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Disparities in food insecurity during the COVID-19 pandemic: A two-year analysis

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ABSTRACT

While the overall level of food insecurity in the United States has remained stable during the COVID-19 pandemic, certain individuals and regions have fared worse than others. This study examines state-level variables affecting individual- and household-level food insecurity during the recent two years of the pandemic beginning in 2020 by utilizing the Household Pulse Survey, a new nationally representative dataset developed by the United States Census Bureau. The results of this study suggest a set of statewide factors, such as pandemic-driven market conditions, COVID-19 prevalence, and the implementation of federal programs, are associated with the level of food insecurity that individuals have experienced during the pandemic over the past two years. The associations varied by household income levels, indicating a strong relationship between higher-income households and market conditions, as well as the importance of federal programs and state policies in alleviating food insecurity among lower-income households. The food insecurity indices also overlapped with different socioeconomic and health hardships caused by the pandemic, such as employment income loss, housing instability, and mental health problems. The findings of this study highlight state-level factors, particularly the role of state governments, in responding to pandemic-related food insecurity.

1. Introduction

The outbreak of the COVID-19 pandemic in early 2020 resulted in acute and omnipresent global food access issues, especially during the early months of the pandemic. Many parts of the world experienced an increased level of hunger and social unrest due to disruptions in food supply chains and consequent fluctuations in food prices (Florida et al., 2020). As the pandemic continues into 2022, general trends in global food chains have demonstrated resilience to the impact of the pandemic, as evidenced by the rebound of global agricultural trade in the third and fourth quarters of 2020 (Arita et al., 2022). Certain populations in the United States (U.S.), however, have remained more vulnerable than others due to the impact of COVID-19, indicating disparities in food insecurity (Gundersen, 2018).

Food insecurity, defined as the limited availability and unassured access to adequate food for a healthy and active life, is a long-standing global challenge initially exacerbated by the pandemic. Early COVID-19 studies reported a double increase in food insecurity compared to the pre-pandemic period (Baker et al., 2020; Schanzenbach & Pitts, 2020). By the end of 2020, however, the spiked numbers significantly declined to near pre-pandemic levels, motivating researchers to focus on widening disparities in food insecurity during the pandemic (Data Foundation, 2020; Karpmam et al., 2020), variations by demographic subgroups (Callen, 2020; Monte & O’donnell, 2020; Waxman, Gundersen, & Fiol, 2021, Waxman, Gupta, & Pratt, 2021), associations with socioeconomic statuses (Waxman, 2020b; Waxman et al., 2020), and local policy responses (Bauer, 2020; Bauer et al., 2020). Still, it is unclear which statewide variables are most strongly correlated with a higher prevalence of COVID-19 food insecurity and populations. Furthermore, the issue of unequal pandemic impacts on food security across different income groups, as well as the effects of other COVID-19-induced social and economic disruptions, such as job loss and housing payment delays, on food insecurity, remains understudied. This study fills those gaps by investigating the association between statewide characteristics and the extent of their impact on food insecurity by utilizing the Household Pulse Survey (HPS), a survey launched by the
United States Census Bureau to produce near-real-time information on how individuals and households have fared throughout the pandemic.

To the best of our knowledge, this is the first study to analyze food insecurity during the entire two years of the pandemic in the U.S. We attempted to make three contributions to the COVID-19 scholarship; first, we identify possible associations between individual-level food insecurity and state-level characteristics which include pre-pandemic socioeconomic contexts, current pandemic market conditions, and pandemic policy responses. While many of these factors have undergone separate COVID-19 studies, none of the studies have yet considered them in a single comprehensive study to illustrate the scene of food insecurity during the pandemic. Second, we examine whether state-level characteristics mitigate or exacerbate the detrimental impact of the pandemic on food insecurity among low-income household populations. Third, we investigate the extent to which state-level characteristics play a role in explaining individual-level food insecurity compounded by socioeconomic and health hardships – income loss, housing instability, and health problems – which are all highlighted during the pandemic.

We first review studies on food insecurity during the COVID-19 pandemic and offer a theoretical framework on government agencies and statewide contexts as food security determinants; this is followed by the formulation of overarching research questions. Next, we compile HPS data and a variety of state variables. Building multilevel mixed-effects logistic regression models, we examine the relations between the likelihood of experiencing COVID-19 food insecurity and individual and state variables. Lastly, we discuss policy implications to address food insecurity and prepare for the post-pandemic time.

2. Background

2.1. Literature review

The first confirmed case of COVID-19 was reported on January 20, 2020 in the United States. It took only two months for the virus to spread across the entire nation (see Fig. 1). New cases surged and declined repeatedly resulting in a series of COVID-19 waves throughout the first year of the pandemic. The advent of COVID-19 waves significantly reduced new cases as the calendar turned to 2021. As the year turned to 2022, the Omicron variant hit the nation and documented the peak of daily new cases.

During the initial phase of the pandemic, food acquisition became an even more fundamental and challenging aspect of daily life and livelihoods (Baker et al., 2020). According to the U.S. Census Bureau, around 10 % of adults across the nation failed to obtain enough food at some point during the pandemic, while another 32 % reported that they secured enough but not the kinds of food they needed (Callen, 2020). Nearly 8.8 million adults nationwide reported a household decrease in food availability since the start of the pandemic (Monte & O’Donnell, 2020).

Unlike the early estimates, recent studies in the U.S. find that food security has proven resilient to the impacts of the COVID-19 pandemic. According to the annual and national report published by the U.S. Department of Agriculture (USDA), the prevalence of food insecurity in 2020 was largely unchanged from 2019 (U.S. Department of Agriculture, 2021a). In 2020, 10.5 % of U.S. households were food insecure at least sometime during the year, including 3.9 % (5.1 million households) that had very low food security. Overall, food insecurity remained stable compared to the same estimate (10.5 %) in 2019. Based on National Data from the Urban Institute’s Health Reform Monitoring Survey, Waxman and her colleagues also found that food insecurity was reduced by nearly 30 % between spring 2020 and 2021 (Waxman & Gupta, 2021). While 21.7 % of adults reported experiencing food insecurity in the previous 30 days during the first few weeks of the pandemic shutdown in March and April 2020, this estimate dropped to 15.3 % by April 2021.

However, despite the national trend, food insecurity indices vary significantly across population subgroups and regions. The Brookings Institution took the lead on COVID-19 food insecurity research in the U.S., finding a much higher incidence of food insecurity among low-income households and households with children (Bauer, 2020; Bauer & O’donnell, 2022).
et al., 2020). The Institute for Policy Research at Northwestern University reported much higher food insecurity among those with only a high school diploma as opposed to those with at least a bachelor's degree (Schanzenbach & Pitts, 2020). The Health Reform Monitoring Survey, conducted by the Urban Institute, also revealed that Blacks and Hispanics experienced higher COVID-19 food insecurity than Whites during March and April 2020 (Karpman et al., 2020; Waxman, 2020a,b; Waxman et al., 2020). Other recent studies have found that vulnerable groups, such as seniors (Levy, 2022), teachers (Martin et al., 2022), and people in need of medical care (Bertoldo et al., 2022), have limited access to food.

The COVID Impact Survey, a nationwide non-profit survey, also confirmed the ever-higher level of nationwide food insecurity prevalence in the nation, but the degree varied considerably across regions (Data Foundation, 2020). People in the states where business conditions were hardest hit by the COVID-19 pandemic were more likely to rely on emergency sources for food such as food banks, religious organizations, community programs, and family, friends, or neighbors (Monte & O’Donnell, 2020). The regional disparities in food insecurity may worsen, particularly in rural areas where on-demand food delivery and online platforms are less developed and food supply chains are not well connected across administrative and geographical boundaries (Lever et al., 2022; Talamini et al., 2022).

### 2.2. Government agency and statewide contexts as food security infrastructure

While state-level contexts and government initiatives may substantially affect the individual- and community-level food security, the role of state governments in addressing both chronic and acute food insecurity incidence has received limited attention. Bartfeld et al. (2006) identify some state-level factors that influencing the degree of food insecurity within the state, such as the supply of affordable housing, federal-level food assistance programs, and the task burden for low-income populations. Such characteristics at the state level, including the availability and accessibility of the Supplemental Nutrition Assistance Program (SNAP), state policies to improve the economic well-being of low-income households, and general economic and social contexts, constitute “the state food security infrastructure” (Bartfeld & Dunfion, 2006). In the case of Hawaii, Kent (2015) pinpoints the historical absence of state-level agencies in alleviating poverty-induced food insecurity and food crises caused by disasters, arguing for the enhanced responsibility of the state to ensure the food security of residents. Similarly, Slade et al. (2016) point out the lack of coordinated and multilevel institutional governance in responding to the issue of food security, especially between local, state, and federal governments. They claim that the incongruence or lack of comprehensive understanding of food security across different administrative levels, particularly at the state level, creates systemic barriers to better planning solutions.

Clapp and her colleagues (Clapp et al., 2021) recently suggested a new framework to understand and evaluate food security status, adding two components to the existing four pillars of availability, access, utilization, and stability: agency and sustainability. Agency, here, refers to “the capacity of individuals and groups to exercise a degree of control over their own circumstances and to provide meaningful input into governance process” (Clapp et al., 2021, p. 3). Agency can help people build relationships with food systems and cope with the imbalance of power within them (Sen, 1985) as a critical element to achieve equitable livelihoods and build sustainable food systems. While the concept of agency is primarily discussed at the individual or community level in their study, Clapp et al. (2021) acknowledge the need for reinforcing collective agency through public policy and measures, such as social protection programs for disadvantaged populations. In this study, we conceptualize the state government as a societal entity and an aggregated agency which creates crucial context and barriers to food security experienced at the individual or community level.

### 2.3. Research questions

Although previous COVID-19 studies demonstrated that the pandemic has resulted in a disproportionate, adverse impact on food insecurity across populations and places in the U.S., associations between contextual factors and food insecurity during the pandemic remain not fully explained. This study aims to identify possible associations by answering three overarching research questions.

Firstly, we attempt to address the nature of the association between statewide variables and individual-level food insecurity during the pandemic. Specifically, we set pre-pandemic socioeconomic contexts, pandemic food market conditions, and pandemic policy responses for the statewide variables. While researchers have separately examined each of the three statewide factors (Baker et al., 2020; Bauer et al., 2020; Karpman et al., 2020), none of the current COVID-19 studies have assessed all three factors in a single analysis. A more thorough analysis of statewide conditions may help identify the most significant contributor to pandemic-induced food insecurity, as well as prioritize the most effective pandemic responses at the state level. This assessment will present the net of any possible interactions between statewide contexts and individual characteristics, leading to the next question.

Secondly, we ask whether statewide variables moderate or strengthen the relationship between household income and food insecurity. Are low- and high-income households equally affected by the pandemic-induced food market disruptions? Are the targeted populations of the existing food assistance and nutrition programs benefiting from available resources during the pandemic?

The final question concerns how much the statewide variables play a role in explaining food insecurity compounded by pandemic-induced socioeconomic and health hardships. As food acquisition at the individual or household level tends to be significantly affected by changes in socioeconomic status, social and economic hardships during the pandemic might have exacerbated food insecurity, especially when coupled with abrupt income loss. A close analysis of food insecurity associated with other COVID-19 difficulties will help explain how the complex nature of the pandemic-induced food insecurity can double-burden people across income levels and regions.

### 3. Data and methods

#### 3.1. Household pulse survey in COVID-19 pandemic

The Household Pulse Survey (HPS) is a national survey implemented by the United States Census Bureau cooperatively with USDA that investigates food insecurity and socioeconomic experiences among adult (18 or older) Americans during the COVID-19 pandemic (U.S. Census Bureau, 2020b). We used publicly available microdata containing individual responses to the HPS questions (U.S. Census Bureau, 2020a). Tracing the same respondents across all survey weeks is unavailable. Instead, the survey collected cross-sectional data that amounts to an analytic sample of 2,042,140 participants who responded in the 45 survey weeks (April 23, 2020–May 9, 2022; see Fig. 1) and answered all individual responses to the HPS questions. We examine Yijk representing the food insecurity status of person i in state j in week k (0 for a survey respondent without difficulty in securing food and 1 for a

$$Y_{ijk}$$
respondent with difficulty). The multilevel model is stated as:

**Level-1 Model**

\[
Y_{ijk} = \beta_{0jk} + \beta_{1jk}D_{ijk} + \beta_{2jk}S_{ijk} + \beta_{3jk}H_{ijk} + \beta_{4jk}F_{ijk} + \mu_{ijk}
\]

**Level-2 Model**

\[
\beta_{0jk} = \gamma_{0jk} + \gamma_{1jk}P_{jk} + \gamma_{2jk}F_{jk} + \varepsilon_{jk}
\]

In the level-1 and level-2 models, \(D_{ijk}\) is a group of demographic variables; \(S_{ijk}\) is a set of social and economic statuses; \(H_{ijk}\) is a series of COVID-19 pandemic hardships; \(F_{ijk}\) is spatial and temporal fixed-effects; \(\mu_{ijk}\) is an error term in level-1 model; \(P_{jk}\) is a set of pandemic conditions and COVID-19 prevalence; \(F_{jk}\) is a series of federal programs and socioeconomic contexts; \(\varepsilon_{jk}\) is an error term in level-2 model that can correlate in the same state. To correct for the correlations in the error term and address heteroscedasticity, we use clustered standard errors (state level) throughout this article. The model is observational and unable to assess causal relationships and therefore we cautiously interpret the estimation results.

3.3. Variables

3.3.1. COVID-19 food insecurity outcome

The survey asked a food security evaluation question “In the past weeks, which of the following statements describes the food eaten in your household?” with four answer options:

1) Enough of the kinds of food (I/we) wanted to eat
2) Enough, but not always the kinds of food (I/we) wanted to eat
3) Sometimes not enough to eat
4) Often not enough to eat

We define a binomial variable of food insecurity, which equals zero (secure status) if a survey participant selected option 1, and one (insecure status) if any of options 2, 3, or 4 is selected to indicate the status of food insecurity. Given the universal nature of the pandemic-induced disruptions in food systems, we specifically test two alternative and narrower measures of food insecurity to capture more serious food hardships: one for options 3 and 4 as the state of food insecurity and the other for only option 4, respectively.

Fig. 2 displays the national trend in food insecurity for the entire period of the COVID-19 pandemic starting from April 23, 2020, to May 9, 2022, which is derived from the United States Census Bureau’s tabulations based on HPS data. Despite the unexpected shock of the pandemic in early 2020, the level of food insecurity did not increase substantially and was recorded at average of 10.9 % throughout the year. The HPS-based statistic roughly matched the USDA’s calculation based on CPS data (10.5 % in 2020) which was slightly higher than 9.8 % in 2019 but close to 10.4 % in 2018 (U.S. Department of Agriculture, 2021b, Table 1A, p. 8). It is also notable that the level of food insecurity was even higher in the early 2010s (between 12.0 % and 14.5 %) than in 2020, indicating the COVID-19 pandemic did not severely worsen the problem of food insecurity. More recently, as shown in Fig. 2, the level of food insecurity eased in 2021 (9.5 % on average) and then slightly increased in early 2022 (10.6 % on average).

![Fig. 2. Trends in COVID-19 food insecurity in the United States, April 23, 2020–May 9, 2022.](image-url)

Sources: U.S. Census Bureau, Household Pulse Survey (HPS), Interactive Tool, Week 1 (April 23–May 5, 2020) through Week 45 (April 27–May 9, 2022).
Fig. 3 shows the percentage of the adult population in each state who experienced food insecurity in the latest week of the Household Pulse Survey (April 27–May 9, 2022), with states ranked within the census region by their food insecurity incidence. Nationwide, 11.2% of adults experienced food insecurity. Despite the national average experience, Mississippi and other Southern states seemed much worse off than states in other census regions. In addition to the cross-region difference, states within the same region showed a large disparity in food insecurity (e.g., 15.7% in Connecticut and 6.6% in Vermont in the Northeast region).

3.3.2. Person- and household-level variables

A series of person- and household-level variables are included in our model by using the HPS microdata: 1) demographic attributes including age group, gender, race and Hispanic origin, marriage, children in the household, and number of household members, and 2) social and economic characteristics including educational attainment, household income, and housing tenure (Bartfeld & Dunifon, 2006; Hatab et al., 2019; Hosseini et al., 2017; Hu et al., 2020; Maconachie et al., 2012; Smit, 2016). We also consider a set of socioeconomic and health hardships – employment income loss, housing instability, and mental health problems – which are known to intersect with food-related hardships during the pandemic (Fitzpatrick et al., 2021; Mendez-Smith et al., 2020; Monte & O’Donnell, 2020; Mouratidis & Yiannakou, 2022; Park, 2021; Park & Ahn, 2022; Park et al., 2022; Park & Kim, 2021). Table 1 shows descriptive statistics of variables and data sources are listed in Supplemental Table 1.

The HPS asked respondents whether they used a specific type of food assistance program only in the later weeks of the survey. Therefore, we include indicators of the availability of such programs as level-2 variables, focusing on the role of food assistance programs as a component of the state-level contexts. This approach allows us to examine how food insecurity varies by state according to the availability of food aid programs.

3.3.3. State-level variables

3.3.3.1. Pandemic conditions and COVID-19 prevalence. We consider local small business closures and food retail sales during the pandemic (Hu et al., 2022) by utilizing the Small Business Pulse Survey (SBPS). It is a nationally representative survey deployed by the United States Census Bureau. The survey records a variety of difficulties experienced by small businesses (e.g., local groceries, restaurants, and bars with 1 to 499 employees) during the COVID-19 pandemic (U.S. Census Bureau, 2020d). Focusing on the early impact of the COVID-19 pandemic, we specify the state wide closure of local small businesses between April 2020 and June 2020 (weeks 1 through 9 of the HPS) as a % of small businesses which temporarily closed for one or more days last week. We also include the monthly state retail sales to characterize food and beverage retail market conditions, available from the U.S. Census Bureau’s Monthly State Retail Sales (MSRS) report (U.S. Census Bureau, 2020c). We operationalize the year-by-year percentage changes in retail sales in each state. The state count of confirmed cases per 100 people was computed by using CDC’s data (U.S. Centers for Disease Control and Prevention, 2020). We averaged the daily numbers to link to individual weeks of the HPS and then divided it by the total state population in 2019. The unemployment rate is considered to identify the status of labor market in the pandemic. We utilized the state unemployment data administered by the Bureau of Labor Statistics every month.

3.3.3.2. Federal programs and socioeconomic contexts. Of particular interest in this study is the extent to which inter-state differences in the availability of food assistance and safety net programs are related to variations in food insecurity outcomes during the COVID-19 pandemic. We consider the availability of the Supplemental Nutrition Assistance Program (SNAP, formerly known as Food Stamp), the Women, Infants and Children (WIC) program, and the Temporary Assistance for Needy Families (TANF) with indicators of the statewide participation rate. Participation rates are frequently used to measure policy outcomes (Bartfeld & Dunifon, 2006). Due to limited data availability, we operationalized the availability of each program as a single measure throughout all weeks of our analytic period. We also consider rental housing costs measured by the 2019 American Community Survey (ACS). We calculated the ratio of median gross rent (i.e., contract rent plus utility payments) to median renter household income in each state. Lastly, Black share of the total population was computed by using 2019 ACS to consider statewide demographic composition.

3.3.4. Spatiotemporal fixed-effects

We include a set of binary variables of HPS week, which denotes survey week to reflect on unobservable time-variant factors that may have influenced food insecurity across the weeks of the COVID-19 pandemic. This variable allows us to observe the volatility and dynamism of the status of food insecurity every two weeks for the past two years of the pandemic.

An additional time-invariant variables considered in our model is the geographic location of residence in the 15 most populous metropolitan areas (e.g., New York and Los Angeles). We include the metropolitan fixed-effects to consider food insecurity that may have been acute in the largest metropolitan areas.

4. Results

4.1. Base model result

Table 2 shows that most of the person- and household-level variables have a significant relationship with food insecurity, which is largely consistent with the existing studies on pre-pandemic and pandemic food insecurity. We find that individuals are more likely to experience food insecurity when they are middle age, female, racial and ethnic minorities, unmarried, having children and more household members, less educated, earning lower income, and renter. An additional set of strong predictors is pandemic hardships, suggesting that experiencing socioeconomic and health hardships is associated with a higher incidence of food insecurity: 2.0 times for employment income loss, 2.4 times for housing instability, and 3.0 times for mental health problems.

Regarding state-level variables, findings show that states with a greater decline in food retail sales are related to a higher risk of food insecurity. However, we find that the closure of small businesses has no association with food insecurity. The prevalence of COVID-19 cases is related to a greater incidence of food insecurity. The unemployment rate has no relation to the food insecurity of individuals, which is likely because the level-1 model includes unemployment status.

Among statewide socioeconomic contexts, we find a significant relation between rental unaffordability and food insecurity. The results reveal that a 1% increase in the median rent relative to median income is related to 5.6 times greater odds of food insecurity. We interpret that the rental unaffordability is related to fewer resources left for food expenditure.

As for federal programs, findings show that a greater rate of participation in TANF programs is related to a lower risk of COVID-19 food insecurity. It appears that adult Americans in states where safety net programs are more highly utilized have a lower risk of food insecurity. Contrarily, there is not a significant relation between the participation of SNAP and WIC and food insecurity. We interpret that this is a result of how the implementation of SNAP and WIC tends to fall under the state’s discretion. However, the estimated coefficients become significant in the following interaction models and show differences in the role of SNAP and WIC across income groups supposedly because the eligibility for SNAP and WIC is primarily based on household income.

Living in one of the largest metropolitan areas is related to a lower risk of food insecurity during the pandemic. This reflects a better
circumstance for food access and retail operations in the most populous metropolitan areas. For the last two years of the pandemic, the risk of food insecurity was mostly as or lower than the earliest survey week (April 2020). The two-year trend estimated in the model matches the trendline in Fig. 2.

4.2. Interactions between key state-level variables and household income

As shown in Table 2, household income has a significant relation with food insecurity which may differ based on a wide range of statewide socioeconomic conditions and COVID-19 prevalence. Household income may also play a role in determining individual households’ eligibility for food assistance programs in different government contexts across states. Table 3 presents the results that include interaction variables to examine whether some select state-level (level-2) variables moderate the relations between household income and food insecurity during the pandemic. We relate household income variables (level-1) with a level-2 variable to test the potential role of the state variable for adults in the household at particular income levels.

The results suggest that state variables strengthen or moderate the relations between household income and COVID-19 food insecurity, reflecting the unequal experiences by different income groups. We find that an increase in statewide retail sales is associated with a lower risk of COVID-19 food insecurity particularly among higher-income groups, leaving lower-income groups lacking benefits from retail recovery. Similarly, the statewide rate of small business closure appears to slightly moderate the relations between household income and COVID-19 food insecurity. The prevalence of COVID-19 seems to worsen the problem of food insecurity among lower-income groups more acutely than higher-income groups. We also find an unequal relationship between statewide unemployment and food insecurity among different income groups. Despite a statistical significance, the Black share of the state population did not have a substantively different relationship with food insecurity between different income groups.

Turning to food programs, we find a significant relationship between SNAP participation and COVID-19 food insecurity which differs by income group. A higher rate of SNAP participation in a state is related to a lower risk of COVID-19 food insecurity in the state. However, the relationship weakens among higher income groups. That is, the low-income groups (less than $50,000) have a lower risk of COVID-19 food insecurity in the state where SNAP is more available. Adult individuals from low-income households eligible for the SNAP might be more responsive to variations in program availability, whereas adult individuals in middle- and higher-income households ineligible for public assistance are unlikely to be related to the SNAP availability. The finding is consistent with WIC and TANF, showing higher participation in those programs associated with lower food insecurity rates among adults with higher household incomes.

4.3. Food insecurity compounded by socioeconomic and health hardships during the COVID-19 pandemic

In this section, we examine the COVID-19 food insecurity that intersects with socioeconomic and health hardships. We define the compounded types of food insecurity on the basis of three kinds of hardships—employment income loss, housing instability, and mental health problems—that a survey participant identified he or she has experienced in addition to food insecurity.

We build three binomial variables about the socioeconomic and health hardships due to the COVID-19 pandemic. Firstly, income loss has a value of 1 when a respondent replies he (she) experienced a loss of income, and 0 otherwise. Then, housing instability has a value of 1 when a survey respondent answers he (she) was not able to pay rent (mortgage) last month, and 0 otherwise. Lastly, mental health problem has a value of 1 when a survey participant replies he (she) has a symptom of anxiety and/or depression, and 0 otherwise. A correlation test between food insecurity and the three specified hardships confirms positive correlations—food insecurity with employment income loss ($r = 0.253$), food insecurity with housing instability ($r = 0.237$), and food insecurity with mental health problems ($r = 0.277$) (see Supplemental Table 3). These correlations imply that the problem of food insecurity is entangled with socioeconomic and health hardships due to the COVID-19 pandemic.
Table 1

Descriptive statistics of variables in the models.

| Variables | Full sample (n = 2,042,140, % of n or Mean (SD)) | Food insecurity | No (n = 1,407,725, % of n or Mean (SD)) |
|-----------|-----------------------------------------------|-----------------|----------------------------------------|
|           | Yes (n = 634,415, % of n or Mean (SD))         |                 |                                        |
|           | No (n = 1,407,725, % of n or Mean (SD))        |                 |                                        |
| **Level 1 (person- and household-level)** | | | |
| Demographic characteristics | | | |
| Age | | | |
| 18–24 (ref) | 6.8 | 79 | 6.2 |
| 25–34 | 21.3 | 22.9 | 20.2 |
| 35–44 | 21.2 | 22.3 | 20.4 |
| 45–54 | 18.2 | 18.8 | 17.9 |
| 55–64 | 16.9 | 15.9 | 17.5 |
| 65–74 | 12.0 | 9.7 | 13.5 |
| 75+ | 3.6 | 2.5 | 4.4 |
| Gender | | | |
| Female (ref) | 52.2 | 55.1 | 50.3 |
| Male | 47.8 | 44.9 | 49.7 |
| Race/ethnicity (ref) | | | |
| Non-Hispanic white | 62.7 | 53.1 | 68.9 |
| Non-Hispanic black | 11.6 | 15.1 | 9.4 |
| Non-Hispanic &PI | 5.0 | 4.3 | 5.4 |
| Non-Hispanic other | 3.9 | 4.8 | 3.3 |
| Hispanic | 16.9 | 22.7 | 13.1 |
| Marital status | | | |
| Unmarried (ref) | 44.7 | 53.3 | 39.1 |
| Married | 55.3 | 46.7 | 60.9 |
| Children in household | | | |
| No child (ref) | 59.1 | 53.9 | 62.5 |
| One or more children | 40.9 | 46.1 | 37.5 |
| Household size | | | |
| Single person (ref) | 8.4 | 8.1 | 8.6 |
| 2-Person | 29.9 | 24.6 | 33.4 |
| 3-Person | 20.3 | 20.4 | 20.3 |
| 4-Person | 19.9 | 20.1 | 19.8 |
| 5-Person | 10.9 | 12.6 | 9.8 |
| 6 or more persons | 10.5 | 14.2 | 8.2 |
| Socioeconomic statuses | | | |
| Education | | | |
| Less than high school (ref) | 7.1 | 11.3 | 4.3 |
| High school graduate | 28.0 | 34.2 | 24.0 |
| Some college or associate degree | 31.3 | 34.5 | 29.2 |
| Bachelor's degree or higher | 33.7 | 20.0 | 42.5 |
| Household income | | | |
| Less than $25,000 (ref) | 14.8 | 24.8 | 8.4 |
| $25,000–49,999 | 23.8 | 33.2 | 17.8 |
| $50,000–74,999 | 17.7 | 18.4 | 17.3 |
| $75,000–99,999 | 12.4 | 10.4 | 15.3 |
| $100,000–149,999 | 15.7 | 8.8 | 20.2 |
| $150,000 and above | 14.5 | 4.5 | 20.9 |
| Tenure | | | |
| Renter-occupied housing (ref) | 39.1 | 51.7 | 31.0 |
| Owner-occupied housing | 60.9 | 48.3 | 69.0 |
| COVID-19 pandemic hardships | | | |
| Employment income loss | No (ref) | 61.9 | 45.1 | 72.7 |
| Yes | 38.1 | 54.9 | 27.3 |
| Housing instability | No (ref) | 88.6 | 78.8 | 94.9 |

**Table 1 (continued)**

| Variables | Full sample (n = 2,042,140, % of n or Mean (SD)) | Food insecurity | Yes (n = 634,415, % of n or Mean (SD)) | No (n = 1,407,725, % of n or Mean (SD)) |
|-----------|-----------------------------------------------|-----------------|----------------------------------------|----------------------------------------|
| Mental health problem | | | | |
| No (ref) | 78.3 | 63.9 | 87.5 |
| Yes | 21.7 | 36.1 | 12.5 |
| **Level 2 (state-level)** | | | | |
| Socioeconomic statuses | | | | |
| % non-Hispanic black population | 12.13 (8) | 12.41 (8.06) | 11.96 (7.96) |
| % rental sales | 8.72 (13.12) | 7.48 (12.6) | 9.52 (13.39) |
| % small business closure | 13.51 (2.42) | 13.5 (2.32) | 13.52 (2.48) |
| COVID-19 cases per 100 persons | 7.16 (7.04) | 6.6 (7.07) | 7.53 (7) |
| % unemployment | 7.66 (3.69) | 8.01 (3.78) | 7.43 (3.61) |
| Federal programs and socioeconomic contexts | | | | |
| % TANF participants per 100 poor persons | 103.86 (29.34) | 102.93 (27.87) | 104.46 (30.24) |
| % SNAP participants per 100 poor persons | 14.84 (2.66) | 14.8 (2.64) | 14.87 (2.67) |
| % WIC participants per 100 poor persons | 5.11 (4.13) | 5 (4.17) | 5.18 (4.11) |

Notes: Statistics in this table were weighted by person-level weight (wweight variable in the HPS microdata). Descriptive statistics of spatiotemporal fixed-effects are shown in Supplemental Table 4.

Table 4 presents results for the compounded types of food insecurity, revealing data largely consistent with the base estimation (Table 2) except for the role of statewide (level-2) variables. First, the likelihood of experiencing both food insecurity and employment income loss is higher in states featuring a greater rate of statewide unemployment, which was not significant in the base model. The food insecurity compounded by housing instability is not related to the statewide prevalence of rental unaffordability presumably because the dependent variable reflects the housing hardship. Instead, we find that people are more likely to experience the food-housing hardship in states where more small businesses closed and where the Black share of the population is higher. The rate of food insecurity combined with mental health problems is lower in the states where WIC is more available but the relationship is weak.

4.4. Robustness check

We first acknowledge a possibility that an alternative model may show a distinct estimation result. We adopt an ordinary least squares (OLS) model to test the robustness of our base multilevel logit estimations (Table 2) which are based on a series of assumptions about the distribution of the error term (see column (a) in Supplemental Table 2). We find that the base model estimations are largely stable with the OLS estimates.

A second robustness test concerns the operationalization of the dependent variables for food insecurity (see column b in Supplemental Table 2). Our base definition matches the CPS-FSS-based definition being used as a common measure of food insecurity. Yet, the pandemic has imposed unprecedented difficulties and inconvenience in food security on numerous people in the U.S. in any form, particularly in the early days of the pandemic. A narrower definition of food insecurity specifically focusing on higher levels of food security is expected to perform better in the 2021 estimation.
Table 2 
Multilevel mixed-effects logistic regression results for the COVID-19 food insecurity, United States, April 23, 2020–May 9, 2022.

| Demographic characteristics | OR     | Sig. | SE    | P-value |
|-----------------------------|---------|------|-------|---------|
| Age (ref = 18–24)           | 1.270 *** | 0.016 | <0.001 |
| 25–34                       | 1.507 *** | 0.020 | <0.001 |
| 35–44                       | 1.577 *** | 0.022 | <0.001 |
| 45–54                       | 1.484 *** | 0.020 | <0.001 |
| 55–64                       | 1.306 *** | 0.018 | <0.001 |
| 65–74                       | 1.109 *** | 0.020 | <0.001 |
| Gender (ref = female)       | 0.981 ** | 0.007 | 0.007  |
| Race/ethnicity (ref = non-Hispanic white) |          |       |       |         |
| Non-Hispanic black          | 1.253 *** | 0.019 | <0.001 |
| Non-Hispanic A&PI           | 1.297 *** | 0.048 | <0.001 |
| Non-Hispanic other          | 1.407 *** | 0.017 | <0.001 |
| Hispanic                    | 1.316 *** | 0.020 | <0.001 |
| Marital status (ref = unmarried) |     |       |       |         |
| Married                     | 0.939 *** | 0.006 | <0.001 |
| Children in household (ref = no child) | | | | |
| One or more children        | 1.112 *** | 0.007 | <0.001 |
| Household size (ref = single person) | | | | |
| 2-Person                    | 1.146 *** | 0.009 | <0.001 |
| 3-Person                    | 1.314 *** | 0.013 | <0.001 |
| 4-Person                    | 1.382 *** | 0.017 | <0.001 |
| 5-Person                    | 1.566 *** | 0.019 | <0.001 |
| 6 or more persons           | 1.760 *** | 0.031 | <0.001 |
| Socioeconomic statuses     |         |       |       |         |
| Education (ref = less than high school) | | | | |
| High school graduate        | 0.827 *** | 0.012 | <0.001 |
| Some college or associate degree | 0.824 *** | 0.012 | <0.001 |
| Bachelor’s degree or higher | 0.572 *** | 0.010 | <0.001 |
| Household income (ref = less than $25,000) | | | | |
| $25,000–49,999              | 0.685 *** | 0.008 | <0.001 |
| $50,000–74,999              | 0.445 *** | 0.007 | <0.001 |
| $75,000–99,999              | 0.318 *** | 0.005 | <0.001 |
| $100,000–149,999            | 0.223 *** | 0.005 | <0.001 |
| $150,000 and above          | 0.130 *** | 0.003 | <0.001 |
| Tenure (ref = renter-occupied housing) | | | | |
| Owner-occupied housing      | 0.823 *** | 0.008 | <0.001 |
| COVID-19 pandemic hardships |         |       |       |         |
| Employment income loss (ref = no) | | | | |
| Yes                         | 1.960 *** | 0.019 | <0.001 |
| Housing instability (ref = no) |         |       |       |         |
| Yes                         | 2.442 *** | 0.045 | <0.001 |
| Mental health problem (ref = no) |     |       |       |         |
| Yes                         | 2.955 *** | 0.018 | <0.001 |
| Level 2 (state-level) variables |     |       |       |         |
| Pandemic conditions and COVID-19 prevalence | | | | |
| % retail sales              | 0.996 *** | 0.001 | <0.001 |
| % small business closure    | 1.005 *** | 0.003 | 0.173 |
| COVID-19 cases per 100 persons |         |       |       |         |
| % unemployment              | 1.000    | 0.004 | 0.989 |
| Federal programs and socioeconic contexts | | | | |
| % non-Hispanic black population | 1.002 | 3.399 | 0.009 |
| Rental housing unaffordability | 5.298 ** | 0.001 | 0.177 |
| SNAP participants per 100 poor persons | 1.000 | 0.000 | 0.598 |
| poor persons                | 0.996 ** | 0.004 | 0.370 |

Table 2 (continued)

| OR     | Sig. | SE    | P-value |
|--------|------|-------|---------|
| TANF participants per 100 poor persons | 0.983 *** | 0.004 | <0.001 |
| WIC participants per 100 poor persons | 0.983 *** | 0.004 | <0.001 |

Spatiotemporal fixed-effects

| 15 largest MSAs (ref – none) | OR     | Sig. | SE    | P-value |
|-------------------------------|---------|------|-------|---------|
| New York                      | 0.956 + 0.025 | 0.088 |
| Los Angeles                   | 1.004 ** 0.003 | 0.249 |
| Chicago                       | 0.943 ** 0.068 | 0.412 |
| Dallas                        | 0.963 *** 0.002 | <0.001 |
| Houston                       | 0.968 *** 0.003 | <0.001 |
| Washington, D.C.             | 0.955 ** 0.016 | 0.007 |
| Miami                         | 0.955 *** 0.004 | <0.001 |
| Philadelphia                  | 0.971 ** 0.015 | 0.051 |
| Atlanta                       | 0.893 ** 0.003 | <0.001 |
| Phoenix                       | 0.966 *** 0.002 | <0.001 |
| Boston                        | 0.907 ** 0.027 | 0.001 |
| San Francisco                 | 0.968 *** 0.005 | <0.001 |
| Riverside                     | 1.080 ** 0.003 | <0.001 |
| Detroit                       | 1.060 ** 0.003 | <0.001 |
| Seattle                       | 0.928 *** 0.004 | <0.001 |

Notes: Standard errors were clustered at the state level. **p < 0.10, *p < 0.05, **p < 0.01, ***p < 0.001. A&PI = Asians and Pacific Islanders. MSA = metropolitan statistical area. TANF = Temporary Assistance for Needy Families.
better capture comparatively more serious hardships in food security. We repeat the base regression with two narrower measures of food insecurity, which define food insecure status when a respondent sometimes or often did not have enough to eat or only often did not have enough to eat. The results confirm that the coefficients are largely unaffected, with fewer significant variables at the state level.

Lastly, there may be questions about the sample that consists of all adult Americans in place of specific vulnerable groups such as low-income households and households with children. We estimate the baseline model with two subsamples, adults in low-income households (<$50,000) and adults with children (column c in Supplemental Table 2). We find evidence that COVID-19 food insecurity among low-income adults and those with children are explained differently from the base model estimates. First, in the pandemic market conditions and COVID-19 prevalence, there are similar results for adults with children, but very different ones for low-income adults. The level of retail sales, which was significant for the entire sample and adults with children, proves insignificant in the low-income model, suggesting disrupted food conditions for the most impoverished population in the pandemic. This finding implies the greater importance of food assistance policies and programs in addressing food insecurity for the lowest-income individuals.

In contrast, we find significant and stronger coefficients for federal programs. The WIC is not significant in the full sample model, but significant in adults from low-income households. This result underscores the idea that WIC, as a major program, plays a vital role in meeting the food needs of the poorest people during the pandemic. As discussed in the market conditions, state reopening policies and subsequent reopening of grocery stores by themselves do greatly alleviate matters for the most vulnerable populations.

We find that socioeconomic variables are largely consistent (across the models), but a noteworthy difference is a rental unaffordability. The rental unaffordability is half as strong as all adults for the low-income model, which is likely because most federal, state, and local rental assistance is targeted at low-income groups.

5. Discussions and conclusion

5.1. Food policy implications and limitations

Our results support a set of vital implications for policy discourse in improving food security in the United States during and after the COVID-19 pandemic. This study shows 1) consistent associations between statewide contexts and food insecurity, 2) varying effects of pandemic market conditions and policy responses across different income groups, and 3) an emerging issue of food insecurity compounded by other hardships. The results of this study may contribute to identifying policy target groups most in need of food assistance and can aid policymakers' determination of priorities in the face of pandemic-induced challenges.

5.1.1. Consistent associations between statewide contexts and COVID-19 food insecurity

The consistent associations between statewide variables and COVID-19 food insecurity experienced at the individual level are confirmed, even with a comprehensive set of variables controlled. The baseline model results (Table 2) show that the worsening pandemic market conditions, as well as vulnerable pre-pandemic contexts, were related to

Table 3
Summarized multilevel mixed-effects logistic regression results with interaction terms between key state-level variable and household income, United States, April 23, 2020–May 9, 2022.

| Key variable of interest: | % retail sales | % small business closure | COVID-19 cases per 100 persons | % unemployment rate |
|--------------------------|----------------|-------------------------|--------------------------------|--------------------|
| Level 1 Household income (ref – less than $25,000) | | | | |
| $25,000–49,999            | 0.693 ***       | 0.695 ***                | 0.692 ***                     | 0.658 ***          |
| $50,000–74,999            | 0.469 ***       | 0.408 ***                | 0.475 ***                     | 0.366 ***          |
| $75,000–99,999            | 0.344 ***       | 0.278 ***                | 0.352 ***                     | 0.231 ***          |
| $100,000–$149,999         | 0.248 ***       | 0.179 ***                | 0.261 ***                     | 0.139 ***          |
| $150,000 and above        | 0.151 ***       | 0.109 ***                | 0.166 ***                     | 0.068 ***          |
| Level 2 (state-level) key variable | 1.004 ***       | 0.998                    | 1.022 ***                     | 0.967 ***          |
| Cross-level interactions between key variable | | | | |
| ×$25,000–49,999           | 0.999 +         | 0.999                   | 1.006 **                      |                   |
| ×$50,000–74,999           | 0.994 ***       | 1.006                    | 0.991 ***                     | 1.027 ***          |
| ×$75,000–99,999           | 0.991 ***       | 1.010 +                  | 0.985 ***                     | 1.043 ***          |
| ×$100,000–$149,999        | 0.986 ***       | 1.016 *                  | 0.975 ***                     | 1.063 ***          |
| ×$150,000 and above       | 0.978 ***       | 1.012                    | 0.957 ***                     | 1.084 ***          |

| Key variable of interest: | % non-Hispanic black population | SNAP participants per 100 poor persons | WIC participants per 100 poor persons | TANF participants per 100 poor persons |
|--------------------------|---------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|
| Level 1 Household income (ref – less than $25,000) | | | | |
| $25,000–49,999            | 0.657 ***                      | 0.656 ***                            | 0.650 ***                            | 0.680 ***                            |
| $50,000–74,999            | 0.425 ***                      | 0.395 ***                            | 0.396 ***                            | 0.431 ***                            |
| $75,000–99,999            | 0.301 ***                      | 0.271 ***                            | 0.275 ***                            | 0.306 ***                            |
| $100,000–$149,999         | 0.210 ***                      | 0.183 ***                            | 0.194 ***                            | 0.208 ***                            |
| $150,000 and above        | 0.125 ***                      | 0.113 ***                            | 0.119 ***                            | 0.125 ***                            |
| Level 2 (state-level) key variable | 0.998 **                     | 0.999 **                             | 0.990 **                             | 0.978 **                             |
| Cross-level interactions between key variable | | | | |
| ×$25,000–49,999           | 1.004 ***                      | 1.000                                | 1.004                                | 1.001                                |
| ×$50,000–74,999           | 1.004 **                       | 1.001 **                             | 1.008                                | 1.007 +                              |
| ×$75,000–99,999           | 1.005 **                       | 1.002 **                             | 1.010                                | 1.012 **                             |
| ×$100,000–$149,999        | 1.006 **                       | 1.002 **                             | 1.010                                | 1.012 **                             |
| ×$150,000 and above       | 1.004 *                        | 1.001 **                             | 1.006                                | 1.008 +                              |

Notes: Standard errors were clustered at the state level. + = p < 0.10, *p < 0.05, **p < 0.01, ***p < 0.001. TANF = Temporary Assistance for Needy Families program. WIC = Women, Infants, and Children program. SNAP = Supplemental Nutrition Assistance Program. OR = odds ratio. Full model results are available upon request.
Table 4
Multilevel mixed-effects logistic regression results for the compounded types of food insecurity, United States, April 23, 2020–May 9, 2022.

| Food insecurity compounded by | Employment income loss | Housing instability | Mental health problem |
|-------------------------------|------------------------|---------------------|-----------------------|
|                               | OR                     | Sig.                | OR                    | Sig.                |
| **Level 1 (person- and household-level) variables** | | | | |
| Demographic characteristics  | | | | |
| Age (ref = 18-24)             | | | | |
| 25-34                         | 1.058 ***               | 1.479 ***           | 1.062 ***             | |
| 35-44                         | 1.227 ***               | 1.951 ***           | 1.051 **              | |
| 45-54                         | 1.396 ***               | 2.114 ***           | 1.018                 | |
| 55-64                         | 1.262 ***               | 1.584 ***           | 0.859 ***             | |
| 65-74                         | 0.797 ***               | 0.877 ***           | 0.603 ***             | |
| 75+                           | 0.447 ***               | 0.590 ***           | 0.399 ***             | |
| Gender (ref = female)         | | | | |
| Male                          | 1.122 ***               | 1.025               | 0.890 ***             | |
| Race/ethnicity (ref = non-Hispanic white) | | | | |
| Non-Hispanic black            | 1.084 ***               | 1.974 ***           | 0.723 ***             | |
| Non-Hispanic A&PI             | 1.038 ***               | 1.419 ***           | 0.798 ***             | |
| Non-Hispanic other            | 1.297 ***               | 1.456 ***           | 1.195 ***             | |
| Hispanic                      | 1.319 ***               | 1.341 ***           | 0.871 ***             | |
| Marital status (ref = unmarried) | | | | |
| Married                       | 0.925 ***               | 0.931               | 0.802 ***             | |
| Household size (ref = single person) | | | | |
| One or more children          | 0.794 ***               | 1.415 ***           | 0.894 ***             | |
| Socioeconomic statuses       | | | | |
| Education (ref = less than high school) | | | | |
| High school graduate          | 0.894 ***               | 0.956               | *                     | 1.010                 |
| Some college or associate degree | 0.959 ***               | 0.909               | ***                   | 1.093 ***             |
| Bachelor’s degree or higher   | 0.686 ***               | 0.586               | ***                   | 0.783 ***             |
| Household income (ref = less than $25,000) | | | | |
| $25,000-49,999                | 0.862 ***               | 0.839               | ***                   | 0.706 ***             |
| $50,000-74,999                | 0.593 ***               | 0.579               | ***                   | 0.514 ***             |
| $75,000-99,999                | 0.430 ***               | 0.407               | ***                   | 0.386 ***             |
| $100,000-$149,999             | 0.288 ***               | 0.251               | ***                   | 0.271 ***             |
| $150,000 and above            | 0.149 ***               | 0.109               | ***                   | 0.153 ***             |
| Tenure (ref = renter-occupied housing) | | | | |
| Owner-occupied housing        | 0.778 ***               | 0.584               | ***                   | 0.786 ***             |
| COVID-19 pandemic hardships   | | | | |
| Employment income loss (ref = no) | | | | |
| Yes                           | –                      | 3.275 ***           | 2.209 ***             | |
| Housing instability (ref = no) | | | | |
| Yes                           | 3.278 ***               | –                   | 2.460 ***             | |
| Mental health problem (ref = no) | | | | |
| Yes                           | 2.723 ***               | 2.573 ***           | –                     | |
| **Level 2 (state-level) variables** | | | | |
| Pandemic conditions and COVID-19 prevalence | | | | |
| % retail sales                | 0.998                   | *                   | 1.000                 | 0.996 ***             |
| % small business closure      | 1.002                   | 1.011               | *                     | 0.995                 |
| COVID-19 cases per 100 persons | 1.010                   | 0.991               | *                     | 1.013 ***             |
| % unemployment               | 1.015 ***               | 0.994               | 1.002                 | |
| Federal programs and socioeconomic contexts | | | | |
| % non-Hispanic black population | 0.999                   | 1.005               | *                     | 1.002                 |
| Rental housing unaffordability | 14.060 ***              | 1.591               | 10.604 ***            | |
| SNAP participants per 100 poor persons | 1.000                   | 1.000               | 1.000                 | |
| WIC participants per 100 poor persons | 1.005                   | 0.997               | 0.991                 | |
| TANF participants per 100 poor persons | 0.993                   | +                   | 0.987                 | *                     |
| Spatiotemporal fixed-effects  | | | | |
| 15 largest MSAs (ref = none)  | | | | |
| New York                      | 1.186 ***               | 1.297               | **                    | 0.945 ***             |
| Los Angeles                   | 1.199 ***               | 1.156 me            | ***                   | 0.991 **              |
| Chicago                       | 1.175 ***               | 1.122 ***           | 0.990                 | |
| Dallas                        | 1.084 ***               | 1.004               | 1.004                 | |
| Houston                       | 1.244 ***               | 2.190               | 0.990                 | **                    |
| Washington, D.C.              | 1.063 ***               | 1.041               | 0.958                 | **                    |
| Miami                         | 1.120 ***               | 1.247               | 0.904 ***             | **                    |
| Philadelphia                  | 1.036 +                 | 1.074               | 1.045                 | *                     |
| Atlanta                       | 1.185 ***               | 1.001               | 0.943                 | ***                   |
| Phoenix                       | 1.092 ***               | 1.127               | 1.047 ***             | ***                   |
| Boston                        | 0.999                   | 0.986               | 0.872 ***             | ***                   |

(continued on next page)
the development of novel state-level food programs and initiatives for
amend and fully utilize the existing state guidelines for federal food
assistance programs. To address newly emergent compounded issues,
pandemic-driven food insecurity challenges, highlighting the need to
indicate the importance of state-level conditions in addressing the
between statewide variables and COVID-19 food insecurity outcomes
COVID-19 food insecurity. These base findings are consistent with
execution of state reopening policies are related to a lower risk of
contrast, greater availability of federal assistance programs and effective

Table 4 (continued)

| Employment income loss | Housing instability | Mental health problem |
|------------------------|---------------------|----------------------|
| OR                     | Sig.                | OR                   | Sig.                | OR                   | Sig.                |
| San Francisco          | 1.081 ***            | 1.081 ***            | 0.992 ***            |
| Riverside              | 1.063 ***            | 1.092 ***            | 1.068 ***            |
| Detroit                | 1.195 ***            | 1.090 ***            | 1.036 ***            |
| Seattle                | 1.033 ***            | 1.104 ***            | 1.050 ***            |
| HPS (ref = week 1, 4.23-5.5, 2020) |
| Week 2 (5.7-12)        | 1.239 ***            | 1.075 *              | 1.213 ***            |
| Week 3 (5.14-19)       | 1.112 ***            | 1.080 ***            | 1.126 ***            |
| Week 4 (5.21-26)       | 1.100 ***            | 1.082 *              | 1.134 ***            |
| Week 5 (5.28-6.2)      | 1.030 ***            | 1.024                | 1.129 ***            |
| Week 6 (6.4-9)         | 1.041                | 1.025                | 1.135 ***            |
| Week 7 (6.11-16)       | 1.134 ***            | 1.127 **             | 1.253 ***            |
| Week 8 (6.18-23)       | 1.145 ***            | 1.139 ***            | 1.206 ***            |
| Week 9 (6.25-30)       | 1.215 ***            | 1.161 ***            | 1.348 ***            |
| Week 10 (7.2-7)        | 1.273 ***            | 1.159 ***            | 1.349 ***            |
| Week 11 (7.9-14)       | 1.284 ***            | 1.230 ***            | 1.391 ***            |
| Week 12 (7.16-21)      | 1.281 ***            | 1.239 ***            | 1.451 ***            |
| Week 13 (8.19-31)      | 1.226 ***            | 1.211 ***            | 1.322 ***            |
| Week 14 (9.2-14)       | 1.282 ***            | 1.334 ***            | 1.339 ***            |
| Week 15 (9.16-28)      | 1.255 ***            | 1.204 ***            | 1.388 ***            |
| Week 16 (9.30-10.12)   | 1.256 ***            | 1.307 ***            | 1.393 ***            |
| Week 17 (10.14-26)     | 1.285 ***            | 1.278 ***            | 1.433 ***            |
| Week 18 (10.28-11.9)   | 1.339 ***            | 1.370 ***            | 1.556 ***            |
| Week 19 (11.11-23)     | 1.361 ***            | 1.397 ***            | 1.528 ***            |
| Week 20 (11.25-12.7)   | 1.394 ***            | 1.408 ***            | 1.568 ***            |
| Week 21 (12.9-21)      | 1.478 ***            | 1.500 ***            | 1.645 ***            |
| Week 22 (1.6-18, 2021) | 1.183 ***            | 1.393 ***            | 1.383 ***            |
| Week 23 (1.20-2.1)     | 1.138 **             | 1.337 ***            | 1.295 ***            |
| Week 24 (2.3-15)       | 1.139 ***            | 1.404 ***            | 1.247 ***            |
| Week 25 (2.17-3.1)     | 1.920 +              | 1.368 ***            | 1.228 ***            |
| Week 26 (3.3-15)       | 1.102                | 1.375 ***            | 1.283 ***            |
| Week 27 (3.17-29)      | 0.926                | 1.155 +              | 1.086               |
| Week 28 (4.14-26)      | 0.384 ***            | 1.363 ***            | 1.281 ***            |
| Week 29 (4.28-5.10)    | 0.346 ***            | 1.423 ***            | 1.184 ***            |
| Week 30 (5.12-24)      | 0.354 ***            | 1.420 ***            | 1.165 *             |
| Week 31 (5.26-6.7)     | 0.338 ***            | 1.498 ***            | 1.123 *             |
| Week 32 (6.9-21)       | 0.349 ***            | 1.503 ***            | 1.180 **            |
| Week 33 (6.23-7.5)     | 0.358 ***            | 1.573 ***            | 1.122 *             |
| Week 34 (7.21-8.2)     | 0.292 ***            | 1.254 ***            | 1.101 ***            |
| Week 35 (8.4-16)       | 0.297 ***            | 1.515 ***            | 1.061               |
| Week 36 (8.18-30)      | 0.297 ***            | 1.323 ***            | 1.138 *             |
| Week 37 (9.1-13)       | 0.308 ***            | 1.405 ***            | 1.120 +             |
| Week 38 (9.15-27)      | 0.304 ***            | 1.387 ***            | 1.115 *             |
| Week 39 (9.29-10.11)   | 0.306 ***            | 1.497 ***            | 1.125 *             |
| Week 40 (12.1-13)      | 0.262 ***            | 1.634 ***            | 1.190 *             |
| Week 41 (12.29-1.10, 2022) | 0.314 *** | 1.605 *** | 1.147 + |
| Week 42 (1.26-2.7)     | 0.354 ***            | 1.712 ***            | 1.129               |
| Week 43 (3.2-14)       | 0.242 ***            | 1.751 ***            | 1.097               |
| Week 44 (3.30-4.11)    | 0.226 ***            | 1.781 ***            | 1.189 +             |
| Week 45 (4.27-5.9)     | 0.236 ***            | 1.812 ***            | 1.191 +             |
| Constant               | 0.060                | 0.016                | 0.018 ***            |
| Number of observations | 2,047,620            | 2,834,453            | 2,045,619            |
| Log pseudolikelihood   | -693,765             | -362,527             | -597,009             |
| Akaike's information criterion (AIC) | 1,387,630 | 725,157 | 1,194,118 |
| Bayesian information criterion (BIC) | 1,388,256 | 725,813 | 1,194,744 |

Notes: Standard errors were clustered at the state level. * = p < 0.10, **p < 0.05, ***p < 0.01, ****p < 0.001. A&PI = Asians and Pacific Islanders. MSA = metropolitan statistical area. TANF = Temporary Assistance for Needy Families program. WIC = Women, Infants, and Children program. SNAP = Supplemental Nutrition Assistance Program. OR = odds ratio. HPS = Household Pulse Survey.

a higher likelihood of experiencing COVID-19 food insecurity. In contrast, greater availability of federal assistance programs and effective execution of state reopening policies are related to a lower risk of COVID-19 food insecurity. These base findings are consistent with alternative dependent variables and subsamples when robust standard errors were applied (Supplemental Table 2). The consistent associations between statewide variables and COVID-19 food insecurity outcomes indicate the importance of state-level conditions in addressing the pandemic-driven food insecurity challenges, highlighting the need to amend and fully utilize the existing state guidelines for federal food assistance programs. To address newly emergent compounded issues, the development of novel state-level food programs and initiatives for the most vulnerable target populations is also necessary. More importantly, considering the lack of federal pandemic leadership – at least, until the end of 2020 – to alleviate nationally-experienced food insecurity, the role the state government can play in improving access to and the availability of healthy foods during and after the pandemic should receive greater attention. In the case of SNAP, essentially overseen by the federal government (USDA), states are responsible for handling application and administration, as well as evaluating statewide efficiency and effectiveness of the program (Lieber, 2020; Waxman, Gundersen, & Fiol, 2021). The state government may also help leverage grassroots movement and local food initiatives, as well as urban agriculture and community gardens, and combine those efforts to lead the
pandemic and post-pandemic food provision (Goodfellow & Prahalad, 2022; Haynes-Maslow et al., 2020; Slater & Birchall, 2022; Son, 2020).

5.1.2. Varying effects of pandemic market conditions and policy responses across income groups

This study reveals that lower-income households generally experienced a higher risk of food insecurity during the COVID-19 pandemic. However, statewide contexts substantially moderated or strengthened the relations between income and COVID-19 food insecurity. The interaction model results (Table 3) show that deteriorating pandemic market conditions – such as small business closures, reduced food retail sales, and soaring local unemployment – are related to a higher likelihood of COVID-19 food insecurity, which affects more acutely middle- and higher-income households. The finding of more robust connections between higher incomes and state market conditions suggests two important implications. First, the pandemic would have a greater impact on disadvantaged groups. However, the results indicate that more affluent populations are often more responsive to disrupted food market conditions, as they spend more on dining out and utilize a greater variety of food sources on the market. Similarly, wealthier individuals may profit more quickly from socioeconomic recovery from the pandemic, leaving those worse off further behind. Second, it is also notable that the association between lower household incomes and a higher risk of food insecurity caused by COVID-19 is commonly moderated by both the existing federal programs (SNAP, WIC, and TANF) and pandemic-specific policies (P-EBT and state reopening), specifically for disadvantaged households with incomes under $50,000. This result highlights the pivotal role of federal food assistance and pandemic-specific aid in easing food hardships for those in the greatest need and who are likely potential beneficiaries of such programs based on income and poverty level.

5.1.3. The emerging issue of food insecurity compounded by other COVID-19 hardships

The findings suggest that statewide characteristics significantly explain a new aspect of the food security issue compounded by other pandemic-induced hardships, including income loss, housing instability, and health problems. The model estimates of food insecurity along with each of the aforementioned hardships (Table 4) reveal that the statewide characteristics were similarly significant and meaningful as were those in the base model (Table 2). This result implies that food insecurity incidence can spatially overlap with other types of COVID-19 hardships in states where pandemic food deficiency and pre-pandemic socioeconomic vulnerabilities coexist. When designing food assistance programs not only during the pandemic but also more generally, policymakers should therefore consider the compounded relationship between food insecurity and other socioeconomic and health hardships. Food insecurity indices alone may be insufficient for identifying policy target groups most in need of government support.

While this study shows disparities in food insecurity for the last two years of the COVID-19 Pandemic, there are critical limitations to discuss. First, additional research is needed to fully control for both individual- and state-level variables. HPS microdata is a set of survey weeks and does not allow researchers to follow the same individuals over time. Upon availability of a new data, a follow-up research can be planned for longitudinal analysis that compares the pre-pandemic period to the pandemic period while focusing on the resiliency of food security and disparities among different population subgroups. For example, an analysis that combines the HPS data and newer CPS-PSS data can also better contextualize pandemic food insecurity as a historic U.S. trend since 1995.

5.2. Conclusion

The COVID-19 pandemic increased the level of food insecurity across income levels and regions in the U.S., especially in the months following the first outbreak in early 2020. Even after the initial pandemic shock on local and global food chains was alleviated in the first year of the pandemic, certain populations have continued to face higher levels of food insecurity as a result of the pandemic. We find that a set of statewide characteristics – pandemic market conditions, pandemic-specific federal programs and state policies, and pre-pandemic socioeconomic contexts – are strongly related to food insecurity experienced at the individual and household levels. The association varies across income groups, highlighting strong connections between higher-income households and market conditions, as well as the critical role of federal food assistance programs and state-level initiatives in reducing food insecurity, particularly among lower-income households. This study also identifies a new aspect of food insecurity compounded by other pandemic hardships. Specifically, food insecurity incidence substantially overlapped with socioeconomic and health hardships during the pandemic, such as employment income loss, housing instability, and health problems. Taken together, the results substantiate the pivotal role of statewide contexts in explaining the incidence and prevalence of food insecurity during the pandemic. These results point to the necessity of a more proactive implementation of federal food assistance programs at the state level and the establishment of more sensible priority criteria to assist the most vulnerable populations. The findings of this study align with other scholarly works arguing for the importance of state- or local-level initiatives to offset the lack of federal leadership in addressing food security, providing new research agendas for creative and responsive food aid in the pandemic period and post-pandemic era.

CRediT authorship contribution statement

JungHo Park: Supervision, Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Visualization. Chaeri Kim: Conceptualization, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing. Seulgi Son: Project administration, Conceptualization, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplemental material

Supplemental data to this article can be found online at https://doi.org/10.1016/j.cities.2022.104003.

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