal poverty level multiplied by 100) and food insecurity. The results showed that food insecurity decreased as the ratio increased. Similarly, assessing the income and food insecurity relationship using the income-to-poverty ratio (the ratio of household income to the federal poverty line for a given family size), Nord and Winicki (2000) showed food insecurity decreased as the income-to-poverty ratio increased. Figure 3, generated by Gundersen, Kreider and Pepper (2011), displays the relationship between food insecurity and income poverty ratio, shown the same result.

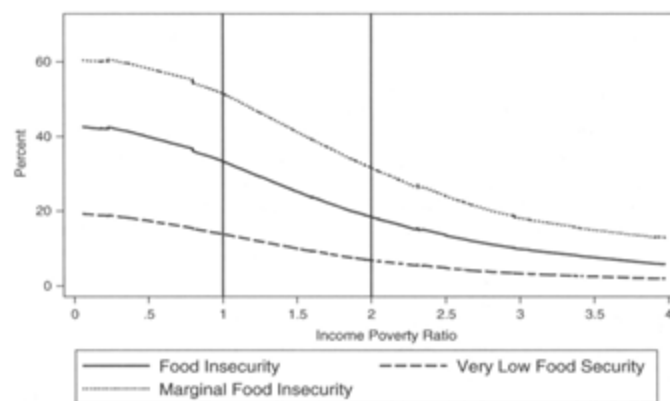


Figure 3. Relationship between food insecurity and income poverty ratio

Note. Gundersen's calculation based on data from 2009 Current Population Survey

The report by National Coalition for the Homeless (2011) pointed out that “the low-income population group is most likely to experience food insecurity, and also most affected by food insecurity because of the complexity of the interrelated issues they must overcome just to put a meal on the table.” A study by Bukenya (2017) found “there is a highly significant ($p < 0.01$) negative relationship between income and food insecurity. Holding other variables constant, food insecurity decreased by a factor of 12.4% as income increased by one level.”

Meanwhile, another study (Gundersen, Kreider & Pepper, 2011) found a large number of poor households that were food secure and a large number of non-poor households that are food insecure. Hence, the current income of households may not be a reliable determinant of food

insecurity. A study by Gundersen and Gruber (2001) found the average household income more than a two-year period could predict whether a household was food insecure better than current income. These results are similar to the results reported by Bukenya (2017), which showed food insufficiency affected not only the poor but also the non-poor. More than 40% of food-insufficient households have incomes above the poverty threshold. If poverty is the only indicator of food insufficiency, this income will be overlooked. Leete and Bania (2010) found households who were liquidity-constrained were more likely to be food insecure than those who are not. This result is consistent with Gundersen and Gruber's (2001) study, comparing with households with liquid assets, households with no liquid assets were significantly more likely to be food insecure.

Poverty. To determine poverty, the Census Bureau used a set of money income thresholds that vary by family size and composition (Bureau, 2020):

If a family's total income is less than the family's thresholds, then the family and every individual in it is considered impoverished. The official poverty definition uses money income before taxes and does not include capital gains or noncash benefits such as Medicaid and food stamps. The poverty line is a measure of the expenditure (or income) required to purchase goods and services for a minimum standard of living, and due to its importance, food must constitute an important part of the poverty line. The incidence of poverty measures the proportion of households whose expenditure (or income) is below the poverty line. Therefore, food insecurity is positively related to poverty incidence.

In 1950's, the research showed that "one-third of the income was spent on food by households from the United States (USDA, 1957) (Rose, Gundersen & Oliveira, 1998). Therefore, the poverty line is set to three times the cost of the economic food program." This study also found that "holding other factors constant, those in poverty were over 3.5 times more likely to be food insufficient." The study also showed that poor households were more likely to be food

insufficient. Although there was a close relationship between poverty and food insufficiency, there did not exist one-to-one relationship (Rose, Gundersen & Oliveira, 1998).

Price. Food insecurity in developing nations increases with food price (Shapouri, 2010). There has been no direct examination of the relationship between food prices and food insecurity for households in the United States due to lack of suitable food price data (Shapouri, 2010). It has been assumed that food prices do not matter as much in the United States, where the cost of food is low as a proportion of total household expenses, relative to other countries. Another study has mentioned this phenomenon as well (Gregory & Coleman, 2013):

This is due in part to the relative lack of food price data that can be matched to household behavior. Much of what we know about the relationship between food prices and food insecurity in the United States is thus somewhat descriptive and relies on our assumptions about the relationship between prices and expenditures.

From 2000 to 2007, food spending of low-income and middle-income households decreased when the food price increased. At the same time, very low food security increased, but whether the increase in food prices caused the increase in food insecurity was not determined (Coleman, Rabbit, Gregory & Anita, 2020). Research has indicated regional food price variation is large, but regional measures of food insecurity do not correlate with prices. For example, one study (Leibtag, 2007) found food prices are lower in the South and Midwest, and higher in the Northeast and West. The monthly food consumption of households in West is \$32 to 48 higher than the U.S. average, households in the South or Midwest is \$12 to 28 less than the U.S. average. However, food insecurity is the highest in the South, where food prices are generally

lowest (Nord & Winicki, 2000). The variation between regions and states in food insecurity are negatively related, rather than proportionately. Gregory and Coleman (2013) found food prices affect food security. It can especially affect food insecurity for households participating in Supplemental Nutrition Assistance Program (SNAP) who have household incomes of 200% or less of the federal poverty line. The results indicate that SNAP could be more effective at ameliorating food insecurity and its effect by indexing benefits to local food prices. However, how to index SNAP benefits is both technically difficult and politically sensitive. Therefore, indexing issues will have to be considered carefully in future research. Warr (2014) indicated higher food price worsen both undernourishment and poverty. Agricultural output must be increased without raising food prices at the same time. The policy implication is that food insecurity can be reduced most effectively by raising agricultural productivity through investments in infrastructure and research, supplemented by food safety nets to assist those unable to benefit from market-based economic development (Warr, 2014). Another study found the prices of necessities such as housing and utilities are associated with higher food insecurity. Bartfeld and Unifon (2006) found higher median rent is associated with a higher likelihood of food insecurity. Furthermore, high heating and cooling costs are linked to an increased likelihood of food insecurity (Bhattacharya, DeLeire, Haider, & Currie, 2003).

Rising COL, particularly the cost of food products is likely to have impacts on food insecurity. While not many research articles have directly linked costs of living with food insecurity, several have reported significant impacts of cost of food or housing on food insecurity. Nord (2000) pointed out that comparing poverty rates among regions is not accurate because official poverty thresholds are constant nationwide, but the COL varies across regions and between rural and urban areas (Nord, 2000). Because of this, the National Academy of

Sciences (NAS) made locational adjustments for cost of housing based on costs for specified quality of housing (Citro & Robert, 1995). To examine the accuracy of the NAS adjusted measurement on COL, Nord (2000) compared the estimates of COL based on the food security/hunger measure with poverty threshold adjusters and found estimates of COL based on food insecurity are statistically significantly related with the adjusters proposed by the NAS panel, however some regions show large discrepancies. Because in general, the NAS adjusters over adjust for cost of living, resulting in estimates that are too high in high-cost-of-living areas and too low in low-cost-of-living areas.

Housing costs are a significant share of COL, especially among low-income households. Fletcher, Andreyeva & Busch (2009) studied whether housing costs will affect the food insecurity rate of families near or at poverty levels, and certain groups of people (for example, people who have received food stamps, individuals receiving housing subsidies, etc.). The results show that rising rent costs have led to increased food insecurity for low-income households. In addition, rental costs only effect the food insecurity rate of renters, but it has no effect on low-income households.

Geography. Food insecurity is often geographically determined (Bukonya, 2017). According to Pinotak and Schulman (2014), households in the South have the highest rates of food insecurity, and this region includes many rural areas. Rural areas, according to this study, have similar issues with household food insecurities as inner cities, but also have additional constraints such as transportation. Location is a big factor of food insecurity. According to the USDA report on rural America, the poverty rate in 2012 was 17.7 percent for non-metropolitan regions, compared to 14.5 percent in metropolitan regions (Piontak & Schulman, 2014).

Food Assistance Programs. Food assistance programs in the United States such as the SNAP, the National School Lunch Program, and the School Breakfast program have been extraordinarily effective in achieving their primary goal of decreasing food insecurity among low-income children (Gundersen, 2015). SNAP, the largest food assistance program in U.S began in 1964 and became a national program in 1974 (Gundersen & Ziliak, 2018). In 2012, more than 14 percent of households in the United States are considered food insecurity since they did not have consistent access to adequate and safe foods (Piontak & Schulman, 2014). Gundersen and Ziliak (2018) reported that increases in SNAP benefits could eliminate food insecurity at a cost of about \$20 billion, whereas an across-the-board increase of SNAP benefits of \$41.62 per week for all households could lead to 62 percent decline in food insecurity among SNAP participants at a cost of about \$27 billion. But, beneficiaries of entitlement programs claim the existing funding is inadequate. Furthermore, beneficiaries feel the program is missing an educational aspect. This also leads to less healthy eating habits, such as buying unhealthy foods, skipping meals on a regular basis, or making tradeoffs between commitments such as paying utility bills or buying food (Kaufman, 2014). Low-income families that rely on SNAP could be especially vulnerable to high food costs. Maximum SNAP benefit allotments are calculated using the national average cost of market baskets of food products that are thought to make up a healthy diet and follow dietary guidelines (Gregory & Coleman, 2013).

Other determinants. Studies have reported several other factors determining the level of food insecurity including education, age, homeownership and employment. For example, education and food insufficiency have an inverse relationship (Rose, Gundersen & Oliveira, 1998). High school graduates are less likely to be food insufficient comparing with those non-high school graduate, even when the effects of income were controlled. Homeownership was

inversely related to food insufficiency. Households headed by those over 60 years of age were less likely to be food insufficient. Finally, household size is proportional to food insufficient (Rose, Gundersen & Oliveira, 1998).

Piontak and Schulman (2014) pointed out that adult unemployment within a household is a significant predictor of food insecurity. The effects of unemployment on food insecurity are further exasperated by the geographical disparity. The unemployment recovery speed is different in rural and urban areas. After the recession in 2008, in rural areas the recovery rate has lagged behind the non-metro areas (Piontak & Schulman, 2014). The effects of race/ethnicity on food insecurity are ambiguous. However, the unemployment rate for non-whites is particularly high, thus having adverse effects on food insecurity (Rose, Gundersen & Oliveira, 1998).

Similarly, studies have found the nature of the family having a role in the level of food insecurity. For example, families with a grandchild present have a higher rate of food insecurity in comparison with those without a grandchild (Gundersen & Ziliak, 2014). Another study (Anderson et al., 2016) found that incarceration increased the likelihood of food insecurity for families with children by about 4%. These findings further support the use of direct indicators of well-being when evaluating policies aimed at improving specific social outcomes, such as reducing hunger and food insecurity.

There are other studies about factors affecting the food insecurity. On such article (Kreider, Pepper & Roy, 2016) demonstrated that Supplemental Nutrition Program for Woman, Infants, and Children Program (WIC) was not specifically designed to reduce food insecurity, but it reduced food insecurity in the United States nevertheless. Even after controlling for a series of other factors, including income, parental education will affect the food insecurity of children

(Gundersen, 2015). Households with at least one disabled person are more likely to face food insecurity than other households (Huang, Guo & Kim, 2010).

DATA SOURCES

To address the research questions, the prevalence of household food insecurity and very low food security were collected as dependent variables. Median household income, unemployment, percentage of SNAP participants and educational annual attainment (Bachelor's degree or higher), percentage of people in poverty, size of households, geographic region and COL were collected as predictor variables. All the data are collected at state level, there are 50 data points in total.

This study uses secondary data mainly collected by government institutions, including Statista, USDA Economic Research Service (ERS), USDA Food and Nutrition Service, U.S. Bureau of Labor Statistics, Federal Economic Research and MERIC (Missouri Economic Research and the Information Center, 2021) in 2019. The list of the data sources and their weblinks are provided in Table 2.

Prevalence of household food insecurity (FI) and prevalence of household very low food insecurity (LFS) were obtained from the USDA's Household Food Security report (2020). The report's original data was taken from the December 2019 Food Security Supplement to the CPS. There were 34,334 households, who completed the Food Security Supplement. The remainder of the households were either unable or unwilling to do so. The Census Bureau measures survey sample weights to determine how many households each household represented. Therefore, the statistics are nationally representative.

Median household income and percentage of all people in poverty are collected from ERS's website, estimated by U.S. Census Bureau. The U.S. Census Bureau's Small Area Income and Poverty Estimates (SAIPE) program provides annual estimates of income and poverty

statistics for all school districts, county, and states. The estimates were not direct counts from administrative records. Instead, the income and poverty models for counties and states were generated by combining census data with population-based county estimates, as well as inputs from federal tax data and multi-year survey data. The SAIPE model is made up of two parts: estimates for the state and county, and estimates for school districts.

The unemployment rate was collected from Labor Area Unemployment Statistics (Local Area Unemployment Statistics Overview, 2016). The LAUS data mainly comes from the current population survey (CPS). The state government first established an unemployment rate prediction model based on the current and historical data from the CPS, the Current Employment Statistics (CES) survey and the State Unemployment Insurance (UI) system. The state monthly unemployment rate is predicted by this model. State monthly model-based estimates are controlled in “real time” to sum to national monthly employment and unemployment estimates from the CPS. The unemployment distribution map is shown in Figure 4.

Since the USDA report does not contain annual information on percentage of annual SNAP participants, the number of SNAP households in April in 2019 was used instead. This data represented an approximation of a number of SNAP participants at a point in time instead using an annual number.

Educational annual attainment data are from Economic Research at the St. Louis Federal Reserve Bank. Data on educational attainment (2019) were derived from a single question that asked, “What is the highest grade of school completed, or the highest degree received?” The first time this question was used was in the 1990 Decennial Census, and it was updated in the CPS in 1992. Prior to this, respondents were asked to answer a two-part question about the highest grade

they had attended and whether or not they had completed it. The American Community Survey included a question about bachelor's degree area. The response categories are in Table 3.

MERIC measures each state's cost-of-living index by averaging the indices of participating cities and metropolitan areas. Cities across the country volunteer to participate in the Council for Community & Economic Research (C2ER) survey. Price information in the survey is governed by C2ER collection guidelines which strive for uniformity. Since the cost-of-living index has no data in 2019, 2020 data was used for reference.

The U.S. Census Bureau divides the U.S. into four main regions, including West, Midwest, Northeast, and South. According to the Census Divisions and Regions map (Brown, 1995) (Figure 4), each state is matched with its region and four dummy variables based on regions were created to evaluate regional disparity in food insecurity.



Figure 4. Map of census divisions and regions
Note: From U.S. Bureau of the Census

Table 2. Data and resources

Variable	Type	Description of data and sources
Prevalence of household food insecurity (PFI)	Dependent variable	Percentage of households identified as food insecure in the state, Coleman-Jensen et al. (2019).
Prevalence of household very low food security (PLFS)	Dependent variable	Percentage of households identified as very low food secure in the state, Coleman-Jensen et al. (2019).
Income	Independent variable	Median household income, USDA Economic Service (2019)
Unemployment	Independent variable	Unemployment rate in the state, USDA Economic Service (2019)
Percentage of households receiving SNAP	Independent variable	Percentage of households participating Supplemental Nutrition Assistant Program, USDA Food and Nutrition Service (2019)
Percentage of bachelor's degree or higher	Independent variable	Annual education attainment (bachelor's degree or higher), Economic Research (2019)
Percentage of people in poverty	Independent variable	Percentage of total population in poverty, USDA Economic Research Service (2019)
Size of households	Independent variable	Average size of households in the United States in 2019, by state, Statista (2020)
Cost-of-living index	Independent variable	Composite cost-of-living index, 2020 annual average, Missouri Economic Research and Information Center
West	Independent variable	The U.S. Census divisions and region, the U.S. Bureau of Census (1995)
Midwest	independent variable	The U.S. Census divisions and region identified as Midwest, the U.S. Bureau of Census (1995)
Northeast	Independent variable	The U.S. Census divisions and region identified as Northeast, the U.S. Bureau of Census (1995)
South	Independent variable	The U.S. Census divisions and region identified as South, the U.S. Bureau of Census (1995)

Table 3. ACS question response categories

Number	Response categories
1	No schooling completed
2	Nursery school
3	Grades 1 through 11
4	12th grade—no diploma
5	Regular high school diploma
6	GED or alternative credential
7	Some college credit, but less than 1 year of college
8	1 or more years of college credit, no degree
9	Associates degree (for example: AA, AS)
10	Bachelor's degree (for example: BA, BS)
11	Master's degree (for example: MA, MS, MEng, MEd, MSW, MBA)
	Professional degree beyond bachelor's degree (for example: MD, DDS, DVM,
12	LLB, JD)
13	Doctorate degree (for example, PhD, EdD)

Source: United States Census Bureau, <https://www.census.gov/topics/education/educational-attainment/about.html>

Research Hypothesis

The literature reviews presented in the prior sections provide guidance regarding the research hypotheses for the study which is presented in Table 4.

Income and food insecurity are expected to have an inverse relationship (Cook et al., 2013). The expected sign of FS and LFS is negative. Therefore, the hypothesis is:

$$H_a: \beta_1 < 0$$

$$H_0: \beta_1 \geq 0$$

Unemployment and PFI/PLFS are expected to have a proportional relationship. The expected sign is positive. Therefore, we set:

$$H_a: \beta_2 > 0$$

$$H_0: \beta_2 \leq 0$$

Percentage of SNAP households and PFI/PLFS are expected to have an inverse relationship. The expected sign is negative. Therefore, the research hypothesis is:

$$H_a: \beta_3 < 0$$

$$H_0: \beta_3 \geq 0$$

Education and PFI/PLFS are expected to have an inverse relationship. High school graduates are less likely to be food insecure even when the income is controlled (Rose, Gundersen & Oliveira, 1998) The expected sign of FS and LFS are negative. Therefore, the hypothesis is:

$$H_a: \beta_4 < 0$$

$$H_0: \beta_4 \geq 0$$

Poor households are more likely to be food insufficient (Rose, Gundersen & Oliveira, 1998). The expected sign of PFS and PLDS is positive. Therefore, the hypothesis is:

$$H_a: \beta_5 > 0$$

$$H_0: \beta_5 \leq 0$$

Size of households and PFI/PLFS are expected to have a proportional relationship, the expected sign of size of households is positive. So, the hypothesis is:

$$H_a: \beta_6 > 0$$

$$H_0: \beta_6 \leq 0$$

Cost of living and PFI/PLFS are expected to have a proportional relationship, the expected sign of cost of living is positive. Therefore, the hypothesis is:

$$H_a: \beta_7 > 0$$

$$H_0: \beta_7 \leq 0$$

Table 4: Hypotheses for variables' effects on prevalence of food insecurity

Independent variable	Expected sign for PFI	Expected sign for PLFS
Income	-	-
Unemployment	+	+
Percentage of households receiving SNAP.	-	-
Percentage of Bachelor's degree or higher	-	-
Percentage of people in poverty	+	+
Size of households	+	+
Cost-of-living index	+	-
West	N/A	N/A
Midwest	N/A	N/A
Northeast	N/A	N/A

The remaining variables are dummy variables representing four regions in the United States: West, Midwest, Northeast, and South. These dummy variables are included in multiple regression model. Dummy variable representing South is dropped while estimating the model. Hence, the estimated coefficients for included regions will be compared with South as a benchmark region. The research hypothesis is that food insecurity is more prevalent in South than the other three regions. Therefore, the signs for the coefficients for the included variables in

the multiple regression models are expected to be negative. However, coefficient signs for the regional variables are not included in Table 4.

METHOD

This is a cross-sectional study. A descriptive statistical analysis of the data is conducted to examine basic statistical attributes of data and identify potential outliers. Further statistical analysis included linear regressions using the Ordinary Least Squares (OLS) technique to examine the relationship between PFI and PLFS among U.S. households and predictor variables. Regression models were estimated in two steps: first, simple regression models with a single key explanatory variable at a time were estimated. Following that a full multi-variable regression model including all the predictor variables was estimated.

The basic empirical models take the form:

$$Y_1 = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + e \quad (1)$$

$$Y_2 = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + e \quad (2)$$

Where

Y_1 = Prevalence of household food insecurity (average from 2017-2019)

Y_2 = Prevalence of household very low food security

X_1 = Median household income

X_2 = Unemployment

X_3 = Percentage of households receiving SNAP

X_4 = Percentage of bachelor's degree or higher

X₅= Percentage of all people in poverty

X₆= Average size of households

X₇= Cost-of-living index

X₈= West (=1, if the state is in west region; =0, otherwise)

X₉= Midwest (=1, if the state is in Midwest region; =0, otherwise)

X₁₀= Northeast (=1, if the state is in Northeast region; =0, otherwise)

X₁₁= South (=1, if the state is in Southern region; =0, otherwise). This variable is dropped while estimating the multiple regression model.

In the end, a sensitivity analysis was conducted to test which of the key predictor variables have the greatest influence on the PFI and PLFS. Sensitivity analysis was conducted using two sets of variables, which are median household income and COL index, and percentage of annual education attainment and all people in poverty. Each set was increased by 5 and 15 percent while keeping the rest of the variables unchanged. Results are presented using GIS maps.

RESULTS AND DISCUSSIONS

Statistical Analysis

The overall results (Table 5) show the descriptive statistics including mean, maximum, minimum, range and standard deviation values of each of the variables used in the analysis. The standard deviation and range of prevalence of household food insecurity and very low food security are small. Therefore, prevalence of household food insecurity has a small variance from state-to-state. Among the predictor variables, the income level has the largest standard deviation and range, followed by the cost-of-living index and education attainment. Finally, the poverty rate is relatively small. Regions, including West, Midwest, and Northeast, are dummy variables which will not be discussed here. The dummy variable for South was dropped while estimating the multiple regression model. That means the coefficients and statistical significance of included dummy variables will be compared with South while interpreting the results.

Previous studies found unemployment is further exasperated by geographical disparities. The unemployment recovery speed is different in rural and urban areas (Piontak, 2014). In this study, the unemployment rate between states does not show a huge gap according to the small range and standard deviation of unemployment of each state. At least, geographical differences are not reflected at state level. Therefore, the impact of urban and rural unemployment rates on food insecurity should be considered for future research.

Simple Linear Regression

Table 6 and 7 show the results from simple linear regressions for prevalence of food insecure households and statistically significant predictor variables at 0.05 significance level.

Since the Average Household Size, West region and Midwest region are not statistically significant, results for these three variables were not included in the tables. The tables also include R-squared values for each of the models.

Coefficient sign and R-squared values for selected models are compared with the posited hypotheses above. The results show income, SNAP households and annual education attainment percentage are inversely related to the prevalence of food insecurity (PFI) and very low food security (PLFS) households. While the results relating to income and education are consistent with posited hypotheses and results reported in previous research, the sign for the coefficient of percentage of SNAP households indicates that percentage of SNAP households was positively related with both levels of food insecurity. A study conducted by Urban Institute (Ratcliff and McKernan, 2010) similarly reported being a SNAP receipt reduces the likelihood of being counted as food insecure household. The coefficient of unemployment, percentage of all people in poverty, and average household size have positive signs and are consistent with posited hypotheses previously stated. The coefficient for COL is reported as negative, hence the data used indicates states with higher costs of living index have lower prevalence of food insecurity.

There are several reasons for this result. First, cost-of-living index is associated with several elements of household expenditures including housing, education, transportation and health care. Among these housing and health care bear larger shares than food. Secondly, often, cost of living tends to be higher among states with large urban population and higher income. Finally, to enable Social Security and Supplemental Security Income (SSI) to keep up with the pace of inflation, in 1973 the legislation was enacted to provide for the cost-of-living adjustment (COLA). The "Social Security Act" provides a formula for determining each COLA. According to the formula, COLA is based on the increase in urban wage income and the consumer price

index (CPI-W) of civilian workers. CPI-Ws are calculated monthly by the Bureau of Labor Statistics. The COLA that took effect in December of the current year is equal to the percentage increase (if any) of the CPI-W from the average of the third quarter of the year to the average of the third quarter of last year (if any). If it increases, it must be rounded to one hundredth. If there is no increase, or the rounded increase is zero, there is no COLA for that year. (*Latest Cost-of-Living Adjustment*, n.d.).

Since COLA adjusted wages and salaries are based on changes in the cost-of-living index, certain correlation between the cost of living and income is expected. The increase in cost of living will cause an increase in income. Whether income or cost of living has a greater impact on food insecurity will be studied in the sensitivity analysis.

The reported coefficient sign of percentage of SNAP households is inconsistent with hypothesized relationship as well. Since SNAP is designed to alleviate food insecurity, the obvious assumption is that SNAP and food insecurity are negatively related. However, the results in this study suggest just the opposite. A similar result has been reported in the previous studies. A study (Nord & Golla, 2009) reported that some food insecure households enrolled in SNAP which accounted for self-selection bias. The result of this study demonstrated that households tended to enroll into SNAP at a time when their food security has worsened. Self-selection based on time-variant factors within the same household—the higher likelihood of a household applying for SNAP at time when food insecurity is more severe—has been hypothesized as the cause of the remaining positive association between food insecurity and SNAP households. But this process had not been convincingly demonstrated by previous research.

In the simple linear regression model, income has a statistically significant ($p < 0.0001$) effect on prevalence of household food insecurity. The coefficient is negative which indicates that income and PFI have an inverse relationship. This result is consistent with previous study that found households with lower income are more likely to experience food insecurity (Gregory & Coleman, 2013). However, average household income over a two-year period is a better predictor of food insecure households than current income (Gundersen & Grunber, 2001). Therefore, for in-depth research on the relationship between income and food insecurity, data should be collected for at least two years to establish a more accurate model.

Unemployment is statistically significant at 0.001 level. The positive coefficient sign shows the positive proportional relationship between unemployment and the prevalence of household food insecurity which is consistent with the theoretical estimation of the coefficient sign. This agree with Piontak and Schulman's (2014) findings, "Unemployment among adults within a household is a key predictor of food insecurity."

Annual education attainment is a crucial factor to reduce food insecurity. According to Table 5, the variable is statistically significant ($p < 0.0001$). The negative coefficient agrees with Rose, Gundersen and Oliveira (1998) result's that found education and food insecurity have an inverse relationship (Rose, Gundersen & Oliveira, 1998). This study also found high school graduates are less likely to be food insufficient, even when the effects of income are controlled. Therefore, receiving education is a basic way to solve food insecurity.

Income, percentage of all people in poverty and annual education attainment have a relatively high R-squared value in the simple linear regression model. For further study on this model, multiple linear regression is conducted.

Multiple linear regression

Table 8 and 9 show the multi-linear regression model on prevalence of household food insecurity and very low food security with its determinants. In these two models, the coefficients of SNAP and the cost-of-living index do not match theoretical expectations. The poverty rate has the largest t value, followed by the average size of household. Therefore, the poverty rate and average household size have a more significant effect on percentage of food insecure households according to this model. This is inconsistent with the analysis result of the simple linear regression. Because the R^2 of percentage of food insecure model is 0.7173, and standard error for both models are small, the model has good predictability.

Sensitivity Analysis

Two sets of variables including income and cost-of-living index in one set and annual education attainment and percentage of all people in poverty in the second set were increased at the same time first by 5% then by 15% (Appendix B). According to previous findings, the prevalence of food insecurity is inversely related to income and annual education attainment, and positively related to the cost-of-living index and percentage of all people in poverty. The degrees of impacts are reported using GIS maps with color coding (Appendix C).

When income and cost-of-living index increases from 5% to 15%, prevalence of household food insecurity and very low food security of all states significantly decreased. Therefore, holding other variables constant, when the income increases in proportion to cost-of-living, income has a greater impact on food insecure households relatively.

Among states, when income and cost-of-living index increased from 5% to 15%, prevalence of very low food security in New Hampshire decreased the most, followed by New Jersey and Massachusetts. Prevalence of food insecurity in Hawaii decreased the most followed by District of Columbia and Massachusetts. Therefore, for these three states, a small percent increase in income could bring significant decrease in prevalence of food insecurity/very low food security.

This finding provides policy guidelines for mitigating potential adverse impacts of COVID-19 on food insecurity through programs such as household income enhancement and adjustment of cost-of-living index.

The pandemic resulted in upward movements for many Bureau of Labor Statistics (BLS) data including food price indices which led to cost of living increase (Mead, Ransom, Reed & Sager, 2020). Apart from the United States, income and employment were strongly affected in many other countries as well. Two-thirds of the people in Kenya and Uganda experienced income shock (Kansiime et al., 2021). In U.S. lower income Americans, particularly women and non-whites, are more likely to lose their income in the first month of the pandemic than Americans in higher income brackets (Bachand, 2021). As a countermeasure, the federal government has allocated a total of \$411 million to individuals to reduce the impact of the COVID-19 (Wheaton, 2021). This policy direction is consistent with the findings of this study. Though cost-of-living index increased as well, extra income (or subsidy) could alleviate food insecurity situation resulted by the on-going pandemic.

When annual education and all people in poverty rate increased from 5% to 15%, the change of predicted prevalence of household food insecurity increased. However, the change of predicted prevalence of very low food security decreased slightly in majority of states.

Therefore, education has greater impact on very low food secure households, relative to the poverty rate, which has greater impact on food insecure households.

For people with very low food security, receiving an education is a more important factor in improving food insecurity situation than poverty alleviation. However, for people in food insecurity situations, poverty alleviation is a key factor. If the poverty problem is not solved fundamentally, even if the percentage of access to education is increased, the impact on food insecurity will not be obvious.

However, reducing the poverty rate is consistent with the goal of reducing the prevalence of food insecurity. Improving the attainment of education and solving poverty issues should be attempted at the same time. These two should not be separated at any time.

Among states, when percentage of all people in poverty and annual education attainment increased from 5% to 15%, prevalence of very low food security decreased. The New Hampshire, Massachusetts, New Jersey and Colorado decreased the most. Therefore, in these four states, improvement in annual education attainment for very low food secure households could reduce the prevalence of very low food security. Among these states, New Hampshire was among those with the largest income inequalities in the U.S. from 2017-2018 (Spantchak, 2019). Similarly, Colorado among those with significant income gap between the rich and the rest. The vast majority of residents of the Colorado city with the largest disparity earn 45 times less than the richest 1% of the population. For the county with the greatest difference between the wealthy and the rest of the population, the number drops to more than 72 times lower (Roberts, 2018). According to U.S. Census Bureau, New Jersey climbed three places to ninth position on the list of the most unequal states in terms of income inequality from 2016. (Raychaudhuri, 2020). Massachusetts has the sixth-biggest gap between its highest-paid residents and everyone else

(Swasey, 2018). Income inequality make the rich getting richer and poor getting poorer. This phenomenon happens not only in these four states. Therefore, for the states like New Hampshire, Massachusetts, New Jersey and Colorado, which have income inequality, increasing the annual education attainment could alleviate the prevalence of food insecurity significantly. Since the COVID-19 pandemic is expected to worsen income inequality, decrease in income, increase in cost of living, further exasperate the unemployment and food insecurity, it is not enough to simply provide subsidies. At the same time education attainment is improved, salaries should be adjusted so that the prevalence of food insecurity can be significantly reduced, and society can recover from the impact of the pandemic.

Table 5. Statistical summary

Variable	Mean	Max	Min	Range	STDEV
Prevalence of food insecurity	11.05	15.70	6.60	9.10	2.22
Prevalence of very low food security	4.39	7.00	2.60	4.40	1.00
Income	65618	90395	45928	44467	11127
Unemployment rate	3.62	6.10	2.40	3.70	0.82
Percentage of households receiving SNAP	0.15	0.73	0.05	0.68	0.09
Percentage of bachelor's degree or higher	32.70	59.70	21.10	38.60	6.54
All people in poverty	12.16	19.50	7.50	12.00	2.64
Average HH size	2.54	3.08	2.28	0.80	0.17
Cost-of-living index	105.67	199.10	84.80	114.30	21.08
West	0.24	1	0	1	0.43
Midwest	0.24	1	0	1	0.43
Northeast	0.18	1	0	1	0.39

Table 6. Simple linear regression of food insecure households and independent variables

Variables	Coefficients	Standard Error	R²
Income	-0.0001****	0.00002	0.43
Unemployment	1.3025***	0.33750	0.23
Percentage of SNAP households	7.0538*	3.26146	0.09
Annual education attainment	-0.1993****	0.03913	0.35
All people in poverty	0.6735****	0.07179	0.64
Cost-of-living index	-0.0466****	0.01347	0.20
Northeast	-2.1191**	0.76486	0.14

Notes: p<0.05(“*”); p<0.01(“**”); p<0.001(“***”); p<0.00001(“****”).

Table 7. Simple linear regression of very low food secure households and independent variables

Variables	Coefficients	Standard Error	R²
Income	-0.0001****	0.0001	0.37
Unemployment	0.5567***	0.1518	0.22
Percentage of SNAP households	2.4653***	1.4702	0.06
Annual education attainment	-0.0764****	0.0186	0.26
All people in poverty	0.2543****	0.0398	0.46
Cost-of-living index	-0.0145**	0.0064	0.10
Northeast	-0.6423	0.3532	0.06

Notes: p<0.05(“*”); p<0.01(“**”); p<0.001(“***”); p<0.00001(“****”).

Table 8. Multiple linear regression 1 (Prevalence of food insecure households)

Variables	Coefficient	Standard Error	t-value
Income	-0.0001	0.0007	-0.0283
Unemployment	0.4572	0.3321	1.3765
% of households receiving SNAP	0.9982	2.2885	0.4362
Annual education attainment	-0.0491	0.0721	-0.6816
All people in poverty	0.4382	0.1913	2.2909
Average HH size	1.3552	1.8220	0.7438
Cost-of-living index	-0.0181	0.0143	-1.2620
West	-0.1377	0.5728	-0.2404
Midwest	-0.1495	0.6228	-0.2400
Northeast	-0.3660	0.6718	-0.5448

R²----0.7173. Adjusted R²=0.6466

Table 9. Multiple linear regression 2 (Prevalence of very low food security)

Variables	Coefficient	Standard Error	t-value
Income	-0.0001	0.0001	-1.2904
Unemployment	0.3281	0.1845	1.7786
% of households receiving SNAP	0.4808	1.2710	0.3783
Annual education attainment	-0.0070	0.0400	-0.17548
All people in poverty	0.0180	0.1062	0.1695
Average HH size	-0.2455	1.0120	-0.2426
Cost-of-living index	0.0056	0.0080	0.7070
West	-0.3050	0.3181	-0.9587
Midwest	-0.4243	0.3459	-1.2264
Northeast	-0.3634	0.3731	-0.9738

R²----0.5676. Adjusted R²=0.4594

KEY FINDINGS

The study mainly has four key findings. 1) Prevalence of food insecurity/very low food security is significantly related to income, unemployment, percentage of SNAP households, cost-of-living index, annual education attainment and percentage of all people in poverty. In addition, prevalence of food insecurity is less among the households in the northeast United States than those in other part of the country; 2) Income has bigger impact on food insecurity compared to cost-of-living index; 3) Improvement in education attainment could significantly reduce prevalence of very low food security while alleviation of poverty rate could significantly reduce prevalence of very low food security; and 4) For states which have income inequality issues, increasing education attainment rate could alleviate prevalence of food insecurity/very low food security significantly.

CONCLUSION

When income increases in proportion to the cost of living, the increase in income significantly reduces the prevalence of food insecurity, and its impact is greater than the cost of living. Annual education and poverty rate have different impact on certain groups. For food insecure households, poverty alleviation is more important than receiving education. However, for very low food secure households, receiving education could reduce food insecurity rate significantly. In addition, increasing annual education attainment in states which have income inequality could alleviate prevalence of food insecurity significantly.

This study provides a direction for future policies toward alleviating food insecurity. It is important to group food insecure households into different groups and make policies and programs based on the group characters. For example, for the states like Colorado, which has a big income gap between the poor and the rich, improving annual education attainment is the key method to alleviate food insecurity.

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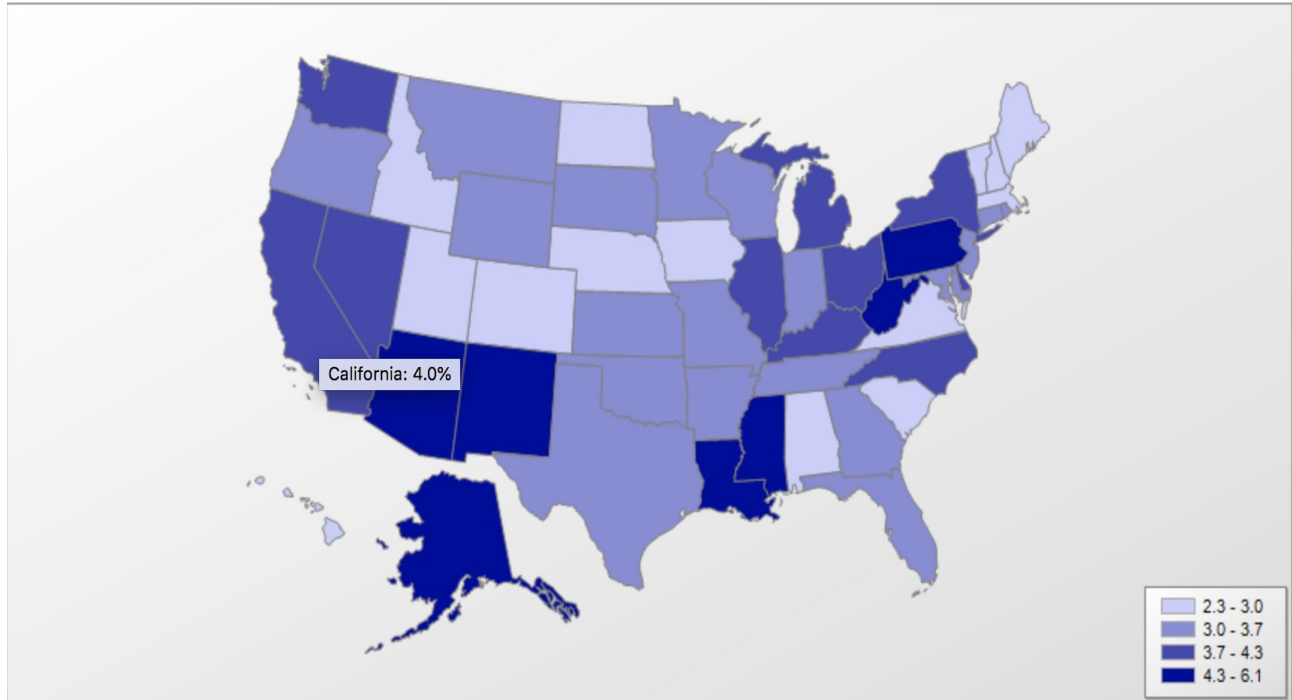
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APPENDICES

Appendix A. Unemployment Rates in the United States, 2019



Source: U.S. Department of agriculture, Economic Research Service

Appendix B. Results of Sensitivity Analysis

Appendix B-1. Sensitivity Analysis (change in predicted prevalence of household food insecurity when income and COL increase by 5%,15% respectively)

Predicted PFI				
State	5%	Change(%)	15%	Change(%)
Alaska(AK)	7.111	-0.335	6.864	-0.359
Arizona(AZ)	8.592	-0.266	8.396	-0.282
Arkansas(AR)	10.225	-0.259	10.055	-0.271
California(CA)	6.402	-0.353	6.135	-0.380
Colorado(CO)	4.971	-0.513	4.768	-0.533
Connecticut(CT)	6.093	-0.528	5.853	-0.546
Delaware(DE)	6.373	-0.375	6.163	-0.396
District of Columbia(DC)	5.691	-0.442	5.383	-0.472
Florida(FL)	7.067	-0.352	6.874	-0.369
Georgia(GA)	7.473	-0.253	7.298	-0.270
Hawaii(HI)	3.586	-0.573	3.209	-0.618
Idaho(ID)	6.409	-0.332	6.226	-0.352
Illinois(IL)	6.568	-0.337	6.381	-0.356
Indiana(IN)	13.567	0.094	13.392	0.080
Iowa(IA)	5.929	-0.249	5.750	-0.272
Kansas(KS)	6.587	-0.473	6.416	-0.487
Kentucky(KY)	9.823	-0.283	9.643	-0.296
Louisiana(LA)	11.036	-0.279	10.857	-0.290
Maine(ME)	5.066	-0.397	4.842	-0.424
Maryland(MD)	4.503	-0.554	4.255	-0.579
Massachusetts(MA)	3.826	-0.545	3.573	-0.575
Michigan(MI)	7.232	-0.407	7.055	-0.422
Minnesota(MN)	4.330	-0.478	4.133	-0.502
Mississippi(MS)	11.575	-0.263	11.413	-0.273
Missouri(MO)	7.131	-0.390	6.958	-0.405
Montana(MT)	6.667	-0.197	6.476	-0.220

Appendix B-1 continued. Sensitivity Analysis (change in predicted prevalence of household food insecurity when income and COL increase by 5%,15% respectively)

Predicted PFI				
State	5%	Change	15%	Change(%)
Nebraska(NE)	5.429	-0.497	5.248	-0.514
New Hampshire(NH)	3.370	-0.489	3.158	-0.521
New Jersey(NJ)	4.527	-0.412	4.297	-0.442
New Mexico(NM)	10.362	-0.314	10.189	-0.325
New York(NY)	6.283	-0.418	6.026	-0.442
North Carolina(NC)	7.794	-0.405	7.608	-0.419
North Dakota(ND)	5.233	-0.370	5.044	-0.392
Ohio(OH)	7.501	-0.405	7.323	-0.419
Oklahoma(OK)	8.724	-0.407	8.555	-0.418
Oregon(OR)	5.790	-0.409	5.532	-0.435
Pennsylvania(PA)	6.690	-0.344	6.491	-0.364
Rhode Island(RI)	5.830	-0.359	5.600	-0.385
South Carolina(SC)	7.541	-0.308	7.356	-0.325
South Dakota(SD)	6.514	-0.402	6.328	-0.419
Tennessee(TN)	7.922	-0.366	7.748	-0.380
Texas(TX)	8.730	-0.334	8.550	-0.347
Utah(UT)	5.423	-0.493	5.231	-0.511
Vermont(VT)	4.138	-0.569	3.914	-0.592
Virginia(VA)	5.206	-0.434	5.006	-0.456
Washington(WA)	5.611	-0.433	5.391	-0.455
West Virginia(WV)	9.901	-0.357	9.723	-0.369
Wisconsin(WI)	5.768	-0.429	5.580	-0.448
Wyoming(WY)	5.801	-0.525	5.615	-0.540

Appendix B-2. Sensitivity Analysis (change in predicted prevalence of very low food secure households when income and COL increase by 5%,15% respectively)

Predicted PLFS				
State	5%	Change(%)	15%	Change(%)
Alaska(AK)	-1.889	-1.889	-2.198	-1.449
Arizona(AZ)	-1.613	-1.613	-1.862	-1.443
Arkansas(AR)	-0.824	-0.824	-1.016	-1.175
California(CA)	-3.042	-3.042	-3.361	-1.934
Colorado(CO)	-3.455	-3.455	-3.777	-1.878
Connecticut(CT)	-3.397	-3.397	-3.717	-1.826
Delaware(DE)	-2.324	-2.324	-2.610	-1.622
District of Columbia(DC)	-2.874	-2.874	-3.231	-1.808
Florida(FL)	-2.444	-2.444	-2.680	-1.609
Georgia(GA)	-2.496	-2.496	-2.752	-1.764
Hawaii(HI)	-3.303	-3.303	-3.605	-2.060
Idaho(ID)	-2.561	-2.561	-2.808	-1.826
Illinois(IL)	-2.721	-2.721	-3.009	-1.792
Indiana(IN)	-2.344	-2.344	-2.577	-1.629
Iowa(IA)	-2.735	-2.735	-2.989	-1.830
Kansas(KS)	-2.680	-2.680	-2.937	-1.534
Kentucky(KY)	-1.175	-1.175	-1.380	-1.288
Louisiana(LA)	-0.903	-0.903	-1.102	-1.157
Maine(ME)	-2.262	-2.262	-2.487	-1.401
Maryland(MD)	-3.263	-3.263	-3.619	-1.724
Massachusetts(MA)	-3.774	-3.774	-4.125	-2.289
Michigan(MI)	-2.136	-2.136	-2.379	-1.506
Minnesota(MN)	-3.308	-3.308	-3.619	-2.065
Mississippi(MS)	-0.471	-0.471	-0.650	-1.105
Missouri(MO)	-2.302	-2.302	-2.535	-1.576
Montana(MT)	-2.075	-2.075	-2.302	-1.590

Appendix B-2 continued. Sensitivity Analysis (change in predicted prevalence of very low food secure households when income and COL increase by 5%,15% respectively)

Predicted PLFS				
State	5%	Change(%)	15%	Change(%)
Nebraska(NE)	-2.779	-2.779	-3.039	-1.707
Nevada(NV)	-2.174	-2.174	-2.425	-1.441
New Hampshire(NH)	-3.668	-3.668	-3.995	-2.537
New Jersey(NJ)	-3.663	-3.663	-4.020	-2.340
New Mexico(NM)	-1.255	-1.255	-1.461	-1.266
New York(NY)	-2.554	-2.554	-2.834	-1.727
North Carolina(NC)	-1.663	-1.663	-1.892	-1.386
North Dakota(ND)	-3.108	-3.108	-3.386	-2.209
Ohio(OH)	-2.069	-2.069	-2.307	-1.427
Oklahoma(OK)	-1.684	-1.684	-1.904	-1.359
Oregon(OR)	-2.316	-2.316	-2.571	-1.598
Pennsylvania(PA)	-2.120	-2.120	-2.376	-1.579
Rhode Island(RI)	-2.672	-2.672	-2.953	-1.952
South Carolina(SC)	-1.954	-1.954	-2.178	-1.544
South Dakota(SD)	-2.436	-2.436	-2.680	-1.570
Tennessee(TN)	-1.752	-1.752	-1.978	-1.373
Texas(TX)	-1.942	-1.942	-2.207	-1.450
Utah(UT)	-3.609	-3.609	-3.927	-2.122
Vermont(VT)	-2.746	-2.746	-2.993	-1.767
Virginia(VA)	-3.134	-3.134	-3.455	-2.080
Washington(WA)	-2.939	-2.939	-3.264	-1.933
West Virginia(WV)	-0.710	-0.710	-0.898	-1.152
Wisconsin(WI)	-2.653	-2.653	-2.916	-1.884
Wyoming(WY)	-2.588	-2.588	-2.861	-1.572

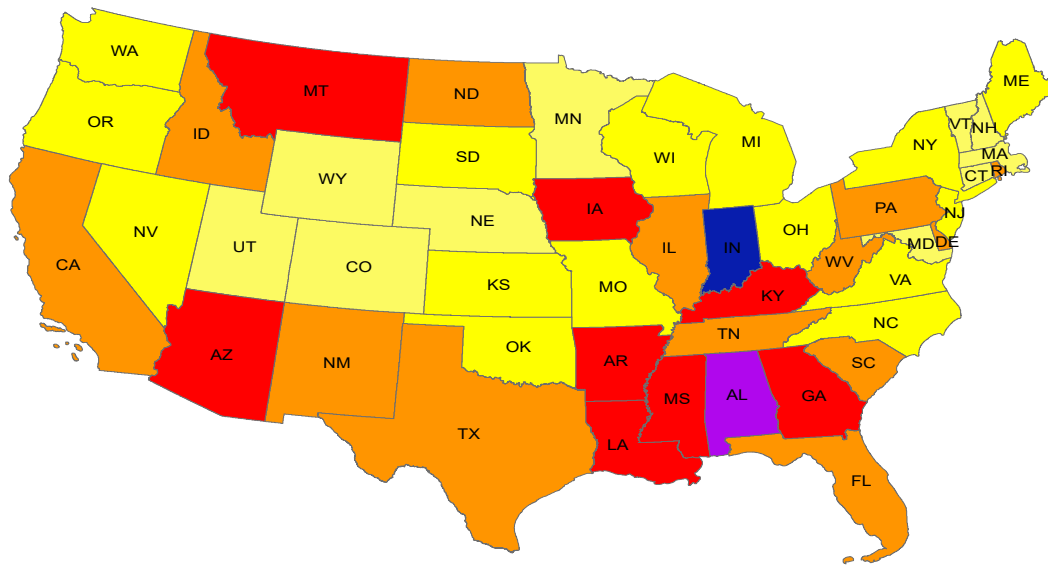
Appendix B-3. Sensitivity Analysis (changes in predicted prevalence of food insecurity when annual education attainment and percentage of all people in poverty increase by 5%)

State	Predicted PFI		Predicted PLFS	
	5%	Change(%)	5%	Change(%)
Alaska(AK)	11.630	0.080	4.907	0.002
Arizona(AZ)	12.702	0.078	4.828	0.130
Arkansas(AR)	13.852	0.003	5.441	-0.066
California(CA)	11.004	0.100	3.766	0.044
Colorado(CO)	8.983	-0.135	3.325	-0.293
Connecticut(CT)	9.224	-0.398	3.646	-0.234
Delaware(DE)	10.907	0.064	4.455	0.057
District of Columbia(DC)	10.391	0.018	4.243	0.058
Florida(FL)	11.763	0.073	4.742	0.072
Georgia(GA)	12.389	0.192	4.638	0.224
Hawaii(HI)	8.136	-0.032	3.487	0.025
Idaho(ID)	10.918	0.120	4.205	0.192
Illinois(IL)	11.070	0.105	4.063	0.065
Indiana(IN)	11.453	-0.082	4.418	0.072
Iowa(IA)	10.434	0.242	4.035	0.108
Kansas(KS)	10.755	-0.162	4.090	-0.345
Kentucky(KY)	13.969	0.019	5.577	0.139
Louisiana(LA)	15.731	0.027	5.849	-0.197
Maine(ME)	9.563	0.121	4.492	-0.380
Maryland(MD)	9.219	-0.095	3.552	-0.408
Massachusetts(MA)	8.291	-0.013	3.037	-0.054
Michigan(MI)	12.081	-0.009	4.630	-0.015
Minnesota(MN)	9.204	0.098	3.486	0.025
Mississippi(MS)	16.639	0.056	6.272	0.011
Missouri(MO)	11.673	-0.002	4.459	0.013

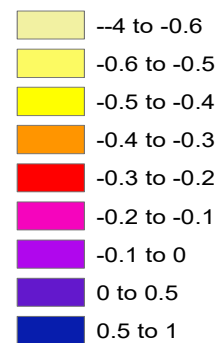
Appendix B-3 continued. Sensitivity Analysis (changes in predicted prevalence of food insecurity when annual education attainment and percentage of all people in poverty increase by 5%)

State	Predicted PFI		Predicted PLFS	
	5%	Change(%)	5%	Change(%)
Montana(MT)	11.203	0.259	4.681	0.167
Nevada(NV)	12.109	-0.057	4.597	-0.196
New Hampshire(NH)	7.795	0.153	3.132	0.170
New Jersey(NJ)	8.987	0.143	3.153	0.049
New Mexico(NM)	15.011	-0.005	5.498	-0.001
New York(NY)	10.852	0.005	4.2283	0.078
North Carolina(NC)	12.352	-0.061	5.0962	0.039
North Dakota(ND)	9.729	0.147	3.6737	0.238
Ohio(OH)	12.051	-0.046	4.6952	-0.150
Oklahoma(OK)	13.322	-0.104	5.0737	-0.045
Oregon(OR)	10.332	0.052	4.4529	0.034
Pennsylvania(PA)	11.220	0.091	4.6504	0.118
Rhode Island(RI)	10.361	0.122	4.1093	0.246
South Carolina(SC)	12.113	0.100	4.8039	0.167
South Dakota(SD)	11.042	0.013	4.3293	-0.086
Tennessee(TN)	12.488	-0.001	5.0068	-0.059
Texas(TX)	13.290	0.014	4.8345	-0.014
Utah(UT)	9.873	-0.084	3.1900	-0.097
Vermont(VT)	8.624	-0.113	4.0161	0.029
Virginia(VA)	9.672	0.049	3.6644	0.127
Washington(WA)	10.092	0.019	3.8623	0.094
West Virginia(WV)	14.540	-0.059	6.0347	0.022
Wisconsin(WI)	10.259	0.016	4.1197	0.199
Wyoming(WY)	10.286	-0.186	4.1910	-0.193

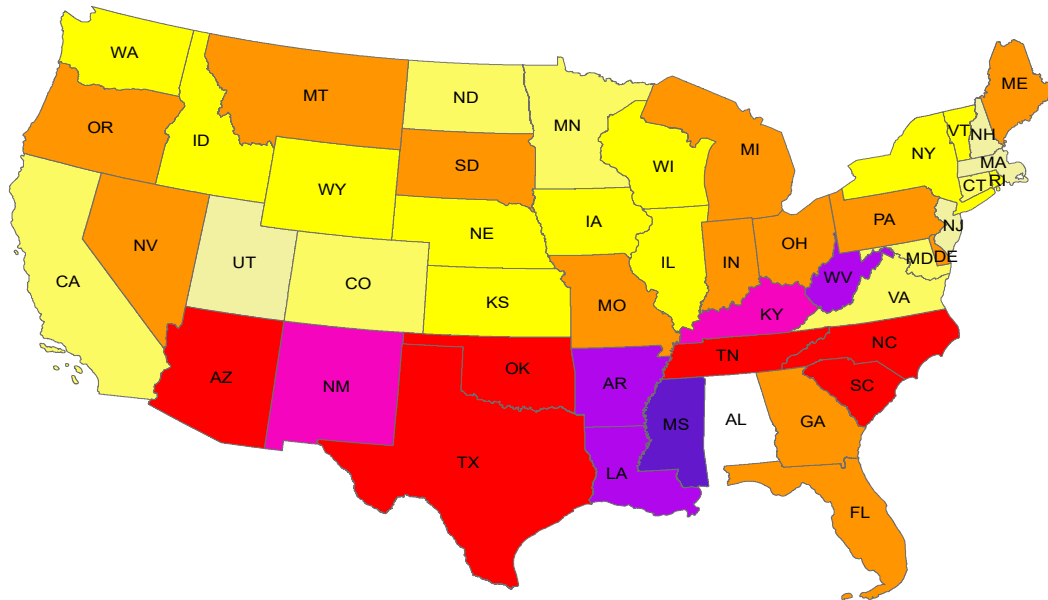
Appendix C-2. Income and cost-of-living increased by 15%, change in predicted prevalence of household food insecurity



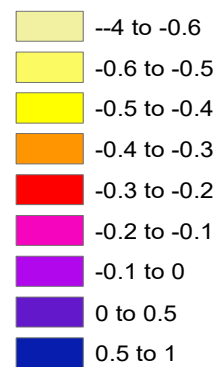
Change in Predicted Percentage of Food Insecure Households/ Very Low Food Secure Households



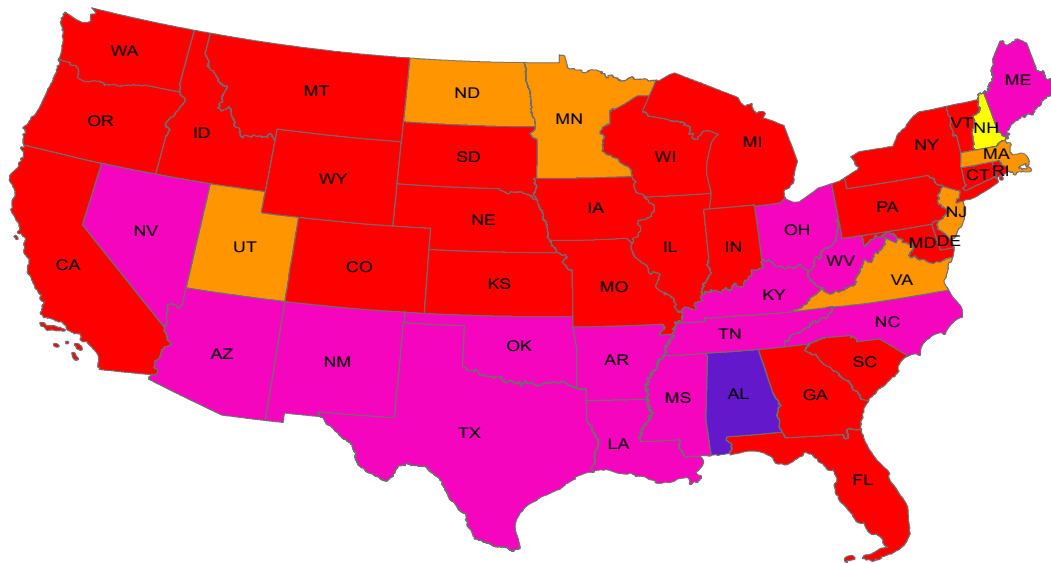
Appendix C-3. Income and cost-of-living increased by 5%, change in predicted prevalence of very low food security



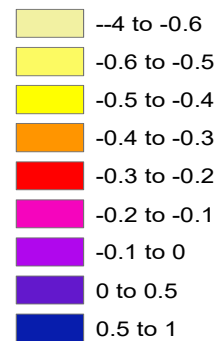
Change in Predicted Percentage of Food Insecure Households/ Very Low Food Secure Households



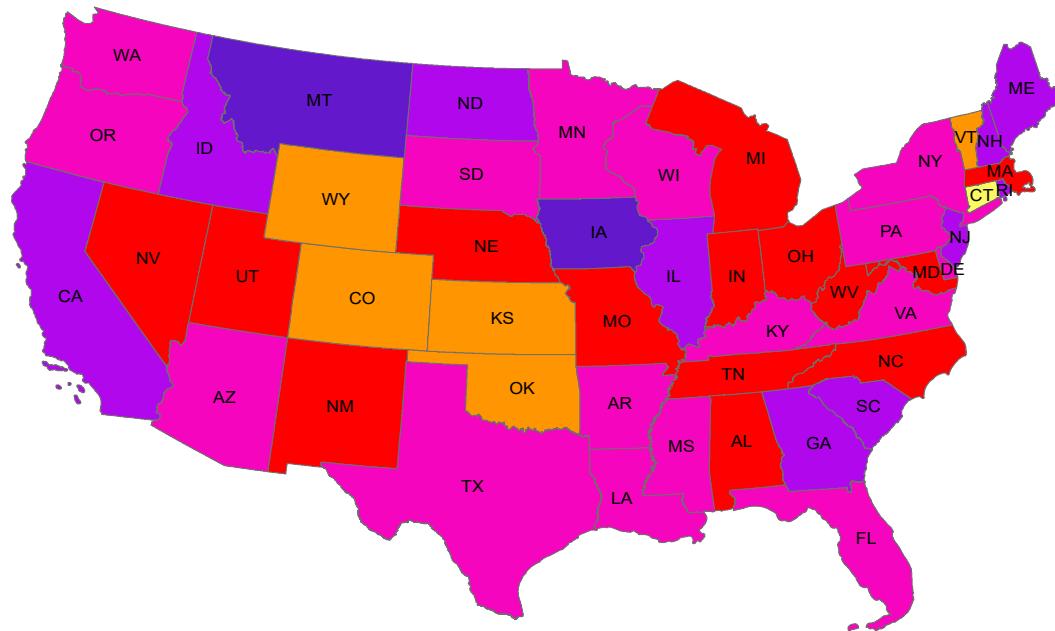
Appendix C-4. Income and cost-of-living increased by 15%, change in predicted prevalence of very low food security



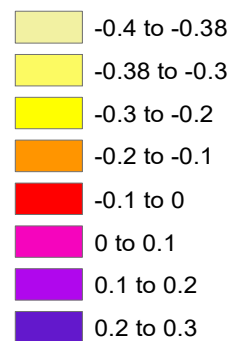
**Change in Predicted Percentage of Food Insecure Households/
Very Low Food Secure Households**



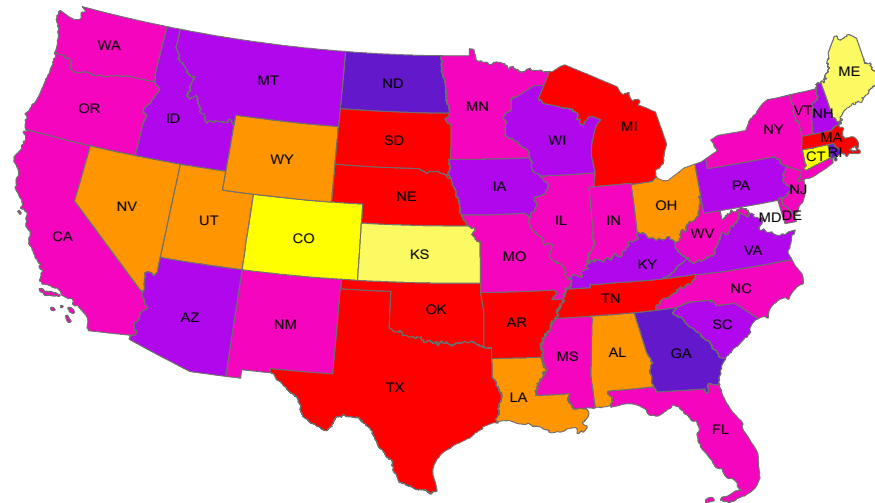
Appendix C-5. Annual education attainment and percentage of all people in poverty increased by 5%, prediction of prevalence of food insecurity



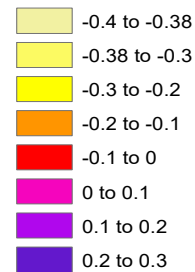
**Change in Predicted Percentage
of Food Insecure Households/
Very Low Food Secure Households**



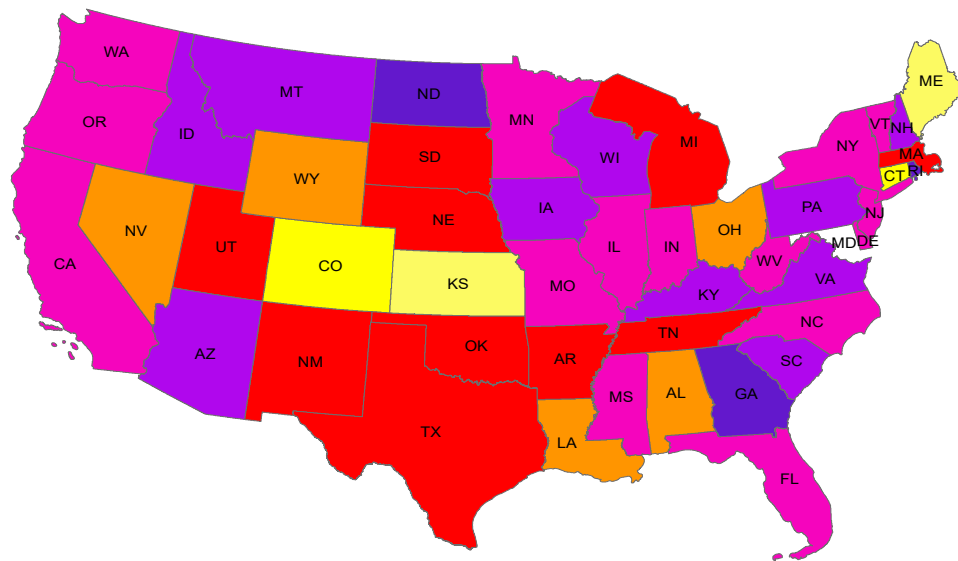
Appendix C-6. Annual education attainment and percentage of all people in poverty increased by 15%, prediction of prevalence of food insecurity



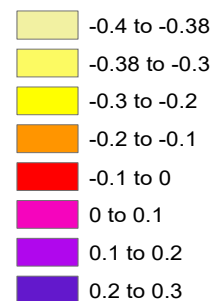
**Change in Predicted Percentage
of Food Insecure Households/
Very Low Food Secure Households**



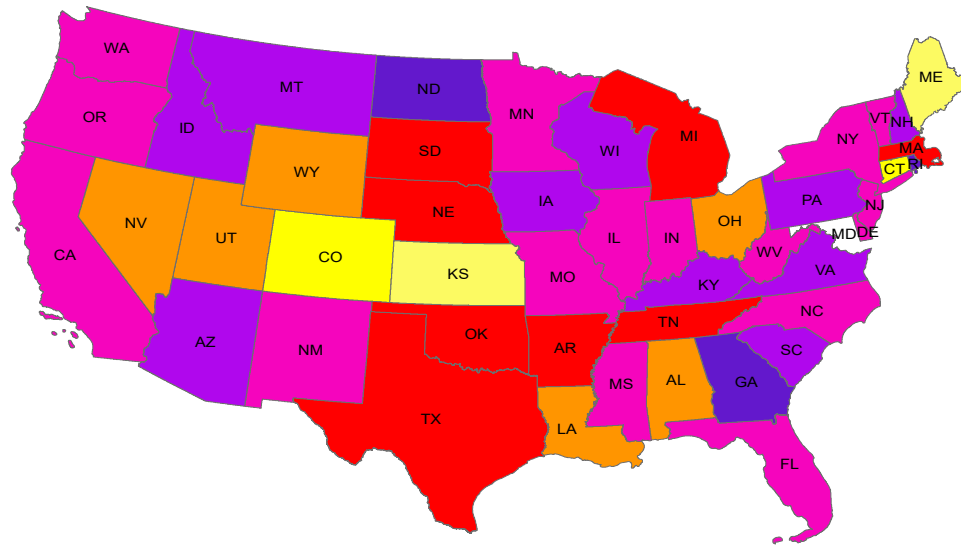
Appendix C-7. Annual education attainment and percentage of all people in poverty increased by 5%, prediction of prevalence of very low food security



Change in Predicted Percentage of Food Insecure Households/ Very Low Food Secure Households



Appendix C-8. Annual education attainment and percentage of all people in poverty increased by 15%, prediction of prevalence of very low food security



**Change in Predicted Percentage
of Food Insecure Households/
Very Low Food Secure Households**

