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ABSTRACT

From Syringes to Dishes: Improving Food Security through Vaccination

This paper examines the impact of COVID-19 vaccination on food insecurity in the United States, using data from the Household Pulse Survey. Our primary research design exploits variation in vaccine eligibility across states over time as an instrumental variable to address the endogeneity of vaccination decision. We find that vaccination had a substantial impact on food hardship by reducing the likelihood of food insecurity by 24%, with even stronger effects among minority and financially disadvantaged populations. Our results are robust to alternative specifications and the use of regression discontinuity as an alternative identification strategy. We also show that vaccine eligibility had a positive spillover impact on food assistance programs, specifically by reducing participation in the Supplemental Nutrition Assistance Program (SNAP), which suggests that vaccination policy can be effective in alleviating the fiscal burden of the pandemic on the government. Furthermore, our analysis indicates that vaccinated individuals exhibit increased financial optimism, as measured by expectations about future loss of employment and income as well as ability to make mortgage and debt payments. Based on the point estimates, the implied elasticity of food insecurity with respect to financial optimism is between -0.57 and -0.86. Our findings suggest that the COVID-19 vaccination program has implications that extend beyond the direct health benefits. Taken together, our results underscore the critical role of medical innovations and health interventions in improving economic optimism and food security, especially among vulnerable populations, during public health crises.

JEL Classification: I14, I18

Keywords: food insecurity, food stamps, vaccination, financial optimism, COVID-19

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1. Introduction

The COVID-19 pandemic has had a significant impact on various aspects of life in the United States. One area that has been particularly affected is food insecurity, a condition in which households lack access to adequate food because of limited money or other resources. The outbreak initially caused a major increase in food insecurity due to soaring unemployment, substantial income loss, and rising food prices (Parekh et al., 2021). Additionally, lockdowns and social distancing measures made it increasingly difficult for people to access food (Arndt et al., 2020; Hamadani et al., 2020). These challenges were further compounded by the closure of many food retailers due to supply chain problems, health concerns, or capacity restrictions (Laborde et al., 2020). As a result, a significant number of Americans, particularly those with lower socioeconomic status or living in regions with inadequate social support, have experienced difficulties in obtaining enough food to sustain their families over the past three years (Wolfson and Leung, 2020; Raifman, Bor, and Venkataramani, 2021). This has reversed years of declining rates of food insecurity in the United States. According to Schanzenbach and Pitts (2020), the proportion of the population experiencing food insecurity doubled from 10.8% in February 2020 to 23% between April and May 2020, as the economic impact of the pandemic unfolded.

The surge in food insecurity persisted throughout the first year of the pandemic, remaining well above its pre-pandemic levels. However, the hardship began to decline in early 2021 following several economic relief packages, including the Coronavirus, Aid, Relief, and Economic Security (CARES) Act and American Rescue Plan Act (ARPA).[1] Additionally, the U.S. Department of Agriculture (USDA) ran the Farmers to Families Food Box Program between May 2020 to May 2021 to provide food to those affected by the pandemic and to support food distribution companies and domestic food producers who faced disruptions. Despite these efforts, around 18 million adults (8.8 percent) reported not having enough to eat sometimes or often in the last seven days in March 2021, a significant increase from 8.5 million adults (3.4 percent) who reported not getting enough to eat at some point in 2019 (Keith-Jennings, Nchako, and Llobrera, 2021).

While food insecurity was dramatically elevated for all populations and in all states during the pandemic, the extent of hardship varied considerably, reflecting both the disproportionate impact of the crisis and long-standing inequities across society. For example, Black and Latino households and households with children experience substantially higher rates of food insecurity than other groups (Wolfson and Leung, 2020). Research from a broad cross-section of disciplines indicates that food insecurity is associated with negative consequences for both adults and children, including delayed

[1] These relief packages included various forms of economic relief, such as stimulus payments, unemployment benefits, small business loans, and funding for healthcare and vaccine distribution.

or neglected medical treatment (Bertoldo et al., 2022), chronic conditions (Seligman, Schillinger et al., 2010), mental health problems (Wolfson, Garcia, and Leung, 2021; Sabião et al., 2022; Whitaker, Phillips, and Orzol, 2006), and cognitive development (Howard, 2011).[2] Therefore, addressing food insecurity would not only improve nutrition intake, but also yield long-term benefits and reduce disparities in health and cognition among different groups in the United States.

This paper explores the causal relationship between COVID-19 vaccination and improvements in food insecurity in the United States, using data from the Household Pulse Survey (HPS) and exploiting the variation in the rollout of vaccine eligibility across states over time. In the early stages of the pandemic in the U.S., economic relief packages played an important role in preventing further increases in food insecurity. However, it was not until early 2021 that the rate of hardship began to decline, which coincided with the commencement of vaccination programs in February.[3] This suggests that vaccination efforts may have also played a role in reducing the number of people struggling with access to sufficient food. However, the extent to which individual decisions to get vaccination impacted food insecurity remains ambiguous, and further research is needed to establish a causal relationship between vaccination and food insecurity.

The role of vaccination in reducing food insecurity highlights the positive spillover effects of health interventions and medical innovations. Specifically, medical innovations, including vaccine development in the current context, can generate a sense of economic optimism (Makris and Toxvaerd, 2020), which can potentially address food insecurity during times of public health crises, provided that they are developed and deployed efficiently under a regulatory framework that ensures their safe and timely availability to the public. Previous scholarship has demonstrated that the benefits of vaccination extend beyond direct prevention of diseases, and often these benefits promote health equity and stabilize health systems across the life course of a vaccinated person (Wilder-Smith et al., 2017). For example, the rollout of vaccines has been demonstrated to have a positive impact on mental health and psychological expectations for the future (Agrawal et al., 2021; Aslim et al., 2022). However, the potential impact of vaccine development and vaccination programs on far-reaching consequences that extend beyond health outcomes, such as food insecurity, has not been previously studied.[4] As a result, the current valuation of vaccines may be underestimated due to the failure to account for the full spectrum of benefits.

As the United States continues to roll out COVID-19 vaccines, it is important to

[2]Moreover, food insecurity increases the likelihood of hospitalizations during the pandemic (Ariya et al., 2021), which may also contribute to long COVID.

[3]See, e.g., Figure 2 in the White House research blog by Cecilia Rouse and Brandon Restrepo: https://bit.ly/401Yy2v.

[4]One exception is Bärnighausen et al. (2013), who considers the effects of vaccine programs on tourism and foreign direct investment in the context of dengue in Brazil.

explore how vaccine uptake can help improve food insecurity among Americans. Such investigations can provide valuable insights for policymakers and other stakeholders who are working to address the economic and social impacts of the pandemic. Even though the government subsidized vaccination program is essentially a health intervention, it can have indirect fiscal implications by reducing the need for government-funded food assistance programs like the Supplemental Nutrition Assistance Program (SNAP) and potentially easing the economic burden on the government. Our study uniquely focuses on the impact of vaccination on SNAP participation, which could provide important policy implications for promoting greater access to healthy and affordable food for those who need it most during these challenging times. Overall, understanding how vaccination impacts social welfare programs like SNAP can provide valuable insights for promoting food security and mitigating the economic and social impacts of the pandemic.

In our research design, we carefully account for potential bias stemming from the likely endogeneity of individual vaccination decisions by using two empirical strategies, each with its own advantages. Specifically, we use an instrumental variables (IV) strategy exploiting the differential rollout of age-specific vaccine eligibility across states and over time as an instrument for vaccine receipt, and a regression discontinuity design (RDD) using a discrete jump in vaccine eligibility around the age cutoff of 65. Using both IV and RDD in a unified framework can provide a more robust analysis as it allows for cross-validation of results. For example, if the results of the IV and RDD are consistent, it can provide more confidence in the validity of our estimates.

The primary pathways providing causal links from vaccination to a decrease in food insecurity are through its positive impact on economic recovery and increased economic optimism. On the one hand, the availability of vaccines can help stabilize the labor market and accelerate the current economic recovery, as evidenced by the gradual reopening of businesses and public spaces, increased job opportunities, and decreased unemployment rates (CRS, 2022). Then it is expected that these improved labor market conditions and increased income can lead to better access to sufficient and higher-quality food, ultimately reducing food insecurity. On the other hand, the mere availability of vaccines can generate economic optimism by signaling that the worst of the pandemic is over and the economy is on the road to recovery (Andersson et al., 2021), potentially improving people's perception of food security. Relatedly, vaccinated individuals may feel more confident in engaging in activities such as shopping and dining out, thereby stimulating economic recovery and potentially reducing food insecurity. In other words, if households anticipate a favorable outlook in the labor market, they may reduce precautionary savings (Ren and Zheng, 2023) and allocate more towards meeting their daily needs, including food. This implies that financial optimism resulting from vaccination can help mitigate cyclical fluctuations in food insecurity.

Our empirical results show that vaccine eligibility increases the likelihood of vaccination by 26.8 percentage points. Furthermore, individual decision to get vaccinated reduces the likelihood of food insecurity by 9.3 percentage points, which corresponds to a 24% decline in food insecurity relative to the pre-vaccination baseline. Additionally, vaccination decreases the likelihood of very low food security, a more severe form of food insecurity, by 6.3 percentage points, corresponding to a 58% reduction relative to the baseline. Our results are not sensitive to different specifications and they are robust to using RDD as an alternative identification strategy. While we observe improvements in food insecurity across individuals with various demographic and socioeconomic backgrounds, the effects are stronger among minority groups and financially disadvantaged households. We also estimate the impact of vaccination on two measures of financial optimism, including the perception of future loss of employment income and confidence in meeting future mortgage and rent payments. The findings confirm that vaccination plays a vital role in enhancing financial optimism among the American population. Furthermore, the implied elasticity estimates obtained from this analysis reveal a negative relationship between financial optimism and food insecurity. This result indicates that financial optimism could be a crucial pathway for explaining the causal relationship between vaccination and food insecurity.

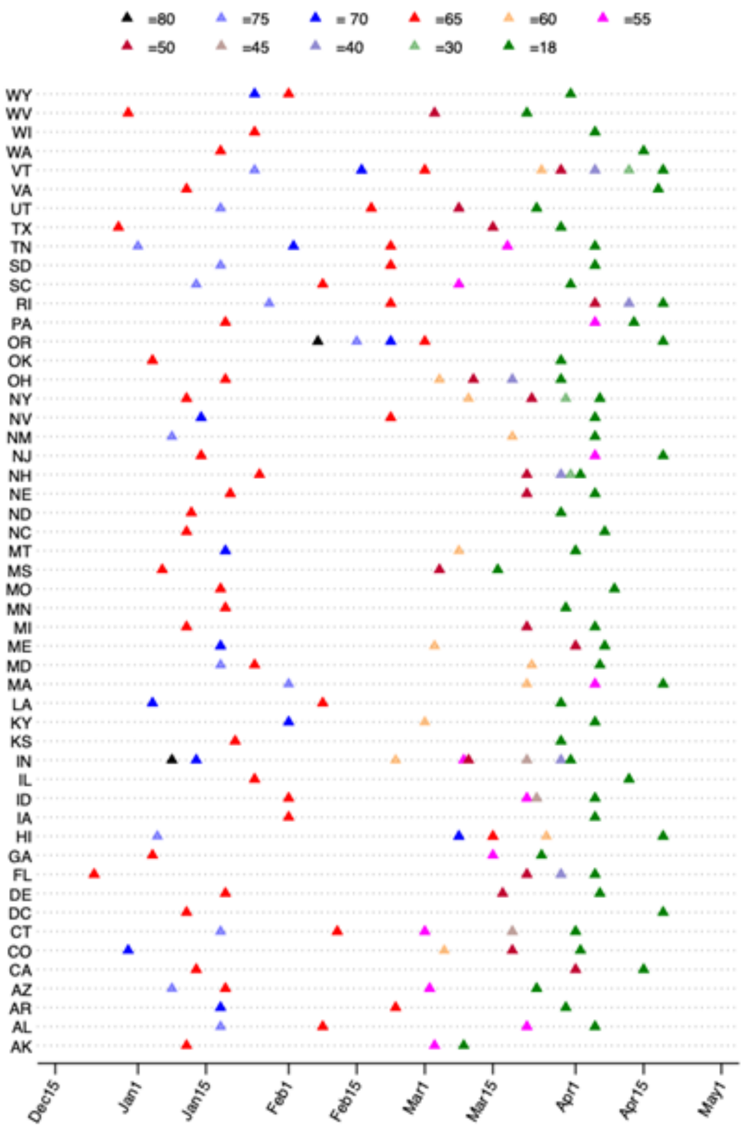
Additionally, our study demonstrates that vaccine eligibility can have a positive impact on food assistance programs by reducing the number of individuals receiving SNAP benefits. This suggests that vaccination not only helps individuals move out of food insecurity by improving their economic conditions and generating economic optimism, but may also lead to decreased reliance on public assistance programs, particularly on food stamps. This ripple effect of vaccination can potentially reduce the need for government-funded food assistance programs during public health crises as more people become vaccinated and their economic conditions improve. This could ultimately lower the cost of implementing vaccination programs.

Taken together, the findings from this paper highlight the effective role that vaccination plays in reducing food hardship at all levels, while also serving as a critical tool in addressing preexisting inequities in food access during a public health crisis. Therefore, vaccination can play a crucial role in promoting food security and mitigating the impact of health crises on vulnerable populations.

2. COVID-19 Vaccine as a Public Health Intervention: Rollout, Context, and Timeline

The development and rollout of COVID-19 vaccines have played a critical role in addressing the pandemic. On December 11, 2020, the Pfizer-BioNTech COVID-19 vaccine was granted emergency use authorization by the U.S. Food and Drug Administration for individuals aged 16 and older. The first dose was administered on December 14 to a healthcare professional in New York State three days after the vaccine's approval.[5] Due to limited vaccine supplies, states implemented a tiered system of vaccine distribution that prioritized the most vulnerable populations. Frontline healthcare workers, healthcare service workers, and long-term care residents were among the first groups to receive the vaccine, followed by adults aged 65 years and older and those with underlying medical conditions. The final group to become eligible for the vaccine was the general public aged 18 and older.

Figure 1. Variation in Age-Specific Vaccine Eligibility



Data Source: COVID-19 U.S. State Policy (CUSP) Database (Raifman et al., 2020).

[5]See the following article from Washington Post for more details: https://wapo.st/3Yu25GC.

Starting in late January 2021, many states began to gradually open up COVID-19 vaccine eligibility to the general public, with different age criteria and timelines across states. Figure 1 displays the variation in age-specific vaccine eligibility across states and over time. Florida, for instance, adopted a four-step approach, starting with those aged 65 and older (65+) on December 23, 2020, followed by those aged 60+ on March 22, 2021, those aged 40+ on March 29, 2021, and finally, all adults aged 18+ on April 5, 2021. In contrast, New York State followed a different timeline, initially making the vaccine available to those aged 65+ on January 11, followed by those aged 60+ on March 10, those aged 50+ on March 23, those aged 45+ on March 30, and finally, all adults aged 18+ on April 6. Florida and New York State are just two examples of the different timelines and age criteria used in the COVID-19 vaccine distribution process across the United States. Throughout March 2021, many states began to expand vaccine eligibility to those below 65, and by mid-April 2021, all states had made the COVID-19 vaccine available to adults aged 18 years and older.

3. Data

3.1. Vaccination, Food Insecurity, and Financial Optimism

Our data on vaccination and food insecurity come from the Household Pulse Survey (HPS). This survey has been deployed by the U.S. Census Bureau to understand household behaviors from a social and economic perspective during the pandemic and the following recovery period, while also providing a unique opportunity to study the near real-time policy responses and public health interventions at the federal and state levels.[6] The data include a broad range of questions on food sufficiency and security, vaccination status, employment, housing security, rental assistance, household spending, and concerns about the economy, among many other variables that gauge household experiences during the pandemic.

The HPS data has been released in multiple phases. The first phase, which covered waves 1-12 from April 23, 2020 - July 21, 2020, provided weekly estimates for each wave. It is worth noting that starting from the second phase (wave 13, from August 19, 2020 - October 26, 2020, and onward), new questions were added to the survey. Additionally, the data collection cycle was increased to two weeks.[7] For instance, the questions related

[6] The survey has been conducted in partnership with various federal agencies, including the Bureau of Labor Statistics (BLS), Centers for Disease Control and Prevention (CDC), and USDA Food and Nutrition Service (FNS), among others.

[7] Moreover, the first phase sampled respondents for up to three weeks, whereas in the subsequent waves (starting from the second phase), samples were independent of each other. In other words, there was no sample rotation across waves.

to COVID-19 vaccination were included on January 6, 2021 (or wave 22), following the availability of COVID-19 vaccines in the United States. To have consistency in the sampling method, our analysis uses data starting from the second phase, covering periods from August 19, 2020 to July 5, 2021, for adults over 19 years of age.[8] In addition, we make weighting adjustments using household weights introduced in the second phase of the HPS to adjust for potential nonresponse bias, a common feature of all statistical surveys (Peterson et al., 2021).

The U.S. Department of Agriculture (USDA) defines food insecurity as "[l]ack of consistent access to enough food to live an active and healthy life" (Rabbitt and Smith, 2021). In the HPS, there is a survey item measuring whether households had enough to eat, which relates to the concept of food insecurity.[9] To measure the severity of food insecurity at different levels, we leverage the following question:

> "*In the last 7 days, which of these statements best describes the food eaten in your household? Select only one answer.*
> *(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* "

Based on USDA, categories (3) and (4) substantially overlap with a more severe measure of food insecurity, classified as *very low* food security.[10] This form of food insecurity implies disruption in eating patterns and reduced food intake (Coleman-Jensen et al., 2022). Category (2) overlaps with a less severe form of food insecurity, defined as *low* food security. However, this category may introduce a different type of hardship experienced by households, namely reductions in quality or variety of food, in turn raising potential concerns about sufficient intake of essential nutrients to live an active and healthy life. Taking these definitions into account, we first construct a broad measure of food insecurity using responses in categories (2)-(4), combining the severity of food security at two levels (*very low* and *low*). This is our benchmark food insecurity measure. Alternatively, we construct a more severe measure of food insecurity, *very low* food

[8] We exclude younger age groups since they are likely to be dependent on their parents. Nonetheless, our baseline results do not change under the sample of adults aged 17+.

[9] Because the objective of Census Bureau's HPS is to provide near real-time data on multiple measures of well-being during the pandemic, they do not provide a full module on food insecurity that captures details of food hardship. Moreover, the survey question intends to describe households' food situation in the last 7 days rather than over the course of a year. This is particularly important in estimating the immediate impact of vaccination on food insecurity. Although there is a full module on food insecurity in the CPS Food Security Supplement (CPS-FSS), the lack of monthly variation in the data prevents researchers from assessing the longer term impact of age-specific vaccine eligibility on food insecurity.

[10] More details about USDA's measurement of food insecurity can be found here: `https://bit.ly/3K6Fn2S`.

security, using responses only in categories (3) and (4). We further define an indicator for vaccination uptake based on a "yes" or "no" question about COVID-19 vaccine receipt.

A potential mechanism through which vaccination affects food insecurity is expectations about future financial and economic conditions. Specifically, if vaccination increases the likelihood of forming optimistic expectations about future finances, it could further smooth out the economic impact of the pandemic. Therefore, we use questions from the HPS regarding the expected loss of employment income and confidence in ability to pay future mortgage or rent, respectively, to study the changes in optimism about future financial conditions. These questions are listed as follows:

> "*Do you expect that you or anyone in your household will experience a loss of employment income in the next 4 weeks because of the coronavirus pandemic? Select only one answer.*
> *(1) Yes*
> *(2) No* "

and

> "*How confident are you that your household will be able to pay your next rent or mortgage payment on time? Select only one answer.*
> *(1) No confidence*
> *(2) Slight confidence*
> *(3) Moderate confidence*
> *(4) High confidence* "

where we construct a high confidence measure, taking the value 1 for category (4) and 0 otherwise. To account for different levels of financial confidence, we create additional measures of moderate confidence using responses in categories (3)-(4) and any confidence using responses in categories (2)-(4). We further create an indicator variable for the expectation measure, taking the value 1 if individuals expect a loss of employment income and 0 otherwise. Exploiting a set of expectation and confidence measures, we study whether vaccination promotes financial optimism and its impact on the level of confidence.

3.2. Vaccine Eligibility

To obtain random variation in vaccination, we exploit the differential rollout of vaccine eligibility across states and over time. Specifically, states determine vaccine eligibility using plausibly exogenous age criteria. We obtain the eligibility data from the COVID-19 U.S. State Policy (CUSP) database (Raifman et al., 2020; Skinner et al., 2022). The data from CUSP has been used in multiple studies to determine the impact of age-specific vaccine eligibility on the likelihood of delaying or forgoing care (Aslim et al., 2022), mental health problems (Agrawal et al., 2021), risk mitigating behaviors or ex-ante moral hazard (Agrawal, Sood, and Whaley, 2022), as well as hospitalizations and deaths (Smits et al., 2022).

A potential challenge in using age-specific vaccine eligibility to recover causal effects is that certain individuals may be eligible for vaccination prior to the policy implementation. On the one hand, non-compliance may bias our first stage estimates towards zero. It is likely that those in high-risk occupation groups (e.g., frontline essential workers and K-12 employees) or adults with high-risk medical conditions may have received vaccination before the implementation of age-based criteria. On the other hand, vaccine eligibility may not be binding for many of these groups, especially if they are not likely to experience food insecurity in the first place.[11] Nonetheless, we address this potential concern in Section 5 using two approaches: (i) showing that the benchmark first stage estimates are relatively strong and (ii) creating a bound for the IV estimates by excluding individuals who receive vaccination prior to the policy, which only accounts for 5.5% of our working sample.

3.3. Reliance on Food Stamps

An important implication of a reduction in food insecurity upon vaccination is fiscal externalities, which can reduce the government's net costs (i.e., mechanical costs net of fiscal externalities) of providing or subsidizing vaccines. Specifically, individuals who transition out of food insecurity may be less likely to rely on welfare programs, such as the food assistance program. To test this hypothesis, we use data on the Supplemental Nutrition Assistance Program (SNAP) from the Current Population Survey Food Security Supplement (CPS-FSS) for the period August 2020 to June 2021. Although our intention is not to measure costs, we explore the second-order effect of vaccination on SNAP receipt, which is an important piece in the welfare calculation of vaccines.[12] Note that the CPS-FSS has been widely used to study the impact of government interventions on enrollment in SNAP (see, e.g., Rozema and Ziebarth 2017).

The data from the CPS-FSS are cross-sectional and available in December of each year. For each respondent, the survey reports the months for which food stamp benefits were received within a year. Therefore, we are able to pool individuals by person identifiers and months.[13] Similar to the HPS, our sample from the CPS-FSS includes adults over 19 years of age.

[11] Moreover, this might not be a serious issue, given that two sources of bias may cancel out in the first stage and the reduced form.

[12] Our estimates could easily be used in future studies that aim to fully explore the welfare effects of vaccination.

[13] We also replicate our analysis using only the reference person, the person designated as the householder within a household. We find that our findings are not sensitive to this restriction. For brevity, we do not report this result.

3.4. Descriptive Evidence

Before turning the focus to our two separate identification strategies and the estimation of causal parameters, we provide descriptive evidence on how food insecurity and measures of financial optimism trend over time. In addition, we provide summary statistics on these outcomes by pre-determined attributes, such as prior household income and race.

3.4.1. Food Insecurity and Measures of Financial Optimism

The first panel of Figure 2 provides graphical evidence of how food insecurity in the last 7 days changed over time. Prior to vaccination, we find that close to 40% of households in the United States experienced food insecurity at the onset of the pandemic. However, we observe a decline in food insecurity after vaccine rollout, depicted by the dashed vertical line. The share of households experiencing food insecurity plummets to 30% over time. This implies an approximately 25% decline in food insecurity relative to its pre-eligibility level.

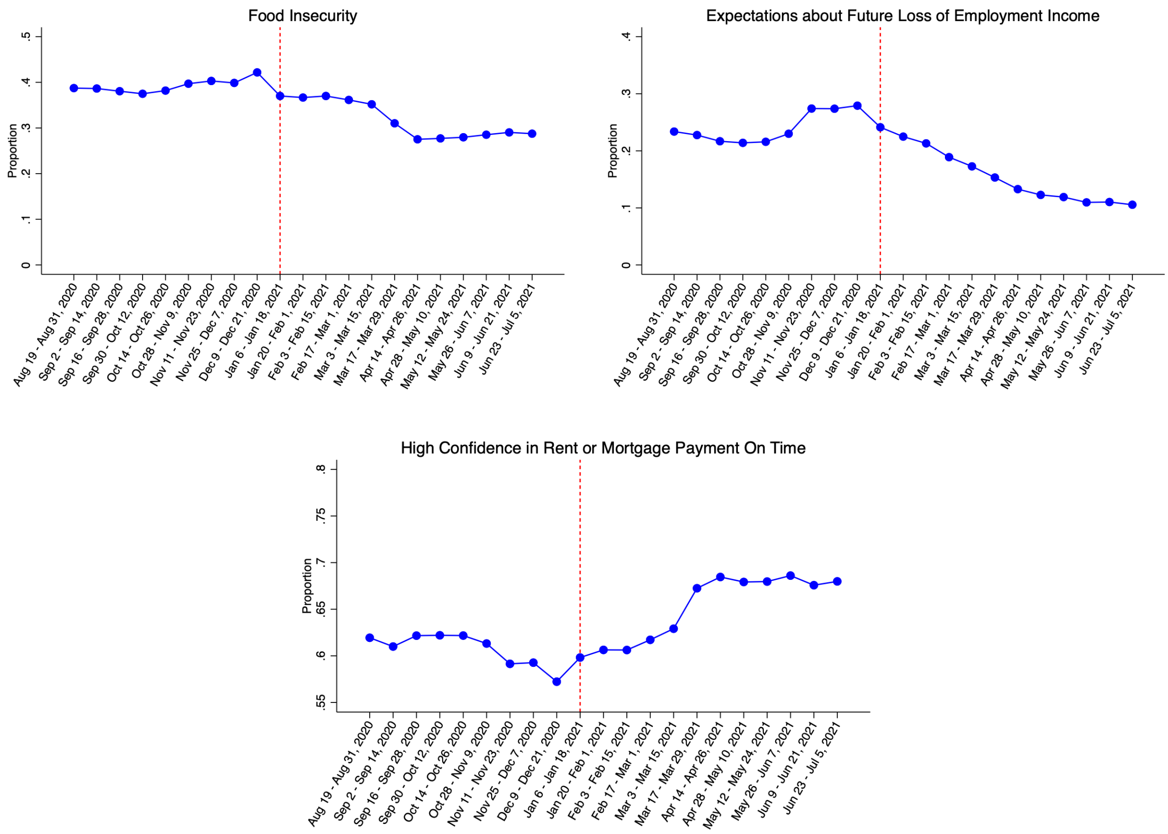
As mentioned above, we explore the changes in expected loss of future employment income and confidence in paying future mortgage or rent payments to study the role of vaccination in forming optimistic financial expectations, which can transition households out of food insecurity. The second and third panels of Figure 2 provide valuable insights into financial optimism. More than 20% of adults were expecting to lose employment income in the future due to COVID-19 in 2020. However, we observe a sharp decline to about 10% over time, following vaccine rollout. We further find a surge in people's high confidence levels in their ability to make timely mortgage or rent payments after vaccine rollout.

Table 1 provides summary statistics for our outcome variables within pre- and post-vaccination waves. On average, 32% of households experience food insecurity after vaccine eligibility, a decline from 39% prior to vaccine eligibility. Similar to the trends above, individuals are more likely to form optimistic expectations about future financial conditions after vaccine eligibility. However, there are heterogeneous changes in confidence levels for meeting future financial obligations, with the largest increase being in high confidence levels. Therefore, while some individuals may experience greater changes in confidence than others, overall, people are more likely to have higher confidence in their ability to make timely mortgage or rent payments after vaccine rollout. We also find that about 52.6% of respondents have received a COVID-19 vaccine by July 5, 2021 (wave 33).[14] These findings suggest that the high vaccine uptake rate may have contributed to the overall decrease in food insecurity and increase in confidence levels observed in

[14]The administrative data from the Centers for Disease Control and Prevention (CDC) show that 56% of the U.S. population has received at least one dose as of July 15, 2021. The estimate of vaccination prevalence from the HPS is close to those from the administrative data.

our data. In the remainder of the paper, we provide empirical evidence to explore this question further.

Figure 2. Food Insecurity and Measures of Financial Optimism Over Time



Notes: Each observation represents the weighted average of the corresponding outcome within each wave from August 19, 2020 (wave 13) through July 5, 2021 (wave 33). The dashed vertical line indicates the introduction of the COVID-19 vaccine in the United States.

Data Source: Household Pulse Survey, U.S. Census Bureau.

3.4.2. Trends by Pre-Determined Attributes

Table A.1 reports summary statistics for pre-determined attributes.[15] An important observation is that both demographic and socioeconomic characteristics are relatively balanced across pre- and post-vaccination waves. This implies that vaccine eligibility is independent of these pre-determined attributes. We do further checks on the independence assumption using our regression framework in Section 5.1.

In our sample, the average age of respondents is around 49. In addition, our

[15] We refer to demographic or socioeconomic characteristics as pre-determined attributes because they have negligible influence on our point estimates. Note also that household income is reported in 2019, which is prior to the pandemic. This alleviates potential concerns about endogenous changes in income with respect to the pandemic or the vaccination policy in general.

sample is composed of mostly married, white individuals, as well as those with relatively higher educational attainment and household income. We have information about health insurance coverage as well. On average, 43% of adults have private insurance, while about 28% report having public coverage (i.e., Medicaid and Medicare). Previous studies have shown an increase in Medicaid coverage during the pandemic (Karpman and Zuckerman, 2021). Our descriptive finding for Medicaid, which show a 0.3 percentage point rise in coverage, is consistent with the existing literature. About 35% of individuals, on average, report the presence of children (aged less than 18) in the household, and the average household size is more likely to be two. A few variables have missing observations, which are controlled for using indicator variables.

Table 1. Summary Statistics, Outcome Variables

	Pre-Vaccination Waves (Waves 13-21)			Post-Vaccination Waves (Waves 22-33)		
	Mean	SD	Obs.	Mean	SD	Obs.
Lack of Consistent Access to Enough Food						
Food Insecurity	0.392	0.488	692,603	0.319	0.466	772,101
Very Low Food Security	0.108	0.311	692,603	0.095	0.293	772,101
Measures of Financial Optimism						
Expectations about Future Loss of Employment Income	0.240	0.427	691,138	0.158	0.365	770,230
Levels of Confidence in Paying Future Rent or Mortgage Payments On Time						
– High Confidence	0.607	0.488	460,240	0.650	0.477	485,749
– Moderate Confidence	0.806	0.395	460,240	0.820	0.384	485,749
– Any Confidence	0.914	0.280	460,240	0.923	0.267	485,749
Vaccination Status						
Received Vaccination	0	0	692,603	0.526	0.499	772,101

Notes: The means are weighted using household weights from the HPS. The information on vaccination status is available after wave 21, following age-specific vaccine eligibility.

The prevalence of food and financial insecurity is likely to be more salient among low-wage earners and minorities, and the pandemic might have exacerbated preexisting inequities (Dubowitz et al., 2021; Perry, Aronson, and Pescosolido, 2021). For that reason, we also provide descriptive evidence regarding the change in outcomes during the pandemic for low-income households and minority groups. In Figures A.1 and A.2, we find substantial disparities in food insecurity and expectations about future financial conditions by income and race. Specifically, households with incomes less than $50,000 and minority groups, on average, are more likely to experience food insecurity, while forming relatively less optimistic expectations about their future financial conditions during the pandemic. Overall, these figures suggest that vaccination may play a more salient role in improving outcomes for disadvantaged populations compared to the baseline. We formally test for heterogeneous effects in Section 5.3.

4. Identification Strategy

4.1. Instrumental Variables

Our objective is to estimate the causal effect of vaccination on the likelihood of food insecurity. To capture this, we estimate the following regression model:

$$Y_{ist} = \alpha_1 + \psi_t + \kappa_s + \theta I_{ist} + \mathbf{X'}_{ist}\beta + \eta_{ist}, \tag{1}$$

where Y_{ist} is a measure of food insecurity for individual i in state s at survey wave t, ψ_t are survey wave fixed effects, and κ_s are state fixed effects. The indicator variable I_{ist} switches on upon vaccination and switches off otherwise. The vector of covariates $\mathbf{X}$ controls for the following individual characteristics: age, gender, marital status, race, educational attainment, household income, health insurance coverage, presence of children, and household size. In this setting, estimating the parameter of interest θ using OLS is likely to induce selection bias, given that individuals are not randomly assigned to receive the vaccine. To address this concern and recover causal effects, we exploit the differential rollout of age-specific vaccine eligibility across states and over time as an instrument for vaccine receipt. The idea is to obtain random variation in the likelihood of vaccination using exogenous eligibility criteria.

We use two-stage least squares (TSLS) to estimate θ in Equation (1), which is our second stage equation, and further use the following specification for first stage:

$$I_{ist} = \beta_1 + \psi_t + \kappa_s + \gamma E_{ist} + \mathbf{X'}_{ist}\delta + \nu_{ist}, \tag{2}$$

where the instrument E_{ist} denotes whether an individual is eligible for vaccine based on the age criteria across states and over time. The remaining fixed effects and individual characteristics mirror those in Equation (1). The validity of our instrument hinges on a set of assumptions, including the relevance condition, the exogeneity of the instrument, and monotonicity (in the presence of heterogeneous treatment effects). Under these assumptions, we can identify the causal effect of vaccination among compliers who would not have received vaccination had they not been eligible for vaccine. In other words, our TSLS estimand would recover the weighted average of local average treatment effects (LATE).

Alternative specifications. – Although there are no direct tests for instrument exogeneity (since η_{ist} is unobservable, e.g., when considering exclusion restriction), we provide a broad range of alternative specifications to test the validity of this assumption. To assess the independence assumption, we conduct robustness checks in the spirit of covariate balancing tests. Specifically, we progressively include pre-determined variables to show that our estimates are unaltered under the presumption that these variables are uncorrelated with vaccine eligibility. This would imply that the instrument is "as good as random," which is sufficient to draw inference about the causal effects of vaccine eligibility on food insecurity.

To recover LATE, however, we also need an exclusion restriction. We make sure that our estimates do not change with the inclusion of region-by-wave fixed effects, state-specific linear trends, as well as state-by-wave fixed effects, respectively. In a few specifications, we also control for lagged economic conditions, health conditions, and policy measures that vary across states and over time, following Aslim et al. (2022).[16] Specifically, we control for the unemployment rate from the U.S. Bureau of Labor Statistics to capture economic conditions. We control for COVID-19 death rates and the stringency index to account for health and state policy measures, respectively.[17] To account for the potential influence of social networks, we further include a measure of friend exposure to vaccine information as part of our state time-varying controls. The idea is that positive or negative messages on social media about vaccination or the availability of food can influence beliefs and behaviors among households. To construct this measure, we use data on social connectedness from Facebook (Bailey et al., 2018) and follow the approach in Bailey et al. (2020).[18] All these different specifications serve as indirect checks for exclusion restriction by closing potential backdoor paths between the instrument and the outcome of interest.

As a final step, we split the sample by observable attributes to show that, despite heterogeneous effects, the first stage estimates range within a narrow window, supporting the validity of the monotonicity assumption. In Section 5, we provide detailed evidence and discussion for each of these cases.

[16] Note that all these measures are lagged to avoid potential interactions with vaccine eligibility.

[17] We obtain data on death rates from The New York Times (2021) and the stringency index from the Oxford COVID-19 Government Response Tracker (Hale et al., 2021).

[18] We utilize two sets of data: administrative data on vaccination rates from the CDC and data on the Social Connectedness Index from Bailey et al. (2018), which are based on Facebook connections. To calculate friend exposure to vaccination for each state at a given time, we use the following formula:

$$FriendExpVax_{st} = \sum_{k \in K,\ k \neq s} FracConnect_{sk} \times VaccinationRate_{kt},$$

where k represents a friend state and K is the set of all 50 states. The fraction of Facebook connections a user in state s has in state k relative to all other friend states serves as a proxy for the strength of social connection between state s and friend state k. We follow the methodology outlined in Bailey et al. (2020) to construct $FracConnect_{sk}$. The product of $FracConnect_{sk}$ and $VaccinationRate_{kt}$, which is the vaccination rate in state k at time t, reflects the exposure of state s to friend state k's vaccination policy at time t via social media. In short, the summation across all friend states is a weighted measure of exposure to vaccination policy from all friend states. We impose a two-week lag to alleviate any potential interactions with the instrument.

4.2. Regression Discontinuity

To confirm that our estimates are not driven by a specific research design, we employ an alternative identification strategy. Using a regression discontinuity (RD) design, we estimate the average causal effects of vaccine eligibility around the age cutoff of 65. We define the reduced-form specification for our RD design as follows:

$$Y_{ist} = \alpha_2 + \psi_t + \kappa_s + g_l(a - c) + \mathbf{1}[a > c](g_r(a - c) + \pi) + \mathbf{X'}_{ist}\tau + \epsilon_{ist}, \quad (3)$$

where a is age, c is the cutoff at age 65, $\mathbf{1}[\mathrm{a} > \mathrm{c}]$ is an indicator variable taking the value 1 above the cutoff and 0 below the cutoff,[19] and $g_l(.)$ and $g_r(.)$ are unknown functions. Our parameter of interest is π, which identifies the intent-to-treat (ITT) effect of vaccine eligibility on outcomes. Note that we separately estimate the reduced form differences in mean food insecurity and vaccination. This approach has the benefit of relying on fewer assumptions for the identification of causal effects. The key assumption is the continuity assumption which asserts that all observable and unobservable factors should trend smoothly at the age cutoff. If the continuity assumption is plausible, then one can identify the average causal effect at the cutoff as:

$$\lim_{65 \leftarrow a} E[Y^1|a] - \lim_{a \rightarrow 65} E[Y^0|a], \quad (4)$$

where Y^1 and Y^0 are potential outcomes for treated and control units, respectively. It is possible to use the first stage estimates to scale up ITT effects. For instance, using a Wald estimator one can obtain LATE by taking the ratio of the ITT estimate and the first stage estimate, given a just-identified system. Notice that this approach requires the same identifying assumptions as the IV design to recover LATE.

We use age 65 as our cutoff for various reasons. First of all, more than half of the states initially provided eligibility to 65+ in earlier waves, and importantly, we are able to sample multiple waves across these states where individuals below 65 were not eligible for vaccination.[20] Moreover, there is evidence that vaccine eligibility among the elderly yields the largest reductions in hospitalizations and COVID-19 cases (Smits et al., 2022). Agrawal, Sood, and Whaley (2022) also find a relatively high take-up of vaccine among individuals aged over 65. Therefore, if there is higher compliance, the average causal effect of vaccination on food insecurity could also be larger among this group. These altogether motivate our analysis.

There is, however, an important challenge to the identification of treatment effects around the 65 age cutoff. Specifically, there is a major policy change at this cutoff, which

[19] Because we do not have information about the exact birth month of respondents, we strictly exclude those at the cutoff ($a = c$) to alleviate potential measurement error in the assignment of treatment.

[20] In our RD analysis, we do not include any states that provided prior eligibility to age groups above 65. Our sample includes 28 states that initially provided eligibility to 65+.

is likely to violate the continuity assumption. Individuals above the 65 age cutoff are eligible for Medicare, a public health insurance program for the elderly in the United States. A potential income effect through Medicare may influence the likelihood of accessing nutritionally adequate food. Moreover, the likelihood of retirement and labor force exits increase among individuals over the age of 65 (Behaghel and Blau, 2012), which in turn could impact food insecurity, once again through the income effect channel. We alleviate these concerns by (i) conducting a placebo analysis, e.g., using waves where individuals below and above the age of 65 are ineligible and (ii) extending our RD design to include these placebo groups from different waves in a *difference-in-discontinuities* design.[21] In Section 6, we show that our estimates from the difference-in-discontinuities design are remarkably robust and the placebo analysis yields precisely estimated null effects of vaccine eligibility.

5. Main Results

5.1. First Stage

We begin by estimating the impact of vaccine eligibility on the likelihood of vaccination. Table 2 reports the estimates from our first stage in Equation (2). We find that vaccine eligibility increases the likelihood of vaccination by about 24 percentage points ($p < 0.01$) in the most parsimonious specification in column (1). We also show that our point estimates barely change when we progressively control for geographic trends (regional or at the state level). In the most conservative specification in column (5), we non-parametrically control for time-varying factors across states, and find a 26.8 percentage points increase ($p < 0.01$) in the likelihood of vaccination. In Table A.2, we repeat our analysis by progressively including pre-determined attributes, and show that the first stage estimates are remarkably robust. These altogether suggest that the identifying variation in our data is likely to be exogenous.

Our analysis lends validity to the relevance assumption as well. We have highly significant estimates, and the Kleibergen-Paap Wald statistic, the multivariate equivalent of the F statistic, is over 420 in most specifications (Kleibergen and Paap, 2006). To further assess the strength of our instrument, we conduct the Lagrange Multiplier (LM) test for underidentification using the Kleibergen-Paap rk statistic. This test allows us to explore whether the minimum correlation between the instrument and the endogenous variable is statistically different from zero (Bazzi and Clemens, 2013). The Kleibergen-Paap rk statistic is over 20 in all specifications, suggesting that there is enough independent variation to contribute to the full rank of the correlation matrix between

[21] We coin the term "difference-in-discontinuities" to refer to the difference in discontinues at the cutoff between two sample periods.

Table 2. Vaccine Eligibility and the Likelihood of Receiving Vaccination

	(1)	(2)	(3)	(4)	(5)
Vaccine Eligibility	0.2380***	0.2447***	0.2453***	0.2418***	0.2683***
	(0.012)	(0.014)	(0.013)	(0.012)	(0.013)
N	1,464,704	1,464,704	1,464,704	1,464,704	1,464,704
State FE	√	√	√	√	√
Survey Wave FE	√	√	√	√	√
Region × Wave FE		√	√		
State time-varying measures			√	√	
State-specific linear trends				√	
State × Wave FE					√
Kleibergen-Paap rk LM statistic	20.53	20.48	20.55	20.38	20.32
Kleibergen-Paap rk Wald F statistic	427.4	325.3	339.9	420.2	436

Notes: The working sample includes observations from August 19, 2020 (wave 13) through July 5, 2021 (wave 33). All specifications control for individual characteristics, including age, gender, marital status, race, educational attainment, household income, health insurance coverage, the presence of children, and household size. State time-varying measures include two-week lagged COVID-19 death rate and stringency index, one-month lagged unemployment rate, and two-week lagged friend-exposure to vaccination information. All regressions are weighted using household weights from the HPS, and standard errors are clustered at the state level. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

vaccine eligibility and vaccination ($p < 0.01$).

5.2. Vaccination and Food Insecurity

Table 3 reports our benchmark point estimates from the OLS and TSLS estimations of Equation (1). Using the TSLS method, our objective is to recover the average causal effects of vaccination among compliers. We find that both the OLS and TSLS methods produce estimates which are remarkably consistent across different specifications in columns (1)-(5). In addition, the TSLS estimates suggest a larger decline in food insecurity than the OLS estimates.[22] Specifically, we show that vaccination reduces the likelihood of food insecurity by about 9.3 percentage points ($p < 0.01$) in column (5). This corresponds to a 24% decline in food insecurity relative to the pre-vaccination baseline.

We replicate our analysis by excluding individuals who report receiving vaccination prior to age-specific vaccine eligibility. Our replication in Table A.3 yields a sizeable decline in food insecurity. Specifically, we find that vaccination reduces the likelihood of food insecurity by 6.7 percentage points ($p < 0.01$) in column (5), which is approximately a 17% decline relative to the baseline. These findings altogether suggest that the reduction

[22]Vaccination take-up, on average, is relatively lower among working-age adults (Diesel et al., 2021). In addition to low vaccination rates, working-age adults are also more likely to experience severe food insecurity (Gregory and Coleman-Jensen, 2017). However, vaccine eligibility shifts some of these adults into receiving the vaccine, while increasing the likelihood of transitioning them out of food insecurity. Therefore, it is plausible to obtain larger average treatment effects for the compliers compared to the whole population.

in food insecurity ranges between 17% and 24%.

Table 3. Vaccination and Food Insecurity

	(1)	(2)	(3)	(4)	(5)
			OLS		
Vaccination	-0.0482***	-0.0481***	-0.0481***	-0.0479***	-0.0479***
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Pre-Vaccination Mean	0.392	0.392	0.392	0.392	0.392
Effect as a Percent of Mean	-12.30%	-12.27%	-12.27%	-12.22%	-12.22%
			TSLS		
Vaccination	-0.0951***	-0.0938***	-0.0942***	-0.0959***	-0.0934***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Pre-Vaccination Mean	0.392	0.392	0.392	0.392	0.392
Effect as a Percent of Mean	-24.26%	-23.93%	-24.03%	-24.46%	-23.83%
N	1,464,704	1,464,704	1,464,704	1,464,704	1,464,704
State FE	√	√	√	√	√
Survey Wave FE	√	√	√	√	√
Region × Wave FE		√	√		
State time-varying measures			√	√	
State-specific linear trends				√	
State × Wave FE					√

Notes: The working sample includes observations from August 19, 2020 (wave 13) through July 5, 2021 (wave 33). All specifications control for individual characteristics, including age, gender, marital status, race, educational attainment, household income, health insurance coverage, the presence of children, and household size. State time-varying measures include two-week lagged COVID-19 death rate and stringency index, one-month lagged unemployment rate, and two-week lagged friend-exposure to vaccination information. Pre-vaccination mean is the weighted sample mean of the outcome between waves 13 and 21. All regressions are weighted using household weights from the HPS, and standard errors are clustered at the state level. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

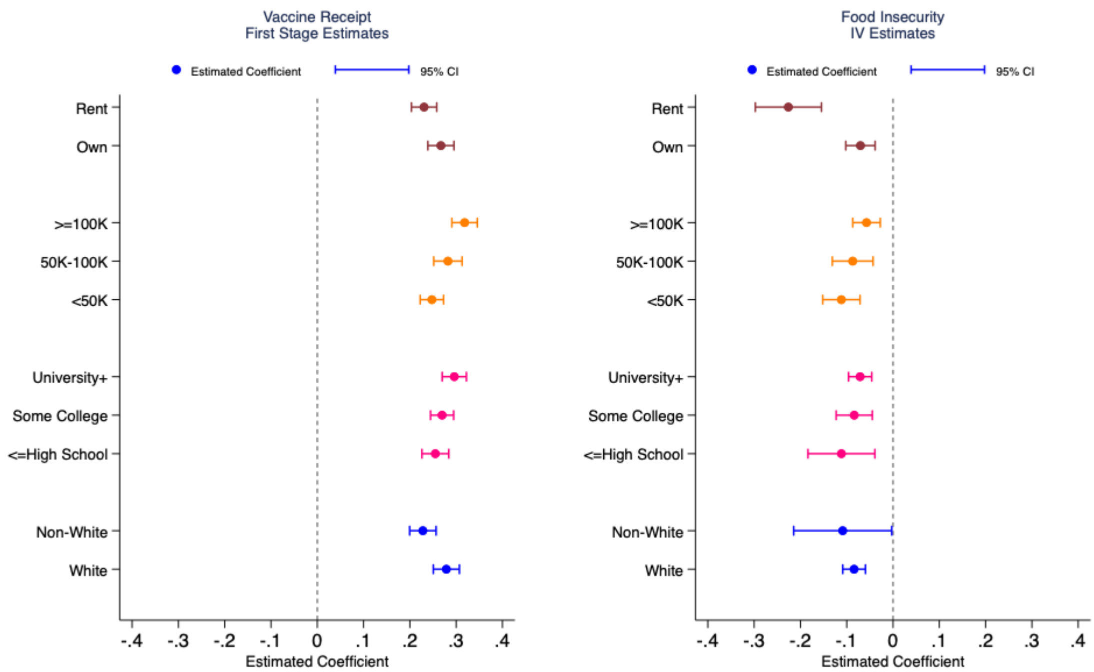
Next, we explore the impact of vaccination on *very low* food security in Table A.4, which is a more severe form of food insecurity. We find that vaccination reduces the likelihood of very low food security by about 6.3 percentage points ($p < 0.01$) in column (5). Given that the pre-vaccination mean is relatively low for severe food insecurity, our estimates correspond to a larger percent reduction, about 58%, relative to this baseline. These findings altogether suggest that vaccination reduces food hardship at all levels, while substantially curbing disruptions in eating patterns and food intake.

Robustness checks. – A potential threat to our identification is that economic conditions, health conditions, and state policy measures may create backdoor paths between vaccine eligibility and food insecurity. Our state-time varying measures, described in Section 4.1, control for these factors. Moreover, trends in vaccination or economic conditions across different geographic levels may influence the behavior of vaccine-eligible adults. We account for such trends using a flexible approach, namely, we progressively control for region-by-wave fixed effects, state-specific linear trends, and state-by-wave fixed effects. In columns (2)-(5) of Table 3, we do not have any evidence that these trends are likely to explain the decline in food insecurity upon vaccination. Taken together, the robustness of the estimates to alternative specifications is particularly reassuring that the exclusion restriction is likely to hold in our TSLS estimation strategy.

5.3. Heterogeneous Effects on Vaccination and Food Insecurity

Next, we explore whether the effects on vaccination and food insecurity are heterogeneous across individuals with different sociodemographic attributes. We now formally analyze our previous descriptive evidence that vaccination improves outcomes for all individuals. We begin by exploring heterogeneous effects in our first stage. The left panel of Figure 3 shows a statistically significant increase in vaccination after individuals become eligible to receive a vaccine. We observe an increasing gradient in vaccination among non-minority groups and those with higher socioeconomic backgrounds. For instance, the effect size is larger for adults with higher educational attainment, incomes above $100,000, and those who own a house.

Figure 3. Heterogeneous Effects on Vaccination and Food Insecurity



Notes: The working sample includes observations from August 19, 2020 (wave 13) through July 5, 2021 (wave 33). The figure displays separate first stage and IV estimates for each subsample, along with 95% confidence intervals. All specifications control for remaining individual characteristics, state fixed effects, survey wave fixed effects, and state-by-wave fixed effects. All regressions are weighted using household weights from the HPS, and standard errors are clustered at the state level.

Despite some heterogeneous effects, we find that the effect sizes vary within a relatively narrow window, namely 0.2 to 0.3. Ex-ante, monotonicity is not necessarily a concern in our setting, as individuals receive eligibility regardless of their race or socioeconomic status. Although there is no reason to believe that there could be defiers based on the eligibility rule, we nonetheless provide evidence that this is not the case.

The right panel of Figure 3 reports our TSLS estimates by observable attributes. Supporting our descriptive evidence, we find improvements in food insecurity across individuals with different sociodemographic backgrounds. However, we also find salient reductions in food insecurity among minority groups and financially disadvantaged households compared to the baseline. These altogether suggest that pharmaceutical interventions, such as the development and administration of vaccines, may play an important role in mitigating preexisting inequities in accessing adequate food, particularly in the midst of a public health crisis.

6. Validity of Food Insecurity Estimates

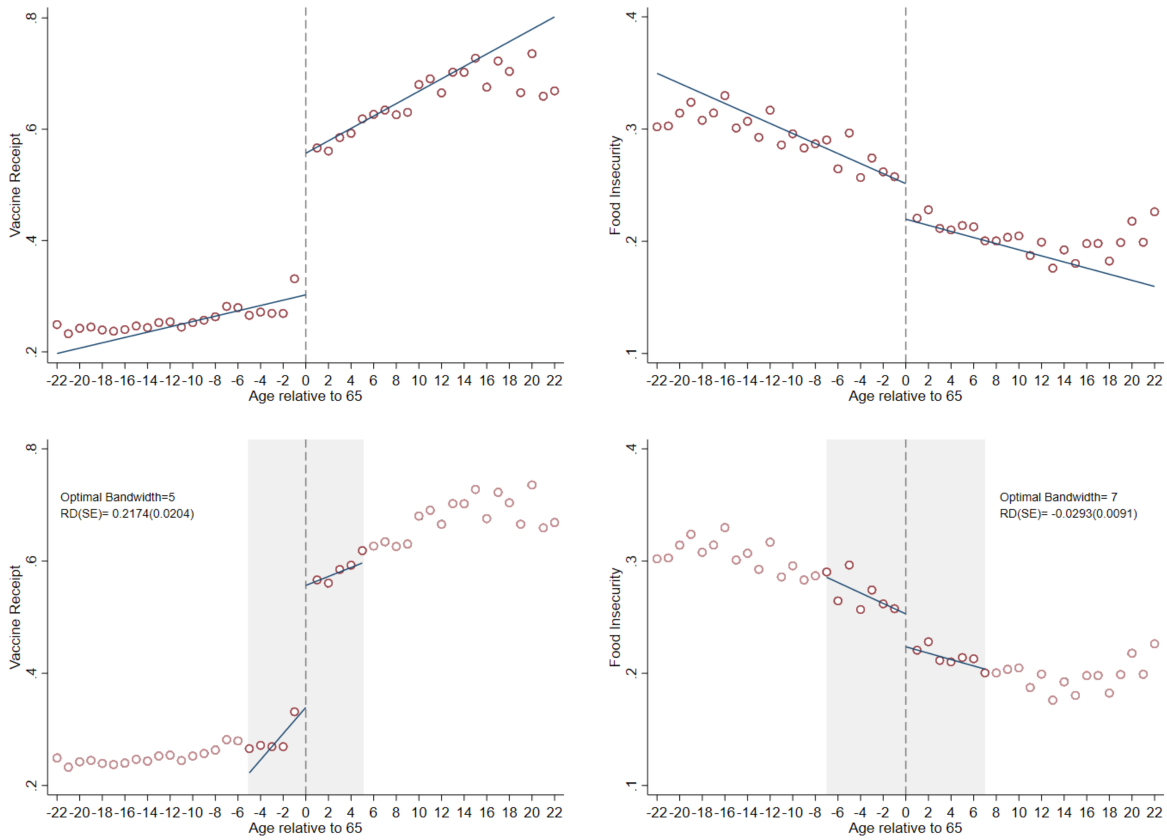
Alternative identification strategy. – To test the validity of our benchmark estimates in Section 5, we use an alternative identification strategy. Specifically, we aim to identify the average causal effects of vaccine eligibility around the cutoff at age 65 using an RD design. To do this, we sample waves between January 6, 2021 (wave 22) and April 26, 2021 (wave 28) across 28 states that initially provided eligibility to those above 65, while those below 65 were not eligible.

One of the compelling features of an RD design is the ability to graphically depict the discontinuity around a plausibly exogenous cutoff. This is exactly what we do in Figure 4. We exploit the raw data to plot the unrestricted means of vaccination and food insecurity within each age bin. In the top panel, we use the full sample of eligible adults (going up to age 87) and impose symmetry around the cutoff. Our visual check of the RD plots reveals a clear increase in vaccine take-up and a decrease in food insecurity. Now, we turn our focus to estimation.

To estimate treatment effects around the cutoff, we use the regression model in Equation 3, with separate local linear polynomials on each side of the age cutoff. In the bottom panel, we report local linear RD estimates and standard errors using a mean squared error (MSE)-optimal bandwidth and triangular kernel. We follow the data-driven bandwidth selection algorithm provided by Calonico et al. (2017) to obtain MSE-optimal bandwidths using the full sample for each outcome.

The figure on the left shows the discontinuity in vaccination, while the figure on the right shows the discontinuity in food insecurity. Consistent with our benchmark estimates, we have a relatively strong first stage, namely, we find a 22 percentage points increase ($p < 0.01$) in vaccination near the age cutoff. In addition to our first stage, we find a 2.9 percentage point decrease in the likelihood of food insecurity among adults above the age 65. This implies approximately a 11% reduction in food security relative to the pre-vaccination baseline.

Figure 4. Effects of Vaccine Eligibility Around the Age Cutoff



Notes: The working sample includes observations from 28 states with different time windows between January 6, 2021 (wave 22) and April 26, 2021 (wave 28). Each observation is the average of the corresponding outcome within age bins. The top panel depicts the discontinuity using a linear estimation for the full sample of eligible individuals above the cutoff. The bottom panel reports the local linear RD estimates using the optimal bandwidth (shaded in gray) and triangular kernel function for weighting. Pre-vaccination mean of food insecurity within the optimal bandwidth is 0.279. Standard errors in parentheses are clustered at the age cohort-state level. All specifications control for gender, marital status, race, educational attainment, household income, state fixed effects, and survey wave fixed effects. Dashed vertical lines denote the eligibility cutoff, which is normalized to zero.

To put the reduction in food insecurity into context, we also estimate the impact of vaccine eligibility on food insecurity across all states and over time. In contrast to the RD sample, we include all eligible age cohorts (aged 20-87) from our primary sample. We report the reduced form estimates in Table A.5. Our findings suggest that the reduction in food insecurity is about 6% ($p < 0.01$). This exercise confirms that the average causal effect of vaccine eligibility on food insecurity is larger in magnitude among the elderly relative to the general eligible population. This finding firmly supports our initial motivation to conduct an RD analysis using the age cutoff at 65.

Following the reduced form analysis, we ask whether the impact of vaccine eligibility on food insecurity is heterogeneous around the age cutoff. Our first stage estimates in Figure A.3 are remarkably consistent with the first stage estimates in TSLS, ranging between 0.2 and 0.3. Despite the increase in vaccine take-up among all subgroups, the heterogeneity analysis for the elderly reveals interesting disparities in the impact of vaccination on food insecurity compared to the patterns obtained for the general population of compliers shown in Figure 3. While the effects were more pronounced among minority and economically disadvantaged groups in the general population, there is a more uniform pattern across different demographic and socioeconomic groups among the elderly, with estimates ranging between 0 and -0.1 as illustrated in the right panel of Figure A.3. In addition to the analysis of food insecurity, we explore the effects of vaccine eligibility on very low food security. Note that only 4.3 percent of adults around the age cutoff experience a severe form of food insecurity prior to vaccination. Although the estimate reported in Figure A.4 has a negative sign, we have a precisely estimated null effect for this case. Put differently, we do not have any evidence of a significant reduction in very low food security among individuals above the age of 65.

Taken together, these findings are consistent with the idea that the benefits of vaccination are more concentrated among younger as well as socially and economically disadvantaged adults. There are multiple reasons supporting this idea in the existing scholarship. First, younger and disadvantaged adults are more likely to experience food insecurity (Raifman, Bor, and Venkataramani, 2021; Bertoldo et al., 2022). Second, older adults are likely to have access to alternative forms of support such as social security, Medicare, and Meals on Wheels, which alleviate some of the financial distress and health-related challenges they face (Agarwal, Pan, and Qian, 2020; Deshpande, Gross, and Su, 2021; Singleton, 2022). In contrast, the general population relies more heavily on labor market income for food security. Therefore, since vaccination may have a direct positive impact on labor market engagement, financial optimism or the income effect channel through vaccination may be less binding for the elderly.

Threats to identification. – There are three potential threats to identification in our RD design that may violate the continuity assumption. First, respondents may misreport their age in a systematic way that is correlated with food insecurity. Although a non-classical measurement error in age may not be common, we nonetheless test for any possible manipulations that can confound our estimates. Following McCrary (2008), we conduct a density test to explore whether there is any sorting near the cutoff. In Figure A.5, we estimate the discontinuity in the density function, measured as the log difference in height, as 0.033, with a standard error of 1.059. Therefore, we do not have any evidence to reject the null hypothesis that the discontinuity in the density of age is zero.

Second, individuals near the cutoff might not be comparable, implying that discontinuities may be driven by other (unobservable) attributes, even in the absence of vaccine eligibility. In Table A.6, we show that pre-determined characteristics are smooth functions of age. Specifically, we do not have any evidence of a statistically significant discontinuity in these characteristics around the age cutoff. Our findings suggest that the age criteria used in our analysis are exogenous, as we observe balance in both observable and unobservable attributes around the cutoff. This, in turn, alleviates potential concerns about omitted variables, providing greater confidence in our conclusions.

We further explore the sensitivity of our benchmark RD estimates to alternative bandwidths. Figure A.6 reports the first stage and reduced form estimates using various bandwidths. To be more flexible and transparent, we incrementally change the bandwidth by 1 year and display the pattern in our estimates. The hollow diamond markers report the benchmark RD estimates using the MSE-optimal bandwidth. We find that our benchmark estimates are exceptionally robust to alternative bandwidths. Specifically, the tradeoff between bias and variance seems negligible in our setting.

However, as an extension to the second point, any other policy changes around the cutoff that correlate with potential outcomes may also violate the continuity assumption. This is an important threat to identification, as Medicare eligibility and the likelihood of retirement change at the age of 65, both of which may impact food insecurity, particularly through the income effect channel. To further assess the validity of the continuity assumption, we conduct two separate placebo analyses. In the first exercise, we restrict our sample to the earlier waves of the pandemic to make sure that all adults are ineligible for vaccines around the age cutoff. The intuition is that, if policies other than vaccine eligibility are effective, we should observe a statistically significant discontinuity in food insecurity with respect to age. Using an ineligible placebo sample, panel (a) in Figure A.7 shows that food insecurity is continuous around the age cutoff.

In the second exercise, we do the opposite by restricting our sample to later waves of the pandemic to ensure that all adults around the age cutoff are eligible for vaccines. This exercise allows us to explore the validity of the continuity assumption for the first stage as well. Using an eligible placebo sample, panel (b) in Figure A.7 shows that both vaccine take-up and food insecurity are continuously related to the running variable at the 5 percent significance level. An additional benefit of conducting these exercises separately for two different time periods is that one can also explore whether there are substantial time-varying changes around the age cutoff. This does not appear to be the case in our setting.

As a final exercise, we combine the placebo samples with our primary sample in a difference-in-discontinuities framework. The idea is to difference out any potential time-invariant changes near the age cutoff. Panel A in Table A.7 reports the estimate for food insecurity using the ineligible placebo sample, including adults from waves 13-21, as a reference group. This analysis shows that vaccine eligibility reduces food insecurity by about 12% once we difference out potential changes across waves. Note that this estimate is close in magnitude to the benchmark RD estimate of 11%, suggesting that the reduction in food insecurity is not likely to be driven by changes in other policies.

Panel B in Table A.7 replicates our difference-in-discontinuities analysis using the eligible placebo sample, including adults from waves 30-33, as a reference group. First, we find a 20.5 percentage points increase in the likelihood of vaccination, which is exactly the same as the first stage estimate in Figure 4. In addition, we find a 13% reduction in food insecurity among vaccine-eligible adults after netting out potential changes across waves. Taken together, our alternative identification strategies further confirm that vaccination plays a crucial role in transitioning households out of food insecurity during the pandemic.

7. Vaccine Eligibility and Reliance on Government Food Assistance

Next, we explore whether there are any positive spillovers of vaccine eligibility on food assistance. Specifically, if vaccination helps individuals transition out of food insecurity by improving their economic conditions, one might expect less reliance on public assistance programs, particularly on food stamps. This would also imply that the net cost of providing vaccines to the government is much lower due to fiscal externalities. The higher the fiscal externalities are the higher the marginal value of public funds devoted toward subsidizing vaccines (see, e.g., Hendren and Sprung-Keyser, 2020). Although our focus is not directly on measuring the magnitude of fiscal externalities, we explore the impact of vaccine eligibility on the likelihood of receiving food stamp benefits, a key input in the calculation of net costs.

Table 4 reports the estimates pertaining to the reduced form effects of vaccine eligibility on food stamp receipt. We find a consistent reduction in food stamp receipt across the board. Specifically, in column (5), we find that vaccine eligibility reduces the likelihood of receiving food stamp benefits by 1.13 percentage points ($p < 0.01$). This corresponds to an approximately 17% reduction in food stamp receipt relative to the pre-vaccination baseline. Given that food assistance programs are means-tested, the effects of vaccine eligibility on food stamp receipt are likely to be salient among low-income individuals.

In Table A.8, we explore the impact of vaccine eligibility on the likelihood of receiving food stamp benefits by family income and educational attainment. A potential caveat of conducting this exercise using family income in the CPS is that income distribution may change endogenously as the pandemic progresses. This may be an issue with educational attainment as well (see, e.g., Meyers and Thomasson, 2017). Nonetheless, we check

Table 4. Vaccine Eligibility and the Likelihood of Receiving Food Stamp Benefits

	(1)	(2)	(3)	(4)	(5)
Vaccine Eligibility	-0.0102***	-0.0098***	-0.0098***	-0.0097***	-0.0113***
	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)
Pre-Vaccination Mean	0.065	0.065	0.065	0.065	0.065
Effect as a Percent of Mean	-15.69%	-15.08%	-15.08%	-14.92%	-17.38%
N	620,027	620,027	620,027	620,027	620,027
State FE	√	√	√	√	√
Survey Month FE	√	√	√	√	√
Region × Month FE		√	√		
State time-varying measures			√	√	
State-specific linear trends				√	
State × Month FE					√

Notes: The working sample comes from the CPS-FSS and uses observations from August 2020 through June 2021. Each column reports the reduced form effects of vaccine eligibility on food stamp take-up across different specifications. All specifications control for individual characteristics, including age, gender, marital status, education attainment, race, household income, the number of children, and household size. State time-varying measures include one-month lagged COVID-19 death rate and stringency index, as well as the unemployment rate. Pre-vaccination mean is the weighted sample mean of the outcome between August 2020 and December 2020. All regressions are weighted using the supplement person weight, and standard errors are clustered at the state level. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

whether there are shifts in the income distribution between 2019 and 2021 in Figure A.8. Despite slight changes, we do not observe any substantial sorting in the lower and middle quartiles, particularly between 2020 and 2021. In short, our analysis in Table A.8 suggests that the effects of vaccine eligibility on food assistance are concentrated among relatively low-income families, those earning less than $50,000. We find approximately a 13% reduction ($p < 0.05$) in food stamp receipt among low-income families. When we repeat our analysis using educational attainment, we observe reductions in food stamp receipt across the board. However, the estimates become closer to zero as the level of educational attainment increases.

8. Vaccination and Financial Optimism

A crucial piece to our understanding of how vaccination affects the likelihood of food insecurity rests on identifying the changes in expectations about future financial and economic conditions. One might expect vaccination to improve future financial and economic conditions through its impact on aggregate activity. For instance, uncertainty shocks, such as those created by pandemics, have contractionary effects on aggregate activity. However, Cakmakli et al. (2021) illustrate that vaccination plays an important role in smoothing out the negative economic impact of the pandemic. In fact, Lhuissier and Tripier (2021) show that optimistic expectations about future financial and economic conditions dampen these negative effects. Additionally, Christelis et al. (2020) find a positive relationship between expected consumption risk and expected consumption growth, suggesting a precautionary motive in savings among households under uncertainty. Given these findings, it is natural to expect improvements in financial expectations and confidence to smooth out cyclical fluctuations in food insecurity as the strength of precautionary saving declines.

Table 5. Vaccination and Expectations about Future Loss of Employment Income

	(1)	(2)	(3)	(4)	(5)
			OLS		
Vaccination	-0.0295***	-0.0290***	-0.0291***	-0.0287***	-0.0286***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Pre-Vaccination Mean	0.240	0.240	0.240	0.240	0.240
Effect as a Percent of Mean	-12.29%	-12.08%	-12.13%	-11.96%	-11.92%
			TSLS		
Vaccination	-0.0944***	-0.0976***	-0.0974***	-0.0974***	-0.1008***
	(0.013)	(0.014)	(0.014)	(0.012)	(0.013)
Pre-Vaccination Mean	0.240	0.240	0.240	0.240	0.240
Effect as a Percent of Mean	-39.33%	-40.67%	-40.58%	-40.58%	-42.00%
N	1,461,368	1,461,368	1,461,368	1,461,368	1,461,368
State FE	√	√	√	√	√
Survey Wave FE	√	√	√	√	√
Region × Wave FE		√	√		
State time-varying measures			√	√	
State-specific linear trends				√	
State × Wave FE					√

Notes: The working sample includes observations from August 19, 2020 (wave 13) through July 5, 2021 (wave 33). All specifications control for individual characteristics, including age, gender, marital status, race, educational attainment, household income, health insurance coverage, the presence of children, and household size. State time-varying measures include two-week lagged COVID-19 death rate and stringency index, one-month lagged unemployment rate, and two-week lagged friend-exposure to vaccination information. Pre-vaccination mean is the weighted sample mean of the outcome between waves 13 and 21. All regressions are weighted using household weights from the HPS, and standard errors are clustered at the state level. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

In this section, we complement the existing scholarship by investigating whether individuals who receive vaccination form optimistic expectations about their future financial conditions. In Table 5, we study the relationship between vaccination and expectations about future loss of employment income. We find that vaccination reduces expectations about future loss of employment income by about 10 percentage points ($p < 0.01$) in column (5), a 42% decline relative to the pre-vaccination baseline. In the top panel of Figure A.9, we also explore whether the changes in expectations are heterogeneous across individuals with different social and economic attributes. We uncover two key findings: (i) vaccination improves financial expectations across all individuals and (ii) financial expectations are more salient among minority groups and economically disadvantaged populations in general.

We show in our main analysis that vaccination reduces the likelihood of food insecurity by 24%. We then combine this parameter with our estimate of the impact of vaccination on financial optimism to obtain the implied elasticity of financial food security with respect to financial optimism. Specifically, we estimate that a one percent decrease in future financial optimism as measured by loss of employment income is associated with a 0.57% increase in food insecurity.

Table 6. Vaccination and Confidence in Paying Future Mortgage or Rent Payments On Time

	High Confidence		Moderate Confidence		Any Confidence	
	(1)	(2)	(3)	(4)	(5)	(6)
			OLS			
Vaccination	0.0391***	0.0392***	0.0319***	0.0318***	0.0188***	0.0187***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)
Pre-Vaccination Mean	0.607	0.607	0.806	0.806	0.914	0.914
Effect as a Percent of Mean	6.44%	6.46%	3.96%	3.95%	2.06%	2.05%
			TSLS			
Vaccination	0.1672***	0.1693***	0.1506***	0.1442***	0.0624***	0.0604***
	(0.021)	(0.019)	(0.018)	(0.016)	(0.011)	(0.011)
Pre-Vaccination Mean	0.607	0.607	0.806	0.806	0.914	0.914
Effect as a Percent of Mean	27.55%	27.89%	18.68%	17.89%	6.83%	6.61%
N	945,989	945,989	945,989	945,989	945,989	945,989
State FE	√	√	√	√	√	√
Survey Wave FE	√	√	√	√	√	√
State × Wave FE		√		√		√

Notes: The working sample includes observations from August 19, 2020 (wave 13) through July 5, 2021 (wave 33). All specifications control for individual characteristics, including age, gender, marital status, race, educational attainment, household income, health insurance coverage, the presence of children, and household size. State time-varying measures include two-week lagged COVID-19 death rate and stringency index, one-month lagged unemployment rate, and two-week lagged friend-exposure to vaccination information. Pre-vaccination mean is the weighted sample mean of the outcome between waves 13 and 21. All regressions are weighted using household weights from the HPS, and standard errors are clustered at the state level. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Next, we study whether vaccination affects the level of confidence in meeting future financial obligations, such as mortgage or rent payments, in Table 6. We find that vaccination leads to an overall increase in financial confidence. However, there are also heterogeneous effects across confidence levels, namely, individuals are more likely to have high financial confidence relative to moderate or any financial confidence. Specifically, we find approximately a 28% increase in the likelihood of having high confidence in paying future mortgage or rent payments on time ($p < 0.01$). The implied elasticity of food security with respect to financial optimism measured by confidence in paying mortgage and making rent payments is 0.86. This implies that a one percent increase in financial optimism as measured by high confidence in paying mortgage and making rent payments is associated with a 0.86% reduction in food insecurity. Echoing our previous findings, the bottom panel in Figure A.9 shows that the increase in high financial confidence is likely to be driven by non-White individuals and those with lower socioeconomic status. Taken together, these findings imply that vaccination promotes financial optimism, particularly among impoverished and minority communities, which can further explain the salient reduction in food insecurity within these communities.

9. Conclusion

The COVID-19 pandemic caused a surge in food insecurity, which disproportionately affected vulnerable populations such as Black and Latino households and households with children. This was due to rising unemployment, income loss, and food prices, as well as the closure of many food retailers. Despite the rollout of several economic relief packages by the US government, food insecurity persisted throughout the first year of the pandemic. However, starting in early 2021, there was a decline in food insecurity rates.

To examine the relationship between vaccination and food insecurity among Americans, we use data from the Household Pulse Survey. To address the endogeneity issue of vaccination decisions, we use the variation in vaccine eligibility across states over time as an instrumental variable.

Our findings indicate that vaccination efforts alleviate the effects of the pandemic on food insecurity. Specifically, vaccine eligibility increases the likelihood of vaccination by 24 percentage points, which led to a 9.3 percentage point decline in food insecurity. While our results demonstrate improvements in food insecurity across all individuals with various demographic and socioeconomic backgrounds, the effects are stronger among minority groups and financially disadvantaged households. Therefore, addressing food insecurity would not only improve nutrition intake but also yield long-term benefits and reduce disparities in health and cognition among different groups in the United States. These results highlight the importance of targeted interventions for vulnerable populations, particularly those with lower socioeconomic status or living in regions with inadequate social support, who are at a higher risk of experiencing food insecurity during health crises. This information can guide policymakers in developing more effective and equitable public health policies and interventions in the future.

Moreover, vaccination played a crucial role in boosting financial optimism among the American population. Specifically, the perception of future loss of employment income and confidence in meeting future mortgage and rent payments both improve significantly with vaccination. This finding provides strong support for the notion that financial optimism represents a crucial pathway for explaining the causal relationship between vaccination and food insecurity. Our findings also suggest that vaccination has positive spillover effects on food assistance programs by reducing SNAP receipts. As a result, the overall cost of providing vaccines to the government may be lower due to fiscal externalities.

Despite previous scholarship on the benefits of vaccination, the potential impact of vaccination programs on far-reaching consequences that extend beyond health outcomes, such as food insecurity, has not been previously studied. Accordingly, our results suggest that the current valuation of vaccines may be underestimated due to the failure to account for the full spectrum of its benefits. By investing in the development and deployment of effective and timely health interventions, governments can generate economic optimism and stability, leading to improved food security and overall well-being for their populations. Additionally, a comprehensive approach that considers the broader spillover effects of health interventions beyond direct disease prevention can help address a wide range of social and economic challenges that arise during public health crises, thereby reducing the negative impact on vulnerable populations.

References

Agarwal, Sumit, Jessica Pan, and Wenlan Qian. 2020. "Age of decision: Pension savings withdrawal and consumption and debt response." *Management Science* 66 (1):43–69.

Agrawal, Virat, Jonathan H Cantor, Neeraj Sood, and Christopher M Whaley. 2021. "The Impact of the COVID-19 Vaccine Distribution on Mental Health Outcomes." National Bureau of Economic Research, Working Paper 29593.

Agrawal, Virat, Neeraj Sood, and Christopher M Whaley. 2022. "The ex-ante moral hazard effects of COVID-19 vaccines." National Bureau of Economic Research, Working Paper 30602.

Andersson, Ola, Pol Campos-Mercade, Armando N Meier, and Erik Wengström. 2021. "Anticipation of COVID-19 vaccines reduces willingness to socially distance." *Journal of Health Economics* 80:102530.

Ariya, Mohammad, Jalal Karimi, Somayeh Abolghasemi, Zeinab Hematdar, Mohammad Mehdi Naghizadeh, Maryam Moradi, and Reza Barati-Boldaji. 2021. "Food insecurity arises the likelihood of hospitalization in patients with COVID-19." *Scientific Reports* 11 (1):20072.

Arndt, Channing, Rob Davies, Sherwin Gabriel, Laurence Harris, Konstantin Makrelov, Sherman Robinson, Stephanie Levy, Witness Simbanegavi, Dirk Van Seventer, and Lillian Anderson. 2020. "Covid-19 lockdowns, income distribution, and food security: An analysis for South Africa." *Global Food Security* 26:100410.

Aslim, Erkmen G, Wei Fu, Chia-Lun Liu, and Erdal Tekin. 2022. "Vaccination Policy, Delayed Care, and Health Expenditures." National Bureau of Economic Research, Working Paper 30139.

Bailey, Michael, Rachel Cao, Theresa Kuchler, Johannes Stroebel, and Arlene Wong. 2018. "Social Connectedness: Measurement, Determinants, and Effects." *Journal of Economic Perspectives* 32 (3):259–80.

Bailey, Michael, Drew M Johnston, Martin Koenen, Theresa Kuchler, Dominic Russel, and Johannes Stroebel. 2020. "Social Networks Shape Beliefs and Behavior: Evidence from Social Distancing During the COVID-19 Pandemic." National Bureau of Economic Research, Working Paper 28234.

Bärnighausen, Till, David E Bloom, Elizabeth T Cafiero, and Jennifer C OâBrien. 2013. "Valuing the broader benefits of dengue vaccination, with a preliminary application to Brazil." In *Seminars in Immunology*, vol. 25. Elsevier, 104–113.

Bazzi, Samuel and Michael A Clemens. 2013. "Blunt instruments: Avoiding common pitfalls in identifying the causes of economic growth." *American Economic Journal: Macroeconomics* 5 (2):152–186.

Behaghel, Luc and David M Blau. 2012. "Framing social security reform: Behavioral responses to changes in the full retirement age." *American Economic Journal: Economic Policy* 4 (4):41–67.

Bertoldo, Jaclyn, Julia A Wolfson, Samantha M Sundermeir, Jeffrey Edwards, Dustin Gibson, Smisha Agarwal, and Alain Labrique. 2022. "Food insecurity and delayed or forgone medical care during the COVID-19 pandemic." *American Journal of Public Health* 112 (5):776–785.

Cakmakli, Cem, Selva Demiralp, Sebnem Kalemli-Ozcan, Sevcan Yesiltas, and Muhammed A Yildirim. 2021. "The economic case for global vaccinations: An epidemiological model with international production networks." National Bureau of Economic Research, Working Paper 28395.

Calonico, Sebastian, Matias D Cattaneo, Max H Farrell, and Rocio Titiunik. 2017. "rdrobust: Software for regression-discontinuity designs." *The Stata Journal* 17 (2):372–404.

Christelis, Dimitris, Dimitris Georgarakos, Tullio Jappelli, and Maarten van Rooij. 2020. "Consumption uncertainty and precautionary saving." *Review of Economics and Statistics* 102 (1):148–161.

Coleman-Jensen, Alisha, Matthew P Rabbitt, Christian A Gregory, and Anita Singh. 2022. "Household Food Security in the United States in 2021." USDA-ERS Economic Research Report.

Congressional Research Service (CRS). 2022. "U.S. Economic Recovery in the Wake of COVID-19: Successes and Challenges." Washington, DC: United States Congress. Accessed Feb 13, 2023: https://bit.ly/3l38wSq.

Deshpande, Manasi, Tal Gross, and Yalun Su. 2021. "Disability and distress: The effect of disability programs on financial outcomes." *American Economic Journal: Applied Economics* 13 (2):151–178.

Diesel, Jill, Natalie Sterrett, Sharoda Dasgupta, Jennifer L Kriss, Vaughn Barry, Kayla Vanden Esschert, Ari Whiteman, Betsy L Cadwell, Daniel Weller, Judith R Qualters et al. 2021. "COVID-19 vaccination coverage among adults–United States, December 14, 2020–May 22, 2021." *Morbidity and Mortality Weekly Report* 70 (25):922.

Dubowitz, Tamara, Madhumita Ghosh Dastidar, Wendy M Troxel, Robin Beckman, Alvin Nugroho, Sameer Siddiqi, Jonathan Cantor, Matthew Baird, Andrea S Richardson, Gerald P Hunter et al. 2021. "Food insecurity in a low-income, predominantly African American cohort following the COVID-19 pandemic." *American Journal of Public Health* 111 (3):494–497.

Gregory, Christian A and Alisha Coleman-Jensen. 2017. "Food insecurity, chronic disease, and health among working-age adults." ERR-235, U.S. Department of Agriculture, Economic Research Service.

Hale, Thomas, Noam Angrist, Rafael Goldszmidt, Beatriz Kira, Anna Petherick, Toby Phillips, Samuel Webster, Emily Cameron-Blake, Laura Hallas, Saptarshi Majumdar, and Helen Tatlow. 2021. "A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker)." *Nature Human Behaviour* 5:529–538.

Hamadani, Jena Derakhshani, Mohammed Imrul Hasan, Andrew J Baldi, Sheikh Jamal Hossain, Shamima Shiraji, Mohammad Saiful Alam Bhuiyan, Syeda Fardina Mehrin, Jane Fisher, Fahmida Tofail, SM Mulk Uddin Tipu et al. 2020. "Immediate impact of stay-at-home orders to control COVID-19 transmission on socioeconomic conditions, food insecurity, mental health, and intimate partner violence in Bangladeshi women and their families: an interrupted time series." *The Lancet Global Health* 8 (11):e1380–e1389.

Hendren, Nathaniel and Ben Sprung-Keyser. 2020. "A unified welfare analysis of government policies." *Quarterly Journal of Economics* 135 (3):1209–1318.

Howard, Larry L. 2011. "Does food insecurity at home affect non-cognitive performance at school? A longitudinal analysis of elementary student classroom behavior." *Economics of Education Review* 30 (1):157–176.

Karpman, Michael and Stephen Zuckerman. 2021. "The uninsurance rate held steady during the pandemic as public coverage increased." Washington, DC: Urban Institute.

Keith-Jennings, Brynne, Catlin Nchako, and Joseph Llobrera. 2021. "Number of families struggling to afford food rose steeply in pandemic and remains high, especially among children and households of color." Center on Budget and Policy Priorities.

Kleibergen, Frank and Richard Paap. 2006. "Generalized reduced rank tests using the singular value decomposition." *Journal of Econometrics* 133 (1):97–126.

Laborde, David, Will Martin, Johan Swinnen, and Rob Vos. 2020. "COVID-19 risks to global food security." *Science* 369 (6503):500–502.

Lhuissier, Stéphane and Fabien Tripier. 2021. "Regime-dependent effects of uncertainty shocks: A structural interpretation." *Quantitative Economics* 12 (4):1139–1170.

Makris, Miltiadis and Flavio Toxvaerd. 2020. "Great expectations: Social distancing in anticipation of pharmaceutical innovations." Cambridge Working Papers in Economics, University of Cambridge.

McCrary, Justin. 2008. "Manipulation of the running variable in the regression discontinuity design: A density test." *Journal of Econometrics* 142 (2):698–714.

Meyers, Keith and Melissa A Thomasson. 2017. "Paralyzed by panic: Measuring the effect of school closures during the 1916 polio pandemic on educational attainment." National Bureau of Economic Research, Working Paper 23890.

Parekh, Niyati, Shahmir H Ali, Joyce O'Connor, Yesim Tozan, Abbey M Jones, Ariadna Capasso, Joshua Foreman, and Ralph J DiClemente. 2021. "Food insecurity among households with children during the COVID-19 pandemic: results from a study among social media users across the United States." *Nutrition Journal* 20:1–11.

Perry, Brea L, Brian Aronson, and Bernice A Pescosolido. 2021. "Pandemic precarity: COVID-19 is exposing and exacerbating inequalities in the American heartland." *Proceedings of the National Academy of Sciences* 118 (8):e2020685118.

Peterson, Sandra, Norilsa Toribio, James Farber, and David Hornick. 2021. "Nonresponse bias report for the 2020 Household Pulse Survey." Washington, DC: United States Census Bureau.

Rabbitt, Matthew P and Michael D Smith. 2021. "Food Insecurity Among Working-Age Veterans." U.S. Department of Agriculture, Economic Research Report Number 829.

Raifman, Julia, Jacob Bor, and Atheendar Venkataramani. 2021. "Association between receipt of unemployment insurance and food insecurity among people who lost employment during the COVID-19 pandemic in the United States." *JAMA Network Open* 4 (1):e2035884–e2035884.

Raifman, Julia, Kristen Nocka, David Jones, Jacob Bor, Sarah Lipson, Jonathan Jay, Megan Cole, Noa Krawczyk, Philip Chan, and Sandro Galea. 2020. "COVID-19 US State Policy Database." Inter-university Consortium for Political and Social Research, https://doi.org/10.3886/E119446V136.

Ren, He and Yi Zheng. 2023. "COVID-19 vaccination and household savings: An economic recovery channel." *Finance Research Letters* :103711.

Rozema, Kyle and Nicolas R Ziebarth. 2017. "Taxing consumption and the take-up of public assistance: The case of cigarette taxes and food stamps." *Journal of Law and Economics* 60 (1):1–27.

Sabião, Thaís S, Raquel D Mendonça, Adriana L Meireles, George LL Machado-Coelho, and Júlia CC Carraro. 2022. "Food insecurity and symptoms of anxiety and depression disorder during the COVID-19 pandemic: COVID-Inconfidentes, a population-based survey." *SSM-Population Health* 19:101156.

Schanzenbach, Diane and Abigail Pitts. 2020. "How much has food insecurity risen? Evidence from the Census Household Pulse Survey." *Institute for Policy Research Rapid Research Report* :1–10.

Seligman, Hilary K, Dean Schillinger et al. 2010. "Hunger and socioeconomic disparities in chronic disease." *New England Journal of Medicine* 363 (1):6–9.

Singleton, Perry. 2022. "The effect of social security benefits on food insecurity at the early entitlement age." *Applied Economic Perspectives and Policy* 45 (1):392 – 413.

Skinner, Alexandra, Kelsey Flannery, Kristen Nocka, Jacob Bor, Lorraine T Dean, Jonathan Jay, Sarah Ketchen Lipson, Megan B Cole, Emily A Benfer, Rachel Scheckman et al. 2022. "A database of US state policies to mitigate COVID-19 and its economic consequences." *BMC Public Health* 22 (1):1–8.

Smits, Joeri, Amyn Abdul Malik, Jad A Elharake, Ahmed Mushfiq Mobarak, and Saad B Omer. 2022. "Did Risk-Based or Age-Based Vaccine Prioritization for COVID-19 Save More Lives?" MedRxiv, https://doi.org/10.1101/2022.10.18.22281237.

The New York Times. 2021. "Coronavirus (Covid-19) Data in the United States." Retrieved December 8, 2021, from https://github.com/nytimes/covid-19-data.

Whitaker, Robert C, Shannon M Phillips, and Sean M Orzol. 2006. "Food insecurity and the risks of depression and anxiety in mothers and behavior problems in their preschool-aged children." *Pediatrics* 118 (3):e859–e868.

Wilder-Smith, Annelies, I Longini, PL Zuber, T Bärnighausen, WJ Edmunds, N Dean, V Masserey Spicher, MR Benissa, and BD Gessner. 2017. "The public health value of vaccines beyond efficacy: methods, measures and outcomes." *BMC Medicine* 15 (1):1–9.

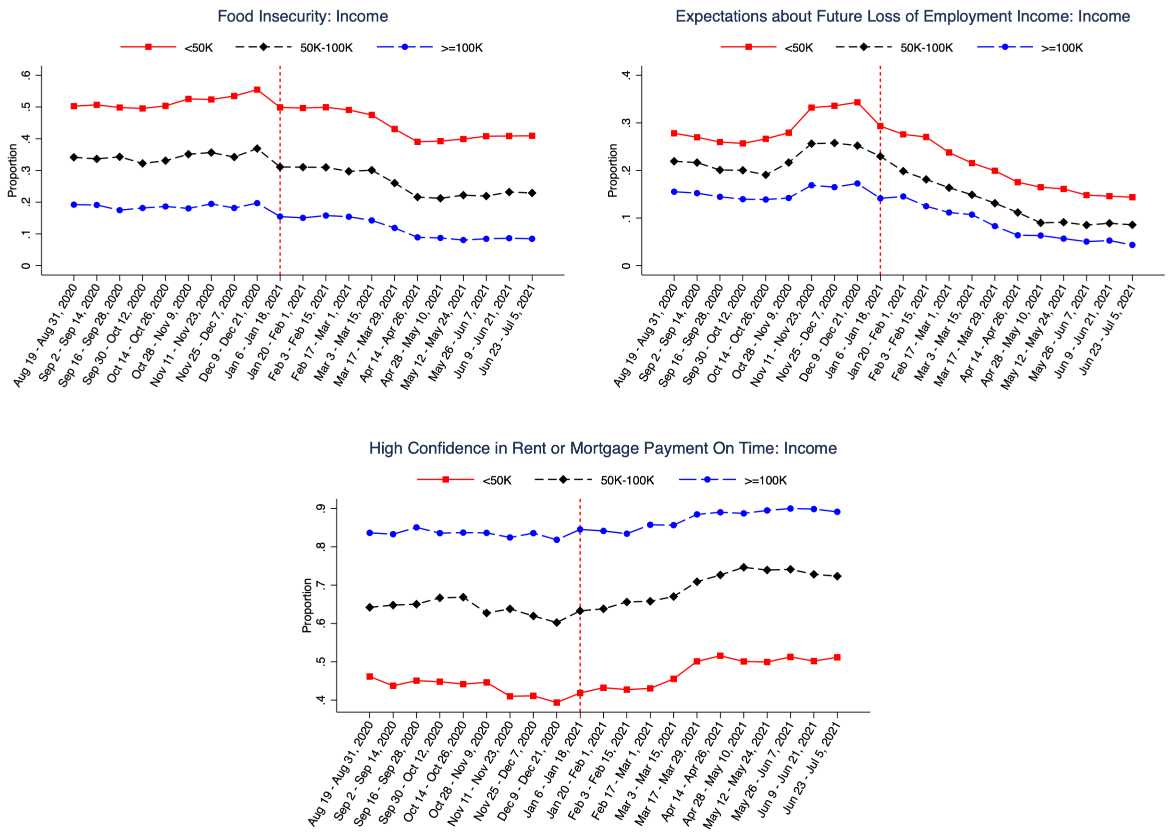
Wolfson, Julia A, Travertine Garcia, and Cindy W Leung. 2021. "Food insecurity is associated with depression, anxiety, and stress: evidence from the early days of the COVID-19 pandemic in the United States." *Health Equity* 5 (1):64–71.

Wolfson, Julia A and Cindy W Leung. 2020. "Food insecurity during COVID-19: an acute crisis with long-term health implications." *American Journal of Public Health* 110 (12):1763–1765.

Appendix: For Online Publication

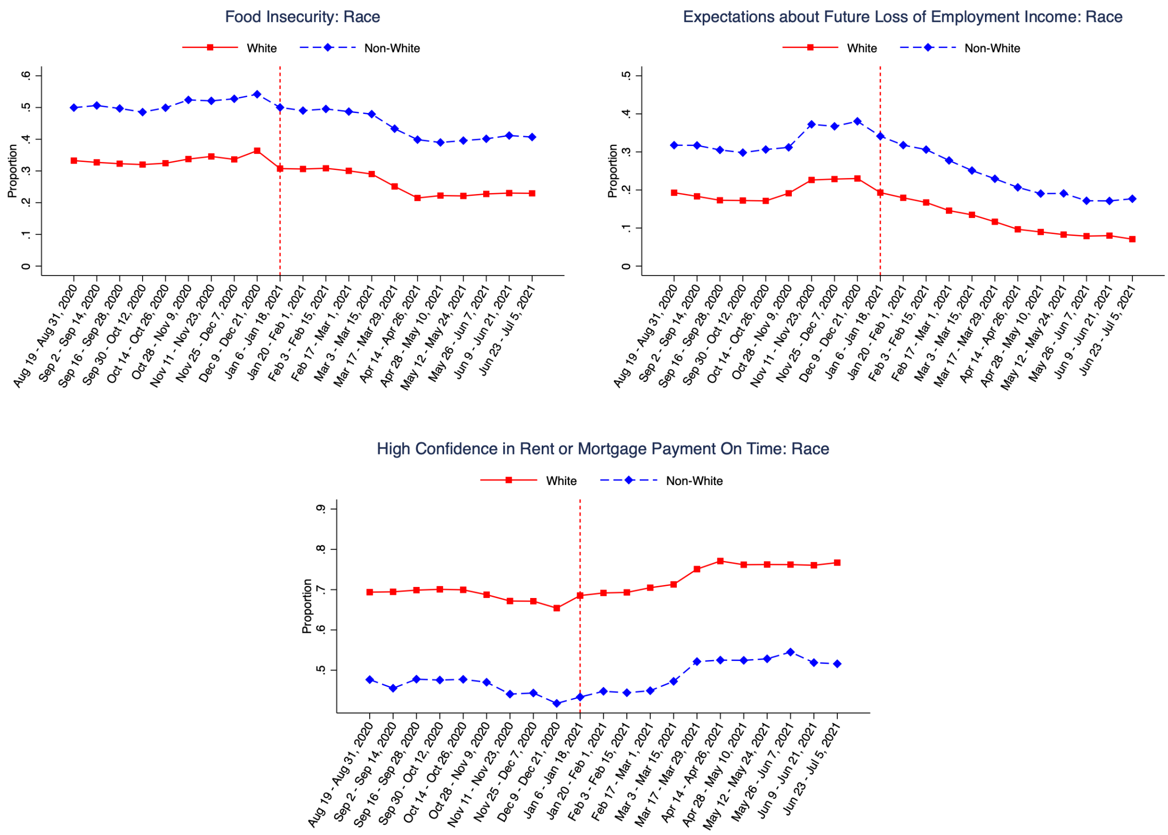
A. Additional Figures and Tables

Figure A.1. Descriptive Evidence by Income



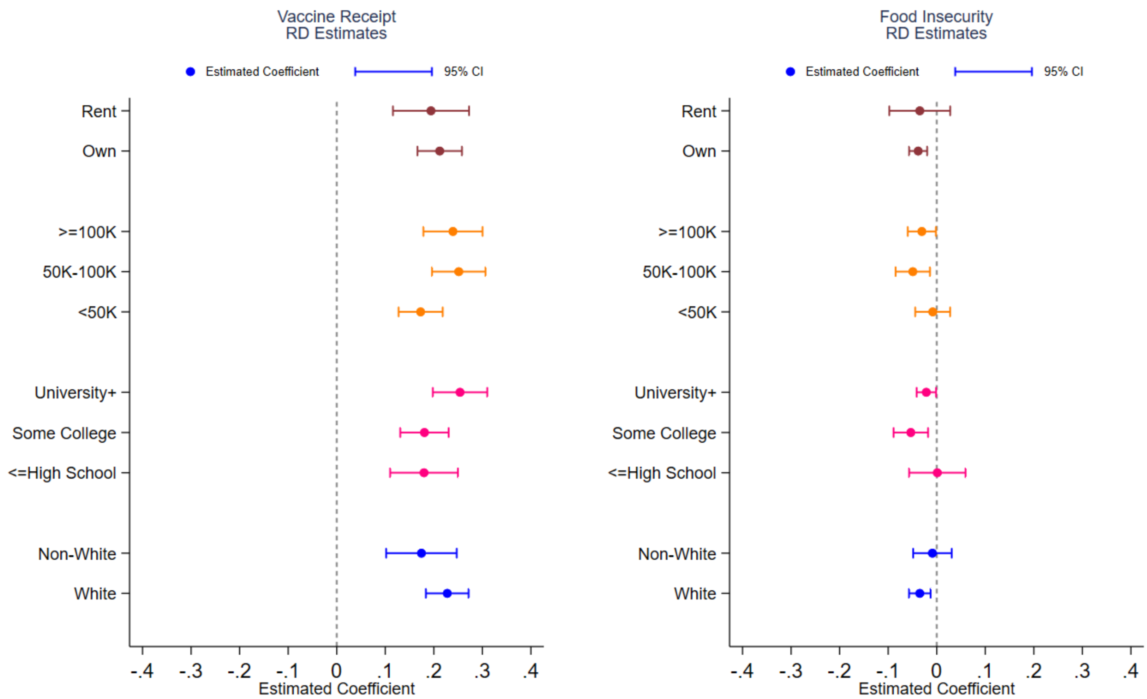
Notes: Each observation represents the weighted average of the corresponding outcome by income within each wave from August 19, 2020 (wave 13) through July 5, 2021 (wave 33). The red vertical line indicates the introduction of the COVID-19 vaccine in the United States.
Data Source: Household Pulse Survey, U.S. Census Bureau.

Figure A.2. Descriptive Evidence by Race



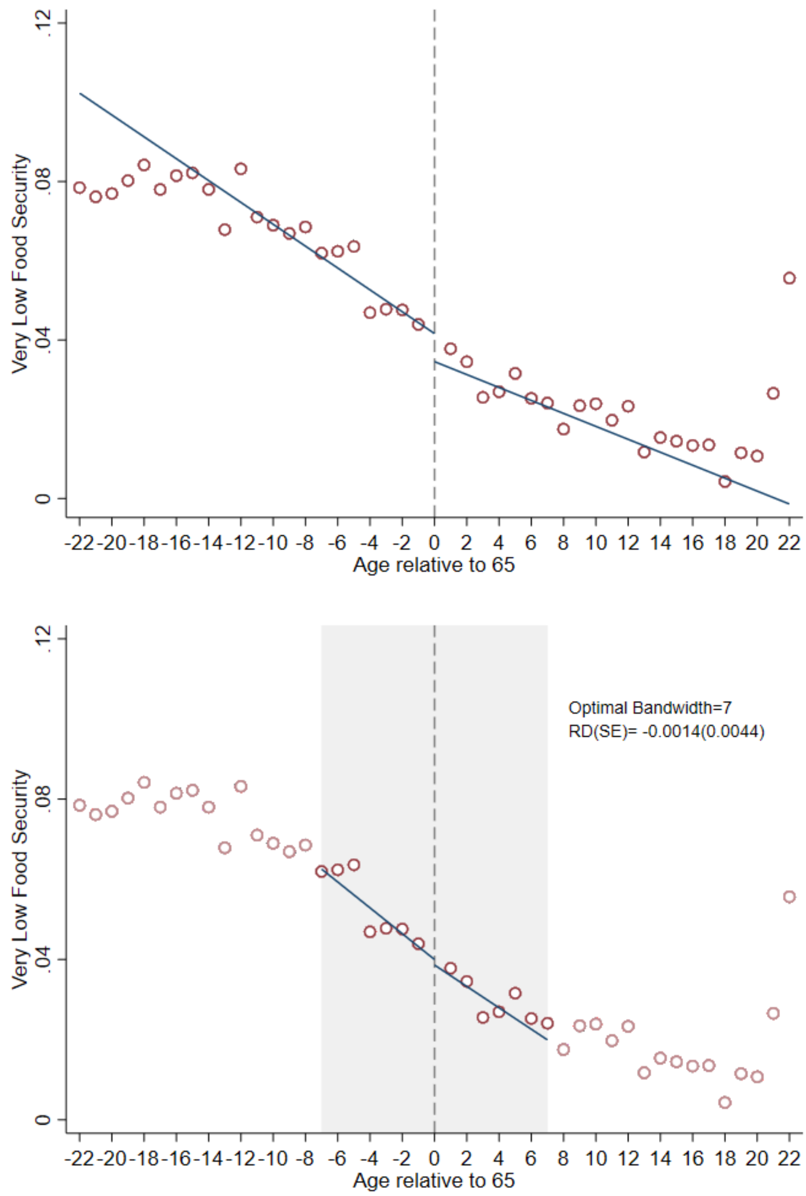
Notes: Each observation represents the weighted average of the corresponding outcome by race within each wave from August 19, 2020 (wave 13) through July 5, 2021 (wave 33). The red vertical line indicates the introduction of the COVID-19 vaccine in the United States.
Data Source: Household Pulse Survey, U.S. Census Bureau.

Figure A.3. Exploring Heterogeneity in the RD design



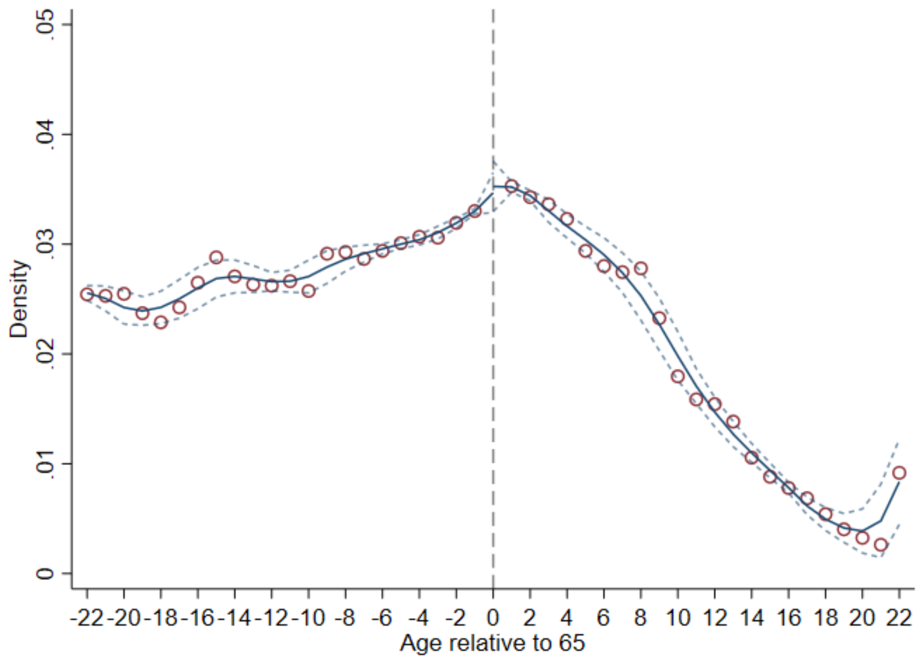
Notes: The working sample includes observations from 28 states with different time windows between January 6, 2021 (wave 22) and April 26, 2021 (wave 28). The figure displays the linear RD estimates for each subsample, along with 95% confidence intervals. All specifications control for remaining individual characteristics, state fixed effects and survey wave fixed effects. Bandwidth and the kernel mirror those in Figure 4.

Figure A.4. Effects of Vaccine Eligibility on Very Low Food Security



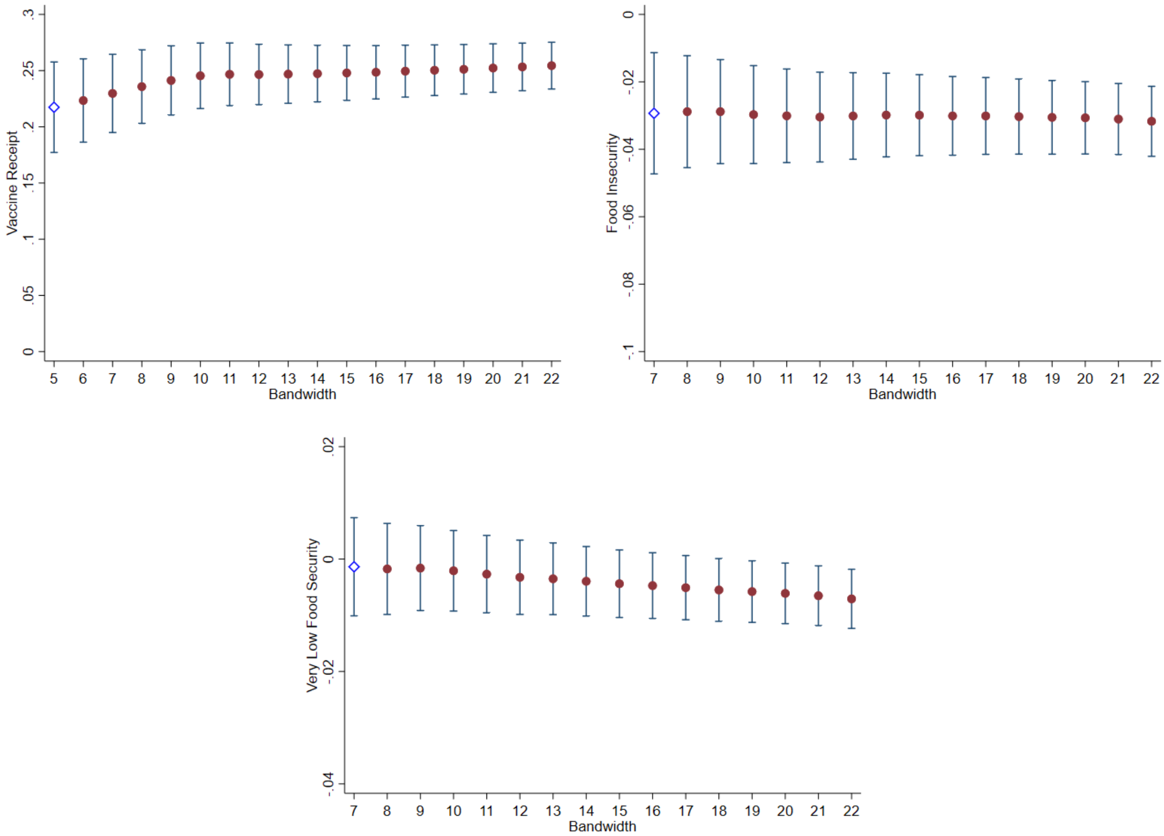
Notes: The top panel depicts the discontinuity using the full eligible sample above the cutoff. The bottom panel reports the linear RD estimates using the optimal bandwidth (shaded in gray). Pre-vaccination mean of the outcome within the optimal bandwidth is 0.043. All regressions use a triangular kernel function for weighting. Standard errors in parentheses are clustered at the age cohort-state level. Control variables mirror those in Figure 4. Dashed vertical lines denote the eligibility cutoff, which is normalized to zero.

Figure A.5. Testing for Discontinuity in the Density of Age



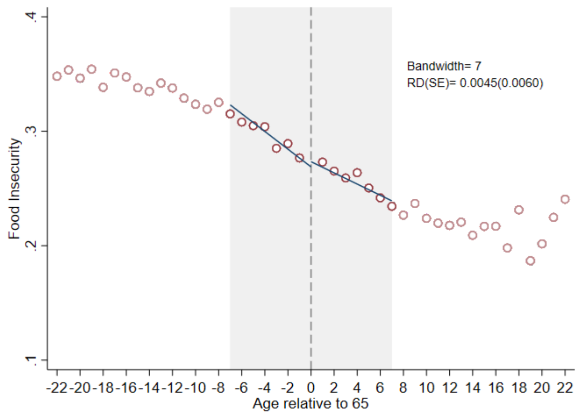
Notes: This figure provides a visual test for potential manipulation in the running variable. The dashed vertical line denotes the eligibility cutoff, which is normalized to zero. Following McCrary (2008), we estimate separate local quadratic regressions on either side of the cutoff, and compute the log difference of the coefficients on the intercepts, with an approximate standard error, to test for the null hypothesis of no manipulation. The log difference in height equals 0.033, and the standard error is 1.059.

Figure A.6. Robustness to Alternative Bandwidths

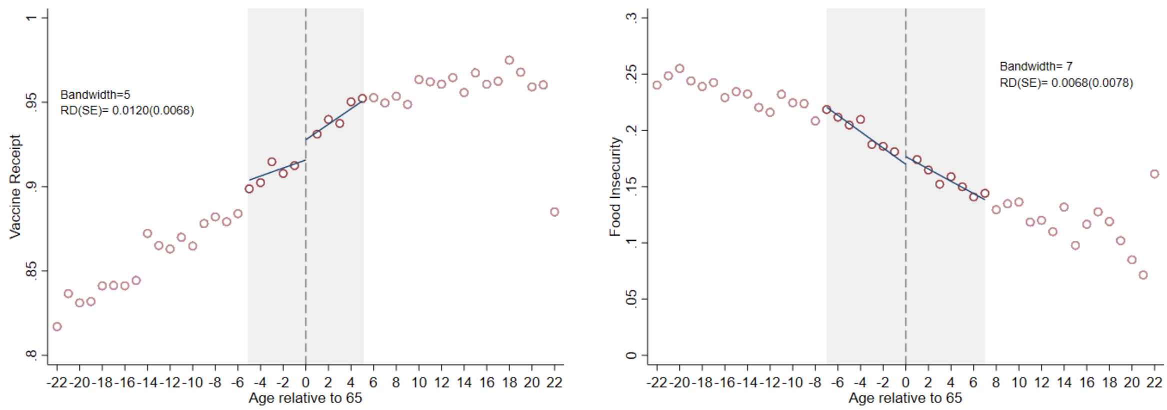


Notes: These figures report a set of linear RD estimates for each outcome, along with 95% confidence intervals, using various bandwidths. The hollow diamond markers report our benchmark RD estimates using the MSE-optimal bandwidth. All regressions use a triangular kernel function for weighting. Standard errors are clustered at the age cohort-state level. Control variables mirror those in Figure 4.

Figure A.7. Assessing the Continuity Assumption Using Placebo Samples



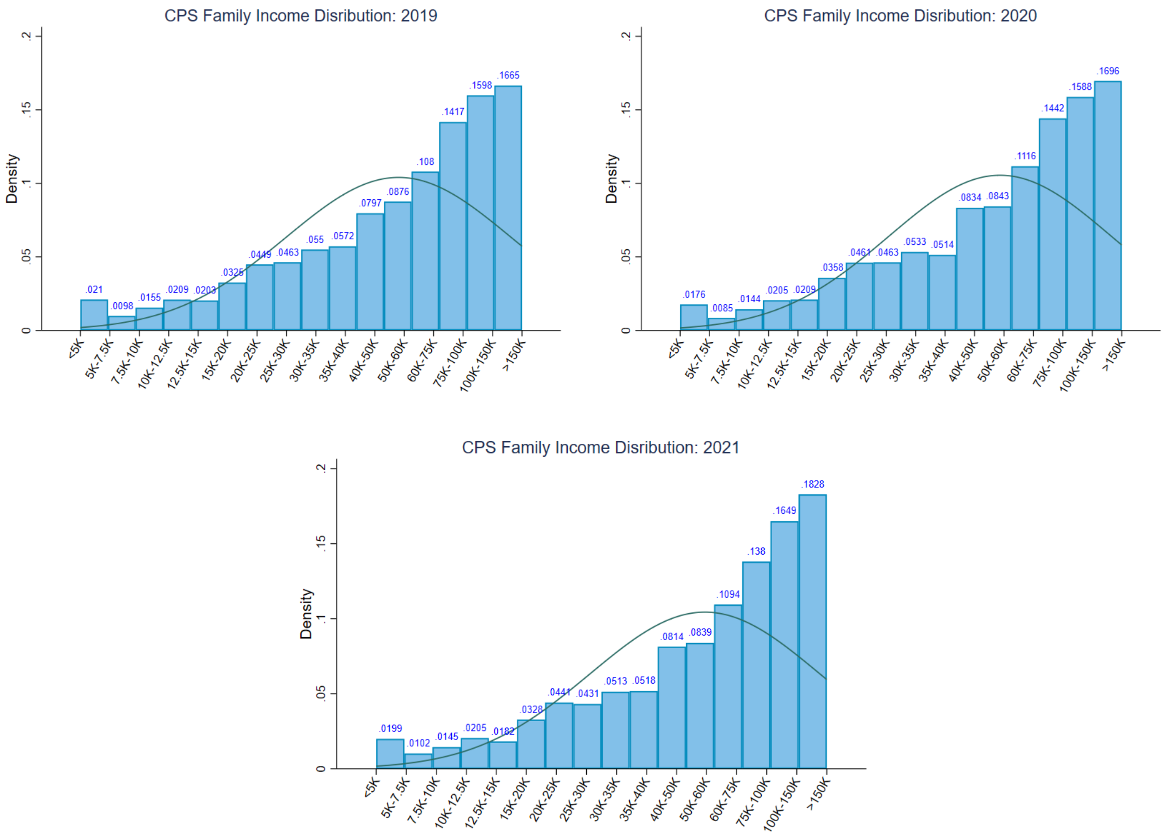
(a) Waves 13-21, Ineligible Sample Around the Cutoff



(b) Waves 30-33, Eligible Sample Around the Cutoff

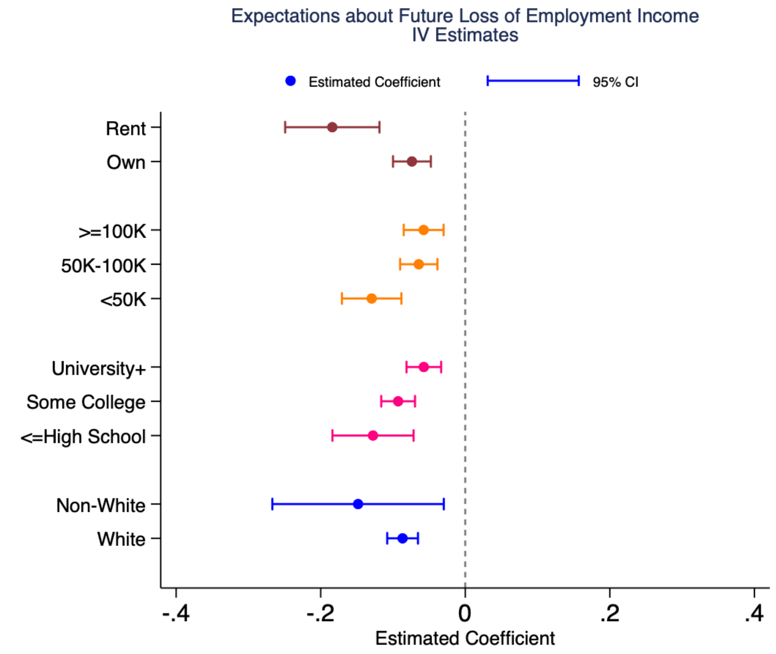
Notes: These figures report the placebo RD estimates using either fully ineligible or fully eligible samples. In Panel (a), individuals are not eligible for vaccines in waves 13-21. For this case, we cannot report first stage estimates since vaccination status is only available after wave 21. In Panel (b), individuals on both sides of the cutoff are eligible for vaccines in waves 30-33. All regressions use a triangular kernel function for weighting. Standard errors are clustered at the age cohort-state level. Control variables and the bandwidth mirror those in Figure 4.

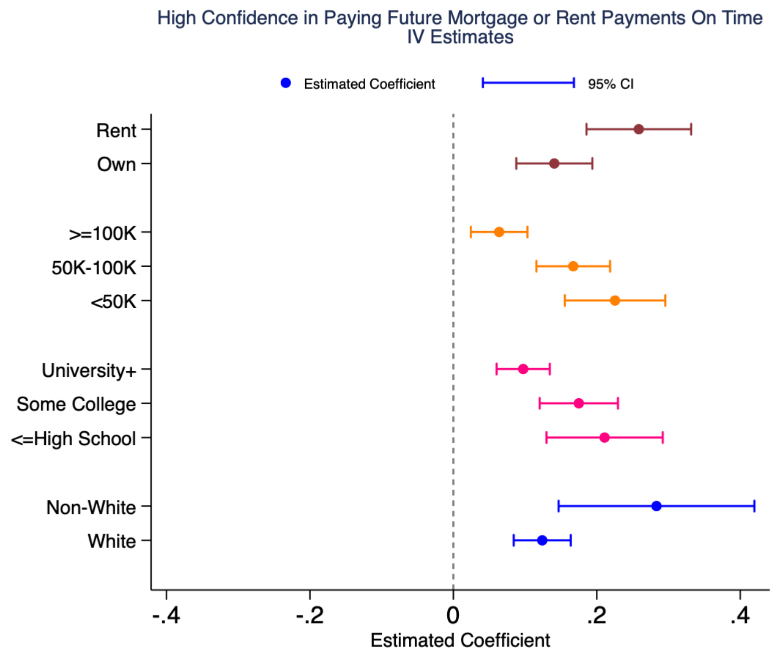
Figure A.8. Changes in Family Income Distribution, 2019-2021



Notes: These figures show the distribution of household income for years 2019 through 2021, respectively. For each distribution, we impose a normal density curve, and use CPS-FSS sampling weights. The number on top of each bin represents the density.
Data Source: Current Population Survey Food Security Supplement (CPS-FSS), U.S. Census Bureau.

Figure A.9. Financial Optimism by Sociodemographic Attributes





Notes: The working sample includes observations from August 19, 2020 (wave 13) through July 5, 2021 (wave 33). The figure displays separate IV estimates for each subsample, along with 95% confidence intervals. All specifications control for remaining individual characteristics, state fixed effects, survey wave fixed effects, and state-by-wave fixed effects. All regressions are weighted using household weights from the HPS, and standard errors are clustered at the state level.

Table A.1. Summary Statistics for Pre-Determined Attributes

	Pre-Vaccination Waves (Waves 13-21)			Post-Vaccination Waves (Waves 22-33)		
	Mean	SD	Obs.	Mean	SD	Obs.
Age	49.471	16.704	692,603	49.926	16.756	772,101
Male	0.472	0.499	692,603	0.473	0.499	772,101
Married	0.533	0.499	692,603	0.535	0.499	772,101
Race/Ethnicity						
White	0.672	0.469	692,603	0.671	0.470	772,101
Black	0.112	0.316	692,603	0.113	0.316	772,101
Asian	0.043	0.204	692,603	0.046	0.209	772,101
Hispanic	0.136	0.343	692,603	0.136	0.343	772,101
Other Races	0.036	0.187	692,603	0.034	0.181	772,101
Educational Attainment						
≤High School	0.365	0.481	692,603	0.357	0.479	772,101
Some College	0.297	0.457	692,603	0.298	0.458	772,101
≥University	0.338	0.473	692,603	0.345	0.475	772,101
Prior Household Income						
<50K	0.330	0.470	692,603	0.327	0.469	772,101
50K-100K	0.261	0.439	692,603	0.254	0.435	772,101
≥100K	0.239	0.426	692,603	0.235	0.424	772,101
Missing Income	0.170	0.376	692,603	0.184	0.388	772,101
Health Insurance Coverage						
Not Insured	0.073	0.261	692,603	0.066	0.249	772,101
Private	0.430	0.495	692,603	0.441	0.497	772,101
Medicare	0.170	0.376	692,603	0.165	0.372	772,101
Medicaid	0.113	0.317	692,603	0.116	0.320	772,101
Other	0.121	0.326	692,603	0.113	0.317	772,101
Missing Insurance	0.092	0.289	692,603	0.098	0.297	772,101
Presence of Children (Age < 18)	0.355	0.479	692,603	0.349	0.477	772,101
Household Size						
1	0.178	0.382	692,603	0.173	0.378	772,101
2	0.369	0.483	692,603	0.372	0.483	772,101
3	0.175	0.380	692,603	0.176	0.381	772,101
4	0.150	0.358	692,603	0.152	0.359	772,101
5	0.074	0.261	692,603	0.073	0.260	772,101
6+	0.055	0.227	692,603	0.054	0.225	772,101

Notes: The means are weighted using household weights from the HPS.

Table A.2. Progressively Including Pre-Determined Attributes in the First Stage

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Vaccine Eligibility	0.2383***	0.2381***	0.2396***	0.2390***	0.2387***	0.2403***	0.2390***	0.2389***	0.2380***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.011)	(0.011)	(0.012)	(0.012)
N	1,464,704	1,464,704	1,464,704	1,464,704	1,464,704	1,464,704	1,464,704	1,464,704	1,464,704
State FE	√	√	√	√	√	√	√	√	√
Survey Wave FE	√	√	√	√	√	√	√	√	√
Pre-Determined Attributes									
Age	√	√	√	√	√	√	√	√	√
Male		√	√	√	√	√	√	√	√
Married			√	√	√	√	√	√	√
Education				√	√	√	√	√	√
Race/Ethnicity					√	√	√	√	√
Prior Household Income						√	√	√	√
Presence of Children							√	√	√
Household Size								√	√
Health Insurance									√

Notes: The working sample includes observations from August 19, 2020 (wave 13) through July 5, 2021 (wave 33). All regressions are weighted using household weights from the HPS, and standard errors are clustered at the state level. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table A.3. Vaccination and Food Insecurity (Excluding Prior Vaccination)

	(1)	(2)	(3)	(4)	(5)
			OLS		
Vaccination	-0.0558***	-0.0556***	-0.0556***	-0.0557***	-0.0553***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Pre-Vaccination Mean	0.392	0.392	0.392	0.392	0.392
Effect as a Percent of Mean	-14.23%	-14.18%	-14.18%	-14.21%	-14.11%
			TSLS		
Vaccination	-0.0663***	-0.0658***	-0.0659***	-0.0668***	-0.0669***
	(0.007)	(0.006)	(0.006)	(0.007)	(0.007)
Pre-Vaccination Mean	0.392	0.392	0.392	0.392	0.392
Effect as a Percent of Mean	-16.91%	-16.79%	-16.81%	-17.04%	-17.07%
N	1,384,200	1,384,200	1,384,200	1,384,200	1,384,200
State FE	√	√	√	√	√
Survey Wave FE	√	√	√	√	√
Region × Wave FE		√	√		
State time-varying measures			√	√	
State-specific linear trends				√	
State × Wave FE					√

Notes: The working sample includes observations from August 19, 2020 (wave 13) through July 5, 2021 (wave 33). All specifications control for individual characteristics, including age, gender, marital status, race, educational attainment, household income, health insurance coverage, the presence of children, and household size. State time-varying measures include two-week lagged COVID-19 death rate and stringency index, one-month lagged unemployment rate, and two-week lagged friend-exposure to vaccination information. Pre-vaccination mean is the weighted sample mean of the outcome between waves 13 and 21. All regressions are weighted using household weights from the HPS, and standard errors are clustered at the state level. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table A.4. Vaccination and Very Low Food Security

	(1)	(2)	(3)	(4)	(5)
			OLS		
Vaccination	-0.0292***	-0.0293***	-0.0293***	-0.0293***	-0.0293***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Pre-Vaccination Mean	0.108	0.108	0.108	0.108	0.108
Effect as a Percent of Mean	-27.04%	-27.13%	-27.13%	-27.13%	-27.13%
			TSLS		
Vaccination	-0.0647***	-0.0641***	-0.0644***	-0.0637***	-0.0625***
	(0.007)	(0.008)	(0.008)	(0.007)	(0.008)
Pre-Vaccination Mean	0.108	0.108	0.108	0.108	0.108
Effect as a Percent of Mean	-59.91%	-59.35%	-59.63%	-58.98%	-57.87%
N	1,464,704	1,464,704	1,464,704	1,464,704	1,464,704
State FE	✓	✓	✓	✓	✓
Survey Wave FE	✓	✓	✓	✓	✓
Region × Wave FE		✓	✓		
State time-varying measures			✓	✓	
State-specific linear trends				✓	
State × Wave FE					✓

Notes: The working sample includes observations from August 19, 2020 (wave 13) through July 5, 2021 (wave 33). See Section 3.1 for the definition of *very low* food insecurity. All specifications control for individual characteristics, including age, gender, marital status, race, educational attainment, household income, health insurance coverage, the presence of children, and household size. State time-varying measures include two-week lagged COVID-19 death rate and stringency index, one-month lagged unemployment rate, and two-week lagged friend-exposure to vaccination information. Pre-vaccination mean is the weighted sample mean of the outcome between waves 13 and 21. All regressions are weighted using household weights from the HPS, and standard errors are clustered at the state level. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table A.5. Vaccine Eligibility and Food Insecurity

	(1)	(2)	(3)	(4)	(5)
Vaccine Eligibility	-0.0226***	-0.0230***	-0.0231***	-0.0232***	-0.0251***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Pre-Vaccination Mean	0.392	0.392	0.392	0.392	0.392
Effect as a Percent of Mean	-5.77%	-5.87%	-5.89%	-5.92%	-6.40%
N	1,464,704	1,464,704	1,464,704	1,464,704	1,464,704
State FE	√	√	√	√	√
Survey Wave FE	√	√	√	√	√
Region × Wave FE		√	√		
State time-varying measures			√	√	
State-specific linear trends				√	
State × Wave FE					√

Notes: This table reports the reduced form effects of vaccine eligibility on food insecurity. The working sample includes observations from August 19, 2020 (wave 13) through July 5, 2021 (wave 33). All specifications control for individual characteristics, including age, gender, marital status, race, educational attainment, household income, health insurance coverage, the presence of children, and household size. State time-varying measures include two-week lagged COVID-19 death rate and stringency index, one-month lagged unemployment rate, and two-week lagged friend-exposure to vaccination information. Pre-vaccination mean is the weighted sample mean of the outcome between waves 13 and 21. All regressions are weighted using household weights from the HPS, and standard errors are clustered at the state level. Significance levels: levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table A.6. Covariate Smoothness Around the Cutoff

	Male	Married	White	Black	Hispanic	Non-White	≤ High School
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Vaccine Eligibility	0.0061	-0.0031	0.0082	0.0091	-0.0007	-0.0082	-0.0019
	(0.012)	(0.011)	(0.008)	(0.006)	(0.006)	(0.008)	(0.008)
N	32,634	32,634	32,634	32,634	32,634	32,634	32,634
	Some College	University +	< 50K	50K-100K	≥ 100K	< 50K, Missing†	Own a House
	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Vaccine Eligibility	-0.0148	0.0167	0.0096	-0.0062	-0.0075	0.0138	0.0067
	(0.012)	(0.012)	(0.010)	(0.010)	(0.010)	(0.011)	(0.008)
N	32,634	32,634	32,634	32,634	32,634	32,634	29,810
Bandwidth	7	7	7	7	7	7	7
State FE	√	√	√	√	√	√	√
Survey Wave FE	√	√	√	√	√	√	√

Notes: Each column replaces the outcome variable with a pre-determined attribute and reports the linear RD estimate using the regression in Equation 3. Our objective is to assess the smoothness of these attributes near the cutoff. †In addition to column (10), the indicator variable for income <50K in column (13) includes missing values. All specifications only control for state and survey wave fixed effects. We use the largest optimal bandwidth in Figure 4. All regressions use a triangular kernel function for weighting. Standard errors are clustered at the age cohort-state level. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table A.7. Difference-in-Discontinuities: Primary Waves vs. Placebo Waves

	Vaccine Receipt	Food Insecurity
	(1)	(2)
Panel A: Reference Placebo Waves 13-21, Ineligible Sample Around the Cutoff		
Treated (Age $>$ 65) $\times$ Primary Waves	–	-0.0337***
	–	(0.012)
Pre-Vaccination Mean†	–	0.279
Effect as a Percent of Mean	–	-12.08%
Bandwidth	–	7
N	–	129,888
Panel B: Reference Placebo Waves 30-33, Eligible Sample Around the Cutoff		
Treated (Age $>$ 65) $\times$ Primary Waves	0.2054***	-0.0363***
	(0.021)	(0.013)
Pre-Vaccination Mean†	–	0.279
Effect as a Percent of Mean	–	-13.01%
Bandwidth	5	7
N	49,419	71,617

Notes: This table reports the difference in linear RD estimates between the primary and placebo samples, which is coined as difference-in-discontinuities. The primary sample refers to the benchmark RD sample between waves 22 and 28. The placebo samples in Panels A and B include waves 13-21 and 30-33, respectively. †Pre-vaccination mean is based on the primary sample of 28 states and age groups within the bandwidth. All regressions use a triangular kernel function for weighting. Standard errors are clustered at the age cohort-state level. Control variables and the bandwidth mirror those in Figure 4. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table A.8. Reliance on Food Assistance by Family Income and Educational Attainment

	< 50K	50K-100K	≥ 100K	≤ High School	Some College	University +
	(1)	(2)	(3)	(4)	(5)	(6)
Vaccine Eligibility	-0.0186**	-0.0006	-0.0009	-0.0193***	-0.0144***	-0.0036*
	(0.008)	(0.002)	(0.001)	(0.007)	(0.004)	(0.002)
Pre-Vaccination Mean	0.148	0.024	0.005	0.114	0.064	0.016
Effect as a Percent of Mean	-12.57%	-2.50%	-18.00%	-16.93%	-22.50%	-22.50%
N	224,598	199,894	195,535	219,907	168,858	231,262
State FE	✓	✓	✓	✓	✓	✓
Survey Month FE	✓	✓	✓	✓	✓	✓
State time-varying measures	✓	✓	✓	✓	✓	✓
State × Month FE	✓	✓	✓	✓	✓	✓

Notes: This table reports the heterogeneous effects of vaccine eligibility on food stamp take-up using data from the CPS-FSS. The working sample uses observations from August 2020 through June 2021. Each column is a separate regression stratified by either family income (<50K, 50K-100K, and ≥100K) or education attainment (≤ high school, some college, and university +). All specifications control for remaining individual characteristics, including age, gender, marital status, education attainment, race, household income, the number of children, and household size. State time-varying measures include one-month lagged COVID-19 death rate and stringency index, as well as the unemployment rate. All regressions are weighted using the supplement person weight, and standard errors are clustered at the state level. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.