FOOD BANK RESPONSES TO MAJOR DISASTERS[1]

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Abstract

The food distributed by food banks in the U.S. is a critical component in efforts to reduce food insecurity. For households, this food is especially needed in response to shocks that impair a household's ability to purchase enough food. One increasingly common shock is natural disasters. Research has not yet quantified how food banks respond to these disasters. This paper fills that knowledge gap by estimating the response of food-bank food distribution to major disasters and exploring how that response varies with demographic features of the people a food bank serves. We use a proprietary quarterly dataset from Feeding America to detail food distribution and data from FEMA and NOAA's storm events database to create severity proxies for major disasters. These data allow us to estimate fixed effects models with interaction effects. We find food banks' food supply increases with disaster severity, with flooding having the strongest impact. These impacts were confined to the affected food banks and did not spillover to neighboring food banks. We find that aid increases even more in areas with a higher proportion of disadvantaged populations.

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1 Introduction

Climate change has exacerbated the frequency and severity of disasters in recent years. These disasters can disrupt access to sufficient food for daily life, particularly affecting those already at risk of food insecurity, among other vulnerable groups. A group that plays a major role in disaster relief for vulnerable people is a nationwide network of food banks. These food banks have been providing crucial food aid to disaster-stricken areas (Narayanan and Altay 2021) while continuing their long-term goal of reducing food insecurity.

Despite the critical role of food banks in disaster response, there is little systematic qualitative or quantitative research on how charitable food assistance providers respond to disasters in the U.S. Moreover, considering that some studies in recent years have demonstrated inequalities across socioeconomic and racial demographics in disaster-related governmental assistance (Bullard and Wright 2018; Bolin and Kurtz 2018), there has also been insufficient examination of non-governmental assistance, such as that provided by food banks, in disaster relief for vulnerable populations.

We fill the gaps in the literature by evaluating four key questions about food bank behavior. First, we investigate how the amount of food distributed by food banks in the U.S. is affected by major disasters. Second, we explore how a food bank's response to major disasters vary with the socio-demographic features of its service area. Third, we examine how the responses of a food bank vary with the socio-demographic features of disaster-affected areas. Fourth, we assess the spillover effects of disasters in one location on neighboring food bank areas that were not themselves affected by declared disasters.

To answer the above questions, we use a quarterly proprietary administrative dataset from Feeding America, which includes the pounds of food distributed by category for all in-network food banks. This dataset provides insights into the supply side of food banks by detailing the pounds of food distributed (Gundersen 2023). Furthermore, we use the Federal Emergency Management Agency (FEMA)'s data and the National Oceanic and Atmospheric Administration (NOAA)'s storm events database to generate severity proxies for major disasters—total number of deaths, total number of injuries, and total value of property damage. We use panel data models with time and food bank fixed effects to measure the food banks' responses to major disasters, and we include interaction terms for socioeconomic features of the overall service area and disaster-affected areas, respectively.

The first key finding is that food banks' food supply increases with the severity of disasters in the U.S., with flooding-related disaster events being more relevant to food bank activities than other types of disasters. Second, we find that food banks' serving areas with higher poverty rates tend to distribute less food. Third, we find no evidence of spillover effects from disaster-declared areas impacting food distribution in neighboring food banks. Lastly, we find that more food aid is distributed when disasters strike areas with a high proportion of disadvantaged populations. The first three findings enhance our understanding of the non-governmental charitable food system's role in disaster relief, filling a gap in the literature, which has primarily focused on governmental support (Domingue and Emrich 2019) and disaster-related donations (Deryugina and Marx 2021). The fourth finding is in contrast to the studies that highlight minority disadvantages in government-led disaster relief (Burda and Harding 2014; O'Neil 2007). For instance, Howell and Elliott (2018) show that the increased Federal Emergency Management Agency (FEMA) funding for disaster relief tends to increase wealth for white residents while decreasing wealth for Black residents. Overall, based on our findings, we call for increased support for food banks in less affluent areas to improve their access to food resources.

The remainder of the paper is structured as follows. Section 2 introduces the background of food bank systems and major disasters in the U.S. and reviews relevant literature. In Section 3, we present details of the datasets. In Section 4, we describe the empirical strategies. Section 5 presents empirical results, and we discuss conclusions and implications in Section 6.

2 Background and Literature Review

2.1 Food Bank Systems in the U.S.

The establishment of food banks in the U.S. was originally driven by the mission to combat hunger, and this objective continues to guide their operations both now and into the future. It is noteworthy that food banks in the U.S. have become a critical complement to public programs, such as Supplemental Nutrition Assistance Program (SNAP, formerly known as the Food Stamp Program), and Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), in addressing food insecurity[5]. In the years of this study, 2016 to 2019, approximately 12.3% (41.2 million people) and 10.5% (35 million people) of the U.S. population, respectively, experienced food insecurity (Coleman-Jensen 2016; 2019). Food banks in the U.S. are essential not only for recipients of public programs who need additional food

[5] Food insecurity in the United States is characterized by limited access to food at the household level due to economic and social factors (Gundersen and Ziliak 2018).

resources but also for those who do not receive such benefits, including individuals who are ineligible.

Currently, the network of 200 food banks under Feeding America[6], the largest anti-hunger organization in the U.S., serves over 40 million food-insecure clients through a vast system of more than 60,000 pantries and agencies, supported by over 2 million volunteers. Figure 1 shows the distribution of Feeding America's food bank network across the continental U.S. The circle dots represent the location of each food bank's main warehouse. Additionally, the blue boundaries represent the overall maximum boundary encompassing all counties covered by each food bank, while the gray boundaries represent county borders. We can observe that the food bank network spans the entire continental U.S., and its distribution is correlated with local population density.

Specifically, food banks in the U.S. bridge the government, private sector, and civil society by managing large-scale acquisition, storage, and distribution operations to combat hunger. They rely on partnerships with the private sector to secure surplus and unmarketable food products (Mook, Murdock, and Gundersen 2020). Additionally, food banks receive government commodities and funds to distribute nutritious foods to low-income individuals. Unlike food banks in other countries, such as the UK, which handle the entire process from sourcing to distributing food to people, U.S. food banks primarily serve as centers for collecting and storing food, with distribution to end-users carried out by partnering agencies, mainly "food pantries."

[6] The 200 food banks in the Feeding America network make up the vast majority of food banks in the U.S.

2.2 Major Disasters in the U.S.

FEMA coordinates federal disaster relief and recovery efforts in the various types of natural or human-made disasters, and therefore has a specific definition of a "major disaster", where one of the most common natural disasters is flooding[7]. With the declaration of a major disaster by FEMA, the local and state governments in the affected area can request a major disaster declaration and apply for federal financial assistance. Through this declaration, the affected individuals and households can apply for individual assistance, including temporary housing, household property loss, and unemployment relief, to relieve their economic burden. In order for an incident to be defined as a major disaster, governors or tribal leaders will first need to apply in writing and have the president approve. Local governments, because of their budget limits, will determine whether the disaster loss is beyond their ability to manage the disaster response.

However, differences exist in disaster vulnerability across race, ethnicity, and economic status (Bolin and Kurtz 2018). While some of the wealthiest areas in the U.S., such as coastal regions, are more frequently impacted by natural disasters than inland areas, disparities in disaster response and recovery remain pronounced. For example, in the case of Hurricane Katrina, households of color and low-income families in disaster-prone areas were particularly vulnerable in terms of housing, social infrastructure, and access to resources (Bullard and Wright 2018). Additionally, research has indicated that lower-income households are less likely to hold insurance or receive sufficient payouts from their insurers in the context of flood-related disasters (Kousky 2011; Highfield, Norman, and Brody 2013; Shao et al. 2017). In other words,

[7] Floods are usually triggered by heavy rains, hurricanes, tropical storms, and melting snow and ice, with a wide range of impacts on loss of life, property damage, and infrastructure damage.

these vulnerable communities are already at higher risk prior to the disasters, and their recovery efforts were often more difficult. In contrast, in the case of wildfires in the U.S., emergency assistance, environmental amenities, and wildfire insurance have enabled economically privileged populations to settle in fire-prone areas (Davies et al. 2018). Nevertheless, census tracts where the majority of the population were Black, Hispanic, or Native American were about 50% more vulnerable to wildfire than other census tracts (Davies et al. 2018).

Recent studies have also highlighted social disparities in disaster relief assistance provided by governmental sources. Often, compared to wealthier families or communities, minority and low-income families receive insufficient support during the recovery and rebuilding phases (Bolin and Kurtz 2018). Some studies have demonstrated that that inequalities may exist across socioeconomic and racial demographics in the distribution of government resources for disaster relief (Liz Hamel et al. 2017; Bullard and Wright 2018). For instance, Hamel et al. (2017) report that in an early assessment of Hurricane Harvey's impact, Black and Hispanic assistance applicants experienced lower approval rates compared to White applicants. In the case of wildfires, Anderson et al. (2020) find evidence of an unequal response of bureaucracies to higher social and economic status communities who receive more public goods when disaster happens.

2.3 Food Banks in Disaster Relief

In terms of the efforts of food banks toward disaster relief, while each member food bank is autonomous, Feeding America headquarters' Disaster Services collaborate regularly with local, regional, and national disaster relief partners, such as the Federal Emergency Management

Agency (FEMA) and the United States Department of Agriculture (USDA), to maximize the support of in-network food banks during disasters. For a major disaster-type incident response, the headquarters incorporates various resources to assist food banks in responding to major disasters. The main support process includes coordinating with food banks on pre-notice events, providing a common operating picture of incidents, and activating national office response teams to support food banks during disaster events. The team facilitates coordination and collaboration efforts, including managing financial donations, liaising with government agencies, national media, and partners to aid food bank responses to disasters while monitoring and updating the status of critical services. Additionally, Feeding America headquarters has developed mutual aid for emergency response, encouraging the exchange of resources and expertise within its food bank network. The support from the headquarters includes resolving food needs, providing guidance, and offering preparedness through planning and training. Human capital development, such as training individuals, has been highlighted as a critical activity in the food bank network during disasters, enabling effective response (Narayanan and Altay 2021). Their study also emphasized the seamless transition of the food bank system from an anti-hunger system to disaster relief, attributing this capability to the food bank's national network and the support from Feeding America's headquarters, including its human resources support. Building on this foundation, we argue that food banks not only need to respond swiftly to the food needs of disaster-affected areas but also might face additional strain as food banks need to ensure that the food supply to their existing clients, who might rely on food banks for sustenance, is not adversely affected during disaster periods (Odubela, Jiang, and Davis 2021).

Understanding the effectiveness of food banks' disaster responses in terms of food supply is of critical importance, as disasters may disproportionately affect vulnerable populations, including low-income and marginalized groups. Even outside of disaster periods, food banks consistently work to address gaps left by public anti-hunger programs, which have not fully alleviated racial disparities in food insecurity (Wilson 2023). Furthermore, existing literature highlights the relationship between wealth and food security (Loibl et al. 2022; Gundersen and Ziliak 2018), indicating that within the service areas of food banks, both food insecurity rates and income levels play a role in shaping food supply. Disasters may exacerbate these pre-existing disparities, further complicating the distribution and availability of resources. Additionally, while disasters can disrupt existing food supply chains, adding further strain on food banks, it is noteworthy that, to date, there have been no reports of food bank warehouses being destroyed by major disasters. Consequently, this aspect is excluded from the subsequent analysis.

2.4 Potential Spillover Effects

Cooperation for disaster relief among food banks can create strain, leading to potential spillover effects. If a food bank whose service area is not directly affected by a major disaster assists nearby food banks dealing with large-scale disasters, it may face additional pressure to provide consistent support to its existing clients. We consider that these strains can affect food banks' disaster response, an area that remains largely unexplored in current research.

We hypothesize that the potential spillover effects of disaster responses may exist in nearby or adjacent food bank areas that were not declared major disasters but are geographically close to disaster-declared areas. First, those adjacent food banks may source from the adjacent disaster-affected area. Second, those adjacent food banks may support food banks in affected areas, and they may find it more difficult to support their existing food-insecure customers if spillover exists. Third, those adjacent food banks, though they did not receive a major disaster declaration, may still experience the impact of disaster to some extent in terms of severe weather conditions, and therefore their own supply chain may be disrupted. All three of these potential spillover effects can be combined with each other.

3 Data and Descriptive Analysis

To evaluate food banks' responses to major disasters, we use a proprietary administrative dataset from Feeding America. This dataset reports the amount of food distributed by category for all 200 food banks in the Feeding America network for each quarter from 2016 to 2019. In our paper, the primary dependent variables at the food bank level are defined as the total amount of food distributed, measured in pounds. This metric accurately reflects the activities of food banks and has been the most commonly used measure across the food bank system since 2016.

To quantify the major disasters in treatment variables, we use all of FEMA's major disaster event declarations[8] at the county-level and match them with the NOAA-storm events database to proxy the severity of each major disaster event. One advantage of using FEMA's declaration for defining major disasters is that we can therefore restrict attention to disasters that are most likely to have prompted a disaster-specific response by food banks. We then aggregate county-level data on disasters to create treatment variables that vary by food bank and quarter. We choose to use the total count of deaths, the total count of injuries, and the total value of

[8] This study included all FEMA-defined major disaster events from 2016–2019 and assumed that these disaster records were not misreported or underreported.

property damage as proxies for disaster severity in this study[9], following previous studies that have used a variety of approaches and measures.

Several prior studies have used a binary indicator variable as the treatment variables, for example in studies of Hurricane Katrina's impact (Groen and Polivka 2008; Deryugina, Kawano, and Levitt 2018; McIntosh 2008). In other studies, flood depth quartiles are used as a set of treatment dosage indicators (Gallagher and Hartley 2017). Deryugina and Marx (2021) discussed potential reporting concern in NOAA records that could affect the use of injuries or damages as measures of disaster severity. They noted that deaths are likely to be reported more accurately than damage or injuries. Furthermore, they found high correlations between deaths and injuries (0.86), as well as between deaths and damages (0.88), leading them to use deaths as the sole measure of disaster severity. However, our study, which applied to all major U.S. disasters rather than just fatal tornadoes, did not consistently find such high correlations among these three measures. Specifically, Table A1 in Appendix presents the correlation coefficients for three measures—the number of deaths, number of injuries, and the value of property damage—at the county and food bank levels in panels (a) and (b), respectively. We observe that the correlation between deaths and injuries is around 0.4 and that the correlation between deaths and property damage is only 0.51 at the county level, and even when the data is aggregated to the food bank-level, the correlation peaks do not exceed 0.75. Furthermore, the correlation between injuries and property damage does not exceed 0.1 at the county level. This highlights the limitations of using a single proxy to measure the severity of disasters for our research topic. In addition, by using these three continuous measures as proxies for severity—rather than employing binary indicators

[9] All three measures are obtained from the NOAA Storm Events Database, which contains events from January 1950 to the present (for more information, see https://www.ncdc.noaa.gov/stormevents/).

to define a disaster—we are able to capture the heterogeneity among different disaster events, as we know that not all disasters are alike and that each can have a unique impact on affected areas. Therefore, in this study, we employ multiple severity proxies—namely, the number of deaths, the number of injuries, and the value of property damage—to provide a more comprehensive representation of the severity of disasters.

Table A2 categorizes the severity of disaster events by deaths, injuries, and property damage (see Appendix). We find that more than 60% of the major disaster declarations did not lead to deaths, and more than 70% of the declarations did not lead to injuries. The left two panels of Figure A1 present the histogram for the percentage of deaths, injuries, and property damage for each major disaster declaration (see Appendix). Since each major natural disaster, such as Hurricane Matthew in 2016, can be composed of multiple major disaster declarations, in the right panels of Figure A1, we show the histogram for the summarized deaths, injuries, and property damage by major disaster events instead of by each declaration. It appears that nearly half of the major disaster events resulted in property damages exceeding 10 million U.S. dollars if we aggregate several relevant major disaster episodes into a single large event. Nevertheless, considering that the majority of storms are not declared major disasters, the proportion mentioned above would be even lower when accounting for all magnitudes of natural disasters.

Figures A2-A4 depict the total numbers of deaths, injuries, and property damage from major disasters, presented on a county-level map of the contiguous U.S. for the years 2016–2019. In Figure A2, we can find that the areas with the highest cumulative deaths from major disasters in the U.S. from 2016 to 2019 appear to be primarily concentrated along the Gulf Coast and eastern seaboard. This concentration may be relevant to hurricanes and other severe weather events that are more frequent in these areas. Additionally, the central areas prone to tornadoes also exhibit a certain level of mortality. In contrast, regions that have experienced major disasters causing property damage cover a broader area than those with reported deaths. However, as shown in Figure A3, some areas report deaths without corresponding injuries, which might be attributed to higher measurement errors associated with injuries, likely due to the challenging nature of defining and reporting injuries accurately.

Turning our focus to the panel data at the food bank level, Figure A5 illustrates the percentage of food banks within the study period that had at least one major disaster declared in their service area for each quarter. We observe that the highest percentage of food banks with a major disaster declared in their service area during a quarter was 27.69%, while the lowest was only 4.62%. Figures A6-A8 are built upon Figure A5, showing the percentage of food banks that reported the total number of deaths, total number of injuries, and total value of property damage, respectively, within their service areas each quarter. Among these, injuries had the lowest percentage on average, followed by deaths, while property damage had the highest. This suggests that although many food banks had major disasters declared in their service areas, many did not experience or report any deaths or injuries. We consider that noticeable changes in food distribution by food banks are more likely to be observed in the context of severe disasters. Therefore, we find using injuries or even deaths as the intervention variable to be consistent with the context of this study.

In addition to developing measure to capture the dependent (food bank provision of food) and treatment (disaster) variables, we use yearly county-level data from the U.S. Census Bureau to create variables that capture socio-demographic features of a food bank's service area so we can test whether the disaster response vary among different types of regions. First, we create a measure of the fraction of households in a food bank's service area that are below the poverty line. Tol (2022) finds that 44 out of 80 recent studies of vulnerability to natural disasters studied the impact of poverty on vulnerability and nearly all found poverty to play an important role in disaster resilience. Second, as discussed, communities of color are often undersupported in the recovery period after disasters; thus, we create a variable capturing the fraction of the population that is Black.

Table 1 presents the summary statistics of this study. Column (1) of Panel (a) in Table 1 shows the average total amount of food distributed and the per capita amount of food distributed across all 195 food banks over 16 quarters (from the first quarter of 2016 to the fourth quarter of 2019). Column (2) displays these statistics for the 31 food banks that did not have any counties in their service area with a major disaster declared during the study period, while Column (3) presents the corresponding statistics for the 164 food banks that had at least one county in their service area with a major disaster declared during this time. Column (4) reports the statistical significance of the differences between these two groups. The results indicate that, on average, over the entire study period, food banks serving areas with counties that declared major disasters distributed a smaller total amount of food per quarter compared to those that did not. Furthermore, the per capita amount of food distributed by these food banks is also lower.

In Panel (b), we present the demographic characteristics of the service areas of the food banks. The setup of Columns (1) through (4) in Panel (b) is the same as in Panel (a). We find that these major disasters disproportionately affected food banks' serving areas with a higher overall proportion of Black residents, but we do not find evidence that disasters disproportionately affected poorer food banks' service areas. Table A3 presents the correlation matrix for the socio-demographic features of the food banks' service areas, showing that poverty is weakly correlated with Black populations (see Appendix). As these two variables are not highly correlated, this supports the inclusion of two separate interaction terms in the regression model in the following sections, each based on one of these variables.

In Panel (c), for the 164 food banks that experienced a major disaster, we show the differences in food supply during disaster and non-disaster quarters. We find that more food is distributed during disaster periods, but there is no statistically significant difference in the per capita amount of food distributed between disaster and non-disaster periods, though, on average, the per capita amount of food during disaster periods is higher than during non-disaster periods.

4 Methods

4.1 Approaches for Estimating the Response of Food Banks

To address the main research questions, we analyze variations in the severity of major disasters within the service areas of food banks to estimate their response to such events across the contiguous U.S. Our primary specification employs a level-level functional form under two-way fixed effects models, conditioning on food bank and time-fixed effects. This methodology is inspired by Deryugina and Marx (2021) and uses NOAA's disaster measures as the proxy for disaster severity.

The main identification assumption of the specifications is that the damage caused by a severe disaster (measured as the total number of deaths, the total number of injuries, or the total value of property damage reported) is unrelated to other determinants of food distribution at food banks. We assume implicitly that after accounting for time and food bank fixed effects, a linear relationship exists between changes in the severity of disasters and variations in the total amount of food distributed by food banks, irrespective of the size of a food bank's service area.

Rather than calculating percentage changes to derive elasticity coefficients, our functional form is a level-level form. This allows us to interpret unit changes in severity, for example, how an additional reported death affects the amount of food distributed by the food bank. The summary statistics in Table A2 in Appendix show that the majority of the severity measure observations are zeros except for property damage. Therefore, it is convenient that this approach avoids the concerns associated with calculating elasticity when the variable includes a large number of zeros, a problem that arises whether using logarithmic transformations or inverse hyperbolic transformations (Bellemare and Wichman 2020).

The three measures we use as severity proxies for major disasters are calculated according to Equation (1)

$$Severity_{i,t}^{m} = \sum_j \sum_k m_{k,i,j,t} \qquad (1)$$

In this notation, *i* denotes a food bank; *t* denotes a time (quarter); and $m_{k,i,j,t}$ refers to the number of deaths, or total number of injuries, or total dollar value of property damage documented for major disaster event *k* in county *j* of food bank *i*'s service area during quarter *t*.

In some regressions, we control for the socio-demographic features of a food bank's overall service area, $Dem_{i,t}^{A}$. This is calculated according to Equation 2

$$Dem_{i,t}^{A} = \frac{\sum_j pop_{i,j,t} \times demographic_{i,j,t}}{\sum_j pop_{i,j,t}} \qquad (2)$$

where $demographic_{i,j,t}$ refers to a socio-demographic characteristic of each county *j* in food bank i's service area during quarter *t*; and $pop_{i,j,t}$ refers to the total population of county *j* in food bank i's area during quarter *t*. Intuitively, these variables measure features of the overall composition of the area covered by a food such as the fraction of the population that is Black or the fraction of the population that lives in poverty.

In other regressions, we control for socio-demographic features of an area that happens to be hit by a major disaster. This is not a stable characteristic of a food bank but should rather be thought of as a feature of the disaster itself. These variables, $Dem_{i,t}^{D}$, are constructed using a similar approach to the food-bank overall demographic measures above, but they only include demographic features of the counties that are actually hit by a particular disaster in quarter *t*. Thus, $Dem_{i,t}^{D}$ is calculated as

$$Dem_{i,t}^{D} = \frac{\sum_j d_{i,j,t} \times pop_{i,j,t} \times demographic_{i,j,t}}{\sum_j d_{i,j,t} \times pop_{i,j,t}} \qquad (3)$$

where $d_{i,j,t}$= 1 if county *j* in food bank i's coverage is hit by disaster in quarter *t*, and 0 otherwise.

To evaluate the food banks' response to disasters, we first estimate the following baseline model:

$$Y_{i,t} = \beta * Severity_{i,t}^{m} + \mu_i + \varphi_t + \varepsilon_{i,t} \qquad (4)$$

where $Y_{i,t}$ refers to the outcome variable, total amount of food distributed (million pounds). The treatment variable, $Severity_{i,t}^{m}$, refers to either total number of deaths, total number of injuries, or total value of property damages accumulated in time t at food bank i's service area (see Equation (1)). μ_i is a food bank fixed effect; φ_t is a quarter fixed effect; and $\varepsilon_{i,t}$ is an error term. The primary interest is the magnitude, direction, and statistical significance of β for understanding how food banks response to major disasters.

Following equations (2) and (3) for the socio-demographics of a food bank's overall service area and the socio-demographic features of a food bank's major disaster declared areas, we define two types of interaction terms of severity measures and the socio-demographics, as follows:

$$Severity_{i,t}^{m} \times Dem_{i,t}^{A} = \sum_j \sum_k m_{k,i,j,t} \times \frac{\sum_j pop_{i,j,t} \times demographic_{i,j,t}}{\sum_j pop_{i,j,t}} \quad (5)$$

$$Severity_{i,t}^{m} \times Dem_{i,t}^{D} = \frac{\sum_j \sum_k m_{k,i,j,t} \times d_{i,j,t} \times pop_{i,j,t} \times demographic_{i,j,t}}{\sum_j d_{i,j,t} \times pop_{i,j,t}} \quad (6)$$

where $Severity_{i,t}^{m} \times Dem_{i,t}^{A}$ shown in Equation (5) refers to the interaction terms generated by the severity measures and the socio-demographic features of the food bank i's entire service area, which is weighted averaged by population of each county j within the service area; $Severity_{i,t}^{m} \times Dem_{i,t}^{D}$ in Equation (6) refers to the interaction terms generated by the severity measures and the socio-demographic features of major disaster declared counties j, where we generate the interactions of severity measures and the socio-demographic features among disaster affected areas at county level first and then aggregated into food bank level.

By doing so, we aim to understand potential disparities in disaster response in terms of pounds of food going to food banks and distributed. Specifically, we are interested in evaluating how the food bank's responses are influenced by the severity of disaster, conditioning on the socio-demographics of the food banks' service area and the disaster-affected area, represented by γ_1 and γ_2, respectively, as follows:

$$Y_{i,t} = \beta * Severity_{i,t}^{m} + \gamma_1 * Severity_{i,t}^{m} \times Dem_{i,t}^{A} + Dem_{i,t}^{A} + \mu_i + \varphi_t + \varepsilon_{i,t} \quad (7)$$

$$Y_{i,t} = \beta * Severity_{i,t}^{m} + \gamma_2 * Severity_{i,t}^{m} \times Dem_{i,t}^{D} + \mu_i + \varphi_t + \varepsilon_{i,t} \quad (8)$$

Note that in equations (4), (7), and (8), we assume that there is no spillover to the neighboring food banks' service area, and therefore we assume the Stable Unit Treatment Value

Assumption (SUTVA) is satisfied. In addition, following Cameron and Miller (2015), Abadie et al. (2017), and Abadie et al. (2022), we use clustered-robust standard error for the error term at food bank-level, which allows for serial correlation and heteroskedasticity.

4.2 Approaches for Estimating the Spillover Effects

Failure to control spillovers in the outcome variable would violate the required assumptions for an SUTVA. Following the methods described in Butts (2021) and applied previously in Manning and Ando (2022), we include the potential effects for neighboring food banks in the model, allowing us to identify any possible spillover effect received in nearby food banks that might coordinate food banks with disaster-declared areas. In other words, the potential spillover of major disasters may exist in nearby food banks' service areas which did not receive major disaster declarations. We add a new term based on the baseline model (see Equation(4)) and estimate the potential spillover effects of major disasters within different distance bins via

$$Y_{i,t} = \beta * Severity_{i,t}^{m} + \theta * Severity_{i,t}^{m,b} + \mu_i + \varphi_t + \varepsilon_{i,t} \quad (9)$$

where $Severity_{i,t}^{m,b}$ refers to the food bank-level spillover received, proxied by the total number of deaths, total number of injuries, or total value of property damage in nearby food banks' service area within a band of distance indexed by b. At the preliminary stage, we define b as "within 100 miles." The primary interest is in the magnitude, direction, and statistical significance of θ for evaluating the potential spillover effects among food banks' service area with major disasters declared and food banks' service area without major disasters declared.

5. Results

5.1 Main Results

Table 2 reports the baseline estimation results (see Equation (4)), presenting the impact of major disaster events on the total amount of food (in million pounds) distributed by food banks. As introduced in the above sections, the severity of these disasters is proxied by the total number of deaths, total number of injuries, and total value of property damage within the food banks' service areas, respectively. Columns (1)-(3) show the responses of food banks to all major disasters during the entire study period, while columns (4)-(6) display the responses to major disasters specifically related to flooding including floods, coastal storms, hurricanes, mud/landslides, and other severe storms that have flooding in the description.

In general, the amount of food distributed by food banks increases during quarters when major disasters hit somewhere in their service areas. That finding holds true for all three proxies of severity when we study the effects of flood-related disasters. The effects are weaker and less stable if we analyze the effects of all major disasters; the magnitude of the coefficient on severity measured by deaths is smaller when we study all events rather than just flooding, and it is not significant at all when we use injuries as a proxy for all events. This suggests that food banks receive more food and increase their food distribution relatively less in response to non-flooding-related disaster events, such as wildfires and snowstorms, compared to flooding-related disasters. In specific, columns (1) and (3) indicate that for each additional death, food banks increase their food distribution by an average of 0.94%[10] (54,800 pounds per death) and 1.23% (71,300 pounds

[10] The percentage increase is calculated by dividing the 0.0548 million pounds increase by 5.8112 million pounds from column (1) of Table 1.

per death) during all major disaster events and flooding-related major disaster events, respectively. Similarly, column (5) shows that for each additional injury reported during a flooding-related disaster, food banks increase their food distribution by 0.23% (133,00 pounds per injury). Columns (3) and (6) report that for every 10 million dollars in property damage, food banks distribute an additional 0.036% pounds (21,000 pounds per 10 million dollars) of food in both all major disaster events and flooding-related disaster events, respectively. This indicates that non-flooding-related disasters, such as snowstorms or wildfires, have a similar impact on food distribution at food banks as flooding-related disasters. Since our severity proxies focus on severe major disasters, as described in Section 3, and based on the findings mentioned above, we have reason to believe that these severe natural disasters trigger food banks' disaster-specific food support efforts.

In Table 3, Panels (a)-(c) report the results from Equation (7) on the interactions between the three severity proxies—deaths, injuries, and property damage—and the overall socio-demographic features of the food banks' entire service area. In the regressions that include measures of poverty, we find that the coefficient on the percent of people who live in poverty is consistently negative and significant. Thus, food banks distribute less food when their areas have more people under the poverty line. Other variables are not significant when we use property damage as a measure. If we focus on flooding related events and measure severity with deaths or injuries, there is some indication that food delivery increases with event severity in food banks that serve areas with large Black populations. With injuries as the proxy, it seems that food bank service actually falls with event severity unless the service area is one with high levels of poverty. Overall, we do not observe stable findings regarding how the demographics of a food bank mediates the impact of a natural disaster on its activity. However, it does seem that food banks serving areas with a high percentage of people under the poverty line tend to have less food distribution.

Next, Table 4 reports the estimation results from Equation (8), where we include interactions of the severity of a disaster with the socio-demographic characteristics of the area hit by the disaster. Most of the results are not significant, but we focus some discussion on the results we see studying the effects of flooding related events where injuries are the proxy for severity. The coefficient on the injuries variable itself is actually negative, perhaps reflecting supply disruption, when we include characteristics of the people affected in the regression. However, the coefficient on the interaction between severity and the percentage of affected residents that are in poverty or Black is mostly positive; more aid flows when the event hits places with high fractions of disadvantaged people.

5.2 Spillover Effects on Food Banks in Non-Disaster-Declared Area

Based on the baseline estimations shown in Table 2, we incorporate variables representing potential spillover effects while relaxing the SUTVA assumption applied in the previous estimations (see Equation (4)). Table 5 reports the spillover effects of disaster-declared areas' food banks on their surrounding areas. Although the service areas of some food banks may be separated by one or a few small counties, we still consider that spillover effects could occur among these food banks during major disasters due to the fact that, while the counties may not be directly adjacent, the distance between them is less than 100 miles. Therefore, we did not use the condition that the service areas of food banks are physically adjacent for estimating the spillovers. Rather, we used a certain distance to cover the above scenario. To specify, we used a 0–100-mile band to estimate potential spillovers among food banks during disasters.

The results in Table 5 indicate that after including the variables that proxy the potential spillover effects, the remaining variables show consistent results with those in Table 2 for the baseline specification, applicable to both estimations of all major disaster events and flooding-related events. We did not find evidence of spillover effects in terms of food distribution from the disaster on nearby food banks within a 100-mile range. Furthermore, since no spillover effect was found on food banks surrounding the disaster declared area, the prerequisite SUTVA assumption for the main estimations in Section 5.1 is highly likely to hold.

6 Conclusion

In this paper, we evaluate how the U.S. charitable food assistance system, specifically the food bank system, responds to major disasters in terms of food distribution. Our primary findings indicate that food banks do deliver more food assistance when disasters strike their service areas. This pattern is strongest for flood related disasters, where the effect is significant regardless of the measure one uses as a proxy for severity. We find that each additional death resulting from a major disaster in the contiguous U.S. leads to an approximately 0.94% increase in food distribution by food banks (measured by weight), with a larger increase of 1.23% observed for flooding-related major disasters. Additionally, for every $10 million in reported property damage, there is a 0.036% increase in food distribution across both flooding-related and non-flooding-related disasters. It is important to note that while we can estimate the relationship between the total food distribution by food banks and the characteristics of the disasters, we cannot determine whether the food distributed to the disaster-affected counties served by the food banks is sourced externally or internally reallocated within the food bank.

While this pattern may imply that food banks serve as vehicles to mitigate increased need at times of crisis, we find that the amount of food distributed by food banks actually falls as the fraction of all people in their service area that live in poverty increases. This may reflect findings from Wells (2024), which show that food banks in well-off regions are better resourced at local. Some food banks serve regions comprised of multiple counties that can vary in their demographic composition, and previous research on environmental justice has found that federal aid has flowed preferentially to areas that are relatively white and well-off. In contrast, we find no evidence that food banks respond by disasters providing more of a boost in food aid when counties that are disproportionately white are affected. If anything, we find some limited evidence that more food aid flows in response to floods with high numbers of injuries when that affected counties have high fractions of residents who are Black or live in poverty.

Finally, we did not find evidence of spillover effects on the nearby food banks within 100 miles. We consider that there are two possibilities for this finding in terms of potential spillover effects. One is that during the disaster, food banks in the disaster-declared areas may have received more emergency food supplies from the sourcing network of food banks elsewhere, far away from the surrounding areas. The other possibility is that food banks, on average, have obtained certain abilities to optimize and respond to major disasters.

Our findings contribute to research on climate resilience and environmental justice in several ways. Overall, the key takeaway is that private food banks may serve as a valuable buffer for communities in the wake of severe natural disasters, potentially complementing the relief efforts provided by federal agencies. Importantly, we find no evidence that the response by food banks is biased against minoritized populations. Nevertheless, we advocate for greater assistance to food banks in less affluent areas to improve their overall access to food resources. Further, given that governmental agencies support food banks to some extent, we suggest that aid agencies consider the private sector's mobilization in response to disasters and assess food banks' strengths and limitations at local levels when planning their own efforts. This approach would enable a more coordinated and comprehensive response, particularly in under-resourced disaster-affected areas.

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7 Figure and Tables

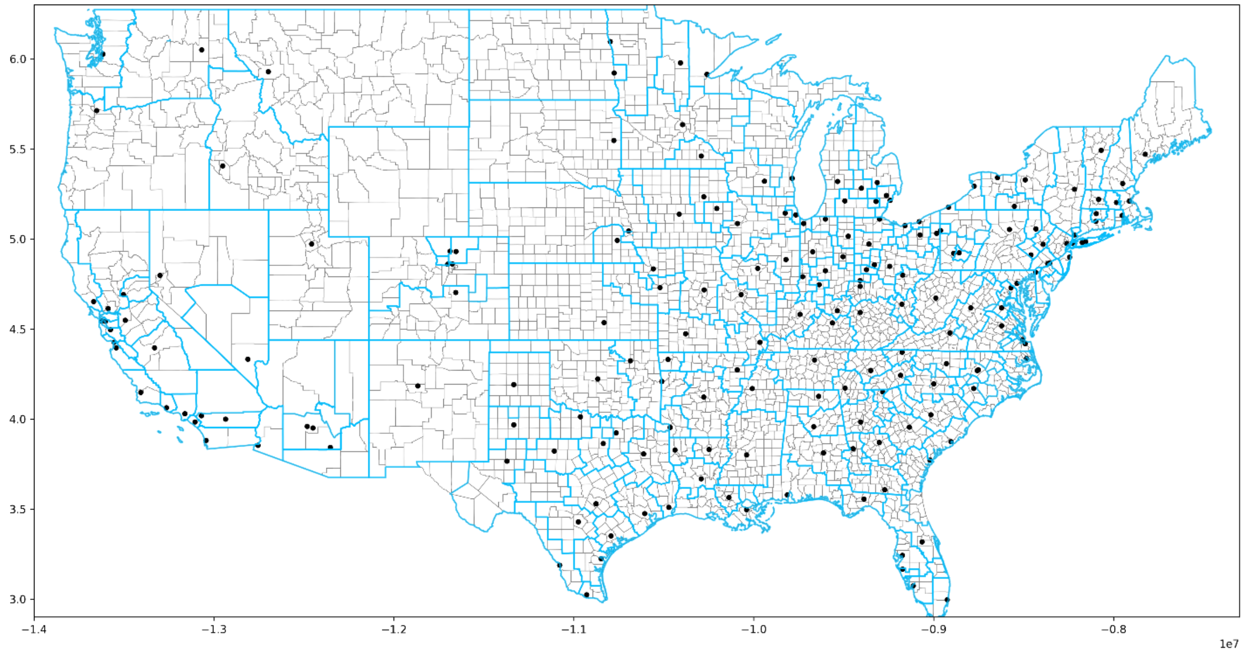

Figure 1. The distribution of the 195 in-network food banks in the contiguous U.S.

Notes: Created by Pseudo-Mercator projection of the main warehouse of 195 in-network food banks. For those cases where some food banks span multiple states, we use the location of the food bank's headquarters. The dots show food bank warehouse locations. Blue boundaries represent the maximum area covered by each food bank, while gray boundaries show county borders.

Table 1. Summary Statistics

(a) Pounds distribution of food banks

	(1)	(2)	(3)	(4)
	All (195 food banks)	Never experienced major disaster (31 food banks)	Ever experienced major disasters (164 food banks)	P-value
Total amount of food (million pounds)	5.8112 (5.318)	6.192 (5.768)	5.740 (5.226)	0.082
Per capita amount of food (pounds)	3.855 (1.805)	4.173 (2.156)	3.795 (1.725)	< 0.001
Observations	3120	496	2624	

(b) Demographics of food banks by disaster experience

	All (195 food banks)	Never experienced major disaster (31 food banks)	Ever experienced major disasters (164 food banks)	P-value
Proportion of the population that is Black	0.112 (0.105)	0.095 (0.077)	0.116 (0.109)	< 0.001
Proportion of the population under poverty line	0.107 (0.036)	0.106 (0.029)	0.107 (0.037)	0.673
Observations	3,120	496	2,624	

(c) Comparison among quarters with and without major disasters for food banks experienced major disasters in the past

	All quarters	Quarters without major disasters	Quarters with major disasters	P-value
Total amount of food (million pounds)	5.740 (5.226)	5.654 (5.154)	6.081 (5.498)	0.093
Per capita amount of food (pounds)	3.795 (1.725)	3.779 (1.763)	3.856 (1.564)	0.364
Observations	2,624	2,098	526	

Notes: P-value is for mean difference between (3) and (4). The values in the table are calculated using balanced panel from 2016 first quarter to the fourth quarter of 2019. The variables *proportion of population is Black* and *proportion of population under poverty line* were generated at the food bank level using county-level yearly data from the American Community Survey 5-Year Data. These variables were calculated as weighted averages based on county population size.

Table 2. The Impact of Major Disasters on Food Banks

	All events			Flooding-related events		
	(1)	(2)	(3)	(4)	(5)	(6)
$Severity^{death}$ (count)	0.0548**			0.0713***		
	(0.0258)			(0.0212)		
$Severity^{injury}$ (count)		0.0034			0.0133*	
		(0.0024)			(0.0075)	
$Severity^{property\ damage}$ (10M $)			0.0021***			0.0021***
			(0.0000)			(0.0000)

Notes: *** p<0.01, ** p<0.05, * p<0.1. All the estimations here are with 3,120 observations (balanced panels). Clustered-Robust standard errors in parentheses. Food bank fixed effects and quarter fixed effects are included in each of the estimations above. "10M $" refers to ten million U.S. dollars. Columns (1)-(3) show food banks' responses to all major disaster events. Columns (4)-(6) show responses to flooding-related disasters, including floods, coastal storms, hurricanes, mud/landslides, and severe storms with flooding.

Table 3. The Impact of Major Disasters on Food Banks (All Service Areas Interactions)

	All events			Flooding-related events		
(a)	(1)	(2)	(3)	(4)	(5)	(6)
Severity^{death} (count)	0.0459	0.0497	0.0656	0.0022	0.0085	0.0656
	(0.0442)	(0.0877)	(0.0942)	(0.0357)	(0.1946)	(0.2060)
Black^{A} (%)	0.0684		0.2752	0.0423		0.2505
	(0.3218)		(0.3202)	(0.3230)		(0.3216)
Severity^{death} × Black^{A}	0.0005		0.0007	0.0041**		0.0042*
	(0.0021)		(0.0030)	(0.0017)		(0.0023)
Poverty^{A} (%)		-0.4129***	-0.4340***		-0.4116***	-0.4320***
		(0.1485)	(0.1489)		(0.1485)	(0.1487)
Severity^{death} × Poverty^{A}		0.0004	-0.0020		0.0051	-0.0055
		(0.0061)	(0.0092)		(0.0145)	(0.0173)

(b)	(1)	(2)	(3)	(4)	(5)	(6)
Severity^{injury} (count)	0.0033	0.0004	-0.0074	-0.0106	-0.0507***	-0.0476***
	(0.0029)	(0.0035)	(0.0090)	(0.0075)	(0.0107)	(0.0160)
Black^{A} (%)	0.0796		0.2900	0.0655		0.2764
	(0.3193)		(0.3177)	(0.3191)		(0.3178)
Severity^{injury} × Black^{A}	0.0000		-0.0004	0.0016***		0.0002
	(0.0002)		(0.0004)	(0.0005)		(0.0006)
Poverty^{A} (%)		-0.4144***	-0.4380***		-0.4128***	-0.4337***
		(0.1482)	(0.1489)		(0.1481)	(0.1488)
Severity^{injury} × Poverty^{A}		0.0002	0.0015		0.0058***	0.0052**
		(0.0003)	(0.0012)		(0.0009)	(0.0021)

(c)	(1)	(2)	(3)	(4)	(5)	(6)
Severity$^{property\ damage}$ (10M $)	0.0016	-0.0076	-0.0089	0.0016	-0.0087	-0.0101
	(0.0011)	(0.0066)	(0.0079)	(0.0012)	(0.0071)	(0.0085)
Black^{A} (%)	0.0665		0.2745	0.0656		0.2736
	(0.3196)		(0.3181)	(0.3196)		(0.3182)
Severity$^{property\ damage}$ × Black^{A}	0.0000		-0.0000	0.0000		-0.0000
	(0.0001)		(0.0000)	(0.0001)		(0.0000)
Poverty^{A} (%)		-0.4139***	-0.4348***		-0.4137***	-0.4345***
		(0.1483)	(0.1488)		(0.1483)	(0.1488)
Severity$^{property\ damage}$ × Poverty^{A}		0.0008	0.0010		0.0009	0.0011
		(0.0005)	(0.0007)		(0.0006)	(0.0007)

Notes: *** p<0.01, ** p<0.05, * p<0.1. All the estimations here are with 3,120 observations for 195 food banks (balanced panels). Clustered-Robust standard errors in parentheses. Food bank fixed effects and quarter fixed effects are included in each of the estimations above. Black^{A} and Poverty^{A} refer to the socio-demographic information of the food bank's entire service area (%). "10M $" refers to ten million U.S. dollars. Columns (1)-(3) show food banks' responses to all major disaster events. Columns (4)-(6) show responses to flooding-related disasters, including floods, coastal storms, hurricanes, mud/landslides, and severe storms with flooding.

Table 4. The Impact of Major Disasters on Food Banks (Disaster Affected Areas Interactions)

	All events			Flooding-related events		
(a)	(1)	(2)	(3)	(4)	(5)	(6)
Severity^{death} (count)	0.0324	-0.0259	-0.0171	0.0297	0.0030	0.0417
	(0.0347)	(0.0586)	(0.0823)	(0.0425)	(0.0833)	(0.0930)
Severity^{death} × Black^{D}	0.0013		0.0005	0.0025		0.0026
	(0.0013)		(0.0026)	(0.0019)		(0.0024)
Severity^{death} × Poverty^{D}		0.0063	0.0049			-0.0011
		(0.0040)	(0.0092)			(0.0090)

(b)	(1)	(2)	(3)	(4)	(5)	(6)
Severity^{injury} (count)	-0.0010	-0.0055	0.0017	-0.0063	-0.0316***	-0.0341**
	(0.0019)	(0.0052)	(0.0122)	(0.0076)	(0.0092)	(0.0150)
Severity^{injury} × Black^{D}	0.0003*		0.0003	0.0011***		-0.0001
	(0.0001)		(0.0005)	(0.0003)		(0.0007)
Severity^{injury} × Poverty^{D}		0.0007	-0.0003		0.0041***	0.0046*
		(0.0004)	(0.0015)		(0.0009)	(0.0025)

(c)	(1)	(2)	(3)	(4)	(5)	(6)
Severity$^{property\ damage}$ (10M $)	0.0013	-0.0006	-0.0022	0.0013	-0.0006	-0.0022
	(0.0009)	(0.0021)	(0.0038)	(0.0009)	(0.0022)	(0.0038)
Severity$^{property\ damage}$ × Black^{D}	0.0001		-0.0001	0.0001		-0.0001
	(0.0001)		(0.0002)	(0.0001)		(0.0002)
Severity$^{property\ damage}$ × Poverty^{D}		0.0003	0.0006		0.0003	0.0006
		(0.0002)	(0.0006)		(0.0002)	(0.0006)

Notes: *** p<0.01, ** p<0.05, * p<0.1. All the estimations here are with 3,120 observations for 195 food banks (balanced panels). Clustered-Robust standard errors in parentheses. Food bank fixed effects and quarter fixed effects are included in each of the estimations above. Black^{D} and Poverty^{D} refer to the socio-demographic information of the disaster declared areas (%). "10M $" refers to ten million U.S. dollars. Columns (1)-(3) show food banks' responses to all major disasters. Columns (4)-(6) show responses to flooding-related disasters, including floods, coastal storms, hurricanes, mud/landslides, and severe storms with flooding.

Table 5. The Spillover of Major Disasters on Neighboring Food Banks, 0-100 miles

	All events			Flooding-related events		
	(1)	(2)	(3)	(4)	(5)	(6)
$Severity^{death}$ (count)	0.0546**			0.0719***		
	(0.0264)			(0.0219)		
$Severity^{death, 0\text{-}100}$ (count)	0.0002			-0.0009		
	(0.0027)			(0.0030)		
$Severity^{injury}$ (count)		0.0034			0.0128*	
		(0.0024)			(0.0076)	
$Severity^{injury, 0\text{-}100}$ (count)		-0.0001			0.0026	
		(0.0007)			(0.0040)	
$Severity^{property\ damage}$ (10M $)			0.0021***			0.0021***
			(0.0000)			(0.0000)
$Severity^{property\ damage, 0\text{-}100}$ (10M $)			-0.0000			-0.0000
			(0.0001)			(0.0001)

Notes: *** p<0.01, ** p<0.05, * p<0.1. All the estimations here are with 3,120 observations (balanced panels). Clustered-Robust standard errors in parentheses. Food bank fixed effects and quarter fixed effects are included in each of the estimations above. “10M $” refers to ten million U.S. dollars. Columns (1)-(3) show food banks’ responses and spillovers to all major disaster events. Columns (4)-(6) show results to flooding-related disasters, including floods, coastal storms, hurricanes, mud/landslides, and severe storms with flooding.