Structural Food Security Dynamics in the United States

Siwen Zhou; Joshua Berning

Abstract

This paper seeks to explore the long-term structural nature of FS dynamics through household financial asset holdings in United States. We use a 19-year panel dataset from the Panel Study of Income Dynamics (2001-2019) to estimate the Structural Probability of Food Security (SPFS) measure. This metric is estimated by the likelihood that a household's assets will meet or exceed a basic adequacy threshold for at least three months. The SPFS metric enables a nuanced distinction between structural and stochastic dynamics in FS over a long period. Our findings indicate a prevalent stability of FS among U.S. households but highlight that 84% of those facing FI do so due to structural inadequacies in financial asset holdings, rather than due to unpredictable stochastic events. Notably, households headed by non-white females without a high school diploma suffer most and are caught in structural FI with a pronounced and persistent risk of severe FI.

Key words: Dynamics, Food security, Assets, Well-being

JEL codes: Q18, C61, I3, D14

1. Introduction

Food insecurity (FI) persists as a significant challenge in the United States, affecting approximately one in every ten households annually since 1995, as reported by the United States Department of Agriculture (USDA). Recognized as a critical issue for many American households (Coleman-Jensen, Rabbitt, Gregory & Singh, 2018), FI, is associated with adverse economic, health, and social outcomes that subsequently impact household incomes, dietary behaviors, and future FS status (Ziliak & Gundersen, 2016). In 2022, the prevalence of FI in the United States reached 12.8% with 5.1% of households experiencing very low food security (FS), both representing statistically significant increases from the 2021 rates of 10.2% and 3.8%, respectively (Rabbitt, Hales, Burke & Coleman-Jensen, 2023). While these alarmingly high prevalence estimates of household FS from the USDA Household FS Survey Measure (HFSSM)[1] capture only a momentary and static timepoint, FS is likely a dynamic condition. Households may persist in their current state or transition in and out of FS as their circumstances evolve (Grineski, Morales, Collins, & Rubio, 2018). A nuanced understanding of the dynamics of FS, particularly transitions triggered by adverse shocks, duration of insecurity, persistence, and vulnerability of specific subpopulations, is crucial for designing and evaluating effective policy interventions. In this study, we develop a method to examine the structural dynamics of FS through household financial assets for the long term.

[1] This official estimate is calculated from the affirmed number of self-reported responses to 18 questions per household (10 questions for households without children) that characterize households when they have difficulty meeting basic food needs, as shown in Coleman-Jensen, Rabbitt, Gregory, and Singh (2018), developed by the USDA. Household FS status is assessed by counting affirmative responses to specific questions and standardizing these counts into 29 discrete scalar values ranging from 0.0 to 9.3 using a Rasch model. These values, or Rasch scores, are categorized into three levels—food secure, low FS, and very low FS—to facilitate comparisons between households with and without children.

Little attention has been devoted to the dynamics of FS at the household level in the United States, primarily due to the challenges of gathering long-term, reliable data. Specifically, it arises from the short duration of surveys tracking the same household and the discrete, ordinal nature of FS measure (Lee et al., 2023). Since 1995, the USDA's Household FS Survey Module (HFSSM) has been the key tool for evaluating FS, primarily in the annual December FS Supplement of the Current Population Survey (CPS-FSS), along with other longitudinal surveys such as the Panel Study of Income Dynamics (PSID), the Survey of Program Dynamics (SPD) and the Early Childhood Longitudinal Survey (ECLS). However, these surveys provide at most five observations per household, which substantially limits the analysis of long-term dynamics. The CPS-FSS data tracks the FS status of households only twice at most over 16 months. The PSID followed household FS across six intervals (1999, 2001, 2003, 2015, 2017, 2019), but a notable break was from 2003 to 2015. The SPD provides only early information on FS status from the HSFM from 1998 through 2002, rendering the dataset insufficient for assessing recent trends. The ECLS, which collected data during 1999-2007 and 2010-2016 periods, lacks comprehensive coverage of the HFSSM and is not nationally representative, focusing only on households with young children. Because of the limitations of these data, the following existing studies vary in the number of consecutive periods a household is food insecure, which is considered as experiencing persistent FI.

The existing literature on FS dynamics offers diverse estimates using these short-pan HFSSM datasets. Prevalent cohort studies examining temporal patterns suggest that persistent FI is not widespread, occurring in a small sample of households, and typically manifests as episodic or transient phenomena. Specifically, Ryu and Bartfeld (2012) analyzed a longitudinal dataset of children from kindergarten through 8th grade, discovering that only 1% of the sample experienced

FI for four consecutive years and 3% for three consecutive years. Similarly, Wilde, Nord, and Zager (2010), utilizing data from the 1998-2001 Survey of Program Dynamics panel, observed that a mere 1% of the U.S. population suffered from persistent FI across four or five consecutive years. In a study of two waves of the SPD (1997 and 1999), Hofferth (2004) reported that approximately 5% of households with children younger than 13 experienced persistent FI over this two-year interval. However, the prevalence of persistent FI is significantly higher among at-risk populations. Jansen et al. (2017) in a study involving a cohort of Head Start preschoolers in Michigan between 2011 and 2015, found that 54% of participants demonstrated persistent FI across two consecutive years, while 36% experienced it only once during the study period. Liese et al. (2021), examining two economically disadvantaged communities in South Carolina from 2013 to 2016, found that 37% of sampled households faced persistent FI over three years. Despite a broader understanding of the dynamics of FS, analyses based on datasets containing fewer than five observations per household may be confounded by measurement errors and transient shocks due to the dataset's short span (Dercon, Shapiro, et al., 2007; Duffy & Zizza, 2016; Naschold & Barrett, 2011).

Additionally, analyses on the transition and persistence of FS dynamics using discrete categorical statuses from HSFM measures may not accurately capture the true dynamics and within-category variation in the severity of FI experienced by households. The broad categories of official and standardized FS status are invariant concerning the specific manifestations of food access. For example, in the cross-section dataset, households that affirm any questions but with the same number are classified as having the same status of FS by the HFSSM measure, despite the fact they may have potentially diverse and severe experiences of FI. Similarly, the FS status for a household that affirms the same number of questions across two consecutive years will be

the same over time, even if some conditions related to food access worsen during that period. So, this categorical measure estimated by the official HFSSM results in limited insights into the cross-sectional, and perhaps especially intertemporal, variation in the severity of FI for the study of household FS dynamics (Bickel et al., 2000; Lee et al., 2023).

To overcome the limitations of existing data and measures, a recent study of FS dynamics by Lee et al. (2023) introduced a continuous measure of household FS based on food expenditures. This method, which examines the severity of FS dynamics in US households from 2001 to 2017, distinguishes between chronic and transient FI. Moving away from the categorical HFSSM data, this truly continuous measure relaxes the previously required strong assumptions necessitated by that categorical measure. It enables a more nuanced analysis of FS dynamics. Using 17 years of Panel Study of Income Dynamics (PSID) data (2001-2017), they found that while roughly two-thirds of households never experience FI, more than half of food-insecure households face chronic FI, not transient, meaning they're expected to be food insecure at every survey period. Even though they distinguish the chronic and transient components in the severity of the FI households experience, the new food expenditure-based measures still fail to distinguish between short-term, stochastic transitions—often driven by luck or unluck—and structural changes, which involve substantial shifts in asset accumulation or loss. So, we must provide a deeper nuanced view of FS dynamics by distinguishing the structural from stochastic FS dynamics.

Drawing on foundational poverty literature (Carter & Barrett, 2006; Carter & May, 2001), this study uses household asset holdings to examine FS dynamics comprehensively. While income and food expenditure are well-documented determinants of FS (Loopstra & Tarasuk, 2013), assets provide a buffer against income shocks and unforeseen expenses, thereby ensuring stable consumption and long-term well-being (Carter & Barrett, 2006; Nam, Ratcliffe, & McKernan,

2008; Pirog, Gerrish, & Bullinger, 2017). Additionally, accessible household financial assets are strong FS indicators (Chang, Chatterjee, & Kim, 2014; Guo, 2011). As Carter and Barrett (2006) put it, the asset-based FS measure will help identify the distinct sorts of experiences in the severity of FI. For instance, transitions from FS to FI may vary widely. For some households with minimal assets, transitioning to FI may merely signify a return to a typical standard of living following a temporary improvement due to favorable circumstances like participating in a food assistance program. For others, this change might result from stochastic events like unexpected setbacks in subsequent survey periods. Additionally, certain households experience a structural decline into FI due to significant asset loss from health issues or worsening economic conditions, such as the Great Recession. Extending the analysis by Lee et al. (2023), our study dissects both stochastic and structural components of FS dynamics, thereby enhancing our understanding of the variations in the severity of FI that households experience.

This study aims to investigate the longer-run, structural nature of household FS dynamics in the United States. For this long-run analysis, we use the Panel Study of Income Dynamics (PSID) from 2001 to 2019, a nationally representative sample of approximately 21,660 survey responses from 2,166 households surveyed every two years over 19 years. This dataset is unique in its collection of detailed wealth data and the USDA's core FS module, which together enables an analysis of long-term FS trends not possible with other datasets. With this leading nationally representative panel dataset, our study makes two contributions to the literature on FS dynamics.

First, we utilize PSID data to develop a new continuous measure of asset-based household FS for long-term study. This measure, termed the Structural (asset-based) Probability of Food Security (SPFS or asset-based PFS), estimates the likelihood that a household's observed financial

asset holdings meet or exceed a threshold defined as 25% of the US Census Bureau's poverty line[2]. This asset threshold is a widely acknowledged criterion that covers basic necessities for three months (Haveman & Wolff, 2004). To estimate the SPFS, we adopt the econometric method outlined by Cissè and Barrett (2018), which has been utilized in various studies to examine FI across low-, middle-, and high-income countries (Knippenberg, Jensen, & Constas, 2019; Lee et al., 2023; Upton, Cissè, & Barrett, 2016; Vaitla et al., 2020). Specifically, the SPFS is estimated using a conditional moments-based framework, where the conditional density of household assets is computed. Then we estimate the inverse cumulative density function for assets exceeding the minimal adequate threshold for each household and survey period and obtain the estimated household-year-specific SPFS.

Our SPFS measure is calibrated to align with the USDA Economic Research Service's (ERS) official HFSSM prevalence estimates, potentially as a complementary measure. The SPFS, derived from household financial asset holdings as a more targeted measure of liquidity constraints, correlates strongly with FS (Brewer, 2020; Chang et al., 2014; Grafova, 2011; Guo, 2011) but may not fully capture household FS resilience. Acknowledging this limitation, the construction of the SPFS incorporates responses based on financial assets and adjusts for home and vehicle ownership and household characteristics that are well-documented correlates of FS. As a result, the SPFS not only maintains a robust correlation with financial asset holdings but also reflects a meaningful relationship with household characteristics. Following Lee et al. (2023) methodology, we calibrate the SPFS to match the HFSSM-based FI prevalence estimates exactly. Comparative tests confirm that the SPFS is a viable alternative to the HFSSM, facilitating the exploration of structural FS dynamics that are not possible with the current measures and adaptable for longer panel studies.

[2] The relevance of the U.S. Census Bureau's poverty threshold to our study stems from its foundation in minimal food cost. Its calculation will be detailed in the data part.

The second and main contribution of the study is to apply our asset-based FS measure to examine long-run U.S. household FS dynamics by distinguishing structural from stochastic dynamics from 2001 to 2019. We use two approaches from the poverty literature: the first is a spells approach, which provides the intertemporal dynamics of FS. Specifically, we focus on the dynamics of household transitions into and out of FI over time, distinguishing between structural and stochastic transitions. Additionally, we examine the spell length of FI, defined as uninterrupted intervals during which households are classified as food insecure. The second approach is the permanent approach, differentiating structural and stochastic FI based on year, household-specific histories. In addition to national estimates, we assess FS dynamics across various subgroups. Furthermore, this study also examines predictors of structural FI.

Estimates from our SPFS measure demonstrate that the vast majority of U.S. households with adequate financial assets consistently avoid FI, consistent with previous studies (Hofferth, 2004; Ryu & Bartfeld, 2012; Wilde et al., 2010). Notably, we find structural FI, primarily resulting from insufficient asset holdings, accounts for most of the observed variations in the estimated FI. To be more specific, using a transition matrix from a spell-based approach for the periods from 2001 to 2019[3], we observe that 82.5% to 86.5% of the population maintain FS across consecutive survey waves. Conversely, 8.1% to 11.7% of households were persistently food insecure, and fewer than 5% transitioned into or out of FS annually with structural or stochastic mobility. Households that are both asset-poor and estimated food insecure—categorized as structurally food insecure—display significant immobility, with 65-71% remaining in FI. Furthermore, consistent with Lee et al. (2023), the duration of FI for a household correlate strongly with its difficulty in transitioning out of this state; longer spells are typically due to structural issues related to financial

[3] Year 2001 is the base year for 2003.

assets, whereas stochastic shocks often trigger shorter spells. Our long-term analysis using the mean intertemporal SPFS over 19 periods confirm that most of U.S. households (78.7%) have never experienced FI, and among those affected, 84% suffer from structural FI. In contrast, Lee (2023) reports that over half of all FI cases are chronic. This finding contrasts sharply with earlier cohort studies (Hernandez, Marshall, and Mineo 2014; Ryu and Bartfeld 2012; Wilde et al. 2010) which describe FI primarily as episodic or transient, attributing this characterization to the small fraction of households that experience persistent FI. Additionally, economic downturns exhibit a significant positive correlation with the duration and the persistence of FI in the United States.

FS dynamics, as measured by the SPFS, exhibit significant variation across household characteristics. Aligning with the findings of Lee et al. (2023), this study highlights that households headed by non-white females without a high school diploma are particularly vulnerable, facing a heightened, persistent, and structural risk of severe FI. Households led by the disabled, single parents, SNAP recipients, and those without homeownership or vehicle ownership are also notably prone to structural and persistent FI due to their increased likelihood of structural immobility and downward mobility. Shocks such as the discontinuation of SNAP benefits notably lead to a substantial increase in the likelihood of newly transitioning into FI. Meanwhile, the loss of vehicle ownership or the onset of a disability is more likely to correlate with persistent FI. Collectively, race, income, participation in food assistance programs, and asset ownership (including homes and vehicles) account for over 60% of the variance in FI, particularly affecting structural FI. Further analysis reveals that factors such as educational attainment, Child Meal program participation, and unemployment shocks are more strongly linked to structural FI than to FI overall. Moreover, geographic factors significantly influence FI patterns, subject to various short-run and long-run regional shocks. The findings of this study are consistent with those of Coleman-Jensen, Rabbitt,

Gregory and Singh (2017), demonstrating that households in the South and Midwest are disproportionately affected by persistent and structural challenges.

In the following sections of this chapter, we start by summarizing the existing literature on FS and household asset holdings in Section 2. Next, we explain the conceptual framework for measuring FI using assets, known as SPFS, which is based on poverty research, in Section 3. Section 4 details the use of the Panel Study of Income Dynamics (PSID) data to analyze FI dynamics in the U.S. Building on recent studies in development resilience (Cissè and Barrett, 2018), we apply this new method to calculate the SPFS using household panel survey data. Following this, we describe our approach to examine household dynamics in Section 5. The findings are presented in Section 6, and the study concludes with a discussion in Section 7.

1. Assets as Predictors of FS: A Literature Review

FI arises when households lack adequate access to food due to limited economic resources. Although household income is frequently employed as a proxy for consumption and significantly affects FS (Loopstra & Tarasuk, 2013), emerging research underscores the vital role of asset holdings. Assets bolster financial resilience against income fluctuations and unforeseen expenses, thus maintaining stable food consumption and promoting long-term well-being (Pirog et al., 2017). Consequently, household assets are essential for fostering self-sufficiency, securing food availability, and mitigating material deprivation (Beverly et al., 2008; Ribar & Hamrick, 2003).

Although the significance of assets in mitigating FI is well-recognized, comprehensive studies on this relationship are scarce. Historically, research shows a positive correlation between food expenditures and asset levels (Ogaki & Atkeson, 1997; Zimmerman & Carter, 2003). Investigations typically focus on tangible assets such as homeownership, vehicles, savings, and investment portfolios (Gundersen & Gruber, 2001; Guo, 2011; Ribar & Hamrick, 2003). Notably,

owning a home or vehicle is associated with reduced FI (De Marco & Thorburn, 2008; Fitzpatrick & Ver Ploeg, 2010; Furness, Simon, Wold, & Asarian-Anderson, 2004). Guo (2011) found that particularly for low-income families, assets—especially savings—serve as the most reliable indicators of FS. Moreover, Chang et al. (2014) illustrated that asset-rich but liquidity-poor households are more vulnerable to FI, despite stable incomes when other variables are controlled.

Household financial assets, especially liquid assets as a household's readily available financial resources are the most effective predictors of FS, outperforming traditional metrics such as total asset value or net worth, which often overlook the specific challenges faced by financially constrained households (Brewer, 2020; Guo, 2011; West & Price, 1976). While traditional measures assess overall wealth, they fail to capture the immediate financial vulnerabilities crucial for maintaining basic living standards, including FS (Grafova, 2011). Chang et al. (2014) further validates this by employing the Haveman and Wolff (2004) asset poverty framework, which highlights vulnerabilities that exacerbate FI. Moreover, research consistently shows that households with inadequate financial assets below the asset poverty line are more likely to suffer material hardship following income shocks (McKernan et al., 2020).

2. Conceptual Framework — Static Asset-Based FI

Drawing upon the theoretical foundations of asset-based poverty measures, as Carter & Barrett (2006) outlined, this section introduces a conceptual framework for assessing asset-based household FS through household financial asset holdings and elucidates FS dynamics by distinguishing structural from stochastic dynamics over two periods in Figure 1.

In Figure 1, the vertical axis is the structural probability of food security (PFS) estimated by household asset holdings. The threshold probability of classifying a household as food secure is denoted by $\underline{P}$, enabling the differentiation between FS (above $\underline{P}$) and FI (below $\underline{P}$). The

horizontal axis reflects accessible financial assets to households, correlating with the likelihood of FS. The ”asset FI line”, represented as $\underline{A}$, marks the minimum asset level required for a household to meet basic living standards and ensure FS. This threshold, in conjunction with the FI line $\underline{P}$ facilitates the distinction between structural and stochastic FI within a single period, as delineated by Carter & May (2001) and Carter & Barrett (2006). A household is deemed structurally food insecure (FI) if its asset holdings fall below $\underline{A}$ and its anticipated or estimated SPFS is also below $\underline{P}$ (for example, a household observed at point $\hat{P}(A')$ in Figure 1). Conversely, a household is considered to experience stochastic FI if its assets exceed the asset line $\underline{A}$ but the actual estimated SPFS unexpectedly drops blow $\underline{P}$ (illustrated by point B in Figure 1). Similarly, households can be categorized as structurally food secure (FS) ($\hat{P}(A'')$ in Figure 1) or stochastically FS (point C in Figure 1), depending on their asset holdings and the realized PFS.

Figure 1 also illustrates the decomposition of FI transitions into structural and stochastic events. Although the actual FI threshold $\underline{P}$ and asset FI line $\underline{A}$ may vary over time, for simplicity, we assume they are constant and static. The dashed curve, $\tilde{P}(A)$, represents the dynamic relationship between FI and asset levels, which may shift from $\hat{P}(A)$ over time due to factors like price fluctuations or technological advancements affecting productivity. For instance, a transition from FS to insecurity over two periods can occur through either structural or stochastic mechanisms. A transition for a household from point C to $\hat{P}(A')$ in Figure 1 exemplifies a stochastic transition back to its expected status if it crosses below the FI threshold ($\underline{P}$) with consistently low financial assets. Conversely, a structural transition is exemplified by a household moving from $\hat{P}(A'')$ to $\hat{P}(A')$, indicating a shift from FS to insecurity due to asset depletion. Likewise, transitions from FI to security, crossing above the threshold $\underline{P}$, can be classified as either stochastic or structural, depending on asset holdings.

Asset-based FI provides a framework for categorizing transitions between food secure and insecure statuses as either structural or stochastic. This approach underscores structural FI as a condition where households fall below the FI threshold due to consistently low or, on average, insufficient assets. Unlike traditional FS classifications, this asset-based perspective emphasizes the impact of inadequate financial assets on the mobility of households' FS statuses.

3. Data

To examine the dynamics of FI in the United States using asset-based measures, this study employs data from the Panel Study of Income Dynamics (PSID) from 2001 to 2019 (Panel Study of Income Dynamics, 2023). Initiated in 1968, the PSID has provided longitudinal data on American families, transitioning from annual to biennial surveys post-1997. Since 1984, the survey has meticulously collected detailed household wealth data, capturing both reported and imputed values across various asset components. This wealth data, collected biennially over the last two decades, forms the bedrock for constructing a longitudinal panel dataset pivotal for our asset-based FI analysis. Additionally, the PSID's integration of the USDA's core food security module during the 1999-2003 and 2015-2017 waves positions it as a critical tool for validating our new asset-based measure against the USDA's official FS metrics derived from CPS data. This unique combination of longitudinal wealth data and FS metrics enables a comprehensive analysis of FI dynamics.

As a first step in our exploration of this dataset, this study only includes two core independent samples in PSID: an over-sample of low-income families from the study of Survey of Economic Opportunity (the "SEO sample") and a nationally representative sample designed by the Survey Research Center (the "SRC sample"). These combined two samples constituting a national probability sample of U.S. families account for 93% of the PSID sample. We did not include the new immigrant refresher sample of PSID added in 1990, 1997, and 2017, because its

representativeness concerning FS status has not yet been validated (Lee et al., 2023; Tiehen, Vaughn, & Ziliak, 2020). To create the longitudinal panel data using the structure of PSID, our study limits its dataset to families in which the head of the household's identity did not vary throughout the period by omitting attritted and split-of units. Finally, we keep a consistent dataset of 21,660 observations from 2,166 families monitored across ten waves between 2001 and 2019. We report the summary statistics of all used variables in Table 1, which are consistent with the summary statistics of Lee et al. (2023). To prevent bias due to PSID's complex design (stratification, clustering, weighting), all reported parameter estimates, and standard errors are robust and adjusted using the primary sampling unit method as recommended by Heeringa, Berglund, and Khan (2011).

The household financial assets in the wealth module are the key information in our study of FI dynamics. Chang et al. (2014) underscores the significance of non-pension financial assets, delineating them as a household's immediately accessible financial reserves. These reserves are crucial for sustaining consumption and ensuring FS when adverse shocks disrupt regular income streams. We construct our financial asset measure using a simple summation of all non-pension financial assets on any given year, including liquid assets, equity in stock, mutual funds, investment trusts, other liquid assets such as bond funds, cash value in life insurance, valuable collections for investment purposes, and rights in a trust or estate. The inherent shortcoming of this wealth data is its pronounced inequality, particularly manifest in the distribution's tails. This disparity often results in estimations being disproportionately skewed by outlier observations. To mitigate this bias and enhance the robustness of our analysis, we exclude the top and bottom one percent of financial asset outliers, as suggested by the literature (Pfeffer, Schoeni, Kennickell, & Andreski, 2016).

After getting our financial asset measure, we use the concept of asset poverty to define the recommended minimal asset threshold to meet basic living standards and ensure FS. A candidate threshold for a static asset line, illustrated in Figure 1 of Section III, is 25% of the US Census Bureau's poverty line, designed to cover basic necessities for three months. This echoes a widely referenced criterion in the asset-based poverty literature (Haveman & Wolff, 2004). The relevance of the U.S. Census Bureau's poverty threshold to our study stems from its foundation in minimal food cost [4], making our chosen asset threshold—25% of the poverty line—a symbolic representation of the financial resources needed for a household to support its basic food needs over a quarter-year, thus directly linking to FS objectives. This threshold also aligns with benchmarks used by policymakers in setting Supplemental Nutrition Assistance Program (SNAP) eligibility criteria, emphasizing its practical relevance for assessing household FS (Ratcliffe et al., 2016). In applying this threshold to our analysis, we utilize the PSID data, specifically a variable labeled "Census Needs Standard" derived from the Census Bureau's documentation, which reflects annual household poverty thresholds adjusted for family size, the number of children under 18, and the age of the household head, thereby allowing us to establish a nuanced, household-year-specific asset threshold.

Figure 2 depicts the distribution of households' FS status, categorized by economic conditions—namely, income poverty, asset poverty, both, or neither. This distribution is visualized through a histogram with two main dimensions: the x-axis distinguishes between food insecure and food secure households, while the y-axis quantifies the proportion (as a percentage) of households in each economic category. Within the categories of FI and security, the histogram

[4] It is calculated based on the economy food budget, specifically three times the cost of a minimum food diet from 1963 (adjusted for today's prices).
https://www.census.gov/content/dam/Census/library/visualizations/2021/demo/poverty_measure-how_print.pdf

further segregates households based on their economic status, displaying four distinct groups: 1) those not classified as income or asset-poor, 2) those identified as income-poor but not asset-poor, 3) those considered asset poor but not income poor, and 4) those recognized as both income and asset poor. The data reveal that 36.95% of food-insecure households fall below the income poverty threshold, encompassing income-poor (regardless of asset status) households. Conversely, nearly 90.37% of food-insecure households fall below the asset poverty threshold, including those asset-poor regardless of income status. In contrast, 93.53% of food-secure households are above the income poverty threshold, whereas 38.11% are still below the asset poverty threshold. This pattern, where the asset poverty line includes a larger proportion of food-insecure households even among those who are not income poor, suggests that assets, which provide a buffer against economic shocks, offer a more comprehensive measure of food insecurity.

4. Empirical Model and Methods

5.1 Construct the Structural Probability of Food Security (SPFS)

In the theoretical framework outlined in Section III, we propose establishing a relationship between household assets and the likelihood of FI, aiming to predict the probability of FS based on household financial assets holdings. Nevertheless, the USDA's core food security module within the PSID dataset is constrained by its sample coverage, limited to 1999-2003 and 2015-2017. This discontinuity restricts our ability to conduct a direct regression analysis of FS status against asset holding across the entire dataset. To devise our new asset-based structural probability of food security (SPFS), we employ an econometric approach for estimating resilience at the individual or household level from panel data, as introduced by Cissè and Barrett (2018); Lee et al. (2023); Upton et al. (2016).

Intuitively, this approach utilizes a conditional moments-based framework, enabling the estimation of the expected probability of a household's FS, given that its asset holdings are sufficient to provide a buffer against FI. Specifically, this technique models the household's FS, as inferred from asset holdings, to behave as a random variable with its distribution across periods. This is crucial for detecting wealth-dependent, heterogeneous responses to shocks, acknowledging the nonlinear durability of such shocks, accounting for heteroscedasticity and the variability of higher-order central moments in path dynamics. The procedure for constructing the SPFS involves a series of conditional moment functions, detailed as follows:

First, for household *i*, in state *j* and year *t*, we parametrically estimate the conditional mean of the FS indicator, household non-pension financial asset in period *t* (A_{ijt}), on a polynomial function of lagged values in prior period (A_{ijt-1}) and a vector of household level covariates (X_{ijt}), including shocks directly experienced by household i or risks to which household i is exposed:

$$A_{ijt} = \sum_{\gamma=1}^{n} \beta_{M_\gamma} A_{ijt-1}^{\gamma} + \delta_M X_{ijt-1} + \theta_{Mj} + \eta_{Mt} + \mu_{Mijt} \quad (1)$$

In Equation (1), A_{ijt} is the aggregated annual household per capital non-pension financial asset for household *i*, in state *j* and year *t*. It is constructed using annual household non-pension financial divided by family size. The variable X_{ijt} encompasses various household characteristics and dynamics. It incorporates household demographics (age and its square for lifecycle effects, gender, race, education of the head), employment and disability status, family size, child proportion, food assistance (SNAP, WIC, Child Meal, Elderly Meal) participation, asset ownership (housing, vehicle), and non-transfer income. Additionally, the model accounts for changes since the last survey in key areas: employment and marital status, disability status, SNAP participation, and changes in home and vehicle ownership. θ_j and η_t are the year and state fixed effects to absorb

time and spatially invariant unobservable variables. The *M* subscript helps distinguish the parameters from the conditional mean.

The predicted dependent variable $\hat{A}_{ijt}$ is the conditional mean of household per capita non-pension financial assets. We assume the assets follow the Gamma distribution because it is continuous and non-negative[5]. We therefore estimate a generalized linear model (GLM) logit link regression for Equation (1). We use the Akaike information criterion (AIC) and t-tests on the equality of means between the predicted values of the higher-order specifications to decide the order of the polynomial function, reported in Table 2. By testing various polynomial specifications in Table 2, we observe a decline in the AIC value with increasing polynomial order, indicating that a specification of a higher order might be preferable. However, the estimated coefficients of the higher-order lagged terms of well-being are effectively zero, suggesting a minimal impact on the model. Concurrently, a t-test examining the mean equality of predicted values from higher-order specifications reveals that differences become statistically non-significant at and beyond the sixth order. Thus, this analysis supports selecting the sixth-order polynomial function of A_{ijt-1} as the optimal choice.

Next, to estimate the conditional variance ($\hat{\sigma}_{ijt}{}^2$) of household financial assets, we utilize the residuals derived from the conditional mean Equation (1). Given the assumption that the random error term μ_{Mijt} in Equation (1) has a zero mean ($\mathrm{E}[\mu_{ijt}] = 0$), the expected value of squared residuals, $E[\mu_{ijt}^2]$, corresponds to the conditional variance. Consequently, by regressing these squared residuals from the conditional mean equation against the covariates, we obtain the

[5] The mean of the outcome differs significantly from its variance in our sample, so we do not use a Poisson distribution, which requires the mean equals the variance.

regression model for the conditional variance of household financial assets. This model uses the same basic specification outlined in Equation (1):

$$\hat{\sigma}_{ijt}{}^2 = (\hat{\mu}_{ijt} - E\left[\hat{\mu}_{ijt}\right])^2 = \hat{\mu}_{ijt}{}^2 = \sum_{\gamma=1}^{n} \beta_{V_\gamma} A_{ijt-1}^{\gamma} + \delta_V X_{ijt} + \theta_{Vj} + \eta_{Vt} + \mu_{Vijt} \quad (2)$$

Where V denotes conditional variance. We apply the same generalized linear model (GLM) with a logit link function as specified in Equation (1) to Equation (2).

Assuming household financial asset $A_{ijt} \sim$ Gamma(α,β), we calibrate the parameters of the household-and-period-specific cumulative density function (CDF) $F(\cdot)$ using the predicted conditional moments such that ($\alpha = \frac{\hat{A}_{ijt}{}^2}{\hat{\sigma}_{ijt}{}^2}$; $\beta = \frac{\hat{\sigma}_{ijt}{}^2}{\hat{A}_{ijt}}$).

Finally, we can estimate SPFS using household assets' complementary cumulative density function (CCDF)[6], the inverse of CDF. For the survey time series defined by $t \geq 0$, we can define a household's FS resilience as the estimated complementary cumulative probability above the asset threshold based on the sequence of estimated probabilities $(\hat{\rho}_{ijt})_{t=1}^{T}$:

$$\hat{\rho}_{ijt} = P(A_{ijt} \geq \underline{A_{ijt}} | A_{ijt-1}, X_{ijt}) = \bar{F}(X_{ijt}, A_{ijt-1} | \underline{A_{ijt}}) = 1 - F(X_{ijt}, A_{ijt-1} | \underline{A_{ijt}}) \in [0,1] \quad (3)$$

Where $F(\cdot)$ is the assumed CDF and $\overline{F}(\cdot)$ is the corresponding CCDF. The SPFS as defined by ρ is our asset-based Household FS Survey Measure representing the probability that household i's non-pension financial assets in period (t) is equal or above the asset FI thresholds. $\underline{A_{ijt}}$ is the static asset threshold illustrated in Figure 1. We adopt asset thresholds based on a household-year-specific calculation, which equates to 25% of the annual poverty line as reported by the US Census

[6] The Complementary Cumulative Distribution Function (CCDF) is formally defined as the probability that a random variable X assumes a value greater than a specific threshold x. This definition underpins its application in forecasting PFS by household asset holdings.

Bureau. This threshold is designed to cover basic needs for three months in our FS analysis, with the calculation methodology detailed in the data section of this paper.

The SPFS measure can categorize households as food secure or insecure using a minimum threshold probability, $\underline{P_t}$, an externally defined cut-off. Following Lee et al. (2023), we use the USDA's annual FI prevalence to set this threshold, aligning the PFS cutoff with the USDA's reported rates. For instance, if 12% of households are reported as food insecure by the USDA in year *t*, the 12th percentile SPFS in the weighted sample becomes the threshold $\underline{P_t}$ for that year. This approach ensures our FI prevalence estimates align with the official USDA figures, adhering to the Household FS Survey Measure (HFSSM).

We further employ a series of crucial tests, as suggested by Boateng et al. (2018) and Lee et al. (2023), to validate the SPFS measure as a representative measure of FS. Our analysis includes: (1) comparing the distribution of SPFS and official HFSSM measure, (2) examining the concordance in household classifications as food secure or insecure by these measures, (3) assessing the correlations between SPFS and the official HFSSM measures through estimation of rank correlations and regression of SPFS on HFSSM, and (4) evaluating whether the associations between SPFS or HFSSM and household characteristics exhibit similarity.

5.2 Structural FS dynamics

Using the static asset threshold, $\underline{A_{ijt}}$, and the cut-off probability of FS (SPFS), $\underline{P_t}$, as outlined by (Carter & May, 2001), We commence our analysis by categorizing household *i* in period *t* based on the estimated FS status by SPFS, delineating between structural and stochastic components. This classification framework is depicted in Figure 1, which presents the conceptual underpinnings of our approach.

1) Structural FI: Identified by its possession of financial assets insufficient to cover the basic needs for a minimum of three months (i.e., below the static asset threshold), coupled with a SPFS indicating a lack of resilience to achieve FS $A_{ijt} < \underline{A_{ijt}}$ And $SPFS < \underline{P_t}$.

2) Stochastical FI: Characterized by adequate financial assets to meet the minimum three-month basic needs yet encountering FI due to unfavorable circumstances $A_{ijt} \geq \underline{A_{ijt}}$ and $SPFS < \underline{P_t}$.

3) Structural FS: Defined by financial assets exceeding the static threshold and a SPFS measure above the FS cut-off, indicating resilience ($A_{ijt} \geq \underline{A_{ijt}}$ and $SPFS \geq \underline{P_t}$);

4) Stochastical FS: Describes a household achieving the estimated FS following a positive shock, despite its assets being below the FI threshold for a single period ($A_{ijt} < \underline{A_{ijt}}$ and $SPFS \geq \underline{P_t}$).

Spell-based approach

After identifying each household's asset-based FS status from 2001 to 2019, we first adopt the spell-based approach borrowing from poverty literature (Jo Bane & Ellwood, 1983) to study household-level dynamics. The spell-based approach explicitly provides the intertemporal dynamics of FI, focusing on its transitions and durations.

First, we aim to elucidate the dynamics of household transitions into and out of FI over time, distinguishing between structural and stochastic transitions, as depicted in Figure 3. This approach diverges from the conventional classifications found in the literature (Lee et al., 2023; Ziliak & Gundersen, 2016), which categorize transitions as remaining food insecure across two successive waves (Still FI); transitioning from FI to FS (New FS); moving from FS to FI (New FI); and remaining FS across both waves (Still FS). Instead, we adopt the theoretical framework

proposed by Carter & May (2001), which allows for a more nuanced analysis of both stochastic and structural transitions.

We classify a household as stochastically upwardly mobile depending on the estimated structural FS statuses by SPFS. A household is deemed stochastically upwardly mobile if it is estimated to transition from being food insecure in year *t-1* to food secure in year *t*, or if it was food insecure and becomes stochastically food secure in year *t*. Conversely, a household is deemed stochastically downwardly mobile if it moves from food secure to stochastically food insecure, or from stochastically food secure to food insecure, showcasing a deterioration in FS status due to stochastic elements. A household remains stochastically immobile if it was stochastically food insecure in both consecutive periods. Lastly, households whose mobility or immobility cannot be solely attributed to stochastic factors fall into the structurally mobile (or immobile) category, suggesting that deeper, structural issues shape their FS status.

Using the transition probability matrix, we derive the joint distributions of the specified categories, as illustrated in Figure 3, across periods for the full sample and for distinct subpopulations. This provides a nuanced decomposition of these distributions into components attributable to structural and stochastic mobilities. Furthermore, we quantify the persistence rate of FI, defined as the conditional probability that a household experiencing FI in one survey wave will continue to do so in the subsequent wave. Complementarily, the entry rate represents the conditional probability that a household transitions to a state of FI in the next wave, given its initial state of FS. Consequently, the exit rate is calculated as one minus the persistence rate. An analytical comparison is also conducted between the estimated persistence and entry rates[7], distinguishing between stochastic and structural FI at the initial period.

[7] The persistence rate for stochastic (alternatively, structural) FI quantifies the conditional probability that a household, identified as being stochastically (or structurally) food insecure in one survey wave, will continue to exhibit FI in the

In the subsequent phase of our analysis, we identify spells of FI, defined as uninterrupted intervals during which households are classified as food insecure. We proceed to characterize the distribution of the lengths of these FI spells, in conjunction with an assessment of conditional persistence—specifically, the probability that a household will continue to be food insecure, given the duration of its current spells of FI. Furthermore, an exploration into the distribution of spell lengths, as delineated by asset holdings and the estimated FS status as determined by SPFS, is conducted within each delineated spell length. This investigation is designed to shed light on the role of structural determinants, focusing on household asset holdings, in influencing the duration and the persistence of FI spells.

Permanent approach

Compared to the spell approach, the permanent approach—also known as the component approach and representing the second method for analyzing household-level FS dynamics—distinguishes between the structural and stochastic components. These components are estimated using the mean intertemporal SPFS. It is less vulnerable to measurement error and more flexible with data truncation and survey intervals (Lawson & McKay, 2002) than the estimates from the spell-based approach. Moreover, it is feasible to use panel data to identify those unlikely to escape economic hardship like poverty and FI permanently over a significant period based on their relevant characteristics. Following the permanent approach from Jalan and Ravallion (1998, 2000), structural FI is identified by mean intertemporal (the average over the observed periods) SPFS and stochastic FI is identified by deviations from the household specific intertemporal mean.

subsequent survey wave. Similarly, the entry rate for stochastic (or structural) FI is defined as the conditional probability that a household, initially food secure, transitions into a state of stochastic (or structural) FI in the following survey period.

First, we define the total FI for household *i* using the observed sequence of SPFS measures based on the static asset line, denoted as TFI_i. Then we denote SFI_i as its structural component. So, the difference between TFI_i and SFI_i is the stochastic component:

$$TFI_i(\alpha, SPFS_{i1}, \ldots, SPFS_{it}) = \frac{1}{T}\sum_{t=1}^{T}\left(1 - \frac{min(SPFS_{it}, \underline{P_t})}{\underline{P_t}}\right)^{\alpha} \quad (4)$$

$$SFI_i(\alpha, SPFS_{i1}, \ldots, SPFS_{it}) = \left(1 - min\left[1, \frac{\sum_{t=1}^{T} SPFS_{it}}{\sum_{t=1}^{T} \underline{P_t}}\right]\right)^{\alpha} \quad (5)$$

Where TFI_i , the total FI over the period for each household, is the weighted sum of TFI over the component sub-periods. When $SFI_i > 0$, this indicates the average SPFS (or the average probability to reach the static asset threshold over time) is below the FS threshold ($\underline{P_t}$). Therefore, the household *i* could be viewed as structurally food insecure. It also means that this household is expected to be structurally (asset-based) food insecure in any observed period or the full period. Conversely, $SFI_i = 0$ suggests a household is not structurally food insecure.

TFI_i and SFI_i are created based on the Foster-Greer-Thorbecke (FGT) poverty measure. There is an important modification that they are aggregated over time within households, whereas the usual FGT measure is aggregated over households within a specific time period. The aversion parameter α, usually used in FGT style measure, reflects the weight placed on the severity of gaps between asset-based $SPFS_{it}$ and $\underline{P_t}$ with the value of 0, 1, 2. The estimated structural FI with α = 0 indicates the frequency (headcount ratio) of structural FI. Higher order measures with α = 1,2 represent the gap of FI and the severity of such shortfalls for each household. Different values of help explain how the changes in the parameter under this component approach affect this aggregate FI dynamics estimation.

Under this permanent approach measure of TFI_i and SFI_i, we can distinguish stochastic and structural FI households from FI households by mean intertemporal SPFS and categorize them

into four categories. First, if $SFI_i > 0$ and $SPFS_{it} < \underline{P_t}\ \forall t$, a household is structurally persistent food insecure. If $SFI_i > 0$ and $\exists t$ such that $SPFS_{it} \geq \underline{P_t}$, the household is structurally but not persistently food insecure. The third one is stochastically food insecure households, i.e., $SFI_i = 0$ and $\exists t$ such that $SPFS_{it} < \underline{P_t}$. Finally, households are never food insecure or persistently food secure if $TFI_i = SFI_i = 0$.

On the 19-year, household-specific histories of PSID panel data, this permanent approach helps us distinguish structurally food insecure households whose mean intertemporal assets predict a standard of living to be food insecure from households with stochastically food insecure whose circumstance, on average, predicts a food secure future standard living. We then conducted a correlation analysis to explore the relationship between household characteristics and FS dynamics, measured by TFI and SFI. We then compared coefficients to evaluate the different relationships of these predictors to TFI and SFI. Finally, we utilize the Shapley decomposition method to identify the sources of variation in these measures, TFI and SFI.

5. Results

6.1 The SPFS Measure & Validation

With the PSID household panel survey data from 2001-2019, we first report the resilience measurement of household-period-specific FI probability, SPFS, using a system of conditional moment functions of household assets illustrated in Equation (1)-(3).

Columns (1) and (2) of Table 3 present the marginal effects estimates for household assets' mean and variance equations using generalized linear model (GLM) logit link regression. One unit increase of lagged asset holding (in the ten-thousands) positively correlates with an average increase of 4.489 (in the ten-thousands) in household financial assets and a 168.838 higher

variance. Notably, the dynamics of household asset holdings exhibit significant nonlinearity, as indicated by the adoption of a sixth-order polynomial function for lagged assets in Table 2, which we have discussed it in Section 5 empirical model and methods. Controlling for other factors, the data show that households led by males, those with higher-educated heads (at least some college), employed household heads, higher income, smaller family sizes, and homeownership are statistically linked with greater financial asset holdings. Furthermore, households receiving benefits from SNAP, Child Meal, or Elderly Meal programs tend to have higher financial assets. Conversely, households experiencing a cessation of SNAP are associated with reduced asset holdings. Additionally, the covariates correlated with the predicted mean value of financial assets are significantly associated with larger conditional variance. The analysis also indicates reduced variance associated with WIC participation and shocks such as unemployment or loss of vehicle ownership.

Using conditional mean and variance estimates derived from columns (1) and (2) in Table 3, we then calculate the probability density function (pdf) of each household's financial assets using a gamma distribution for each period and estimate each household's probability of achieving the static minimum asset holding ($\underline{A_{ijt}}$) for each period. The resulting probabilities (SPFS), specific to each household and period, range between 0 and 1. These SPFS scores are then regressed on the same regressors (see Table 3, column (3)), uncovering a non-linear link between past asset holdings and FS probabilities. Specifically, Figure 4 depicts a rapid increase in FS probabilities with increases in non-pension financial assets per capita up to a point beyond which the increase plateaus or slightly decreases. Statistically, the estimated higher probabilities of FS (SPFS) correlate with households led by older, white, male, or more educated individuals and those with fewer members but more children, owning homes and vehicles, participating in food

assistance programs, or not facing recent adverse events (e.g., losing SNAP benefits or vehicle ownership). Contrary to expectations (Ziliak & Gundersen, 2016), households experiencing unemployment, divorce, or loss of homeownership also showed higher estimated FS probabilities.

Although these associations from GLM models indicate a sensible relationship between SPFS and household characteristics, it is imperative to ascertain the alignment of the SPFS measure with the official USDA's HFSSM measure. To facilitate this comparison, we adjust the HFSSM scale to range from 0 to 1, with higher values indicating greater FS[8].

We conduct validity tests proposed by Boateng et al. (2018) and Lee et al. (2023). First, this study contrasts SPFS and HFSSM distribution patterns and examines the concordance in household classifications as food secure or insecure by these measures. Figure 5 illustrates the density distributions of SPFS and HSFM, revealing a higher concentration of observations within the lower PFS range (0-0.6), predominantly among households identified as food insecure. This pattern suggests that, due to its sensitivity to asset ownership, the SPFS might more accurately capture variations in FI compared to the HFSSM. Regarding classification accuracy, the analysis indicates that 1.93% of households are deemed food secure by our SPFS measure but food insecure by the HFSSM, while 8.78% are categorized as food insecure by SPFS yet food secure by HFSSM. In contrast, Lee et al. (2023) reports that 3.2% of households are classified as food secure based on their food expenditure-based measure but food insecure by HFSSM, and 10.0% are classified as food insecure by their measure yet food secure by HFSSM. Overall, our asset based SPFS demonstrates greater alignment with the HFSSM measure in classifying FS.

[8] $HFSSM_{\text{rescaled}} = \frac{9.3 - HFSSM_{\text{scalescore}}}{9.3}$ where $HFSSM_{\text{scalescore}}$ denotes the household FS scale score (*fsscale*) that varies from 0 to 9.3, as reported in the USDA Household FS Survey Measure.

Second, we investigate the existence of a statistically significant and positive correlation between the HFSSM and SPFS. Initially, we utilize two non-parametric rank correlation coefficients: Kendall's tau and Spearman's rho. These analyses produce correlation coefficients of 0.32 for tau and 0.40 for rho, both statistically significant and different from zero. Hence, we reject the null hypothesis of no correlation between SPFS and HFSSM. The moderate correlations observed may partly stem from the methodological differences in constructing these measures: the HFSSM is derived from a Rasch model applying categorical variables, whereas the SPFS is a continuous probability measure. Subsequently, the HFSSM scale's regression on SPFS, detailed in Table 4, corroborates the statistically significant positive association between HFSSM and SPFS. This conclusion holds under both linear and quadratic model specifications and remains robust after adjusting for state and year-fixed effects, notwithstanding the positive skewness inherent in both measures.

Finally, we compare the correlations between household characteristics and FS, as measured by the Household FS Module (HFSSM) scale and SPFS. Our analysis uses continuous representations of these measures in columns (1) and (2) and binary representations in columns (3) and (4). Most covariates display consistent directional estimates, albeit with magnitude and statistical significance variations. Statistically significant covariates associated with both FSSS and SPFS—and exhibiting identical directional relationships—include high school completion, household income, disability status, the proportion of children in the household, participation in food stamp/SNAP programs, homeownership, and experiencing housing instability. Conversely, certain variables, such as racial status, marital status, gender, education level beyond high school, family size, receipt of WIC benefits, receipt of elderly meal benefits, and housing tenure status, demonstrate significant associations with SPFS but not with HFSSM. Nonetheless, these

associations align with prior research findings (Coleman-Jensen et al., 2018; Liese et al., 2021; Ziliak & Gundersen, 2016).

The significant positive correlation between the SPFS measure and the USDA's Household FS Module (HFSSM) scale, alongside the widespread alignment in their associations with household characteristics, indicates that the SPFS serves as a valuable complement of FS measure to the USDA's measure in the United States.

6.2 Structural FS Dynamics Based on Static Asset Threshold.

FI Prevalence Predicted by SPFS

We first show the distribution of FS status and structural FS status estimated by our SPFS in Figure 6. In Figure 6a, our findings reveal that the prevalence rates of FI, as gauged by the SPFS, align with the annual reports on prevalence issued by the USDA (Rabbitt et al. 2023). Specifically, during periods of economic stability, such as 2001-2005 and 2015-2019, approximately 88.2% to 89.5% of U.S. households were found to be food secure, leaving an estimated 10.5% to 11.8% experiencing FI at some point within these years. However, the incidence of FI rose to between 14.3% and 14.7% during and following the Great Recession, highlighting the impact of economic cycle on household FS.

Figure 6b categorizes the estimated FS into structural and stochastic components. Structurally food secure households, making up 62.3%-69.5% of the food secure, have sufficient financial assets to maintain FS, covering 72%-77% of overall FS prevalence. Stochastically food-secure households, accounting for 19.2%-25.4%, are temporarily food secure due to positive shocks despite being asset-poor. On the other hand, 8.9%-13% of the population are structurally food insecure, lacking adequate financial assets for FS and representing over 85% of all food-insecure cases. This finding is further substantiated by the descriptive results presented in Figure

2, where nearly 92% of these structurally food-insecure households are shown to fall below the asset poverty threshold. The remaining 15% of food-insecure households are stochastically insecure, facing adverse shocks despite being not asset-poor.

Interestingly, an examination of prevalence rates over time reveals that the rate of structural FS remains relatively stable, even during the Great Recession (GR) period. Conversely, the prevalence of stochastically food-secure households, characterized by insufficient financial assets, is significantly impacted by economic downturns, experiencing a decline of approximately 3%-4.5% during the GR period. As the economy recovers post-GR, households with the recovery of income are more likely to slowly accumulate assets above the threshold required for FS (Mitchell, 2020), leading to an increase in the prevalence of structural FS and a decrease in stochastic FS. During the economic downturn associated with the GR (2007-2013), the prevalence of structural FI rose from 9.7% to 13.0%, a trend that persisted until 2013. This pattern suggests that the GR led to a significant loss of financial assets (McKernan, Ratcliffe, Steuerle, & Zhang, 2014), contributing to heightened structural FI. Concurrently, certain households, initially possessing adequate assets but detrimentally impacted by negative economic shocks during the Great Recession (GR), regained FS.

In summary, our estimates of the prevalence of FS and insecurity, utilizing the SPFS measure, reveal that a significant portion of U.S. households achieve FS supported by adequate asset holdings. Conversely, the primary proportion of FI is structural, rooted in inadequate financial assets. While structural FS—characterized by sufficient financial assets and FS—exhibits resilience over time, including during the Great Recession, this period also witnessed a marked increase in structural FI. Additionally, there were fluctuations in stochastic FS and insecurity, underscoring the intricate influence of economic conditions on the various dimensions of FS.

Structural FS Dynamics by Spells approach

i. Transition Matrix of FS Status Across Two Waves

Utilizing the transition matrix from the spells approach in Figure 3, Table 6 offers a detailed examination of transition in FS status across two successive waves within the U.S. population, disaggregated by annual data and household characteristics. This analysis categorizes households into four distinct groups: those remain food secure (Still FS), those transitioning from food insecure to secure (New FS), those persisting in FI (Still FI), and those newly experiencing FI (New FI) between the two observation periods. The proportions of these joint distributions are detailed in columns (2), (3), (6), and (11), respectively. Moreover, we further dissect these transitions into structural and stochastic components, with their respective proportions detailed in columns (4)–(5) for New FS, (7)–(10) for Still FI, and (12)–(13) for New FI.

Table 6 illustrates that a significant majority of the population, between 82.6% and 86.8%, maintained their FS across two consecutive waves from 2003 to 2019. Concurrently, a smaller segment of the population exhibited fluctuations in FS status, underscoring transitions both into and out of FS or staying in FI. Specifically, it is estimated that 8.8% to 11.7% of U.S. households consistently remained food insecure, whereas fewer than 5% of households transitioned into newly food secure or newly food insecure statuses annually.

Figure 7a depicts these transition trends across time, where the top of each bar aligns with FI prevalence rates reported by the USDA and those estimated by our SPFS measure. Notably, households that remained FI from one wave to the next accounted for approximately 61-80% of the FI rate at each subsequent measurement, while less than half transitioned from FS in one wave to new FI in the next. ”Still FI” rates were relatively stable at about 8.4-8.8% before the Great Recession, surging to 9.2% and 11.7% in 2009 and 2011, respectively, then gradually returning to

8.1% by 2019. The incidence of becoming newly food insecure exhibited a similar stability pre-recession, around 2.4%, doubling to 5.1% in 2009, before swiftly declining post-2013.

Decomposing these transitions within Table 6 into structural and stochastic mobility reveals that, in the given year, 75%-92% of households achieving new FS status benefited from stochastic upward mobility, while a smaller fraction achieved FS through structural upward mobility. This pattern indicates that transitions to FS were predominantly driven by stochastic variations, moving from stochastic FI in the preceding year to FS in the current year or transitioning from FI to stochastic FS. Moreover, this analysis places a ceiling of 25% (in the economically favorable year of 2019) on these "New FS" households upward transitioning from structural FI to structural FS, facilitated by asset accumulation.

For current FI households, transitions are detailed in columns (6) to (13) of Table 6 and visualized in Figure 7b, showcasing its mobility trends over the years. Households "still FI" may exhibit one of four mobilities: stochastic FI immobile, structural FI immobile, structurally upward mobile, or structurally downward mobile. Within the PSID sample, 6.8%-9.8% of households remained in structural FI across two waves, peaking in 2011 and 2013, then gradually decreasing by 2017. Meanwhile, transitions in other "still FI" categories accounted for about 1% of U.S. households, respectively. The majority of the variation in households that remain food insecure ("still FI"), approximately 65-71%, can be attributed to those classified as "structurally immobile", who cannot overcome asset poverty and FI. This reflects the broader trend observed in the persistence of FI. For "new FI" households, over 90% experienced stochastic downward mobility, indicating temporary negative shocks that led to FI without substantial financial asset loss.

In our analysis of transitions by diverse household characteristics, as delineated in Table 6, we observe a significantly higher prevalence of remaining food insecure ("still FI") and transitions

into FI ("new FI") among households led by non-Whites, female, individuals lacking a high school diploma, the disabled, single-parent households with children, SNAP/food stamp benefits, those lacking homeownership and vehicle ownership, and residents of the South and Midwest. For shocks, households ceasing to receive SNAP benefits exhibit a 53.9% probability of remaining food insecure across two observation periods. Furthermore, these demographic groups exhibit a higher propensity towards "structural immobility" and "structural downward mobility" indicating a sustained or worsening FI status.

Figure 8 illustrates the dynamics of FS across demographic subgroups, categorized by education level, gender, and race. This analysis distinguishes between households newly facing FI due to stochastic downward mobility (Panel A) and those experiencing persistent FI without mobility (Panel B), emphasizing variations within these demographic segments. Households led by individuals with a high school education or less, comprising 38% of the population, represent approximately 50-65% of the newly food insecure (stochastic downward mobility) and 70-80% of the persistently food insecure (immobile) groups. This indicates a pronounced correlation between lower educational attainment and higher rates of FI, particularly among persistently food-insecure households. Additionally, female-headed and non-white households exhibit greater variability in persistent FI, whereas male-headed and white households show more variation among those newly experiencing FI due to stochastic downward mobility. Notably, households led by non-white females without a college degree, making up 4.4% of the population, are disproportionately vulnerable, accounting for about 30% of the persistently food insecure group. In contrast, households led by white males without a college degree constitute a larger share of those newly food insecure due to stochastic downward mobility.

The trends depicted in Figure 8 reinforce the conclusion that particularly vulnerable subgroups, notably non-white females with only a high school education, have exhibited relatively stable rates of FI, with a pronounced emphasis on structural immobility, in the periods before and after the recession. Additionally, it can be inferred that the Great Recession primarily precipitated a significant asset loss among less vulnerable groups like white males with college degrees, leading to their transition into a state of structural and persistent FI (structurally food insecure immobility). This finding aligns with the findings of Smeeding (2012), who reported that the middle classes experienced the most significant proportional losses in wealth during the Great Recession.

In our estimation of persistent and entry rates of FI—conditional on the FS status in the preceding year, as presented in Table 7, we observe that households previously identified as food insecure exhibit a greater than 80% average probability of remaining food insecure (persistent rate) in the subsequent wave, with this likelihood peaking at 85.4% in 2009 during the GR. This finding contrasts with earlier research; for instance, Lee et al. (2023) analysis using food expenditure to measure FS indicates a lower persistence range of 51% to 72%. Households classified as structurally food insecure, with asset holdings below the threshold, demonstrate an 80% - 88.3% likelihood (reaching 88.3% in 2009) of persisting in FI in the following wave. Conversely, households initially deemed stochastically food insecure, possessing assets above the threshold but being food insecure, show a 25.2% - 67.2% probability (highest during the GR) of remaining food insecure. The GR notably exacerbates the likelihood of persistent FI among households initially categorized as stochastically FI.

Conversely, for households that were food secure in the previous year, the entry rate (probability of transitioning to FI) in the current wave ranges between 1.5% and 5.8%, peaking during the GR. This rate of transition into FI notably contrasts with the findings of Ziliak and

Gundersen (2016), who report an entry rate from full FS (FFS) to marginal FI (MFI) of 6%-8%[9]. Similarly, Lee et al. (2023)'s study suggests an entry rate of 5 - 8%. Our analysis further distinguishes between transitions into stochastic FI (0.4% - 1.1% transition rate) and structural FI (1.0% - 4.4% transition rate), with both categories peaking in 2009 among households initially food secure, according to SPFS estimates.

Persistent and entry rate analysis reveals that households led by non-Whites, women, individuals without a high school diploma, the disabled, single parents, SNAP recipients, and those lacking homeownership or vehicle ownership, particularly in the South and Midwest, are significantly more likely to persist in or transition into FI. Notably, households experiencing the loss of vehicle ownership or onset of disability exhibit the highest rates of persistent FI, at 96.6% and 94.4% respectively, with the former also facing the highest entry rate into FI at 27.5%. Additionally, discontinuing SNAP benefits is associated with a relatively high entry rate into FI at 15.5%. These findings again highlight the profound impact of socio-economic status and shocks on FS, underscoring the need for targeted interventions to address the structural vulnerabilities that heighten the risk of persistent FI.

ii. Spell Length

Analyzing the distribution of FI spell lengths alongside the estimated conditional persistence and the differentiation between structural and stochastic FS statuses reveals nuanced insights into household experiences of FI from 2001-2019 (Table 8). Given the biennial nature of PSID data, a single wave spell can represent up to 4 years of persistent FI for a household between survey waves. Conversely, a household could experience FI less than a year, captured just after the entry, indicating shorter spell lengths.

[9] Our study defines FI strictly as low FS (LFS) and very low FS (VLFS) following the guidance of USDA, unlike Ziliak and Gundersen (2016) which also includes marginal FS (MFS). This different definition likely accounts for the differing values observed.

Our analysis first reveals that less than half (43.08%) of sample households experience FI for a single wave (1-4 years). This finding suggests that spells of FI in the U.S. are more likely to be persistent, not stochastic. Moreover, the conditional persistence of FI increases, albeit weakly and statistically, with the spell's duration. This pattern implies that the longer a household experiences FI, the more challenging it becomes to escape. Specifically, after a household has been identified as food insecure for two consecutive waves, there is at least an 80% chance that it will continue to be food insecure until the following PSID (Panel Study of Income Dynamics) wave.

Within the subset of each spell length, a distribution based on asset holdings and estimated FS status by SPFS further delineates the severity of FI. Initially, stochastically food-secure households account for a significant proportion of households (47.70%) experiencing one-year spells of FI, indicating stochastically positive shocks in food access despite being asset-poor. In contrast, 40.17% of households within the same spell length enjoy structural FS, benefiting from adequate asset holdings that ensure stable access to food.

However, as FI spells extend, the landscape shifts markedly. The percentage of households identified as stochastically food secure decreases gradually, dropping to 0% by the tenth wave. Simultaneously, the prevalence of structural FI escalates, peaking at 95.25% for households enduring spells of five waves or longer, pointing to a deep-rooted link between long-term persistent FI and asset poverty. The proportion of households facing stochastic FI initially rises with spell length, reaching a peak before stabilizing, while structurally food-secure households dramatically decline to zero, highlighting the complex dynamics that underpin FS status over time. This evidence suggests a critical role of asset holdings in shaping the trajectory and persistence of FI, with longer spells reinforcing the impact of insufficient asset holdings and the challenge of escaping FI.

Figure 9 presents the distribution of the duration of FI spells (measured in years) among households, conditional on the initial year of FI status. We reveal notable distinctions in the durations of FI spells, influenced significantly by the business cycle and categorized by stochastic and structural beginnings. Analysis of spell lengths starting from 2003 to 2017 indicates a wide variance in short-term FI (1 wave spanning 2 years), with incidences peaking at over 70% in 2017—a period marked by economic stability and full recovery from the Great Recession (GR)—and dropping to their lowest at the onset of the GR in 2007. This variation underscores the influence of macroeconomic stability on the prevalence of short-term (one wave) FI. Furthermore, the data exhibit a persistent long tail of FI beyond a single wave, highlighting the persistent impacts of FI. Unconnected dots at the distribution's right extreme represent households with ongoing FI as of the 2019 Panel Study of Income Dynamics (PSID) wave, indicating right-censored data and the potential for even longer spells. Particularly, households initially classified as food insecure during the GR (in 2007 and 2009) or its aftermath (in 2011 and 2013) exhibited a significantly higher proportion of spells exceeding 6 years. This persistence suggests a pronounced business cycle effect on the duration and continuity of FI in the United States. The spell lengths for households entering FI in 2003 and 2005 also expanded during and following the GR, further evidencing the cyclic impact.

To corroborate the hypothesis that structurally food-insecure households are more likely to experience persistent FI, Figures 10b and 10c delineate the spell length distributions for stochastic and structural FI in the initial years, respectively. As anticipated, households with stochastic FI predominantly exhibit single-wave spells, comprising around 60% of the distribution. Exceptions exist for those entering FI during or after the GR (2007-2013), who show a near-zero distribution for extended spell lengths. Conversely, households with structural FI at the onset in Figure 9c

follow a similar pattern with households with FI at the onset in Figure 9a and show a higher propensity for enduring longer spells. These findings emphasize that insufficient financial asset holdings—a key structural reason—contribute to prolonged periods of FI.

Structural FS Dynamics by Permanent approach

The results of examining household-level FI dynamics employing the permanent approach with mean intertemporal SPFS measure are detailed in Table 9. Using the methodology delineated by Equations (5) and (6), we derive the average period-specific total FI (TFI) alongside its mean intertemporal structural component (SFI) for each household, employing an FGT style metric with the parameter α set to zero[10]. The summarized outcomes, encompassing the total households and subgroups, are in columns (1) through (4) of Table 9 Column (3) details the stochastic component, while column (4) indicates the proportion of household FI considered structural. Moreover, we integrate SFI estimates with SPFS-determined FI statuses, enabling the classification of households into four groups based on their mean intertemporal, not period-specific, FI experiences: structurally persistently food insecure, structurally not persistently food insecure, stochastically food insecure, and never food insecure. The distribution is presented in columns (5) through (8) of Table 9.

From 2001 to 2019, an estimated 78.7% of U.S. households never experienced FI (Table 9, column (8)). This persistence ratio exceeds Lee et al. (2023) estimate of 67% based on food expenditure but is comparable to the 87.6% calculated using the official USDA's HFSSM measurement[11]. This difference can be attributed to household assets being a more reliable indicator of long-term welfare, such as FS. Moreover, the asset-based SPFS measure, which spans

[10] We also derive the average period-specific total FI (TFI) alongside its mean intertemporal structural component (SFI) with $\alpha = 2$ in Appendix Table A. There are similar results.

[11] It is roughly calculated using the available HFSSM data during 2001,2003, 2015, 2017 and 2019 in PSID.

ten waves from 2001 to 2019 and includes the Great Recession period, may yield estimates that our persistent ratio of FS is smaller than the USDA's HFSSM estimate which is confined to five waves in PSID data (2001, 2003, 2015, 2017, and 2019) and excludes the recession years. Importantly, among those experiencing FI, 84% face structural challenges, as column (4) shows, aligning closely with the percentages of structural FI and structural mobility in Figure 6 and Table 6.

Furthermore, our analysis using the permanent approach suggests 11.8% of households encounter stochastic FI, with 4.4% facing structurally persistent and 5.2% facing non-persistent structural FI from 2001-2019, as indicated in columns (5) to (7) of Table 9. This intertemporal distribution diverges from the period-specific findings in Figure 6, where 62.3% - 69.5% are structurally FS, and 19.2% - 25.4% experience stochastic FS, 8.9% - 13% are structurally FI and 1.4 - 2.1% are stochastically FI. The variation between the permanent and period-specific approaches reflects their differing methodologies. The former emphasizes stable, long-term household characteristics to derive average trends, potentially overlooking the impact of short-term fluctuations. In contrast, illustrated in Figure 6, period-specific estimations capture FS distributions over time, factoring in asset and FI status changes, though they may encounter measurement errors.

The subgroup analysis, employing a permanent approach with time-invariant variables as presented in Table 9, corroborates that households led by females, non-whites, individuals with lower educational attainment (notably those without a high school diploma), or those living in the South and Midwest regions, exhibit significantly higher TFI indices and a greater propensity to encounter FI—particularly structural and persistent FI—compared to their counterparts (males, whites, individuals with at least a high school education, and residents of other regions).

Furthermore, the observed range of SFI as a percentage of TFI, spanning 87% to 100%, underscores that households within these disadvantaged demographic cohorts are not only more susceptible to FI but also to a substantially greater risk of enduring structural FI, compounded by insufficient financial assets, in contrast to other groups.

In Figure 10, we further illustrate this trend by comparing TFI and SFI across subgroups delineated by gender, race, and education levels. It becomes evident that households led by individuals who are non-white, female, or possess a high school diploma or less constitute the most disadvantaged segment, exhibiting the highest indices of TFI and SFI, along with the largest proportion of the structural component of FI. Holding education level constant, households headed by non-white and female individuals continue to face a heightened risk of enduring structural FI compared to their counterparts with equivalent educational achievements. This underscores that non-white and female groups are particularly vulnerable and should be prioritized in policy interventions. Furthermore, education, particularly attainment beyond a high school diploma, is crucial in mitigating FI and its structural aspects, even among these highly vulnerable groups.

We subsequently conducted a correlation analysis to investigate the relationship between household characteristics and dynamics of FI, as measured by TFI and SFI (Table 10). As anticipated, significant predictors of TFI and SFI include household characteristics such as race, gender, education level, family size, participation in the Supplemental Nutrition Assistance Program (SNAP), child meals programs, and asset ownership, including housing and vehicles. Regarding economic shocks, the discontinuation of SNAP benefits is associated with increased TFI and SFI rates. An unemployment shock is linked to a rise in SFI rates at the 10% significance level, with no significant association observed for TFI. Intriguingly, a higher percentage of children within a household is associated with reduced rates of TFI and SFI, potentially attributable

to eligibility for additional government assistance and social programs designed to mitigate child FI or poverty. Furthermore, the loss of important assets, such as houses and vehicles, is linked to lower rates of TFI and SFI, possibly due to increased cash flow from these transactions.

Upon examining the differences in coefficients between TFI and SFI, our analysis reveals that the lack of home ownership, particularly among renters, is more strongly associated with an increase in TFI than SFI. This suggests that home ownership is more closely linked to general FI than to structural FI. Conversely, receiving child meal benefits is significantly more associated with an increase in SFI than TFI at the 10% significance level, indicating that households benefiting from such programs experience FI and are also at a heightened risk of enduring severe FI. Notably, even after controlling for other variables, higher educational attainment (at least a high school degree) significantly reduced rates of severe structural FI more than general FI at the 5% significance level, underscoring the critical role of education in mitigating persistent FI challenges. Furthermore, unemployment shocks were found to have a stronger association with increases in structural FI. These findings highlight the potential effectiveness of policies targeting education attainment, child nutrition programs, and unemployment insurance for low-income households in reducing both structural and persistent FI.

Figure 11 elucidates the coefficient estimates and corresponding confidence intervals for state/regional effects derived from the model presented in Table 10. Spatial variations exist in TFI and SFI, particularly in the South and Midwest regions of the U.S. The majority of state/regional effects on TFI and SFI do not reach statistical significance, with the exceptions being North Carolina/South Carolina (NC/SC) and Georgia (GA) in the South, and Indiana (IN) and Michigan (MI) in the Midwest. Notably, SFI in these states, where significant regional effects are observed, exceeds TFI. This indicates that households experiencing FI in these regions are structurally and

persistently food insecure. Such findings imply that both short-run and long-run shocks may impact regions differently. It also suggests that FI, especially structural FI, is intricately linked to both household characteristics and geographical location.

Finally, we employed a Shapley decomposition, detailed in Table 11, to elucidate the sources of variation in SFI and TFI in Table 10. Significantly, variables such as race, income, participation in food assistance programs, and ownership of housing and vehicles collectively account for approximately 60% of the variations in both the SFI and TFI, with the largest contribution stemming from racial disparities. Regional fixed effects explain around 8.7% and 8.3% of the variation in the SFI and TFI, respectively. This finding aligns with evidence suggesting that spatial disparities correlate with FI and structural FI, as demonstrated in Figure 11. Further analysis reveals that educational attainment and food assistance program participation account for a greater proportion of the variation in the SFI than in the TFI. This distinction underscores these factors' critical role in mitigating structural FI.

6. Conclusions and Discussion

In conclusion, the primary objective of this study was to examine the structural dynamics of FS in the United States. Building on advances in poverty research, we utilized asset holdings—highlighting structural barriers to economic mobility—to develop a new measure of household FS. This asset-based measure, informed by methodologies from existing literature, enables an exploration of the structural aspects of FI. We define household FS through the SPFS (or asset based PFS), calculated as the likelihood that a household's financial assets meet or exceed the minimum financial resources required to meet basic needs for at least three months. Furthermore, we validate the SPFS against the USDA's official HFSSM based estimates through a series of tests. This measure allows us to comprehensively delineate the structural dynamics of FS by examining

structural and stochastic mobility of the dynamics, analyzing the persistence and duration of FI episodes, decomposing these phenomena into their structural and stochastic components, and identifying the most vulnerable subgroup.

Using the newly measured SPFS and PSID data from 2001-2019, we estimate that approximately 80% of the representative sample successfully maintained food secure, bolstered by adequate financial asset holdings, without experiencing intermittent FI. Among the 20% of households that experience FI, about 85% face structural rather than stochastic challenges attributable to inadequate financial assets, with over half suffering from FI for at least two survey waves (exceeding three years).

U.S. households that are structurally food insecure—defined as both asset-poor and food insecure—are more likely to experience immobility during transitions between FS statuses and to suffer from persistent FI over the long term. Furthermore, the duration of FI in a household directly correlates with increased difficulty of escaping it. Stochastic shocks to food access typically trigger short-term FI, but the longer spell lengths primarily arise from a lack of financial assets—a fundamental structural barrier. Additionally, pronounced business cycles are significantly and positively associated with the duration and persistence of FI in the United States.

The findings also reveal that households headed by non-Whites, female, individuals without a high school diploma, the disabled, single parents, SNAP recipients, and those lacking homeownership or vehicle ownership show a greater tendency towards structural immobility and downward mobility compared to their counterparts, significantly elevating their risk of persistent and structural FI. Negative shocks, such as ending SNAP participation, are linked to a high entry rate into FI. Furthermore, the loss of vehicle ownership or the onset of a disability is associated with the highest rates of persistent FI. Race, income, food assistance participation, and asset

ownership (home and vehicles) together explain over 60% of the variance in the estimated FI by SPFS, particularly structural FI. Notably, educational attainment, Child Meal program participation, and unemployment shocks are more closely associated with structural FI than overall FI. Beyond these household characteristics, FI—especially structural FI—is intricately linked to geographical locations, subject to various short-run and long-run regional shocks.

Our study enhances the understanding of FI's intertemporal dynamics and persistence. In accordance with the recent studies (Lee et al., 2023; Ryu & Bartfeld, 2012), we confirm that most U.S. households never experience FI, and the persistence of FI is positively associated with their current duration and economic downturns. Additionally, the links between FI and predictors such as educational attainment, gender, race, income, and food assistance programs align with existing literature. A key novelty of our study is its emphasis on structural FI, estimated through household financial asset holdings from 2001 to 2019. We find approximately 85% of FI cases are structural, originating from inadequate financial assets and consequently more likely to experience persistent FI with longer spell length. This finding starkly contrasts with those of Lee et al., who report that over half of the cases are chronic, and with Jansen (2017), who identifies 54% of FI cases as persistent within particularly disadvantaged populations. Conversely, prior cohort studies Hernandez et al. (2014); Ryu and Bartfeld (2012); Wilde et al. (2010) using official HSFM typically describe FI as episodic or transient on three or more consecutive assessments of FI. Our findings underscore the critical role of financial assets holdings in maintaining FS among U.S. household.

Our study establishes that structural barriers, rather than stochastic shocks, are the primary drivers of FI among U.S. households, underscoring the necessity for targeted policy interventions. Notably, non-white females with high school education or less are the most vulnerable,

consistently experiencing structural immobility even during recession periods. Policies aimed at dismantling these barriers for these at-risk groups should enhance economic support and asset accumulation like family tax credits, reduce racial disparities, promote educational attainment, and ensure the availability of essential resources such as housing and food assistance programs (including SNAP, WIC, Child Meal, and Elderly Meal Programs). Interestingly, groups traditionally viewed as less vulnerable, such as white males with college degrees, have also faced significant wealth losses during the Great Recession, potentially leading to persistent FI. Targeting these individuals with programs designed to provide short-term safety nets like food assistance and unemployment insurance, could be effective. Additionally, the variability of FI across regions suggests the need for localized policies that consider unique economic conditions and structural vulnerabilities.

It is essential to recognize the limitations of this study and suggest some directions for future studies. First, the sample does not include the immigrant subpopulations, who are generally more prone to FI than their native counterparts; this omission could introduce an upward bias in our estimates of FI. Second, our analysis is limited to households with a consistent head; however, changes such as marital status alterations, deaths, or household splits may influence FI. Controlling for differences in local food prices, housing prices or state-specific assistance programs may further reduce spatial variation. Additionally, incorporating vehicle and home mortgage status, along with credit card debt, into our model might be necessary. But Brewer (2020) found that credit card and housing debt is weakly linked to reduced food insecurity when controlling for individual and household characteristics. And our model already accounts for changes in home and vehicle ownership, reflecting variations in the related disposable financial resources. However, we should consider including unpaid medical bills and other unsecured debts (Brewer, 2020), such

as student loans, in our model to improve its accuracy in predicting household food insecurity. Finally, our SPFS measure is based on the static asset threshold which is an arbitrarily defined living standard and fail to reflect potential changes in asset values and future returns. Consequently, it cannot reliably predict whether households currently in FI will persist so in the long run. Future research could follow the poverty literature to investigate those trapped in FI by finding a dynamic asset threshold. Further studies can explore how assistance programs variably impact structural versus stochastic FI.

Reference

Beverly, S., Sherraden, M., Cramer, R., Williams Shanks, T., Nam, Y., & Zhan, M. (2008). Determinants of asset holdings. *Asset building and low-income families*, 89–151.

Bickel, G., Nord, M., Price, C., Hamilton, W., Cook, J., et al. (2000). Guide to measuring household food security. Revised.

Boateng, G. O., Neilands, T. B., Frongillo, E. A., & Young, S. L. (2018). Best practices for developing and validating scales for health, social, and behavioral research: a primer. *Frontiers in public health*, 6, 366616.

Brewer, M. (2020). Household debt and children's risk of food insecurity. Social Problems, 67(3), 565-584.

Carter, M. R., & Barrett, C. B. (2006). The economics of poverty traps and persistent poverty: An asset-based approach. The Journal of development studies, 42(2), 178199.

Carter, M. R., & May, J. (2001). One kind of freedom: Poverty dynamics in post-apartheid South Africa. *World development*, 29(12), 1987-2006.

Chang, Y., Chatterjee, S., & Kim, J. (2014). Household finance and food insecurity. *Journal of Family and Economic Issues*, 35, 499–515.

Cissè, J. D., & Barrett, C. B. (2018). Estimating development resilience: A conditional moments-based approach. *Journal of Development Economics*, 135, 272–284.

Coleman-Jensen, A., Rabbitt, M. P., Gregory, C. A., & Singh, A. (2017). Household food security in the United States in 2016.

Coleman-Jensen, A., Rabbitt, M. P., Gregory, C. A., & Singh, A. (2018). Household food security in the United States in 2017.

De Marco, M., & Thorburn, S. (2008). The association between sociodemographic factors, participation in assistance programs, and food insecurity among Oregon residents. *Journal of Hunger & Environmental Nutrition*, 3(1), 36–50.

Dercon, S., Shapiro, J. S., et al. (2007). Moving on, staying behind, getting lost: Lessons on poverty mobility from longitudinal data. *Moving out of Poverty*, 1, 77–126.

Duffy, P. A., & Zizza, C. A. (2016). Food insecurity and programs to alleviate it: what we know and what we have yet to learn. *Journal of Agricultural and Applied Economics*, 48(1), 1–28.

Fitzpatrick, K., & Ver Ploeg, M. (2010, September). On the road to food security? Vehicle ownership and access to food. In *Conference on SES and Health Across Generations and Over the Life Course, Ann Arbor, Michigan, September* (pp. 23-24).

Furness, B. W., Simon, P. A., Wold, C. M., & Asarian-Anderson, J. (2004). Prevalence and predictors of food insecurity among low-income households in Los Angeles County. *Public health nutrition*, 7(6), 791–794.

Grafova, I. B. (2011). Financial strain and smoking. *Journal of Family and Economic Issues*, 32, 327–340.

Grineski, S. E., Morales, D. X., Collins, T. W., & Rubio, R. (2018). Transitional dynamics of household food insecurity impact children's developmental outcomes. *Journal of Developmental & Behavioral Pediatrics*, 39(9), 715–725.

Gundersen, C., & Gruber, J. (2001). The dynamic determinants of food insufficiency. In *Second food security measurement and research conference* (Vol. 2, pp. 11-2). Food Assistance and Nutrition Research Report.

Guo, B. (2011). Household assets and food security: Evidence from the survey of program dynamics. *Journal of family and economic issues*, 32, 98–110.

Haveman, R., & Wolff, E. N. (2004). The concept and measurement of asset poverty: Levels, trends and composition for the us, 1983–2001. *The Journal of Economic Inequality*, 2, 145–169.

Heeringa, S. G., Berglund, P. A., & Khan, A. (2011). Sampling error estimation in design-based analysis of the PSID Data. *Ann Arbor: Survey Research Center–Institute for Social Research, University of Michigan*, 11-05.

Hernandez, D. C., Marshall, A., & Mineo, C. (2014). Maternal depression mediates the association between intimate partner violence and food insecurity. *Journal of women's health*, 23(1), 29–37.

Hofferth, S. L. (2004). Persistence and change in the food security of families with children, 1997-99.

Jalan, J., & Ravallion, M. (1998). Transient poverty in postreform rural china. J*ournal of Comparative Economics*, 26(2), 338–357.

Jalan, J., & Ravallion, M. (2000). Is transient poverty different? evidence for rural china. *The Journal of Development Studies,* 36(6), 82–99.

Jansen, E. C., Kasper, N., Lumeng, J. C., Herb, H. E. B., Horodynski, M. A., Miller, A. L., ... & Peterson, K. E. (2017). Changes in household food insecurity are related to changes in BMI and diet quality among Michigan Head Start preschoolers in a sex-specific manner. Social Science & Medicine, 181, 168-176.

Knippenberg, E., Jensen, N., & Constas, M. (2019). Quantifying household resilience with high frequency data: Temporal dynamics and methodological options. *World Development*, 121, 1–15.

Lawson, D., & McKay, A. (2002). Chronic poverty: a review of current quantitative evidence. *Chronic Poverty Research Centre Working Paper*(15).

Lee, S., Barrett, C. B., & Hoddinott, J. F. (2023). Food Security dynamics in the united states, 2001–2017. *American journal of agricultural economics*.

Liese, A. D., Sharpe, P. A., Bell, B. A., Hutto, B., Stucker, J., & Wilcox, S. (2021). Persistence and transience of food insecurity and predictors among residents of two disadvantaged communities in South Carolina. *Appetite*, *161*, 105128.

Loopstra, R., & Tarasuk, V. (2013). Severity of Household Food Insecurity Is Sensitive to Change in Household Income and Employment Status among Low-Income Families1–3. *The Journal of nutrition*, 143(8), 1316-1323.

McKernan, S. M., Ratcliffe, C., Steuerle, E., & Zhang, S. (2014). Impact of the great recession and beyond. *Urban Institute. Washington DC: Urban Institute (April 2014). https://www. urban.org/sites/default/files/alfresco/publication-pdfs/413102-Impact-of-the-Great-Recession-and-Beyond. PDF*.

Nam, Y., Ratcliffe, C., & McKernan, S.-M. (2008). Effects of asset tests and ida programs. *Asset building and low-income families*, 153–173.

Naschold, F., & Barrett, C. B. (2011). Do short-term observed income changes overstate structural economic mobility? *Oxford Bulletin of Economics and Statistics,* 73(5), 705–717.

Ogaki, M., & Atkeson, A. (1997). Rate of time preference, intertemporal elasticity of substitution, and level of wealth. *Review of Economics and Statistics*, 79(4), 564– 572.

Panel Study of Income Dynamics. (2023). Panel Study of Income Dynamics (PSID). University of Michigan. Retrieved from https://psidonline.isr.umich.edu/ doi: {10.3886/ICPSR00001}

Pfeffer, F. T., Schoeni, R. F., Kennickell, A., & Andreski, P. (2016). Measuring wealth and wealth inequality: Comparing two us surveys. *Journal of economic and social measurement*, 41(2), 103–120.

Pirog, M., Gerrish, E., & Bullinger, L. (2017). TANF and SNAP Asset Limits and the Financial Behavior of Low-Income Households. *Pew Charitable Trusts. https://www. pewtrusts. org//media/assets/2017/09/tanf_and_snap_asset_limits_and_the_financial_behavior_of_low_income_households. pdf*.

Rabbitt, M. P., Hales, L. J., Burke, M. P., & Coleman-Jensen, A. (2023). Household food security in the United States in 2022.

Ratcliffe, C., McKernan, S.-M., Wheaton, L., Kalish, E. C., Ruggles, C., Armstrong, S., & Oberlin, C. (2016). Asset limits, snap participation, and financial stability.

Ribar, D. C., & Hamrick, K. S. (2003). Dynamics of poverty and food sufficiency.

Ryu, J.-H., & Bartfeld, J. S. (2012). Household food insecurity during childhood and subsequent health status: The early childhood longitudinal study—kindergarten cohort. *American Journal of Public Health*, 102(11), e50–e55.

Smeeding, T. (2012). Income, wealth, and debt and the Great Recession. *Report. New York, NY, The Russell Sage Foundation and the Stanford Center on Poverty and Inequality*.

Tiehen, L., Vaughn, C. N., & Ziliak, J. P. (2020). FI in the psid: A comparison with the levels, trends, and determinants in the cps, 1999–2017. *Journal of Economic and Social Measurement*, 45(2), 103–138.

Upton, J. B., Cissé, J. D., & Barrett, C. B. (2016). Food security as resilience: reconciling definition and measurement. *Agricultural economics*, *47*(S1), 135-147.

Vaitla, B., Cissé, J. D., Upton, J., Tesfay, G., Abadi, N., & Maxwell, D. (2020). How the choice of food security indicators affects the assessment of resilience—an example from northern Ethiopia. *Food Security*, *12*, 137-150.

West, D. A., & Price, D. W. (1976). The effects of income, assets, food programs, and household size on food consumption. *American Journal of Agricultural Economics*, 58(4), 725–730.

Wilde, P. E., Nord, M., & Zager, R. E. (2010). In longitudinal data from the survey of program dynamics, 16.9% of the us population was exposed to household food insecurity in a 5-year period. *Journal of Hunger & Environmental Nutrition*, 5(3), 380–398.

Ziliak, J. P., & Gundersen, C. (2016). Multigenerational families and food insecurity. *Southern Economic Journal*, 82(4), 1147–1166.

Zimmerman, F. J., & Carter, M. R. (2003). Asset smoothing, consumption smoothing and the reproduction of inequality under risk and subsistence constraints. *Journal of Development Economics*, 71(2), 233–260.

Tables and Figures

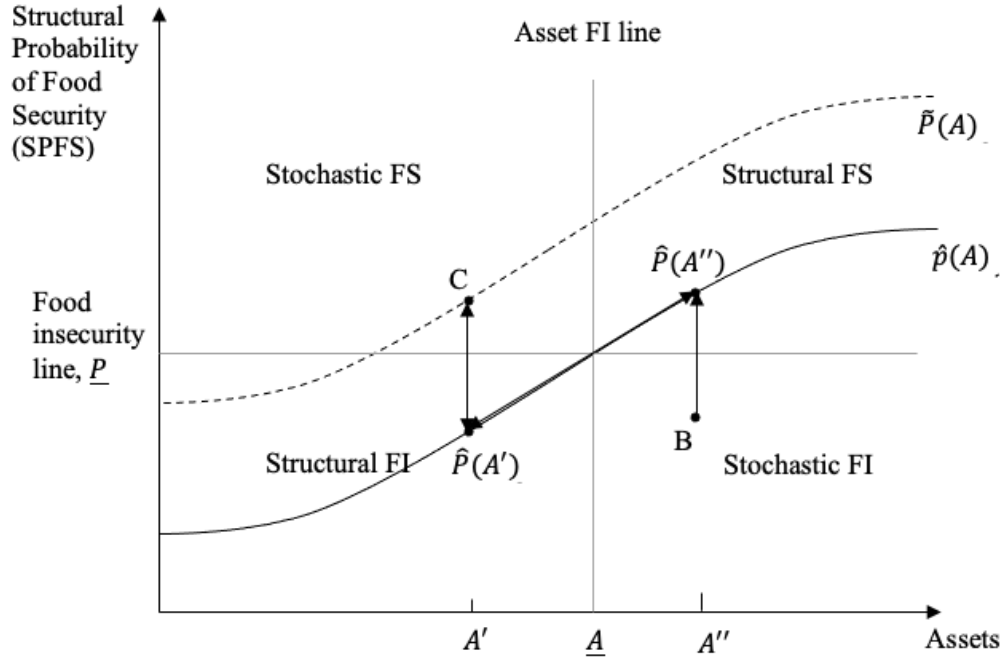

Figure 1. Conceptual Framework of SPFS and Static Asset FI at Single Period.

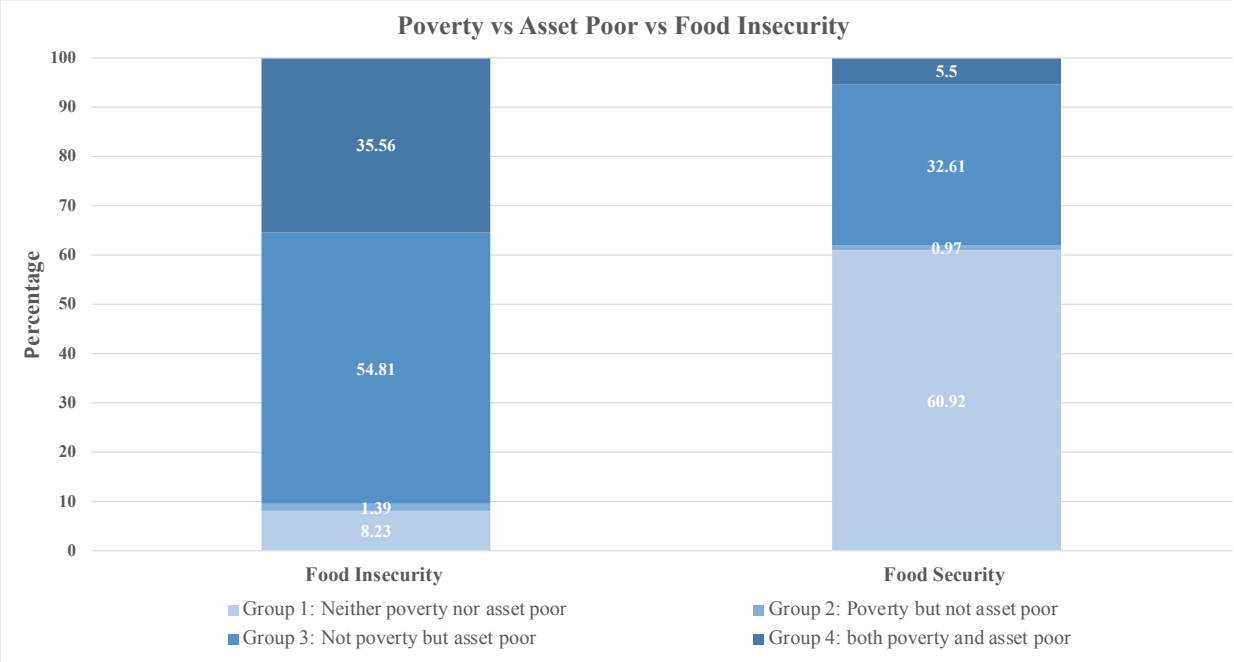

Figure 2. The Distribution of Households' FS Status by Different Economic Conditions.

Note: This distribution uses the PSID sample in 2001, 2003, 2015, 2017 and 2019 during which the Household FS Survey Measure (HFSSM) is included. The household poverty is defined by the household-year specific US Census Bureau's poverty line. The asset poor is defined by whether household financial asset per capital is above or below the asset poverty line (25% of US Census Bureau's poverty line).

Period t-1		Period t			
		Food insecurity (FI)		Food security (FS)	
		Stochastic FI	Structural FI	Stochastic FS	Structural FS
FI	Stochastic FI	—	↓	↑	↑
	Structural FI	↑	—	↑	↑
FS	Stochastic FS	↓	↓	**Never FI**	
	Structural FS	↓	↓		

—Immobile;
Bold Arrow in bold: structural mobile;
Not bold Arrow: stochastic mobile

Figure 3. Decomposition of FI Transitions Based on Static Asset threshold

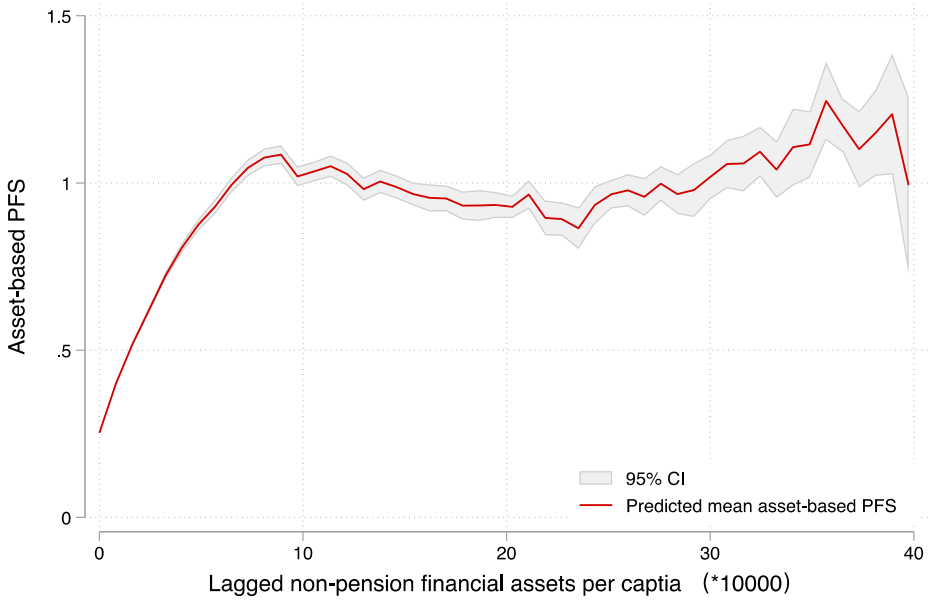

Figure 4. Estimated SPFS Dynamics.

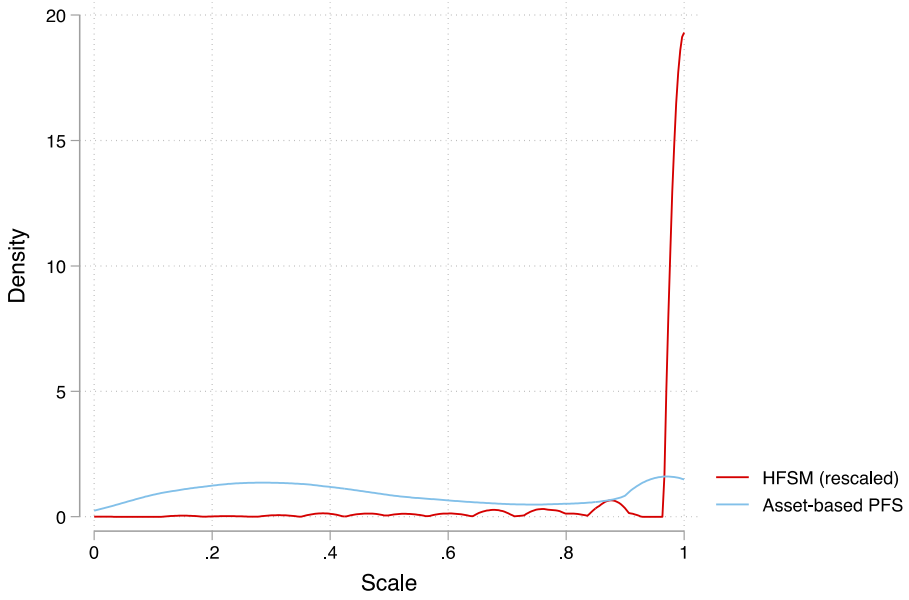

Figure 5. Density Distribution of FS Indicators.

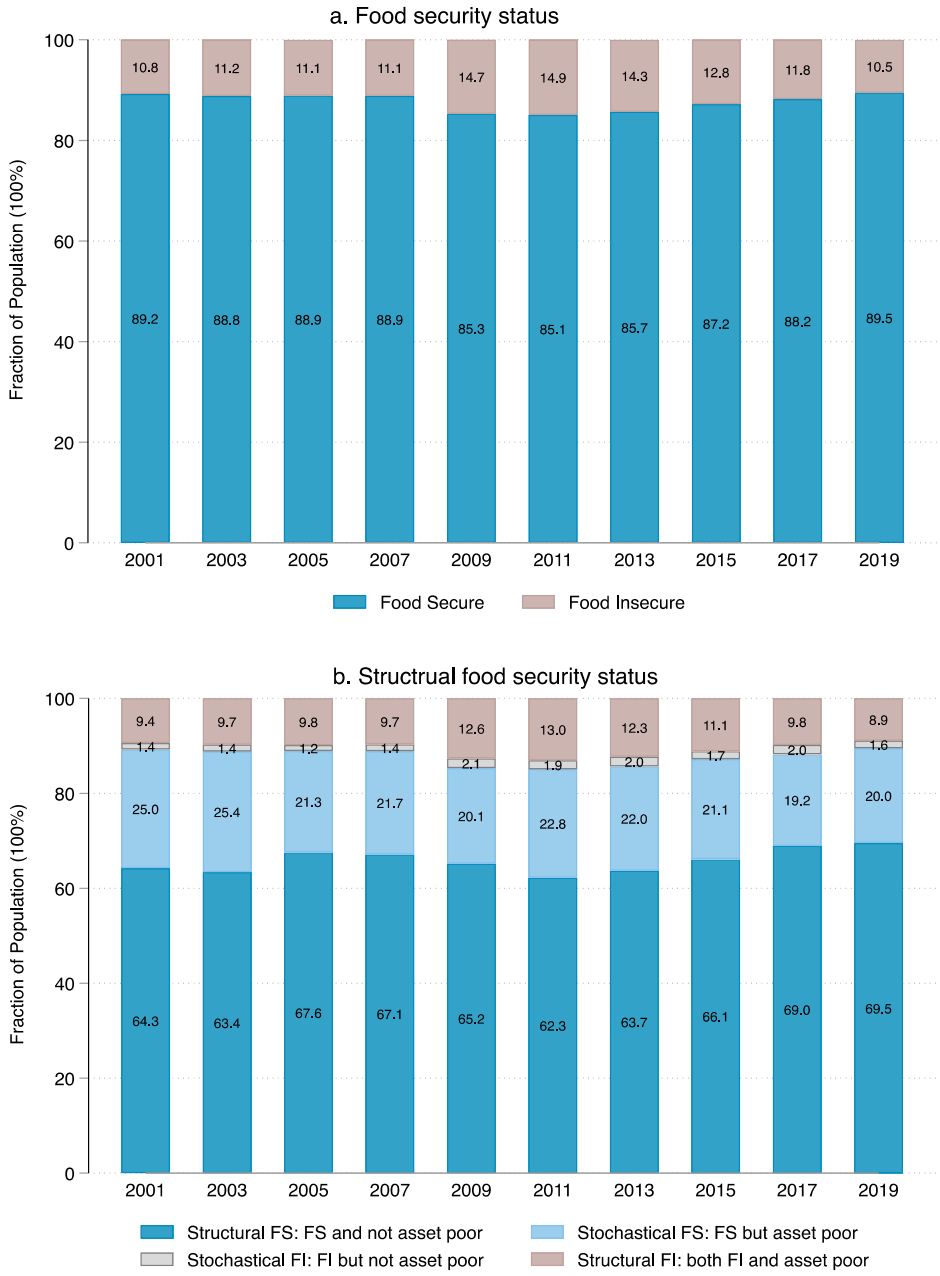

Figure 6. Prevalence of FS Status and Structural FS Status Estimated by SPFS.

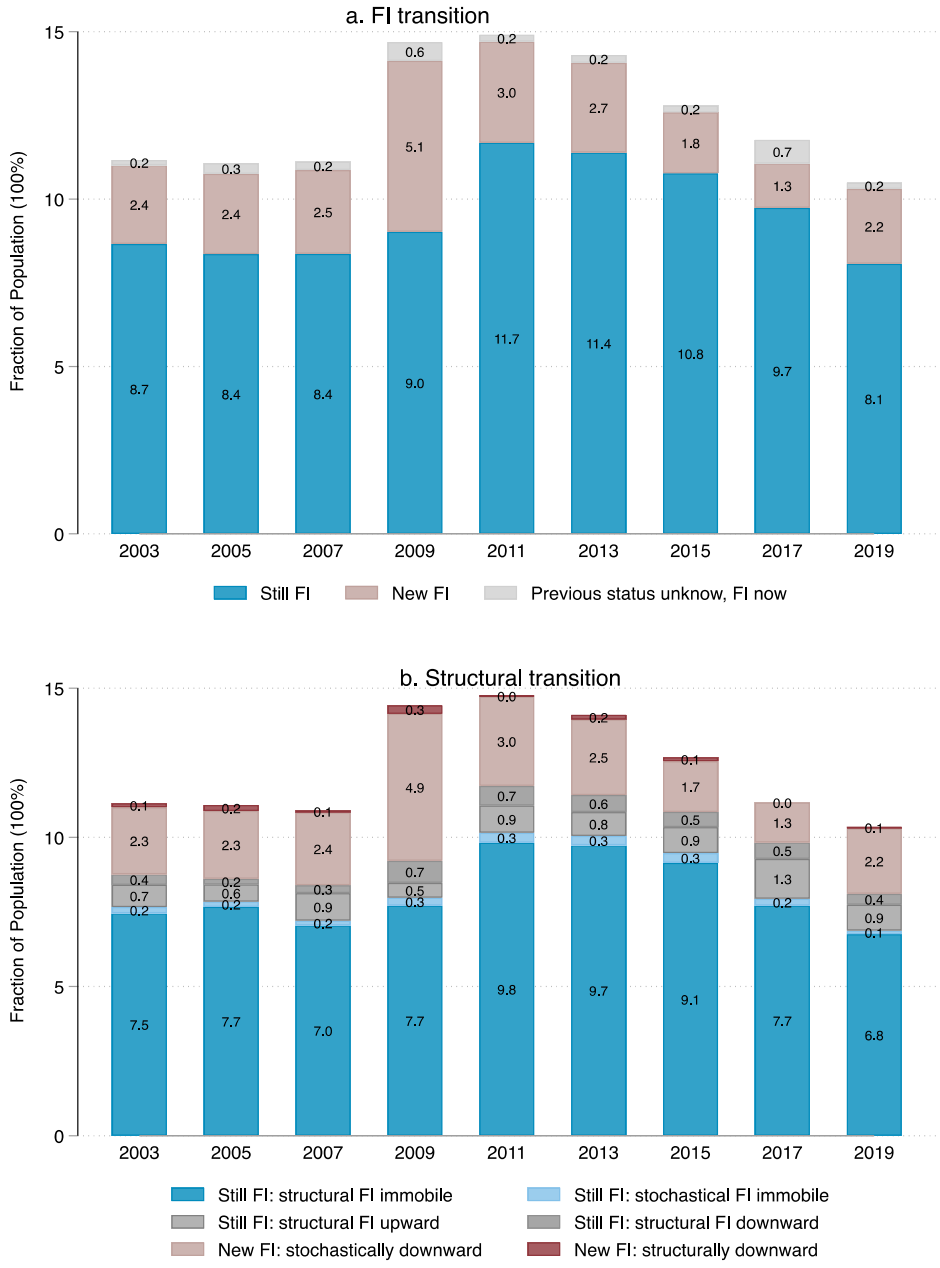

Figure 7. Change In Estimated Structural FI Status.

Note: Sample includes households from 2003 to 2019. "Still FI" and "New FI" refer to households that were or were not estimated to be food insecure under the SPFS (Section 5 has the detailed explanation of how we categorize FI status with the SPFS) in the preceding survey wave, respectively. "Previous status unknown" refers to households whose SPFS in the preceding wave is missing. We further decompose the changes in FS status into structural and stochastic mobile based on Figure 7b. The prevalence reported at the top of each bar matches the official FSSS by construction.

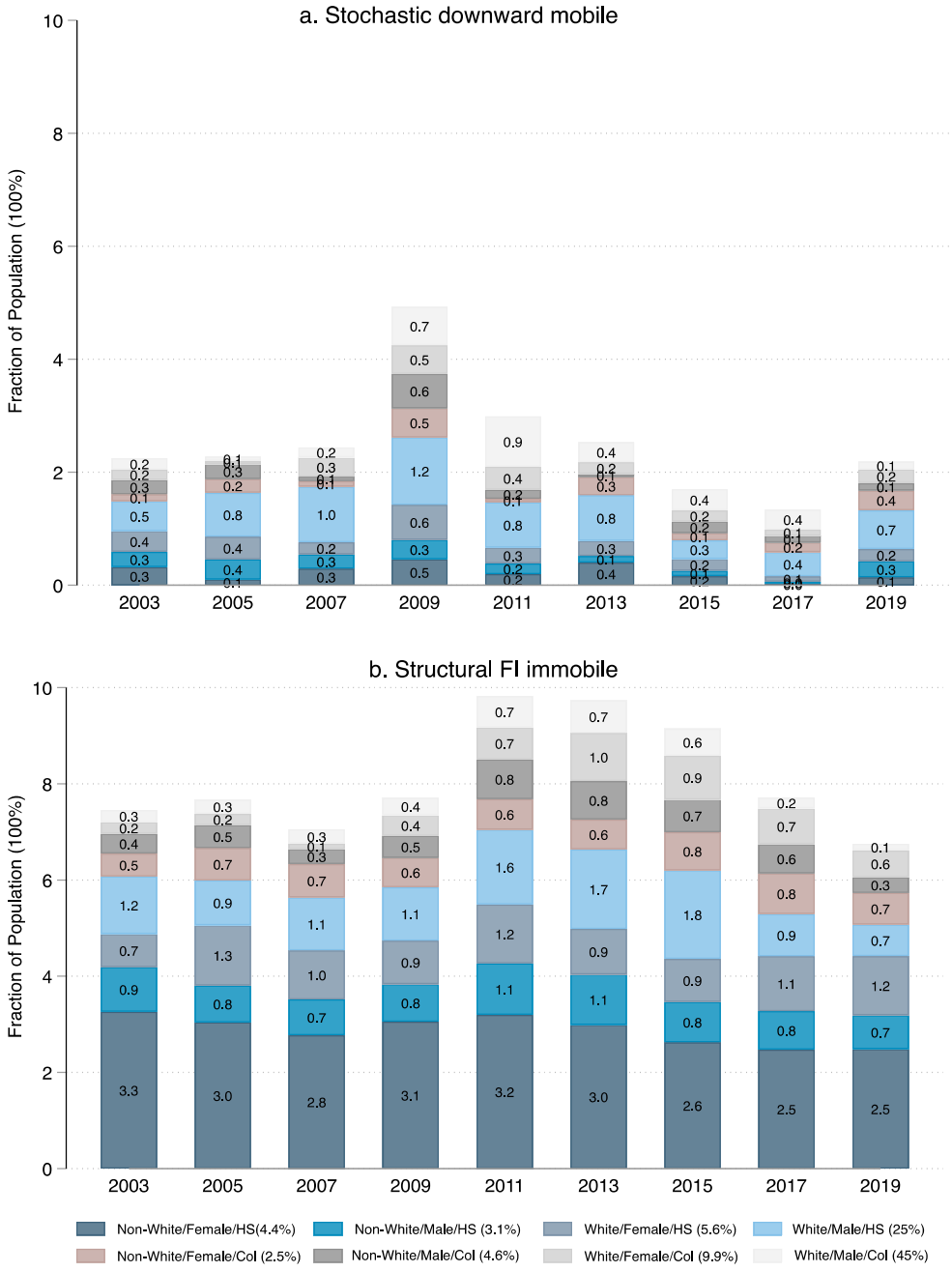

Figure 8. Estimated Stochastic Downward Mobile and Structural FI Immobile by Subgroups.

Note: "stochastic downward mobility" (Panel A) and "structural FI immobile" (Panel B), capture most of variations in "Newly FI" and "Still in FI", respectively. A household is deemed stochastically downwardly mobile if it moves from FS to stochastical FI, or from stochastical FS to FI. A household remains structurally immobile if it was structurally food insecure in both consecutive periods. "HS" indicates the head has no education beyond high school. "Col" indicates that the head has at least some college education. "Non-White" indicates the head's race is not White. Percentages in parentheses report each category's share of the total population.

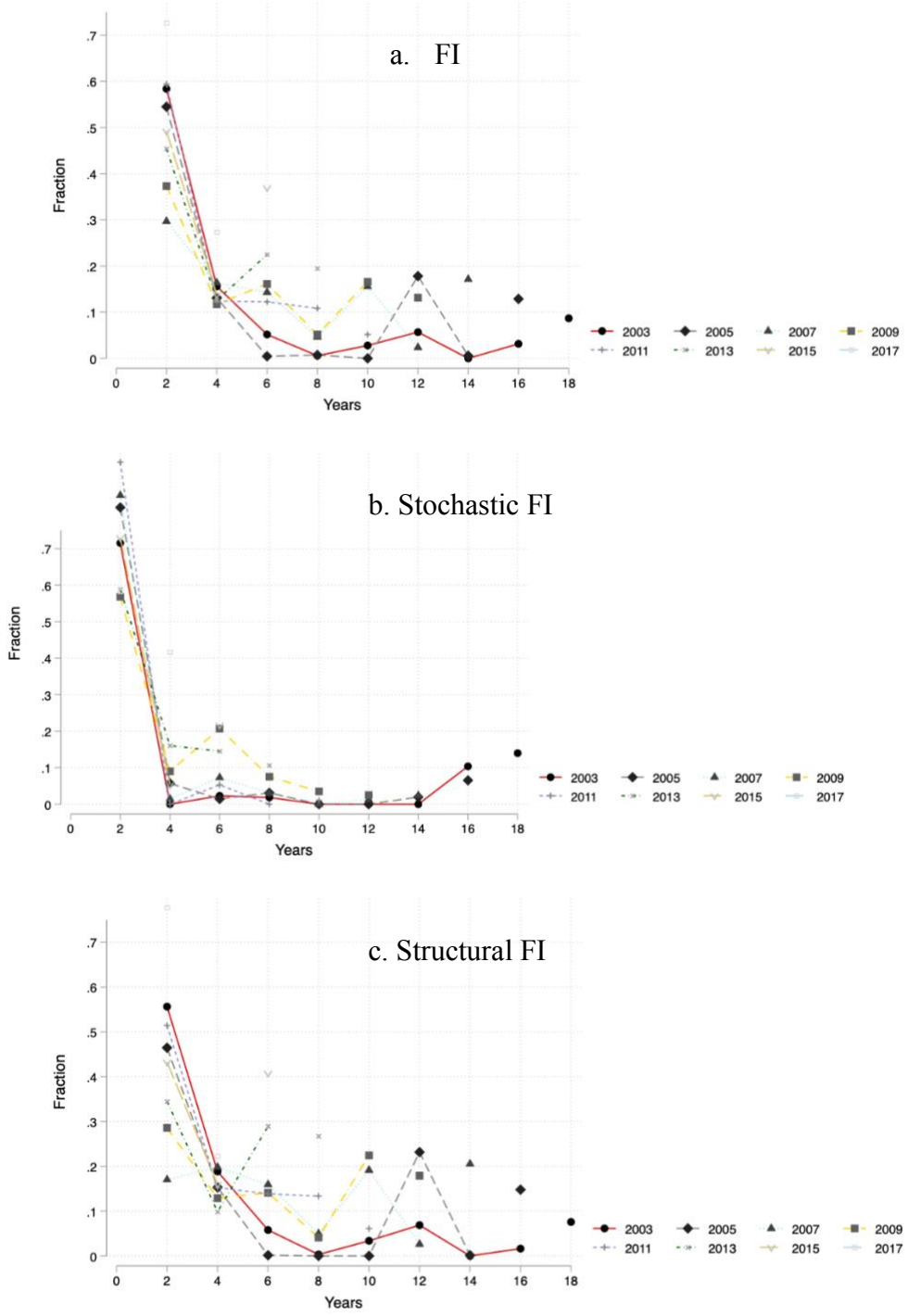

Figure 9. Spell Length of Estimated FI by SPFS Measure (2003–2019).

Note: Sample includes households with SPFS observations from 2001 to 2019. The unconnected rightmost dots reflect the right-censored share. The different panels from a to c represents the estimated FI status at initial period.

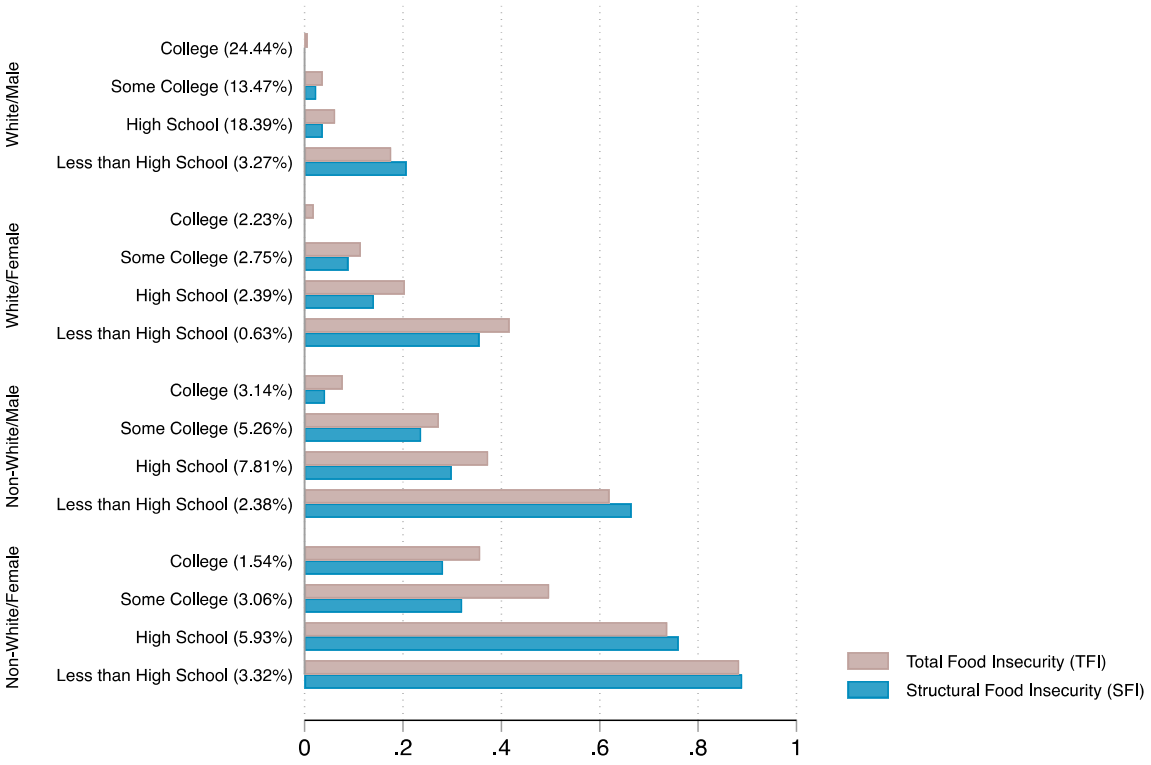

Figure 10. Estimated Structural FI by Subgroups.

Note: Sample include households with non-missing SPFS for 5 or more years from 2001 to 2019. The horizontal axis indicates the estimated mean of TFI and SFI for each subgroup. The vertical axis shows the categories or subgroup to which household heads belong. The percentage in parentheses indicates that category's population share. "Some college" indicates the household head at least attended college. "College" indicates the household head earned at least a bachelor's degree. Because PSID does not report educational status for every individual in every round, we base the head's educational status on the earliest available status recorded for that individual in the 2001–2019 period.

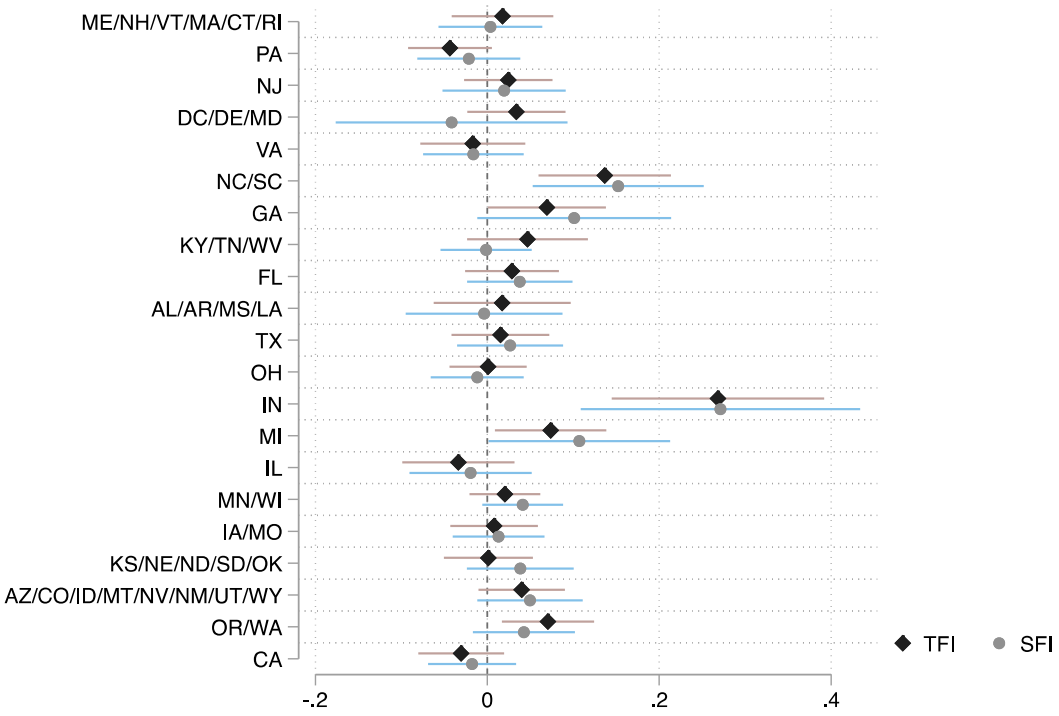

Figure 11. Spatial Variation of TFI/SFI.

Note: TFI and SFI are estimated total FI and structural FI by permanent approach. Base region is NY. AK, HA, and other U.S. territories are excluded. We aggregate states with a limited number of observations with neighboring states that exhibit similar economic characteristics, thereby creating a consolidated region for analysis (so for example, we combine Delaware, Maryland, and Washington DC into one region).

Table 1. Description of Variables and Summary Statistics.

Variable	Description	Total	
		Mean	SD
Age	household head's age	57.45	12.97
Race			
White	binary, =1 if household head is White	0.85	0.35
Non-white	binary, =1 if household head is non-White	0.15	0.35
Female	binary, =1 if household head is female	0.22	0.42
Highest Education Degree			
Less than high school	binary, =1 if household head neither completed high school nor achieved GED	0.08	0.26
High school	binary, =1 if household head completed high school but did not attend college (attended school 12 years)	0.30	0.46
Some college	binary, =1 if household head attended college but did not hold the bachelor's degree (attended school between 13 to 15 years)	0.25	0.43
College	binary, =1 if household head completed the bachelor's degree (attended school 16 years or longer)	0.37	0.48
Employed	binary, =1 if household head is employed	0.66	0.47
Disabled	binary, =1 if household head self-report as physical or nerous condion that limit them work	0.19	0.39
Income per captia	Total annual household income per capita (thousand dollars)	41.67	34.68
Household financial assets per capita	Total annual household financial assets per capita (ten thousand dollars)	5.86	13.89
Family Size	Total number of people in household	2.25	1.24
% of children	Percentage of the number of children (0-17) to total number of family members	0.10	0.19
Household composition			
Single without child	binary, =1 if single household without children	0.33	0.47
Single with children	binary, =1 if single household with children	0.04	0.19
Married without children	binary, =1 if married household without children	0.44	0.50
Married with child	binary, =1 if smarried household with children	0.19	0.39
Food stamp/SNAP recipient	binary, =1 if household received food stamp/SNAP any time this year	0.05	0.22

WIC recipient	binary, =1 if household received WIC any time this year	0.01	0.10
Elderly Meal recipient	binary, =1 if household received Elderly Meal any time this year	0.01	0.08
Home ownership			
Own	binary, =1 if household own home	0.78	0.41
Rent	binary, =1 if household rent home	0.19	0.39
Neither	binary, =1 if household neither own or rent home	0.03	0.18
Vehicle ownership	binary, =1 if household own vehicle	0.92	0.26
Shocks			
No longer received food stamp/SNAP	binary, =1 if household receive SNAP in previous wave (2 years ago) but not receive in current wave	0.26	0.12
No longer employed	binary, =1 if household was employed in previous wave (2 years ago but not employed in current wave	0.04	0.19
No longer married	binary, =1 if household was married in previous wave (2 years ago) but not married in current wave	0.01	0.11
Became disabled	binary, =1 if household was not disabled in previous wave (2 years ago) but diabled in current wave	0.07	0.26
no longer own home	binary, =1 if household owned home in previous wave (2 years ago) but not own in current wave	0.02	0.15
no longer own vehicle	binary, =1 if household owned vehicle in previous wave (2 years ago) but not own in current wave	0.02	0.14
Region			
Northeast	binary, =1 if household is in ME/NH/VT/MA/CT/RI/NY	0.10	0.30
Mid-Atlantic	binary, =1 if household is in PA/NJ/DC/DE/MD/VA	0.15	0.36
South	binary, =1 if household is in NC/SC/GA/KY/TN/WV/FL/AL/AR/MS/LA/TX	0.25	0.43
Midwest	binary, =1 if household is in OH/IN/MI/IL/MN/WI/IA/MO	0.27	0.44
West	binary, =1 if household is in KS/NE/ND/SD/OK/AZ/CO/ID/MT/NV/NM/UT/WY/OR/WA/CA	0.22	0.42
SPFS	The Probability of FS ([0, 1]) estimated by household financial asset holdings	0.51	0.31

Note: The PSID sample consists of the households from the SRC and the SEO sample surveyed from 2001 to 2019. Top and bottom 1% values of income and household assets values are winsorized.

Table 2. Estimates of Annual Per Capita Household Financial Assets (ten thousand).

	A_{ijt} (1)	A_{ijt} (2)	A_{ijt} (3)	A_{ijt} (4)	A_{ijt} (5)	A_{ijt} (6)	A_{ijt} (7)
A_{ijt-1}	0.057***	0.143***	0.242***	0.371***	0.507***	0.645***	0.796***
	(0.004)	(0.006)	(0.010)	(0.016)	(0.023)	(0.033)	(0.047)
${A^2}_{ijt-1}$		-0.001***	-0.006***	-0.018***	-0.038***	-0.067***	-0.111***
		0.000	0.000	(0.001)	(0.002)	(0.005)	(0.010)
${A^3}_{ijt-1}(*10^2)$			0.005***	0.035***	0.124***	0.324***	0.744***
			0.000	(0.003)	(0.009)	(0.027)	(0.076)
${A^4}_{ijt-1}(*10^4)$				-0.021***	-0.173***	-0.747***	-2.555***
				(0.002)	(0.013)	(0.071)	(0.291)
${A^5}_{ijt-1}(*10^7)$					0.857***	8.145***	46.408***
					(0.069)	(0.839)	(5.663)
${A^6}_{ijt-1}(*10^9)$						-3.363***	-42.370***
						(0.372)	(5.433)
${A^7}_{ijt-1}(*10^{11})$							15.294***
							(2.034)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AIC	86.581	82.932	81.350	80.350	79.678	79.311	79.004
T-test[a]	0.000***	0.000***	0.000***	0.000***	0.000***	0.291	

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

[a] P-value of the t-test on the equality of means between predicted values from the specific estimation and the 7th order polynomial specification.

Table 3. Marginal Effects—Generalized Linear Model Estimates.

VARIABLES	Financial Assets per capita (1)	Variance (financial Assets per capita) (2)	SPFS (3)
(Lagged) Financial Assets per capita	4.489***	168.838***	0.161***
	(0.330)	(29.072)	(0.0002)
Age	0.113	0.159	0.007***
	(0.105)	(8.007)	(0.0000)
Non-white	0.420	227.898	-0.116***
	(0.970)	(137.679)	(0.0001)
Married	-0.091	-107.975	0.081***
	(0.726)	(80.919)	(0.0001)
Female	-1.354*	-83.629*	-0.008***
	(0.710)	(47.099)	(0.0000)
High school	1.308*	59.086**	0.022***
	(0.667)	(22.459)	(0.0000)
Some college	2.121***	84.234***	0.056***
	(0.650)	(23.621)	(0.0001)
College	4.107***	192.012***	0.071***
	(0.737)	(37.223)	(0.0001)
Employed	1.024*	-76.222**	0.006***
	(0.590)	(35.077)	(0.0000)
Disabled	-1.099	-53.958	-0.018***
	(0.788)	(52.479)	(0.0000)
ln(income per capita)	1.619***	41.235*	0.051***
	(0.330)	(21.694)	(0.0001)
Family size	-0.964***	-34.992	-0.020***
	(0.267)	(25.852)	(0.0000)
% of children	0.108	-49.731	0.044***
	(1.656)	(119.003)	(0.0001)
Received Food Stamp/SNAP	-2.739*	-75.072	-0.275***
	(1.374)	(88.302)	(0.0220)
Received Child Meal	-3.763***	-165.131***	-0.172***
	(0.416)	(23.416)	(0.0092)
Received WIC	-1.133	-156.368***	0.173***
	(1.379)	(38.584)	(0.0002)
Received Elderly Meal	-4.364***	-183.161***	-0.015
	(0.677)	(31.173)	(0.0308)
Rent	-2.373***	-117.526***	-0.062***
	(0.589)	(33.052)	(0.0001)
Neither owns nor rents	-2.813***	-149.202***	-0.048***
	(0.979)	(42.854)	(0.0001)
Not own vehicle	0.066	93.798	-0.075***
	(1.765)	(136.739)	(0.0001)
No longer receive Food	-5.259***	-354.054***	-0.159***

Stamp/SNAP			
	(1.262)	(94.767)	(0.0331)
No longer employed	-0.716	-137.854***	0.049***
	(0.811)	(50.528)	(0.0001)
No longer married	1.199	-51.801	0.087***
	(1.277)	(84.741)	(0.0001)
Became disabled	1.256	146.225*	-0.048***
	(1.007)	(83.342)	(0.0001)
No longer own home	2.230***	99.628	0.067***
	(1.062)	(75.588)	(0.0001)
No longer own vehicle	-4.345*	-276.487**	-0.012***
	(2.198)	(134.990)	(0.0000)
N	21,115	21,115	21,114
Population size	482,367.48	482,367.48	482,363.27

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Gamma distribution is assumed for Column (1) and (2). For (3), a binomial distribution is assumed.

Table 4. Regression of the HFSSM on SPFS.

VARIABLES	HFSSM (1)	HFSSM (2)	HFSSM (3)	HFSSM (4)
SPFS	0.102***	0.481***	0.108***	0.515***
	(0.009)	(0.048)	(0.010)	(0.050)
$SPFS^2$		-0.334***		-0.356***
		(0.036)		(0.037)
Constant	0.916***	0.842***	0.943***	0.853***
	(0.007)	(0.014)	(0.009)	(0.016)
Subpop. no. obs	10,505	10,504	10,505	10,504
Subpop. size	255,552.09	255,547.87	255,552.09	255,547.87
R-squared	0.086	0.140	0.106	0.163
State & year FE	NO	NO	YES	YES

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Table 5. FS Indicators and Their Correlates.

VARIABLES	Continuous HFSSM (1)	Continuous SPFS (2)	Binary HFSSM (1=Food Secure) (3)	Binary SPFS (1=Food Secure) (4)
Age	-0.001	0.007***	-0.002	0.000
	(0.001)	(0.002)	(0.002)	(0.002)
Age^2/1000	0.021***	-0.002	0.034**	0.031
	(0.006)	(0.014)	(0.013)	(0.019)
Non-white	0.002	-0.135***	0.012	-0.189***
	(0.006)	(0.013)	(0.011)	(0.019)
Married	0.004	0.115***	0.007	0.056***
	(0.006)	(0.014)	(0.012)	(0.013)
Female	-0.016*	-0.022	-0.027*	-0.041**
	(0.009)	(0.014)	(0.014)	(0.017)
High school	0.020**	0.027*	0.037**	0.066***
	(0.009)	(0.014)	(0.017)	(0.019)
Some college	0.017	0.076***	0.028	0.094***
	(0.011)	(0.014)	(0.021)	(0.021)
College	0.017	0.169***	0.031*	0.094***
	(0.010)	(0.015)	(0.018)	(0.018)
Employed	0.011***	-0.060***	0.017**	0.016*
	(0.004)	(0.009)	(0.008)	(0.008)
Disabled	-0.033***	-0.069***	-0.048***	-0.035***
	(0.007)	(0.009)	(0.011)	(0.013)
ln(income per capita)	0.019***	0.110***	0.030***	0.045***
	(0.004)	(0.007)	(0.007)	(0.006)
Family size	0.001	-0.041***	0.000	-0.017***
	(0.003)	(0.005)	(0.006)	(0.005)
% of children	0.044***	0.079***	0.074***	0.123***
	(0.012)	(0.024)	(0.026)	(0.026)
Received Food Stamp/SNAP	-0.090***	-0.024	-0.153***	-0.418***
	(0.017)	(0.017)	(0.032)	(0.036)
Received Child Meal	-0.018	0.006	-0.043	-0.196***
	(0.015)	(0.016)	(0.031)	(0.024)
Received WIC	-0.014	0.141***	-0.035	0.167***
	(0.021)	(0.022)	(0.043)	(0.028)
Received Elderly Meal	-0.008	-0.155***	-0.027	-0.037
	(0.030)	(0.032)	(0.053)	(0.047)
Rent	-0.027***	-0.094***	-0.043***	-0.079***
	(0.007)	(0.012)	(0.014)	(0.015)
Neither owns nor rents	-0.012	-0.083***	-0.013	-0.063**
	(0.014)	(0.018)	(0.028)	(0.024)
Not own vehicle	-0.000	-0.036**	-0.017	-0.154***

	(0.019)	(0.017)	(0.037)	(0.032)
No longer receive Food Stamp/SNAP	-0.034**	-0.037**	-0.065*	-0.191***
	(0.017)	(0.016)	(0.036)	(0.033)
No longer employed	-0.020	0.078***	-0.045**	0.017
	(0.012)	(0.014)	(0.020)	(0.015)
No longer married	-0.019	0.064***	-0.045**	0.072***
	(0.014)	(0.018)	(0.021)	(0.022)
Became disabled	0.021**	-0.012	0.020	-0.040**
	(0.009)	(0.011)	(0.016)	(0.016)
No longer own home	0.011	0.048**	0.028	0.083***
	(0.013)	(0.019)	(0.021)	(0.025)
No longer own vehicle	-0.024	-0.025	-0.011	-0.024
	(0.026)	(0.023)	(0.045)	(0.043)
Constant	0.756***	-0.963***	0.617***	0.406***
	(0.043)	(0.085)	(0.088)	(0.097)
Subpop. no. obs	10,505	10,504	10,505	10,504
Subpop. size	255,552.09	255,547.87	255,552.09	255,547.87
R-squared	0.208	0.632	0.164	0.600
State FE	YES	YES	YES	YES
Wave FE	YES	YES	YES	YES

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Table 6. Transitions in Estimated Structural FS Status Over Two Consecutive Waves.

			New FS			Still FI					New FI		
	N	Still FS	All	Stoc upward mobile	Struc upward mobile	All	Stoc FI immobile	Struc FI immobile	Struc upward mobile	Struc downward mobile	All	Stoc downward mobile	Struc downward mobile
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Year													
2003	2010	0.868	0.021	0.020	0.001	0.088	0.002	0.075	0.007	0.004	0.024	0.023	0.001
2005	2021	0.864	0.025	0.022	0.003	0.086	0.002	0.077	0.006	0.002	0.025	0.023	0.002
2007	2088	0.868	0.023	0.021	0.002	0.084	0.002	0.070	0.009	0.003	0.025	0.024	0.001
2009	2080	0.840	0.016	0.013	0.002	0.092	0.003	0.077	0.005	0.007	0.052	0.049	0.003
2011	2131	0.826	0.026	0.024	0.002	0.117	0.003	0.098	0.009	0.007	0.030	0.030	0.000
2013	2113	0.826	0.033	0.031	0.002	0.114	0.003	0.097	0.008	0.006	0.027	0.025	0.002
2015	2102	0.849	0.024	0.022	0.002	0.109	0.003	0.091	0.009	0.005	0.018	0.017	0.001
2017	2105	0.858	0.030	0.026	0.004	0.098	0.002	0.077	0.013	0.005	0.013	0.013	0.000
2019	2102	0.864	0.033	0.028	0.005	0.081	0.001	0.068	0.009	0.004	0.023	0.022	0.001
Gender													
Male	14739	0.911	0.021	0.019	0.002	0.048	0.001	0.038	0.005	0.003	0.020	0.019	0.001
Female	4013	0.642	0.043	0.039	0.004	0.269	0.006	0.232	0.019	0.012	0.046	0.044	0.002
Race													
white	12797	0.918	0.019	0.017	0.002	0.044	0.001	0.037	0.003	0.002	0.019	0.019	0.000
Non-white	5955	0.448	0.066	0.061	0.005	0.420	0.010	0.348	0.039	0.022	0.066	0.061	0.005
Highest Education Degree													
< HS	1714	0.504	0.057	0.050	0.007	0.376	0.004	0.334	0.025	0.012	0.063	0.060	0.003
HS	6412	0.792	0.033	0.031	0.002	0.141	0.004	0.117	0.013	0.007	0.035	0.033	0.002
some Col	4629	0.853	0.033	0.029	0.004	0.087	0.002	0.072	0.008	0.004	0.027	0.027	0.001
Col	5997	0.964	0.011	0.008	0.002	0.015	0.001	0.010	0.002	0.002	0.010	0.010	0.000
Disability													
Yes	3274	0.723	0.036	0.032	0.004	0.188	0.004	0.159	0.018	0.007	0.052	0.050	0.003
No	15478	0.883	0.024	0.021	0.002	0.074	0.002	0.062	0.006	0.004	0.019	0.018	0.001
Household composition													
single w/o chid	4895	0.721	0.046	0.042	0.004	0.183	0.004	0.154	0.016	0.009	0.050	0.047	0.002
single w/ chidren	1293	0.352	0.052	0.052	0.000	0.548	0.012	0.471	0.040	0.024	0.047	0.045	0.002

married w/o children	8365	0.971	0.010	0.008	0.001	0.012	0.000	0.010	0.001	0.001	0.007	0.007	0.000
married w/ child	4199	0.878	0.027	0.023	0.004	0.069	0.003	0.056	0.006	0.004	0.026	0.025	0.001
Food stamp/SNAP recipient													
Yes	1560	0.138	0.053	0.050	0.003	0.693	0.014	0.606	0.047	0.027	0.115	0.108	0.007
No	1718 4	0.893	0.024	0.022	0.003	0.062	0.002	0.051	0.006	0.003	0.021	0.020	0.001
Home ownership													
Own	1430 5	0.928	0.016	0.014	0.002	0.042	0.002	0.033	0.005	0.002	0.013	0.013	0.001
Rent	3907	0.552	0.059	0.054	0.005	0.319	0.005	0.277	0.023	0.014	0.069	0.066	0.003
Neither	540	0.614	0.091	0.075	0.016	0.208	0.000	0.179	0.016	0.013	0.087	0.083	0.004
Vehicle ownership													
Yes	1708 6	0.888	0.024	0.021	0.002	0.067	0.002	0.055	0.007	0.003	0.020	0.019	0.001
No	1666	0.372	0.056	0.049	0.007	0.477	0.006	0.413	0.032	0.024	0.095	0.090	0.005
Region													
Northeast	1344	0.928	0.019	0.018	0.001	0.034	0.000	0.025	0.006	0.003	0.019	0.017	0.002
Mid-Atlantic	2545	0.893	0.021	0.018	0.004	0.063	0.001	0.054	0.006	0.002	0.022	0.021	0.000
South	5907	0.784	0.035	0.033	0.002	0.149	0.005	0.123	0.014	0.007	0.033	0.032	0.001
Midwest	4724	0.831	0.027	0.023	0.003	0.115	0.003	0.097	0.009	0.006	0.027	0.024	0.002
West	3515	0.901	0.021	0.018	0.003	0.057	0.000	0.051	0.003	0.002	0.021	0.021	0.000
Shocks													
No longer received food stamp/SNAP	427	0.163	0.219	0.175	0.043	0.589	0.002	0.512	0.060	0.014	0.030	0.030	0.000
No longer employed	777	0.764	0.091	0.075	0.016	0.130	0.002	0.114	0.012	0.001	0.015	0.015	0.000
No longer married	251	0.857	0.058	0.057	0.001	0.065	0.001	0.065	0.000	0.000	0.020	0.017	0.003
Became disabled	1240	0.746	0.009	0.009	0.000	0.156	0.004	0.131	0.013	0.007	0.089	0.086	0.003
No longer own house	487	0.795	0.071	0.070	0.001	0.098	0.003	0.083	0.010	0.003	0.036	0.035	0.001
No longer own vehicle	455	0.502	0.010	0.010	0.000	0.297	0.007	0.270	0.006	0.015	0.191	0.183	0.008

Note: Column (1) report the number of observations in each subgroup. The transition shares of column (2), (3), (6) and (11) sum up to one. The sum of structural and stochastic transition shares in column (2), (4), (5), (7)-(10) and (12)-(3) also equal to one. These transition shares are calculated by the weighted joint distribution.

Table 7. Persistent and Entry Rate Across Two Consecutive Waves.

	Persistent Rate			Entry Rate		
	FI	Stochastical FI	Structural FI	FI	Stochastical FI	Structural FI
Year						
2003	0.809	0.393	0.872	0.027	0.005	0.022
2005	0.776	0.252	0.855	0.028	0.006	0.022
2007	0.783	0.379	0.830	0.028	0.004	0.024
2009	0.854	0.672	0.883	0.058	0.015	0.044
2011	0.817	0.483	0.872	0.035	0.007	0.028
2013	0.776	0.463	0.822	0.032	0.011	0.021
2015	0.821	0.447	0.883	0.021	0.005	0.016
2017	0.764	0.447	0.814	0.015	0.005	0.010
2019	0.712	0.257	0.804	0.025	0.007	0.018
Gender						
Male	0.692	0.352	0.762	0.021	0.005	0.016
Female	0.863	0.500	0.908	0.067	0.015	0.051
Race						
white	0.691	0.329	0.749	0.020	0.004	0.016
Non-white	0.864	0.490	0.923	0.128	0.039	0.089
Highest Education Degree						
less than high school	0.869	0.475	0.904	0.111	0.020	0.091
high school	0.811	0.468	0.865	0.042	0.010	0.032
some college	0.726	0.328	0.797	0.031	0.008	0.023
college	0.586	0.391	0.661	0.011	0.003	0.007
Disability						
Yes	0.839	0.432	0.894	0.068	0.017	0.051
No	0.759	0.413	0.819	0.021	0.005	0.016
Household composition						
single without chid	0.799	0.410	0.859	0.065	0.014	0.050
single with chidren	0.913	0.555	0.957	0.118	0.034	0.084
married without children	0.557	0.264	0.616	0.007	0.002	0.005
married with child	0.723	0.433	0.782	0.029	0.008	0.021

Food stamp/SNAP recipient						
Yes	0.929	0.604	0.961	0.454	0.095	0.359
No	0.718	0.368	0.785	0.023	0.006	0.017
Home ownership						
Own	0.725	0.377	0.805	0.014	0.004	0.010
Rent	0.844	0.498	0.883	0.112	0.026	0.086
Neither	0.696	0.290	0.767	0.124	0.017	0.106
Vehicle ownership						
Yes	0.739	0.374	0.805	0.022	0.006	0.016
No	0.895	0.567	0.932	0.203	0.035	0.168
Region						
Northeast	0.641	0.382	0.685	0.020	0.003	0.017
Mid-Atlantic	0.747	0.247	0.827	0.024	0.005	0.019
South	0.810	0.434	0.875	0.040	0.010	0.030
Midwest	0.813	0.496	0.862	0.031	0.008	0.023
West	0.734	0.324	0.786	0.023	0.006	0.017
Shocks						
No longer received food stamp/SNAP	0.729	0.216	0.783	0.155	0.016	0.139
No longer employed	0.588	0.126	0.644	0.020	0.005	0.014
No longer married	0.531	0.029	0.683	0.023	0.008	0.015
Became disabled	0.944	0.668	0.974	0.106	0.024	0.083
No longer own house	0.580	0.172	0.681	0.043	0.004	0.039
No longer own vehicle	0.966	0.751	0.988	0.275	0.049	0.226

Note: Persistence $Pr = (FI_t|FI_{t-1})$; Entry $Pr = (FI_t|FS_{t-1})$; The persistence rate for stochastic (alternatively, structural) FI quantifies the conditional probability that a household, identified as being stochastically (or structurally) food insecure in one survey wave, will continue to exhibit FI in the subsequent survey wave. Similarly, the entry rate for stochastic (or structural) FI is defined as the conditional probability that a household, initially food secure, transitions into a state of stochastic (or structural) FI in the following survey period.

Table 8. Spell Length Distribution.

Spell length survey waves	Proportion	Conditional Persistence (Std.Error)	Proportion of estimated structural FS status			
			Structural FS	Stochastical FS	Stochastical FI	Structural FI
1 (1-4 years)	43.08%	0.58 (0.03)	40.17%	47.70%	4.59%	7.54%
2 (3-6 years)	11.01%	0.8 (0.02)	25.73%	45.15%	9.12%	20.00%
3 (5-8 years)	10.18%	0.79 (0.03)	15.68%	41.12%	10.90%	32.30%
4 (7-10 years)	3.61%	0.92 (0.03)	13.20%	28.34%	12.60%	45.86%
5 (9-12 years)	5.73%	0.8 (0.04)	6.86%	31.85%	8.71%	52.57%
6 (11-14 years)	5.94%	0.84 (0.04)	4.22%	21.69%	8.50%	65.59%
7 (13-16 years)	2.11%	0.96 (0.01)	3.57%	15.97%	7.00%	73.47%
8 (15-18 years)	3.21%	0.87 (0.04)	5.00%	12.73%	15.90%	66.37%
9 (17-20 years)	1.78%	0.92 (0.04)	4.83%	7.46%	3.96%	83.75%
10 (20+ years)	13.35%		0.00%	0.00%	4.75%	95.25%

Note: Sample consists of the balanced panel of households with SPFS estimates from 2001 to 2019. Duration reflects the number of consecutive (biennial) survey waves and years households experienced FI. As data are right censored, there is no upper limit on the range for the spell length of nine survey waves, the entire study period. Other spell lengths can likewise be right censored if the household was food insecure in 2019.

Table 9. Estimated Structural FS Status from the Permanent Approach.

Category	N	TFI	SFI	TFI-SFI	(SFI/TFI)	Structural & persistent FI	Structural, but not persistent FI	Stochastical FI	Never FI
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Total	21064	0.122	0.103	0.020	0.839	0.044	0.052	0.118	0.787
Gender									
Male	16512	0.067	0.054	0.014	0.794	0.014	0.036	0.098	0.852
Female	4552	0.314	0.274	0.040	0.872	0.151	0.110	0.188	0.550
Race									
White	14326	0.062	0.045	0.017	0.729	0.010	0.031	0.102	0.856
Non-white	6738	0.483	0.446	0.037	0.922	0.252	0.179	0.214	0.355
Highest Education Degree									
Less than high school	2316	0.418	0.429	-0.011	1.027	0.221	0.192	0.195	0.392
High school	7335	0.162	0.131	0.031	0.807	0.049	0.074	0.159	0.718
Some college	4934	0.105	0.077	0.028	0.737	0.033	0.039	0.128	0.800
College	6067	0.019	0.008	0.011	0.425	0.002	0.006	0.056	0.937
Metropolitan area									
Metro	15910	0.121	0.101	0.021	0.830	0.044	0.050	0.117	0.789
Non-metro	5064	0.127	0.111	0.017	0.870	0.043	0.059	0.121	0.777
Region									
Northeast	1514	0.051	0.022	0.029	0.429	0.015	0.005	0.112	0.868
Mid-Atlantic	2846	0.084	0.058	0.027	0.683	0.021	0.034	0.109	0.837
South	6625	0.185	0.161	0.024	0.870	0.076	0.075	0.141	0.709
Midwest	5319	0.140	0.128	0.012	0.917	0.058	0.062	0.112	0.769
West	3953	0.077	0.062	0.015	0.807	0.013	0.045	0.105	0.837

Note: Sample include households with non-missing SPFS for 5 or more years from 2001 to 2019. It is the headcount ratio (HCR) of FI measure using the SPFS following the method from Jalan and Ravallion (2000). The last four columns describe the distribution of households' status which add up to one. SFI can be greater than TFI, like household head with Less than high school degree. That's the very definition of a household that is structurally food insecure but occasionally food secure (i.e., structurally but not persistently food insecure).

Table 10. Regression of TFI and SFI on Characteristics.

VARIABLES	TFI (1)	SFI (2)
Age	-0.002 (0.00)	-0.003 (0.00)
Age^2	-0.017 (0.02)	-0.015 (0.02)
Non-white	0.222*** (0.02)	0.213*** (0.03)
Married	-0.056*** (0.01)	-0.045** (0.02)
Female	0.061*** (0.02)	0.050** (0.02)
High school	-0.072*** (0.02)	-0.117*** (0.03)
Some college	-0.109*** (0.02)	-0.150*** (0.03)
College	-0.116***(0.02)	-0.156*** (0.03)
Employed	-0.008 (0.01)	-0.010 (0.01)
Disabled	0.046*** (0.01)	0.041** (0.02)
ln(income per capita)	-0.036*** (0.00)	-0.033*** (0.01)
Family size	0.013*** (0.00)	0.013* (0.01)
% of children	-0.109*** (0.02)	-0.114*** (0.03)
Received Food Stamp/SNAP	0.250*** (0.03)	0.261*** (0.04)
Received Child Meal	0.138*** (0.02)	0.171*** (0.03)
Received WIC	0.0153 (0.02)	-0.0215 (0.03)
Received Elderly Meal	-0.031 (0.03)	-0.019 (0.03)
Rent	0.081*** (0.01)	0.045** (0.02)
Neither owns nor rents	0.074*** (0.02)	0.029 (0.03)
Not own vehicle	0.152*** (0.03)	0.140*** (0.04)
No longer receive Food Stamp/SNAP	0.181*** (0.02)	0.187*** (0.03)
No longer employed	0.010 (0.01)	0.021* (0.01)
No longer married	-0.018 (0.02)	-0.009 (0.02)
Became disabled	-0.018 (0.01)	-0.017 (0.01)
No longer own home	-0.042*** (0.01)	-0.026 (0.02)
No longer own vehicle	-0.087*** (0.03)	-0.078** (0.04)
N	21064	21064
Population size	481,819.72	481,819.72
R^2	0.666	0.517

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Sample include households with non-missing SPFS for 5 or more years from 2001 to 2019. The FI measure for TFI and SFI is the headcount ratio (HCR) using the SPFS.

Table 11. Shapley Decomposition of the TFI and the SFI.

	TFI		SFI	
Component	R^2	Share	R^2	Share
Region	0.064	0.087	0.050	0.083
Age	0.020	0.027	0.014	0.023
Race	0.165	0.225	0.122	0.206
Marriage status	0.062	0.084	0.046	0.078
Sex	0.055	0.074	0.043	0.073
Education	0.053	0.073	0.051	0.087
Income	0.081	0.110	0.066	0.111
Food assistance (SNAP, WIC, child meal and Elderly meal)	0.092	0.126	0.086	0.145
House and vehicle ownership	0.095	0.130	0.075	0.127
Others	0.043	0.059	0.037	0.062
Total	0.729	0.993	0.590	0.994

Note: This decomposition is from the unadjusted (unweighted, no panel data adjustment) regression. Sample include households with nonmissing SPFS for 5 or more years from 2001 to 2019. "Others" include family size, % of children, employment, disability, and change in status. Variation from time FE (less than 0.06) is omitted from this table.

Appendix

A. Estimated Structural FS Status from the Permanent Approach using SFIG.

Table A. Estimated Structural FS Status from the Permanent Approach using SFIG.

Category	N	TFI	SFI	TFI-SFI	(SFI/TFI)	Structural & persistent FI	Structural, but not persistent FI	Stochastical FI	Never FI
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Total	21064	0.027	0.019	0.007	0.722	0.044	0.052	0.118	0.787
Gender									
Male	16512	0.011	0.005	0.005	0.514	0.014	0.036	0.098	0.852
Female	4552	0.085	0.069	0.016	0.813	0.151	0.110	0.188	0.550
Race									
White	14326	0.008	0.004	0.004	0.477	0.010	0.031	0.102	0.856
Non-white	6738	0.138	0.112	0.026	0.811	0.252	0.179	0.214	0.355
Highest Education Degree									
Less than high school	2316	0.133	0.106	0.027	0.794	0.221	0.192	0.195	0.392
High school	7335	0.029	0.020	0.009	0.692	0.049	0.074	0.159	0.718
Some college	4934	0.019	0.012	0.007	0.645	0.033	0.039	0.128	0.800
College	6067	0.003	0.001	0.002	0.449	0.002	0.006	0.056	0.937
Metropolitan area									
Metro	15910	0.027	0.019	0.007	0.722	0.044	0.050	0.117	0.789
Non-metro	5064	0.028	0.020	0.008	0.724	0.043	0.059	0.121	0.777
Region									
Northeast	1514	0.010	0.006	0.004	0.616	0.015	0.005	0.112	0.868
Mid-Atlantic	2846	0.017	0.012	0.005	0.707	0.021	0.034	0.109	0.837
South	6625	0.041	0.032	0.010	0.768	0.076	0.075	0.141	0.709
Midwest	5319	0.035	0.026	0.009	0.757	0.058	0.062	0.112	0.769
West	3953	0.014	0.007	0.007	0.484	0.013	0.045	0.105	0.837

Note: Sample include households with non-missing SPFS for 5 or more years from 2001 to 2019. It is the FI measure using the SPFS with $\alpha = 2$ following the method from Jalan and Ravallion (2000). The last four columns describe the distribution of households' status which add up to one. SFI can be greater than TFI, like household head with Less than high school degree. That's the very definition of a household that is structurally food insecure but occasionally food secure (i.e., structurally but not persistently food insecure).