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Demographics and Monetary Policy Shocks

We show that consumption expenditures for older households are more responsive to monetary policy shocks than for young- or middle-aged households. A one-standard-deviation expansionary monetary policy shock induces a statistically significant and quantitatively large (1.7%) increase in aggregate consumption for old households over the ensuing 3 years. The responses for young- and middle-aged households are smaller and not statistically significant. We also present evidence, suggesting that life-cycle wealth effects play a role in driving the responses. We then build the wealth mechanism into a partial equilibrium life-cycle model, which can qualitatively match the empirical patterns.

JEL codes: E4, E52, E21, J11, D15
Keywords: Monetary policy shocks, Consumption, Demographic change, Life cycle

THIS PAPER STUDIES HOW CONSUMPTION expenditures for different age groups respond to monetary policy shocks. When we decompose the aggregate consumption response into contributions from households at different stages of the life cycle, we find that monetary policy shocks have a larger impact on the expenditures of older households. According to our estimates, an expansionary monetary policy shock, equivalent in size to one standard deviation of the federal funds

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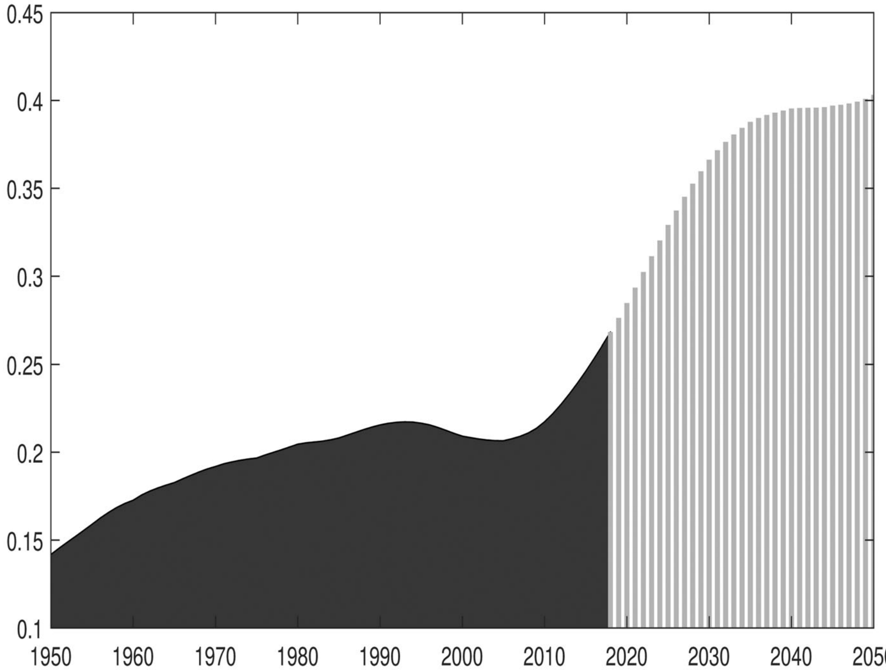

Fig 1. Ratio of U.S. Population Aged 65+ to Population Aged 25–64: 1950–2050.

NOTES: Data are from the UN World Population Prospects 2017 Revision. The gray area are projected figures.

rate, induces a statistically significant 1.7% increase in consumption by older households over the ensuing 3 years. The analogous consumption response for middle-aged households is 0.9%; it is negative for young households, but neither of these latter two estimates are significant. We also present several pieces of evidence that suggest that life-cycle wealth effects are driving these heterogeneous consumption responses. We try to understand the age-related heterogeneity in consumption responses in the context of a partial-equilibrium life-cycle model of consumption, saving, and labor-supply decisions. The model is able to endogenously produce age-related consumption response heterogeneity to interest rate shocks in a manner that is largely consistent with the data.

Two motivations drive our inquiry. First, since consumption is the largest component of GDP, a better understanding of age-related heterogeneity in consumption responses to monetary policy shocks can improve our knowledge of the aggregate transmission channel and about those population segments most impacted by monetary policy. The second motivation is the rapid aging of the population, currently underway in the U.S. and other developed economies. As seen in Figure 1, the ratio of the U.S. population over 65 to those between 25 and 64 is, in demographic time, rapidly increasing. The ratio, which had been fairly steady around 0.2 from 1980 to

2010, is projected to double by 2050 as postwar baby boomers age into retirement. Age-related heterogeneity in consumption responses could potentially alter the effectiveness of monetary policy as the population ages.

We employ local projections (Jordà 2005) to estimate the age-group-specific consumption responses to monetary policy shocks.[1] Using consumption data from the U.S. Consumer Expenditure Survey (CEX), we classify households into young (household head aged 25–34), middle (35–64), and old (65+), and study how aggregate within-group consumption responds to four alternative monetary policy shocks. The U.S. monetary policy shocks were identified and constructed by other researchers. Three of the shocks, constructed using the high-frequency identification (HFI) methods, are from Barakchian and Crowe (2013), Gorodnichenko and Weber (2016), and Gürkaynak, Sack, and Swanson (2005). The fourth uses the narrative/Greenbook methodology of Romer and Romer (2004).[2] Our general finding across the three high-frequency identified shock series is that old households have the highest proportionate consumption response to monetary policy shocks. The evidence on the relative responsiveness between young and middle household consumption is less definitive. We find smaller differences across age groups with the Romer–Romer-type shocks.

We report additional empirical work that supports the hypothesis that a life-cycle wealth effect is an important mechanism driving the results. First, data from the Survey of Consumer Finances (SCF) shows that older households have much higher net wealth than younger households. Since they are wealthier than younger households, a given interest rate decline generates a larger capital gain for the old. Second, older households may be more sensitive to interest rate changes due to the composition of their portfolios. In the SCF, the composition of wealth for older households is tilted toward long-term assets (home equity, bond retirement funds, and equities) whose value is more interest-rate sensitive than short-term assets. Third, we find that consumption of old homeowners is more responsive than that of old nonhomeowners. Fourth, conditional on owning a house, consumption of the old responds more than the young. These last two pieces of evidence are significant for the wealth-effect story since housing is a major component of household wealth.

Our paper focuses on measuring the aggregate within-age group consumption response because this directly translates into understanding the effects of monetary policy shocks on the aggregate economy. Our aggregative empirical approach is fundamentally different from analyses of the household-level (or average household) response undertaken by research such as Cloyne, Ferreira, and Surico (2020) and Wong (2018, 2019). We contrast our approach with theirs and demonstrate how the estimated aggregate effects and household-level effects can diverge. Wong (2018, 2019),

1. We also have done the analysis using structural vector autoregressions (VARs), arriving at similar conclusions. The online Appendix reports the structural VAR results.

2. See Nakamura and Steinsson (2018a) and Nakamura and Steinsson (2018b) for more on estimating monetary policy shocks.

for example, obtains a high household-level response for young households and uses this evidence to motivate the importance of housing in monetary policy transmission. While our own household-level estimates continue to show the old to have the highest responsiveness, we also demonstrate that the household-level response for the young is higher than the aggregate young response. If responsiveness is not symmetrically distributed across households, there is no reason for the household-level and aggregate estimates to coincide. We also show that aggregated CEX responses match up well to National Income and Product Accounts (NIPA) consumption that is of direct interest to policymakers.

Drawing on our supporting evidence for life-cycle wealth effects, we undertake a complementary analysis for how age and wealth heterogeneity can drive these consumption response patterns using a quarterly life-cycle model of consumption, saving, and labor-supply decisions. Preferences in the model are given by Epstein and Zin (1989)–Weil (1989) recursive utility. Finitely lived people work and earn labor income from ages 25–64. From age 65 to (at most) 86, they live on pension income and accumulated assets. Both labor and retirement income are subject to idiosyncratic uncertainty, as is the time of death, which gives people both a precautionary and a retirement, or life cycle, motive to save. People can borrow or lend during their working years by taking short or long positions in a long-term asset but are not allowed to die with negative net worth. We adopt a long-term asset to be consistent with observed household net wealth patterns, which are weighted toward long-term assets. Younger households tend to finance consumption with labor income. Their consumption is less interest-rate sensitive than older-retired households who do not have a labor supply margin and whose consumption relies on assets whose value is interest-rate sensitive. Also, older households discount the future more heavily on account of a higher probability of death. This, combined with shorter planning horizons, makes monetary policy shocks to feel more permanent for the older households, and induces additional interest-rate sensitivity into their consumption. Significantly, consumption impulse responses to interest rate shocks in the model match the age-related pattern of responses in the data—older households have the largest consumption responses. Quantitatively, the model-generated response among older households is several times larger than that for the middle-aged in the first year after a shock, while in some of our empirical estimates, the difference is not as extreme. Overall, though, the model, with only a few essential features, can qualitatively generate the salient consumption-response patterns from our empirical estimates.

The remainder of the paper is organized as follows. The next section further discusses the related literature. Section 2 gives an overview of the data and Section 3 reports the main empirical analyses. Section 4 studies data from the SCF. Section 5 studies NIPA consumption. Section 6 compares our approach with the household-level analysis of Wong (2018, 2019). Section 7 presents the model and its implications. Section 8 concludes the paper. The online Appendix describes the construction of our micro and macro data sets, alternative results using structural VARs, additional robustness analyses, and additional information about the model.

1. RELATED LITERATURE

Our paper is part of the growing interest in the macroeconomic implications of agent heterogeneity. Studies of monetary policy transmission with heterogeneity include Gornemann, Kuester, and Makoto (2012), McKay, Nakamura, and Steinsson (2016), and Luetticke (2016). Fujiwara and Teranishi (2007) embed life-cycle behavior in a New Keynesian model, and, similarly, Bielecki, Brzoza-Brzezina, and Kolasa (2018) consider how demographic change affects the natural rate of interest in a New-Keynesian model of monetary policy. Coibion et al. (2017) study how monetary policy shocks affect inequality in the United States, while Bunn, Pugh, and Yeates (2018) do so for the United Kingdom. Leahy and Thapar (2019) ask how variations in demographic composition affect income and employment responses to monetary policy shocks and find lower responses in U.S. states with higher percentages of young people.

Research that examines the role of wealth effects for monetary policy include Krueger and Perri (2006), who study the effects on consumption volatility in Italian and U.S. data; Sterk and Tenreyro (2018), who focus on the inflationary consequences of monetary policy for wealth and durables spending; and Auclert (2019), who stresses heterogeneity in the duration of an agent's net worth (among other channels). Doepke and Schneider (2006) find large responses by older households, but they focus on how unexpected inflation over a 10-year horizon has differential wealth effects on net nominal lenders and borrowers, as opposed to the effects of identified monetary policy shocks studied in more recent papers. Also, Storesletten, Telmer, and Yaron (2007) consider idiosyncratic shocks in a life-cycle model, but their focus is on explaining the equity premium puzzle.

Several recent papers research the transmission of monetary policy to consumption through its impact on mortgage finance.[3]Cloyne, Ferreira, and Surico (2020) study how monetary policy shocks affect nondurable consumption across households with different home ownership categories and find a higher response by renters and those with outstanding mortgages, who tend to be younger than homeowners without mortgages. Di Maggio, Kermani, and Ramcharan (2014) study how households of different income levels respond to reductions in mortgage interest payments, Aladangady (2017) studies how spending induced by changes in house prices varies with household's debt service obligations, while Wong (2018, 2019) and Eichenbaum, Rebelo, and Wong (2018) study how expansionary monetary policy shocks, working through mortgage refinance, change consumption for younger households.

Our results appear not to align with those in Wong (2018, 2019). While we find consumption of the old to be more responsive than the young and middle, Wong reports the young to be more responsive than the middle and old. The reasons for these

3. Relatedly, Mian and Sufi (2009), Mian and Sufi (2011), and Mian, Rao, and Sufi (2013) stress that changes in housing wealth affect household consumption. Although Guren et al. (2021) and Guren et al. (2020) argue that housing wealth effects may be moderate in size. The mechanism that we put forth stresses wealth effects across a broad range of assets.

differences are twofold. First, in terms of the empirical methodology, Wong estimates household-level responses, whereas we estimate the consumption response at the aggregate (within age group) level. We do this because we focus on how monetary policy affects the macroeconomy; thus, it is sensible to look at the aggregate consumption responses. Second, Wong only reports how consumption changes 1 year after the shock. In our work, we generate impulse responses for 5 years after the shock. Much of the difference between the old and young occurs *beyond* a year after the shock.[4] Indeed, in Section 6, we show that the 1-year results (similar to those in Wong 2018, 2019) are overturned by 2-year impulse responses even when estimating household-level responses (as in Wong 2018, 2019). Wong argues that the transmission mechanism runs, in part, through mortgage refinance because mortgages are taken primarily by the young. However, two pieces of recent evidence challenge this argument. First, the fraction of old people taking out mortgages has been steadily increasing over time. Collins, Hembre, and Urban (2018), in analyzing the American Housing Survey and Census PUMS data, find the proportion of 65 and older holding mortgages to be roughly the same as the proportion under 35. Second, in the CEX data, it is the middle (36–64) who comprise the overwhelming majority of mortgage holders. From 2004 to 2007, the percent of each age group holding mortgages was 18% young, 11% old, and 72% middle.[5] For these same reasons, we do not view our results to be in conflict with Cloyne, Ferreira, and Surico (2020), who employ updated narrative/Greenbook shocks of Romer and Romer (2004) and report that the largest consumption responses to monetary policy shocks are for mortgagees. First, because the presumption that only the young have mortgages, while the old do not is unwarranted, and second, because we find smaller differences across age groups using these particular monetary policy shocks.

On the other hand, our results align with Campbell and Cocco (2007), Glover et al. (2020), and Coibion et al. (2017). Studying U.K. data, Campbell and Cocco (2007) find the consumption response to changes in house prices of old homeowners to be the most responsive, followed by young homeowners, then old renters and finally young renters. Glover et al. (2020) discuss how changes in asset prices during the last recession disproportionately impacted older households. Coibion et al. (2017) find that expansionary monetary policy generates a larger (percentage) increase in consumption by low-consumption people than that of high-consumption people. The low-consumption people tend to be the old. As shown in Hurst (2008), consumption expenditures decline upon retirement such that expenditures by the old are lower

4. A potential explanation is that monetary policy shocks have persistent effects. For example, Paul (2020) finds that monetary policy shocks have persistent effects on housing and equity values. The impact on other assets, for example, long-term bonds, is also likely to be persistent and probably bigger. We return to this discussion below.

5. If we were instead to consider total housing value held or mortgage value, then young households would, by far, hold the least, making it very unlikely that young mortgage holders drive the aggregate consumption response.

than that of the middle and the young. This is also true in the CEX data.[6] Hence, the reduction in consumption inequality from expansionary monetary policy found by Coibion et al. (2017) may well be driven by the more responsive expenditures of the old.

2. THE DATA

This section describes the data used in our main empirical analysis where we estimate the within-age group aggregate consumption response to unanticipated monetary policy shocks. The consumption data are described in Section 2.1 and the monetary policy shocks are discussed in Section 2.2.

2.1 Consumption Expenditures

The household consumption expenditure data come from interview samples of the CEX, spanning from 1984Q1 to 2007Q4.[7] We collect quarterly household consumption expenditures on 19 broad categories. We deflate these expenditures by the corresponding categorical price indices from the Consumer Price Index (CPI) to convert into real terms. We follow Krueger and Perri (2006) in matching categories between the CEX and CPI. Aggregating over the 19 real expenditure components within each household gives our measure of total real consumption by household. The age of the household head is used to classify households into young (25–34), middle (35–64), and old (65+) age groups. Our rationale for these age categories is as follows. The 25–34 age group is when long-term asset accumulation generally begins, while people 65 and older are usually retired.

To obtain real per capita household consumption, we divide total real household consumption by the number of household members that is then aggregated within age groups. The data are not seasonally adjusted, so we include seasonal dummy variables in all of the regressions. We do not employ the CEX-provided weights because Dynan (2009) (among others) warns that the CEX weights are not justifiable when observations are grouped by demographic characteristics. The online Appendix gives a detailed description of the construction of the consumption data. Many additional computations and a demonstration of robustness to application of the CEX weights are also contained in the online Appendix.

6. Mean consumption for the young, middle, and old in our CEX sample is 2,115, 2,274, and 2,094, respectively. Data construction is described in the next section

7. U.S. Department of Labor, Bureau of Labor Statistics, Consumer Expenditure Survey, Interview Survey. Continuous CEX availability begins in 1984. We end our empirical analysis in 2007 due to the ending of conventional monetary policy in the U.S. resulting from the global financial crisis.

2.2 Monetary Policy Shocks

We consider four alternative measures of identified U.S. monetary policy shocks. These shocks are not our own, but were constructed by other researchers. Using different methodologies and underlying data, the creators sought to identify the portion of changes to the federal funds rate that are both unanticipated and exogenous to current economic conditions. The original monetary policy shock series are monthly. To match the sampling frequency of our consumption data, we cumulate these monthly observations to a quarterly frequency.

The first measure we consider comes from Barakchian and Crowe (2013) who employ a HFI method. Their signal of the policy stance is the term structure of the federal funds futures contracts for the current month and at 1–5 months ahead. The information in the six contract horizons is represented by a factor model, and the policy shock is the change in the first factor on the day of an announcement following a Federal Open Market Committee (FOMC) meeting. The change in the factor is intended to capture the unexpected change in the term structure of federal funds futures prices induced by policy surprises. Their series begins in 1988Q4 with the establishment of federal funds futures at the Chicago Board of Trade. We refer to this term-structure-based shock series as HFI-TRM.

The second monetary policy shock series is the instrument employed in Gertler and Karadi (2015), which they call FF4. They employ the HFI approach of Gürkaynak, Sack, and Swanson (2005) and use the change in the 3-month ahead federal funds futures price within a 30-minute window of an FOMC announcement. The idea of the short window is to capture that part of the futures price response only to FOMC announcements and not to other news. We refer to this shock series as HFI-3MO.[8]

Our third shock series combines Gürkaynak, Sack, and Swanson (2005) from 1990 through 1993, and the monetary policy surprises from Gorodnichenko and Weber (2016) (online Appendix Table 16) from 1994 through 2007. Their shock is based on the change in current month federal funds futures within a 60-minute window around FOMC announcements. We label this shock HFI-CMO.[9]

The fourth shock series is constructed following the approach in Romer and Romer (2004). They first draw on narrative accounts from FOMC meetings to create the *intended* federal funds rate. Then to control for anticipated movements in the federal funds rate, they regress the change in the intended federal funds rate on unemployment, Greenbook estimates of past and future inflation and real output, and revisions in these forecasts. The shock is then the residual series, which is argued to be exogenous to current economic conditions and free from anticipatory movements. We use the Romer and Romer (2004) updated series by Wieland and Yang (2016), and we refer to the narrative/Greenbook series as NAR-GBK. Their series starts in 1969, but we begin with 1984Q1.

8. The HFI-3MO and HFI-TRM shock series are from Valerie Ramey: http://econweb.ucsd.edu/vramey/research.html#data, accessed in August 2017.

9. This is also the shock used by Wong (2018, 2019).

TABLE 1

Summary Statistics for Alternative Monetary Policy Shocks

	A. Mean and standard deviation Mean	St. Dev.
HFI-TRM	−0.014	1.249
HFI-3MO	−0.045	0.110
HFI-CMO	−0.042	0.124
NAR-GBK	0.047	0.284

B. Correlations

	HFI-TRM	HFI-3MO	HFI-CMO	NAR-GBK
HFI-TRM	1			
HFI-3MO	0.374	1		
HFI-CMO	0.372	0.778	1	
NAR-GBK	0.308	0.324	0.340	1

C. Autoregressions

Lag	HFI-TRM	HFI-3MO	HFI-CMO	NAR-GBK
1	−0.076	0.161	0.071	0.276
	(−1.017)	(1.393)	(0.613)	(2.920)
2	0.102	0.253	0.084	0.120
	(1.075)	(3.421)	(0.745)	(1.075)
3	0.179	0.132	0.246	0.083
	(1.934)	(1.388)	(2.193)	(0.847)
4	−0.034	−0.068	0.013	0.060
	(−0.338)	(−0.823)	(0.114)	(0.601)
R^2	0.043	0.143	0.089	0.154
p-Value (Wald)	0.365	0.000	0.138	0.003

Note: In Panel C, Newey-West *t*-ratios are in parentheses. The Wald test is for joint significance of the 4-lag coefficients. The starting dates for the series are: 1988Q4 for HFI-TRM, 1990Q1 for HFI-3MO, 1990Q1 for HFI-CMO, and 1984Q1 for NAR-GBK. The ending dates are 2007Q4.

Table 1 reports basic features of the four shock series through 2007Q4. Panel A shows that the shock means are insignificantly different from zero but the shocks differ in their volatility. As one might expect, Panel B shows that HFI-3MO and HFI-CMO are highly correlated with each other. However, the generally low pairwise correlations with the other shocks point to heterogeneity of information content across the alternative shocks.

Truly exogenous monetary policy shocks should be serially uncorrelated. To check this, Panel C shows fitted fourth-order autoregressions for each of the shocks. The HFI-TRM and HFI-CMO shocks come closest to satisfying this criteria, as the Wald test for joint significance of lagged coefficients is insignificant for these shocks, while significant for HFI-3MO and NAR-GBK.[10] Although the autoregressions display some evidence against exogeneity for these latter two shock series, we proceed by

10. Ramey (2016) also points out the serial correlation in the HFI-3MO shock and that the Greenbook forecasts are a predictor of this series. Gertler and Karadi (2015) implicitly recognize this and explore whether the shocks can be explained by, e.g., the Federal Reserve's private information. While Gertler and Karadi (2015) do find a connection, they conclude that it is quantitatively small.

imposing the assumption of exogeneity in the empirical work. If we were to have a "preferred" shock, it might be HFI-CMO. Arguments in favor of the HFI are compelling and among the three such series, HFI-CMO is the shock used by Wong (2018, 2019), so it allows a closer comparison to be made to the literature.

To facilitate comparisons of the consumption responses across the alternative monetary policy shock series, we normalize each shock to have the same standard deviation as quarterly changes in the real federal funds rate, which is 0.88% per annum. Hence, the response to a one-standard-deviation innovation in the monetary policy shock series is comparable to a one-standard-deviation unanticipated change in the policy rate.

3. EMPIRICAL RESULTS

Subsection 3.1 reports our main empirical findings based on local projections. Subsection 3.2 describes a battery of robustness checks, with the results collected in the online Appendix. Across the four shocks and many robustness checks, the weight of the evidence is that older households have the highest consumption response to monetary policy shocks and the differences in the consumption responses across age groups are quantitatively large.

3.1 Local Projections

We examine the consumption responses by age group to a monetary policy shock using local projections (Jordà 2005). We control for past consumption growth, past real federal funds rate, and seasonality in the regressions. The local projections are the sequence of regressions at horizons $h = 1, \ldots, 20$, estimated separately for each age group (group and seasonal subscripts suppressed),

$$100 \ln\left(\frac{c_{t+h}}{c_t}\right) = \beta_h s_t + a_{h,1} \ln\left(\frac{c_t}{c_{t-3}}\right) + a_{h,2} \ln\left(\frac{c_{t-4}}{c_{t-7}}\right) + \sum_{j=0}^{7} b_{h,j} r_{t-j} + u_{t+h}, \qquad (1)$$

where c_t is average per capita consumption within an age group at time t, s_t is the identified monetary policy shock, and r_t is the real federal funds rate. To preserve degrees of freedom, we control for past consumption growth with only two longer term growth lags.[11]

The coefficient of interest is β_h, which measures the percent change in the consumption response from time t to $t + h$ due to the monetary policy shock at time t. To express the response to an expansionary shock, Figure 2 displays plots of $-\beta_h$ with

11. If the shocks s_t are truly exogenous, controlling for lagged consumption and the real federal funds rate may not be necessary. In the online Appendix, we show that our local projection results are robust to omitting these controls or controlling for different lags.

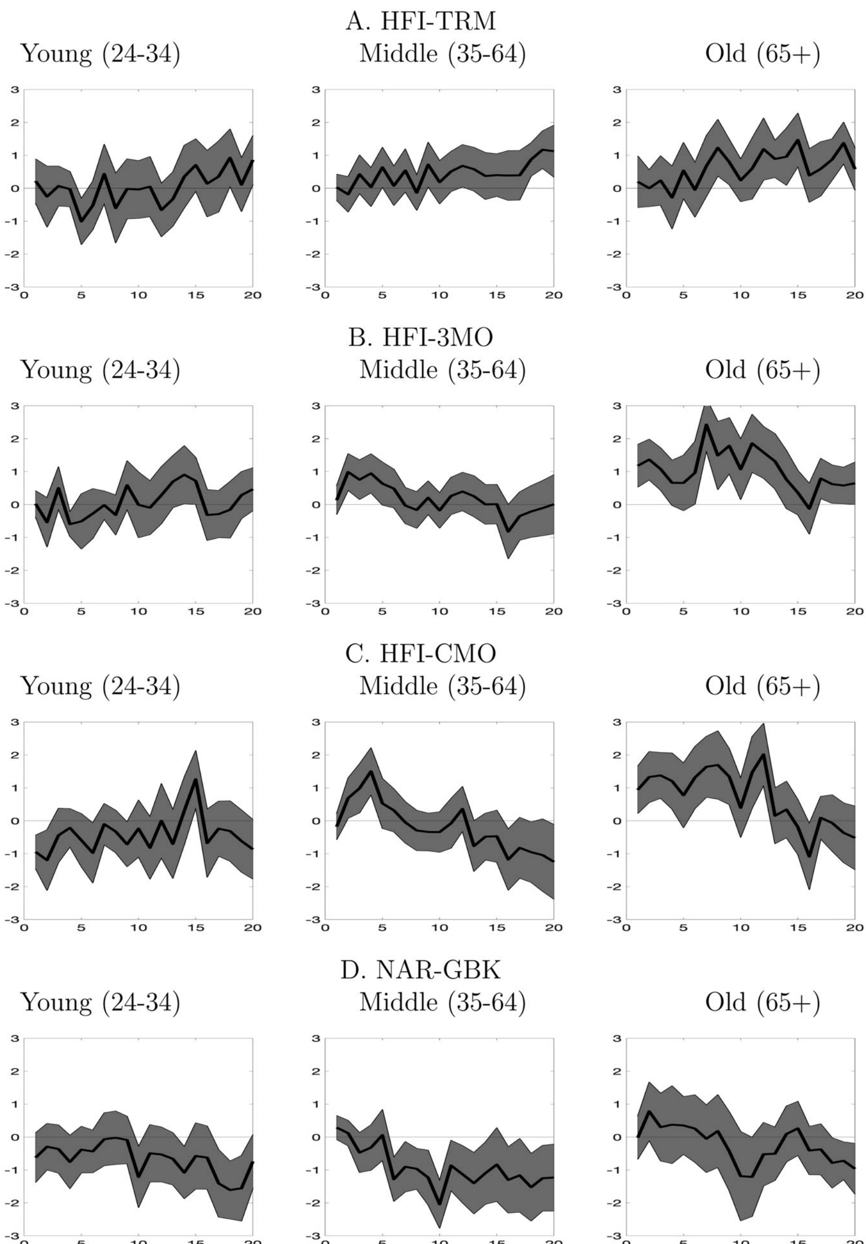

Fig 2. Local Projection Impulse Response of Cumulated Consumption Growth to Expansionary Monetary Policy Shock by Age Group.

NOTES: This figure plots $-\beta_h$ from equation (1). Shaded areas are $\pm$ one standard error Newey and West (1987) confidence bands. The horizontal axis indicates the number of quarters for up to 5 years after the shock. The vertical axis is measured in percent.

± 1Newey and West (1987) standard-error bands at $h = 1, \ldots, 20$ for each age group and all four shocks.

Following an expansionary HFI-TRM shock (Panel A), the response of the old is higher than the two younger age groups over much of the following 20 quarters. A striking contrast in consumption across age groups is found in response to the HFI-3MO shock (Panel B). Here, the consumption response for the youngest group is relatively muted. Middle consumption increases two to five quarters after the shock, but this response is short lived. Consumption by the old increases significantly and the peak consumption response is over twice as high as it is for the middle. An expansionary HFI-CMO shock (Panel C) also leads to an increase in consumption by older households. The shock also induces a relatively large but short-lived increase in middle consumption, whereas the response by the young is mainly negative. Responses to the NAR-GBK shock (Panel D) are relatively subdued compared to the other policy shocks. Young and middle consumption responds negatively. The old initially show little response then a modest decline after 4 years or so.[12]

Looking across the different shocks in Figure 2, the largest consumption response comes from the old. To directly compare responses between age groups, Figure 3 plots the old minus young consumption response and the old minus middle consumption response. These old minus responses are mostly positive. We note that for the three high-frequency shocks, the peak response by the oldest households occurs more than a year after the shock. We discuss this finding further below, when we compare our results to others in the literature.

Since the consumption responses show such persistence, estimating the response of the cumulated consumption flow over time is another way to see the impact of monetary policy shocks. Table 2 shows the estimated shock coefficient from regressing the future k-quarter consumption flow relative to current consumption, for $k = 4, 8, 12, 16$.

$$100 \ln\left(\frac{\sum_{h=1}^{k} c_{t+h}}{c_t}\right) = \beta s_t + a_1 \ln\left(\frac{c_t}{c_{t-3}}\right) + a_2 \ln\left(\frac{c_{t-4}}{c_{t-7}}\right) + \sum_{j=0}^{7} b_j r_{t-j} + u_{t+k}. \quad (2)$$

In this analysis, the 4, 8, and 12 quarter cumulated consumption flow responses of the old to the HFI-3MO and HFI-CMO shocks are positive and significant at the 5% level. This illustrates the importance of capturing the impact of monetary policy shocks at longer horizons as a significant amount of the cumulative responses for the old occur after four quarters and does not peak until 3 years after a policy shock. In addition, for each shock at these horizons, the old always have the highest consumption response, while the responses for the young are never statistically significant and are often negative.

12. We note that the responses are somewhat choppy over time; this is not uncommon with local projections. See Barnichon and Brownlees (2019) for an alternative estimation method that generates smoothed impulse responses.

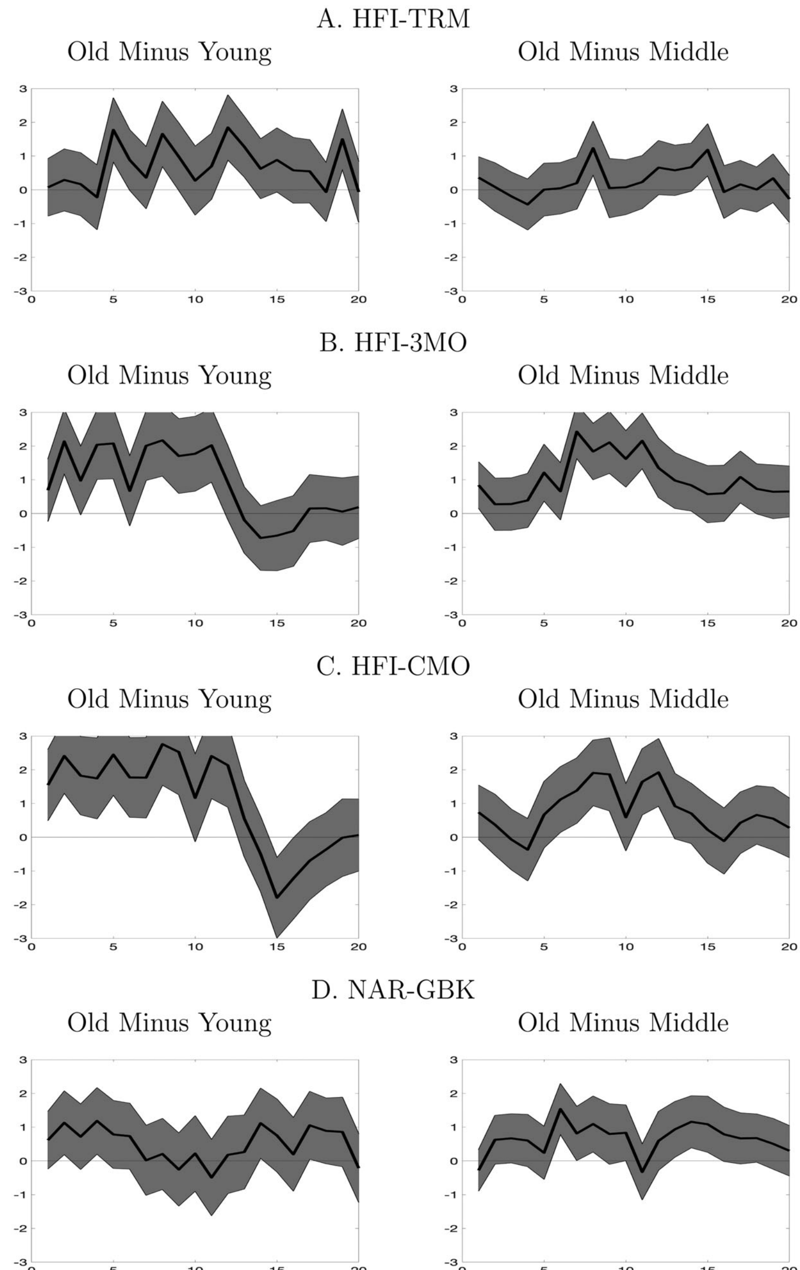

Fig 3. Local Projection Old Minus Young and Old Minus Middle Impulse Responses of Cumulated Consumption Growth to Expansionary Monetary Policy Shock.

NOTES: Shaded areas are ± one standard error confidence bands. The horizontal axis indicates the number of quarters for up to 5 years after the shock. The vertical axis is measured in percent.

TABLE 2

Cumulated Consumption Flow Response to Expansionary Monetary Policy Shock

	HFI-TRM	HFI-3MO	HFI-CMO	NAR-GBK
A. 4 quarters				
Young	0.002	−0.107	−0.590	−0.730
	(0.529)	(0.459)	(0.694)	(0.640)
Middle	−0.004	0.993	1.032**	0.167
	(0.454)	(0.564)	(0.455)	(0.363)
Old	0.140	1.294**	1.261**	0.601
	(0.711)	(0.570)	(0.579)	(0.858)
B. 8 quarters				
Young	−0.332	−0.052	−0.466	−0.462
	(0.563)	(0.453)	(0.627)	(0.616)
Middle	0.064	0.755	0.882	−0.047
	(0.498)	(0.473)	(0.456)	(0.471)
Old	0.422	1.529**	1.461**	0.355
	(0.772)	(0.738)	(0.704)	(0.904)
C. 12 quarters				
Young	−0.414	0.190	−0.153	−0.534
	(0.606)	(0.422)	(0.656)	(0.674)
Middle	0.077	0.667	0.884	−0.178
	(0.497)	(0.450)	(0.392)	(0.418)
Old	0.526	1.640**	1.697**	0.059
	(0.756)	(0.836)	(0.857)	(0.952)
D. 16 quarters				
Young	−0.417	0.412	0.035	−0.542
	(0.726)	(0.489)	(0.712)	(0.727)
Middle	−0.068	0.619	0.703	−0.135
	(0.527)	(0.447)	(0.379)	(0.404)
Old	0.593	1.439	1.211	0.367
	(0.727)	(0.842)	(0.897)	(0.879)

Note: Responses to expansionary monetary policy shock. Newey–West standard errors computed with Andrews automatic bandwidth selection are shown in parentheses. ** indicates significance at the 5% level.

Why is the old response delayed and persistent? We argue that it is due to a life-cycle wealth effect. We will be discussing in more detail below, but here, we mention the following. In Section 4, we show that the old have higher net wealth than the other age groups and that their wealth is tilted toward more interest-sensitive long-term assets. In Section 7, we show that the interest rate (the federal funds rate) responses to the monetary policy shocks are persistent. Moreover, Paul (2020) shows that housing and equity values—the types of assets likely to figure prominently in portfolios of the old—display highly persistent responses to monetary policy shocks.[13]

The main result of this section and a specific take-away from the paper is this: Following an expansionary HFI-CMO monetary policy shock, consumption of the old over the ensuing 3 years increases by 1.7% and this estimate is statistically significant. The analogous consumption response for the middle is 0.9% and is negative for the young, but neither of these estimates is significant.

13. Other studies also find that monetary policy shocks have persistent effects on macroeconomic outcomes. For instance, Romer and Romer (2004) find persistent effects on output and Coibion et al. (2017) find persistent effects on income inequality.

Changing monetary policy effectiveness over time. The heterogeneous consumption responses found across age groups suggest that the demographic transition will lead to greater future monetary policy effectiveness. We estimate the potential impact by aggregating our age-specific responses and combining them with demographic profiles from different points in time, assuming that the age-specific responses are constant over time. We abstract from changes in family size and composition within-age groups.

Let c_A be real per capita consumption and N_A be the number of people in the aggregate. Similarly, let c_y, c_m, c_o (N_y, N_m, N_o) be consumption (numbers of) of young, middle, and old, respectively. Then aggregate consumption is $N_A c_A$, and the approximate relative change in this aggregate in $h = 1, \ldots, 20$ quarters from a monetary policy shock is

$$N_A \ln\left(\frac{c_{A,t+h}}{c_{A,t}}\right) = N_y \frac{\bar{c}_y}{\bar{c}_A} \ln\left(\frac{c_{y,t+h}}{c_{y,t}}\right) + N_m \frac{\bar{c}_m}{\bar{c}_A} \ln\left(\frac{c_{m,t+h}}{c_{m,t}}\right) + N_o \frac{\bar{c}_o}{\bar{c}_A} \left(\frac{c_{o,t+h}}{c_{o,t}}\right), \quad (3)$$

where estimates of the change in young, middle, and old household real per capita consumption come from the estimated local projections. The number of young, middle, old, and aggregate $(N_A = N_y + N_m + N_o)$ population are from the UN World Population Prospects 2017 Revision data (as in Figure 1). For the weights $\bar{c}_y/\bar{c}_A$, etc., we use average age-group consumption shares of aggregate consumption.

We estimate the response of cumulated aggregate consumption growth to each of the four monetary policy shocks using demographic profiles in years 1990, 2010, and 2030. Figure 4 displays the results. Panel A plots the difference in the responses to expansionary monetary policy shocks between 2010 and 1990 and between 2030 and 1990. According to our results, population aging from 1990 through 2030 increases monetary policy effectiveness.

In Panel B, we cumulate the estimated consumption flow differences between 2010 and 1990 and between 2030 and 1990 estimates for the 5 years following the shock. According to the HFI-CMO estimates, the cumulated 5-year consumption flow response is nearly 2% greater in 2030 than it was in 1990, due to the aging of the U.S. population.

Nondurable consumption. The consumption data used to this point include durables, whose purchases may be debt financed. Researchers and policymakers may also be interested in understanding patterns of nondurable consumption. To examine this, and to verify that our results are not driven entirely by durable expenditures, we also have examined the nondurable consumption responses to monetary policy shocks for each age group. Our measure of nondurable expenditures follows Krueger and Perri (2006).[14]

14. Real nondurable consumption expenditures is the sum of consumption components 1–13 given in the online Appendix Table A1.

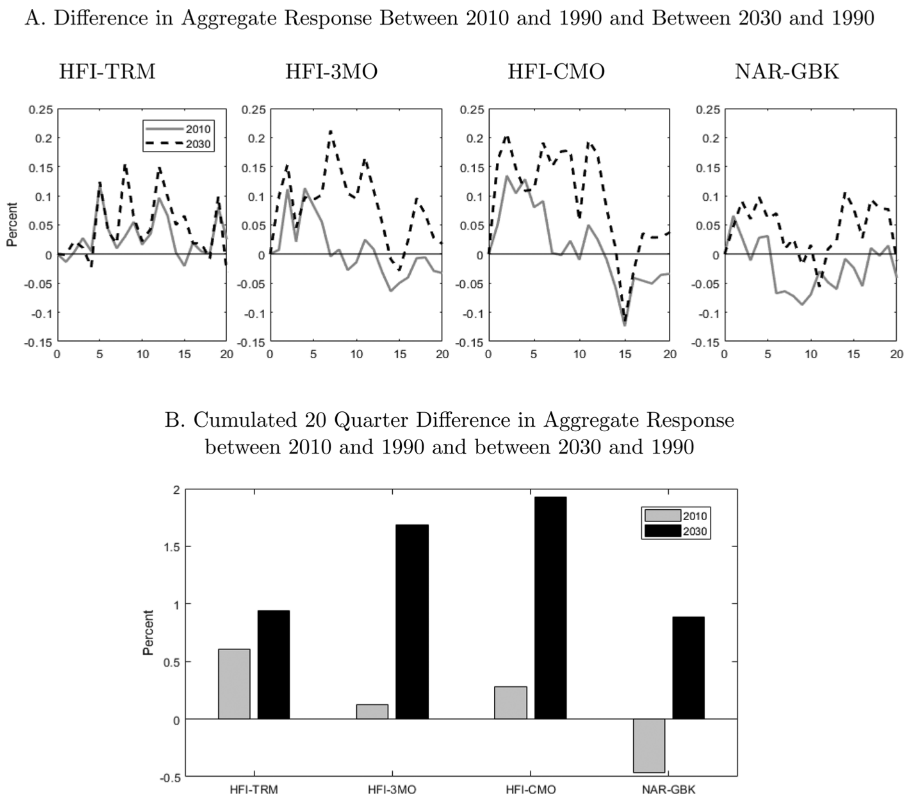

Fig 4. Monetary Policy Effectiveness.

NOTES: In Panel A, the horizontal axis indicates the number of quarters for up to 5 years after the shock. The vertical axis is measured in percent in Panels A and B. We estimate the consumption responses by age group to an expansionary monetary policy shock and hold them fixed and then change demographics according to UN World Population Prospects 2017 Revision data. Panel A: Absolute difference between responses in 2030 and 2010 relative to 1990. Panel B: Cumulated percent difference in total consumption in 2030 and 2010 relative to 1990.

Figure 5 displays old minus young and old minus middle nondurable consumption responses. As can be seen, both the response patterns and the magnitudes are similar to the total consumption responses displayed in Figure 3. With the possible exception of the NAR-GBK shock, the responses among the old remain the greatest.

3.2 Robustness

We have also conducted the impulse response analysis with structural vector autoregresions (VARs). These results are reported in the online Appendix. The structural VAR analysis confirms the local projection estimates that old consumption increases more than young or middle consumption in response to expansionary monetary policy shocks.

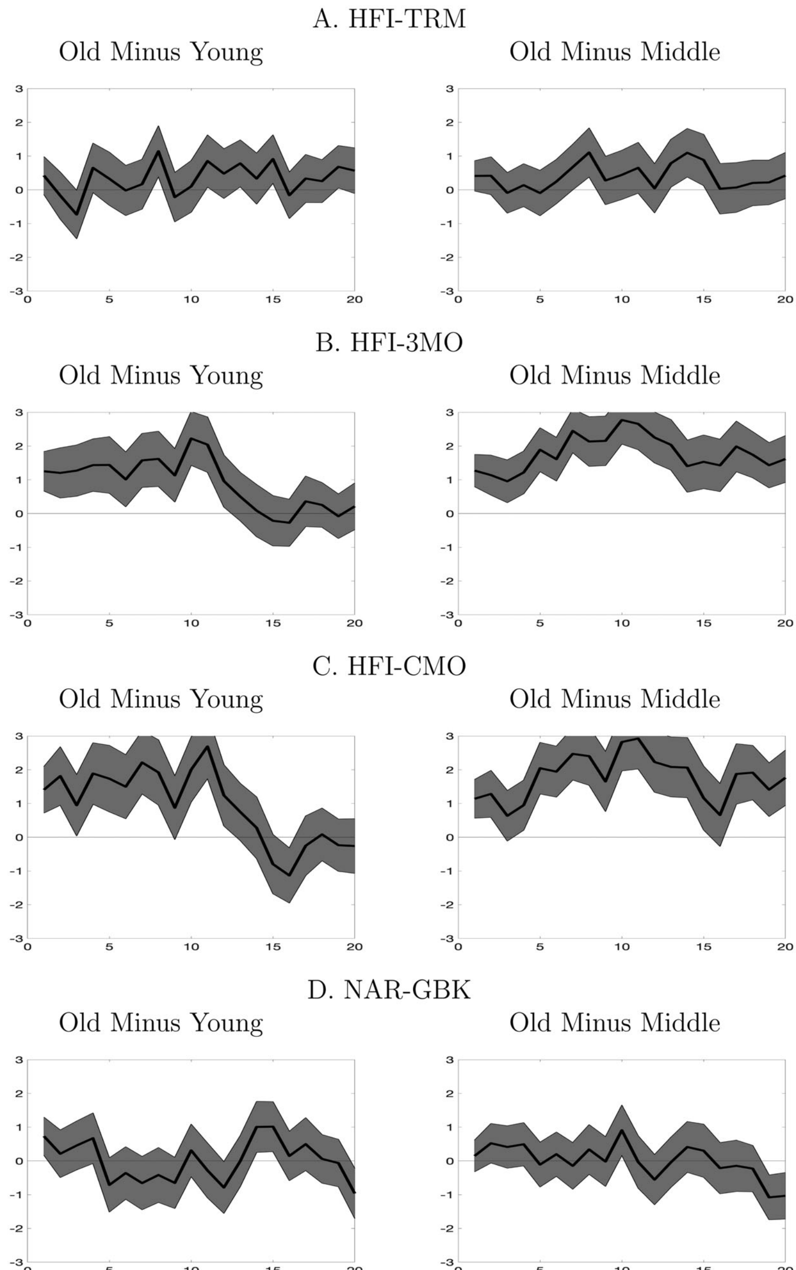

Fig 5. Local Projection Old Minus Young and Old Minus Middle Impulse Responses of Cumulated Nondurable Consumption Growth to Expansionary Monetary Policy Shock.

NOTES: Shaded areas are ± one standard error Newey and West (1987) confidence bands. The horizontal axis indicates the number of quarters for up to 5 years after the shock. The vertical axis is measured in percent.

The online Appendix also reports these analyses of robustness using local projections:

(i) classification of households into six age groups,
(ii) response of durable goods expenditure,
(iii) response of consumption less housing expenditure,
(iv) application of CEX weights in age group consumption aggregation,
(v) omitting lagged consumption and the real federal funds rate.

Throughout the many specifications and across the four shocks, the message remains largely unchanged: aggregate consumption of old households is the most responsive to monetary policy shocks.

Based on the empirics thus far, differences in consumption responses across age groups seem to be driven by how people finance their consumption at different stages of the life cycle. We begin to explore this in the next section by documenting key wealth facts by age group.

4. INCOME, WEALTH, AND PORTFOLIO COMPOSITION BY AGE

This section examines the relation among income, wealth, portfolio composition, and age using data from the 1989, 1998, and 2007 waves of the U.S. SCF to explore potential mechanisms driving our empirical findings that consumption for the old is most responsive to monetary policy shocks. The span of the sample approximately overlaps the time coverage of our CEX sample.[15]

The picture that emerges from this analysis is that retired older households, who typically live off of wealth rather than labor income, have portfolios whose values are tilted toward more interest-sensitive long-term assets. This points to heterogeneity in wealth and labor supply across age groups as a potential mechanism driving the variation in consumption response. Old households adjust to the monetary policy-shock-induced wealth shock primarily by adjusting consumption, whereas younger households can adjust both consumption and labor supply. Because old households have higher net wealth, they have higher exposure to the wealth shock than younger households. Auclert (2019) also makes this point, theorizing that households facing greater unhedged interest rate exposure respond more to monetary policy shocks. These differences combined with differences in marginal propensities to consume are his mechanism in propagating monetary policy shocks.

4.1 Labor Income across Household Age

Figure 6 shows the median and mean wage income as a share of total income by 5 year age groups. We are looking to see where in the life-cycle labor income is replaced

15. The 1989 SCF survey is the first that allows us to identify holdings in stock mutual funds and annuities.

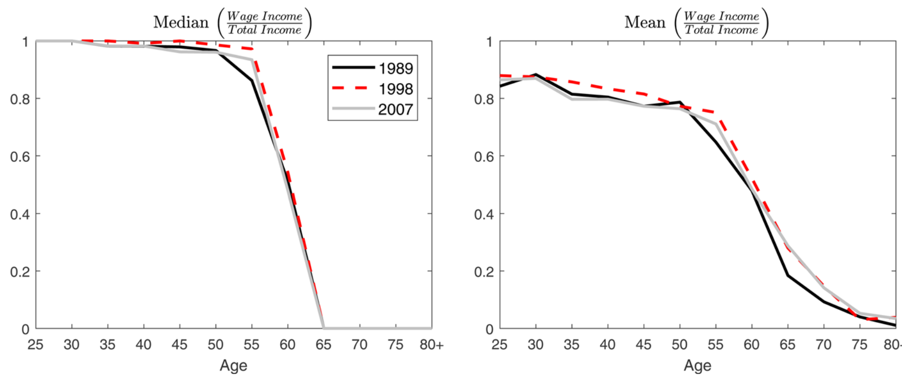

Fig 6. Median and Mean Wage Income as a Share of Total Income by Age: 1989, 1998, and 2007.

NOTES: Median and mean wage income as shares of total income are given by 5 year age group and year. Data are from the Survey of Consumer Finances.

by other sources. Both the median and mean shares begin a rapid decline around age 55. By age 65, the median share of labor income is zero, while the mean share lies in the 20–30% range, depending on the survey year. Retirement, whether voluntary or involuntary, takes place for most people before age 65. The typical older household does not receive much labor income and pays for consumption using other sources.

4.2 Net Wealth and Portfolio Composition by Household Age

Here, we examine net worth and the composition of long versus short-term assets across households of different ages. For each sample year and age group, we construct three measures of net asset positions.

(i) *Net Worth* is total assets as stated by the SCF minus total debts.
(ii) *Net Long Term 1* is the sum of net property equity (value of properties, including own residence, less outstanding debt on the properties), stock holdings, stock mutual funds, and annuities—a measure of long-term, interest-sensitive assets.
(iii) *Net Long Term 2* is *Net Long Term 1* plus nonstock mutual funds (but not money market funds) plus directly held bonds of all types.

Table 3 reports the age-group median *Net Worth* relative to the overall median, from which we see net wealth increasing with age. Since older age groups hold more wealth, they have higher exposure to valuation changes induced by monetary policy shocks.

Table 4 reports *Net Long Term 1* and *Net Long Term 2* as a fraction of *Net Worth* (the median of the ratio across households) by age group and year. Households with higher fractions of these measures have higher proportions of net wealth composed of long-term assets. The table shows that the share of long-term assets in net worth

TABLE 3

Within-Age Group Median Net Worth Relative to Aggregate Median Net Worth

Age group	1989	1998	2007
25–34	0.217	0.216	0.169
35–64	1.633	1.281	1.344
65+	1.655	1.927	1.792

Note: *Net Worth* = total assets − total debts. The table reports median net worth by age and year divided by median net worth of all households in that year. Data are from the Survey of Consumer Finances.

TABLE 4

Median Net Long Term Assets as a Share of Net Worth

	$\frac{Net\ long\ term\ 1}{Net\ worth}$			$\frac{Net\ long\ term\ 2}{Net\ worth}$		
Age group	1989	1998	2007	1989	1998	2007
25–34	0.148	0.078	0.130	0.190	0.108	0.139
35–64	0.568	0.437	0.485	0.603	0.471	0.502
65+	0.573	0.625	0.676	0.625	0.670	0.691

Note: The table reports *Net Long Term 1* and *Net Long Term 2* as a fraction of *Net Worth*(the median of the ratio across households) by age group and year. *Net Worth* = total assets − total debts. *Net Long Term 1* = Net property equity (value of primary residence + other residential property − remaining mortgage and debt secured by primary and other residential property + net equity in nonresidential real estate) + stocks + stock mutual funds + annuities. *Net Long Term 2* = *Net Long Term 1* + nonstock mutual funds (bond and other mutual funds, not including money market funds) + directly held bonds. Data are from the Survey of Consumer Finances.

increases consistently with age. The largest component of net asset holdings for each age group is in property equity.[16] These data show that older households not only have higher net wealth but also that they hold more interest-rate-sensitive assets.

We would like to estimate the local projections using consumption stratified by age and wealth (or a measure of interest rate exposure). Unfortunately, the CEX data do not contain a wealth measure suitable for such analysis. However, housing, as mentioned earlier, is a major component of wealth and therefore provides a potential avenue to examine overall wealth. The CEX data allow us to separate households into those who own a house (outright or with a mortgage) and those who do not.[17] Figure 7 plots the homeowner minus nonhomeowner consumption responses to an expansionary monetary shock by age group, based on local projections. The old homeowners have higher consumption responses than nonhomeowners. This is also true for the middle in response to HFI-3MO, HFI-CMO, and NAR-GBK shocks.

16. While this is an important component of long-term assets, we also find the same relationship of increasing shares of average interest-sensitive asset holdings by age when property equity is excluded in *Net Long Term 1* and *Net Long Term 2* and Net Worth. We also find that the oldest age groups hold (marginally) more stocks as a share of financial asset holdings than the younger cohorts. These results are available upon request.

17. We combine households who own a house with a mortgage and those who own a house without a mortgage because many observations do not identify which of these two groups the household belongs to. This data limitation is unfortunate because we cannot fully explore the refinance channel.

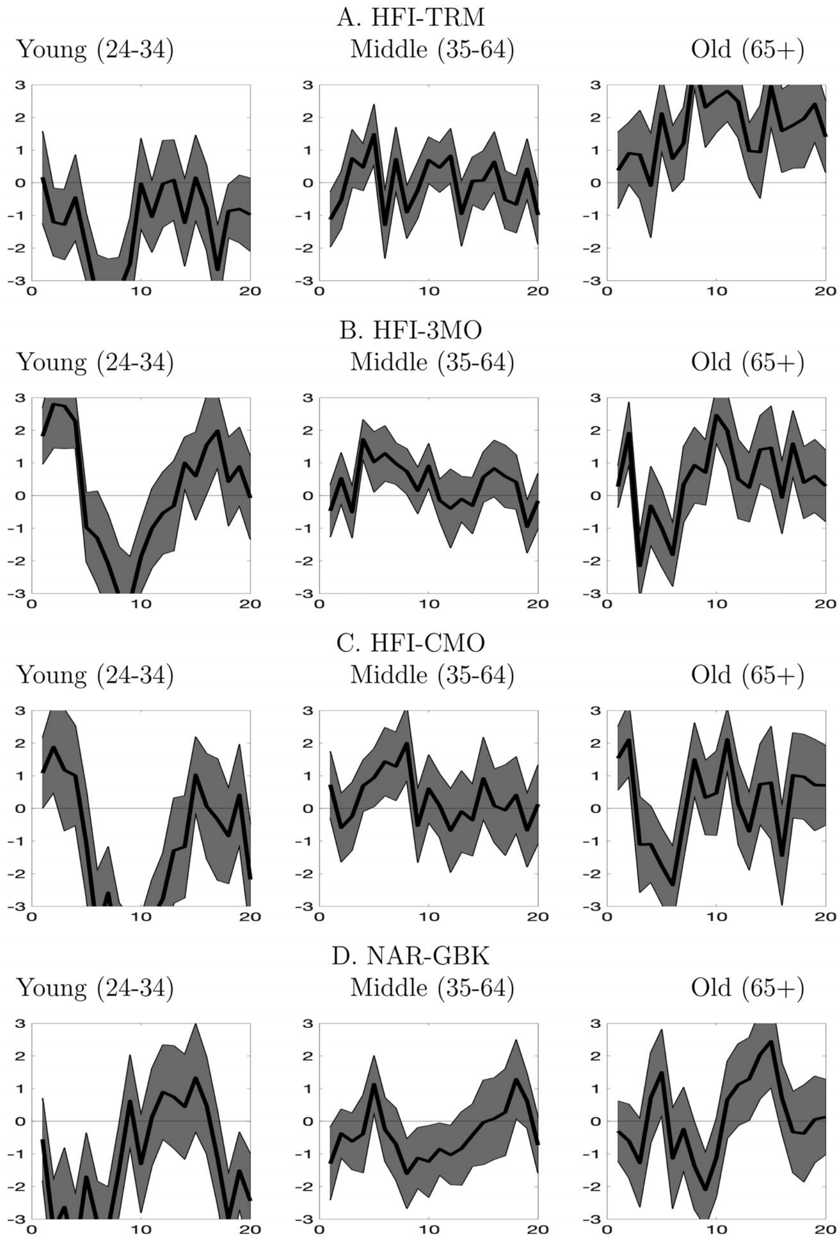

Fig 7. Local Projection Homeowner Minus Nonhomeowner Impulse Response of Cumulated Consumption Growth to Expansionary Monetary Policy Shock by Age Group.

NOTES: Homeowners are those who own a house with a mortgage and those who own a house without a mortgage. Shaded areas are ± one standard error Newey and West (1987) confidence bands. The horizontal axis indicates the number of quarters for up to 5 years after the shock. The vertical axis is measured in percent.

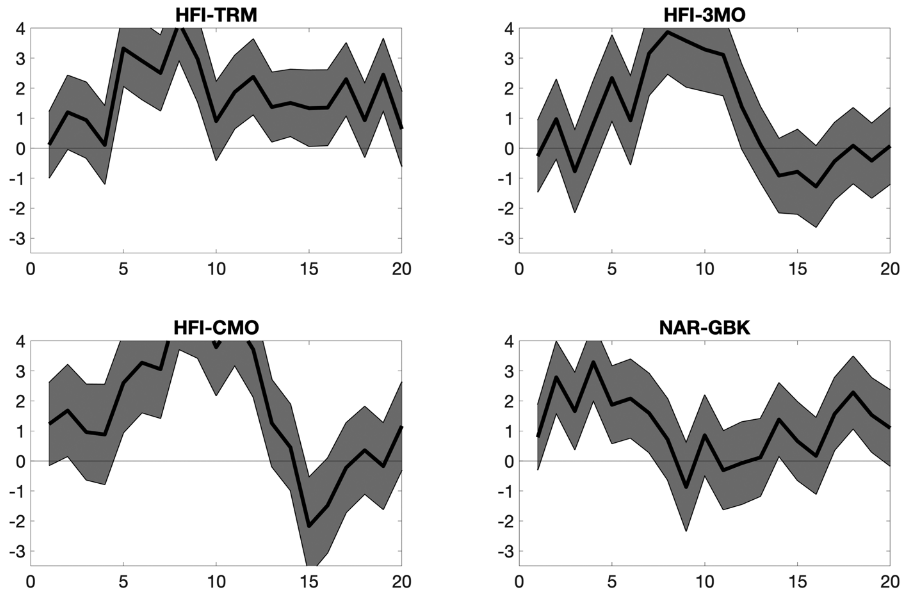

Fig 8. Local Projection Old Minus Young Homeowner Impulse Response of Cumulated Consumption Growth to Expansionary Monetary Policy Shock.

NOTES: Homeowners are those who own a house with a mortgage and those who own a house without a mortgage. Shaded areas are ± one standard error Newey and West (1987) confidence bands. The horizontal axis indicates the number of quarters for up to 5 years after the shock. The vertical axis is measured in percent.

There is a short-lived positive consumption response of young homeowners relative to young nonhomeowners for HFI-3MO and HFI-CMO shocks after which the relative response plunges. If old- and middle-aged homeowners have higher net wealth than nonhomeowners, these results point to a wealth effect.

We can also address a potential issue raised by Wong (2018, 2019). Suppose young homeowners who are just starting out are more likely to have net wealth close to zero because they bought a home with a mortgage almost as large as the home value. These homeowners may experience a positive wealth effect coming from two sources: an increase in the value of the home they own, and a decrease in the net present value of mortgage payments by refinancing to a lower rate. Old households, on the other hand, will tend to have a smaller or possibly no mortgage, so they do not experience the decrease in the net present value of debt. The hypothesis is that young homeowner's consumption will be more responsive to monetary policy shocks. However, we do not find evidence to support this hypothesis. Figure 8 plots old minus young homeowner consumption responses and shows that old homeowner consumption is more responsive than young homeowner consumption.

To summarize, this section shows (i) labor income is not a significant source of support for the old, (ii) the old have higher net wealth than young or middle, (iii) assets

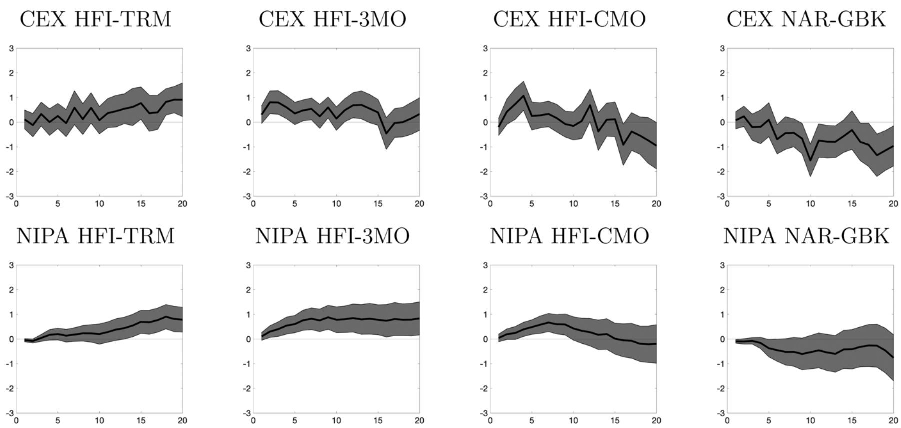

Fig 9. Local Projection Aggregated CEX and NIPA Impulse Responses of Cumulated Consumption Growth to Expansionary Monetary Policy Shock.

NOTES: Shaded areas are ± one standard error Newey and West (1987) confidence bands. The horizontal axis indicates the number of quarters for up to 5 years after the shock. The vertical axis is measured in percent.

of the old are tilted toward more long-term and interest-sensitive, (iv) consumption of homeowning households is more responsive, and (v) consumption of old homeowners is more responsive than that of young homeowners. These results suggest that general wealth is the driving force behind consumption responses of the old.

5. RELEVANCE OF THE CEX FOR POLICYMAKERS

Policymakers discuss how monetary policy shocks affect NIPA consumption, not necessarily CEX consumption. How relevant is CEX consumption to NIPA consumption?[18] Or, more to our point, do the CEX consumption responses match up with NIPA responses? Since NIPA does not decompose consumption by age, we aggregate the CEX consumption and generate impulse responses to monetary policy shocks for the two consumption measures. This "aggregate" CEX is the one-age group (25 and above) version of the consumption data.

Figure 9 shows the local projection results for each shock. The aggregate CEX responses are shown in the top row and the NIPA responses are below. For HFI-TRM shocks, both the CEX and NIPA responses drift upward. For HFI-3MO, both show an increase over the first 14 quarters or so, but NIPA does not dip. For HFI-CMO, both have a hump-shaped response. For NAR-GBK, both show a contraction. In short, the NIPA responses appear as smoothed versions of the aggregated CEX responses.

18. Several papers compare the CEX and NIPA in other contexts. See Bee, Meyer, and Sullivan (2013), for example.

6. AGGREGATE VERSUS HOUSEHOLD LEVEL RESPONSES

We have presented evidence that the *aggregate* within age group consumption response is highest for older households. Wong (2018, 2019), on the other hand, using microlevel (or household level) regressions, reports that the highest *household-level* consumption response to monetary policy shocks is from young households. Wong (2018) obtains separate responses for young, middle-aged and old households and splits shocks into positive and negative values, whereas Wong (2019) estimates young minus old and middle minus old responses and does not distinguish between positive and negative shocks. The two papers employ the same data and methodology but differ in the packaging of the results. Both our aggregate results and the household-level responses of Wong (2018) and Wong (2019) can be true if the consumption distribution and the distribution of the strength of response to monetary policy shocks are not symmetric.

A simple example illustrates how the two measures can diverge. Let there be two agents. Agent 1 consumes 99 and Agent 2 consumes 1. Aggregate consumption is 100 and agents are the same age. Following a shock, Agent 1 consumes 94 and Agent 2 consumes 2. The *aggregate* response is a 4% decline from 100 to 96. This is what we are after—the aggregate response within an age group. The *average household-level* response in growth rates, however, is about a 47% increase (−5% for Agent 1, and +100% for Agent 2).

We emphasize though that the *household-level* effect is not central to our analysis, as we are interested in understanding the effect of monetary policy on the aggregate economy, which naturally means studying the *aggregate* responses. In this section, we compare our aggregate time-series estimates to panel regressions of the form

$$\Delta \ln(c_{i,t}) = b_0 + \sum_{k=1}^{8} \beta_k s_{t-k} + X_{i,t}'\alpha + Z_i'\gamma + \lambda_{Q,t} + \epsilon_{i,t}, \tag{4}$$

which are used in studies of the household level response (e.g., Cloyne, Ferreira, and Surico 2020 and Wong 2018, 2019). The online Appendix provides the details about the construction of the micro data set.

Here, s_t is the monetary policy shock at time t. The vector $X_{i,t}$ includes time varying household-level controls: changes in marital status of the household head (indicators capturing unmarried to married, married to unmarried, or no change), changes in employment status of the household head (indicators capturing not employed to employed, employed to not employed, or no change), changes in household size, household size, changes in the number of persons 18 or younger in the household, and the number of persons 18 or younger.[19] The vector Z_i includes time-invariant household controls: a household-specific fixed effect (to control for any omitted household

19. Arlene Wong provided us with this list of the standard controls for this type of regression.

TABLE 5
HOUSEHOLD LEVEL AND AGGREGATE RESPONSES FOR THE YOUNG AND OLD

	HFI-TRM	HFI-3MO	HFI-CMO	NAR-GBK
A. One-year household level response $\sum_{j=1}^{4} \beta_j$				
Young	−0.233	0.498	0.713	0.197
	(0.457)	(0.412)	(0.465)	(0.450)
Old	0.288	0.354	0.060	0.444
	(0.387)	(0.303)	(0.360)	(0.250)
B. Two-year household level response $\sum_{j=1}^{8} \beta_j$				
Young	−0.403	0.392	0.533	0.166
	(0.759)	(0.623)	(0.658)	(0.745)
Old	0.302	0.835	0.600	0.889
	(0.634)	(0.470)	(0.572)	(0.415)
C. Two-year aggregate response, $\sum_{j=1}^{8} \beta_j$				
Young	−0.404	−3.179	−5.858	−0.120
	(5.059)	(2.829)	(2.737)	(3.860)
Old	2.953	5.282	7.163	2.447
	(4.626)	(3.586)	(4.013)	(3.498)

factors) and the birth year of the household head (to control for cohort effects). A set of quarterly indicators to control for seasonality is captured by $\lambda_{Q,t}$.

The coefficients have been normalized to be responses to expansionary shocks, $-s_t$. We suppress reporting results for middle households since the interesting contrasts are between the old and the young.

Panel A in Table 5 follows Wong (2018) in estimating equation (4) but showing only the cumulated responses over four quarters. Point estimates show old household consumption expands in response to each of the four expansionary monetary shocks. Household observations are weighted by the CEX-supplied weights.[20] Wong uses only the HFI-CMO shock, and our results in column (3) are quite similar to what she reports—that the young expand consumption more than do the old. However, this result is not robust to the HFI-TRM or NAR-GBK shocks.

One reason why Wong (2018) concludes that the young are more responsive than the old is because she reports the four-quarter response. As we discussed in connection to Table 2, this window misses important consumption responses. Peak consumption responses of the old in our local projections occur beyond 1 year after the monetary policy shock. The evidence on long-term asset holdings by the old combined with Paul's (2020) evidence on the persistent effect monetary policy shocks has on housing and equity values points to a life-cycle/wealth mechanism effect behind the consumption responses. When we cumulate the responses over eight quarters, shown in Panel B, the average household-level consumption response for the old always expands by more than for the young. Average young household-level consumption is estimated to contract with HFI-TRM shocks.

20. The results are qualitatively unchanged if the CEX weights are omitted. If we instead weight by household consumption, then the old become even more responsive relative to the young.

Panel C reports the estimation results from

$$\Delta \ln(C_t) = b_0 + \sum_{k=1}^{8} \beta_k s_{t-k} + \lambda_{Q,t} + \epsilon_t, \tag{5}$$

where C_t is aggregate consumption of a particular age group (young, middle, or old). Note that C_t is not the same measure of aggregate consumption used in the local projections. As explained in the online Appendix, a large number of households must be dropped for this analysis, which are not dropped in the local projections analysis.

Equation (5) is estimated separately for each age group. The point estimates consistently show that the aggregate young household responses go in the "wrong" direction following a monetary policy shock.[21] The point estimates of the aggregate old household responses are consistently expansionary following expansionary shocks, as we found with the local projections. The aggregate response to monetary policy shocks is driven by older households.

The data reveal that the household-level response in an age group can differ from the aggregate response for that age group, in both size and sign. This empirical finding is consistent with our hypothesis that households living primarily off of their wealth, tend to be old, are most responsive to interest rate changes. We examine this hypothesis further by embedding it in a life-cycle model.

7. WEALTH EFFECTS AND CONSUMPTION HETEROGENEITY IN A LIFE-CYCLE MODEL

This section presents a life-cycle model of finitely lived households to study how heterogeneity in net wealth, labor-supply choices, planning horizons, and discounting of the future might explain why the consumption of the old is more responsive to monetary policy shocks than young and middle households. The model features several factors driving consumption and saving decisions, including saving for retirement, for income, for precautionary reasons, and to leave bequests. However, the model does not (and probably cannot) contain every relevant decision facing households. So, we use the model to demonstrate our proposed mechanism in order to understand our empirical results, not to provide an encompassing quantitative analysis.

Subsection 7.1 provides an overview of the model. Technical details and model simulations under alternative specifications are relegated to the online Appendix. Subsection 7.2 shows how the model predicts a higher consumption response to monetary policy shocks for old households relative to middle and young households.

21. This result contrasts with the regression estimates reported in Wong (2018). Even after consulting with Arlene Wong on how to specify the regressions, we have not found a way to replicate the findings from Wong (2018) with any combination of the four shock series and several methodologies that we employ in this paper.

7.1 Model Overview

Agents in the model (henceforth, people) face idiosyncratic income risk and live in an incomplete markets environment. Neither contingent claims nor insurance instruments are available.[22] To conform with the long-term interest-sensitive assets that dominate household portfolios (as seen in Section 4), the nonhuman asset is a nonstate contingent long-term (consol) bond that pays one unit of consumption each period (quarter) forever. People accumulate the bond both to help pay for retirement and as a buffer against loss of income. The idea is for the bond to mimic interest-rate sensitivity of home equity, which forms a major part of the typical U.S. household's portfolio, without modeling-specific frictions (e.g., lumpiness, downpayments, mortgage refinance, housing services in utility) associated with housing. Additionally, our previous analysis of the SCF data revealed that older households hold many other long-term and interest-rate-sensitive financial instruments.

People have Epstein and Zin (1989)–Weil (1989) recursive utility. We categorize people into the same three age groups as in the empirical section. They begin making economic decisions at 25 years old and enter economic life with no assets. Young (25–34 years) and middle (35–64 years) aged people receive exogenous, risky labor income (W) and decide labor supply (L), consumption (C), and net asset positions (A). Working-age people can borrow, but are not allowed to die in debt. When people turn 65, they retire, face uncertain death, live off of reduced pension income (S), and accumulated assets. The model is quarterly, and retired people can live to a maximum of 344 quarters (86 years). Retired people also have a bequest motive.[23] There are no liquidity or financial constraints.[24] At each point in time, 248 different decision-making cohorts are alive at different stages of the life cycle.

Individual's exogenous income process. In each period, there are 248 cohorts each of which are made up of many individuals. Exogenous income received by people follows the permanent-transitory income component model employed by Choi, Lugauer, and Mark (2017), who, in turn, drew upon Zeldes (1989), Carroll (1992), and Carroll (1997). Working age people receive labor income W_t, while retirees receive pension income S_t, where t denotes the time period.[25]

22. Our estimation of income shocks in the data is net of all transfers and thus corresponds to the notion of uninsurable risk in the model. Details are in the online Appendix.

23. We do not explicitly link cohorts; upon death, the bequests simply disappear and are not distributed to younger agents.

24. Others (e.g., Parker et al. 2013) have argued that such frictions matter for the consumption responses by age.

25. To increase readability but at the expense of rigor, we suppress notation for cohorts and individuals throughout this section. However, the online Appendix contains the details.

Both labor and retirement income have a permanent and a transitory component specific to each person.[26] During the working years, wage growth is also driven by a common secular component and by the individual's movement along the age-earnings profile. In the period that people retire, the household pension is the replacement rate, paid with certainty. In subsequent periods, retiree income resumes its risky evolution. We subject retiree pensions to permanent income risk to capture events such as bad health shocks that generate large out-of-pocket medical expenses, while recognizing that these may not be utility enhancing consumption expenditures.

We estimate the parameters governing income (common and age-specific growth rates and the transitory shock processes) using biennial waves of the Panel Study of Income Dynamics (PSID) where the sample is selected between 1986 and 2007 to align with the span of our CEX sample. We use the same definition of household income in the PSID as Blundell, Pistaferri, and Preston (2008) and Storesletten, Telmer, and Yaron (2007).

The online Appendix contains the details and full estimation results for the exogenous income process; the key findings are as follows. The annual gross growth rate of the common secular component is 1.006. For the age-income profile, income growth peaks early in the career. Income continues to grow but at decreasing rates until age 51, after which income declines. We estimate the shock processes separately for each age group, and there are some differences. The old are most likely to experience a near zero income event, whereas the volatility of permanent income is highest for the young.[27] Overall, the shape of the resulting life-cycle income process is in line with other recent estimates in the literature (see Guvenen et al. 2015 and Guvenen et al. 2018, for example) based on alternative methodologies.

Preferences and budget constraints. Following Epstein and Zin (1989) and Weil (1989), households have recursive, nonexpected utility. Working people's consumption is C_t and labor supplied is L_t. The time endowment is normalized to 1, so leisure is $(1 - L_t)$. Working age utility is

$$V_t = \left\{(1-\beta)U_t^{(1-\rho)} + \beta\left[\left(E_t\left[V_{t+1}^{1-\gamma}\right]\right)^{\frac{(1-\rho)}{(1-\gamma)}}\right]\right\}^{\frac{1}{(1-\rho)}}, \tag{6}$$

where $U_t = C_t^{\nu}(1 - L_t)^{1-\nu}$ is a Cobb–Douglas index of consumption and leisure with $0 \leq \nu \leq 1$, ρ^{-1} is the intertemporal elasticity of substitution with $\rho > 0$, $\gamma > 0$, and $0 < \beta < 1$ is the subjective discount factor.

26. As in Carroll (1997), the transitory income shock is a mixture of a Gaussian distribution and a low-probability zero income event for that quarter. This mixture of distributions is frequently employed to model the empirical features of income data, which is approximately log-normally distributed except for a concentration of observations at the left tail.

27. We note that Heathcote, Storesletten, and Violante (2010, pages 698, 699) obtain estimates of the standard deviations for the transitory and permanent components of wages (not household income) that are similar to ours. Hence, the distinction between labor wages and total income may not matter substantially for prime age workers, as is also suggested by the empirical work above.

Working-aged people receive exogenous labor income W_t, and can borrow or lend by going short or long the bond. The net number of bonds held by the household is A_t. A borrower, $A_t < 0$, pays one unit of consumption per bond, while a saver receives one unit of consumption per bond.[28] The value of the bond is the inverse of the interest rate, $P_t^a = 1/r_t$. Current wealth for working-aged people consists of the net bond coupon (A_t) plus the market value of the bonds plus labor income less consumption. Their sequential budget constraints are

$$A_{t+1} = A_t + r_t(A_t + L_t W_t - C_t). \tag{7}$$

When people retire, they can die prematurely and must maintain a nonnegative asset position to ensure that they do not die in debt. Retired people also have a bequest motive. Following Gomes and Michaelides (2005), we model the bequest motive as

$$B_t = \frac{1}{1-\gamma} E_t \left(\left(\frac{1}{b} \frac{A_{t+1}}{r_t} \right)^{\nu} \right)^{1-\gamma}.$$

Let the cohort-specific probability of surviving another period be δ_t (cohort index suppressed). Then utility for retired people is

$$V_t = \left\{ (1 - \beta\delta_t)\left(C_t^{\nu}\right)^{(1-\rho)} + \beta\left[\delta_t E_t\left(V_{t+1}^{1-\gamma}\right) + (1-\delta_t)B_t\right]^{\frac{1-\rho}{1-\gamma}} \right\}^{\frac{1}{1-\rho}}, \tag{8}$$

If S_t is pension income, retired people's budget constraints are

$$A_{t+1} = A_t + r_t(A_t + S_t - C_t)$$

with $A_t \geq 0$.

Solution and parameterization. We solve the model on the direct grid of the discretized state space, working backward from the last period of life to get policy functions for the stationary model, where variables are normalized by permanent income. The implied level (unnormalized) values are then obtained by multiplying by permanent income.

To generate the long-term interest rate, we begin with AR(1) dynamics estimated for the federal funds rate and discretized following Tauchen and Hussey (1991). Then we apply the expectations theory of the term structure to obtain the long-term interest rate but with two modifications. The first modification is to approximate the consol rate with the implied 10-year yield. That is because the expectations theory implies a constant consol rate. The second modification is to add a term premium of 1.309%, which is the average 10-year term premium observed in the data from 1990 to 2007.

28. Cash flow effects related to interest rate changes are confined to rebalanced asset holdings. In contrast, Auclert (2019) emphasizes unhedged interest exposures, which arise both from maturing assets and liabilities, as well as short-term assets. The online Appendix reports the results when the saving instrument is instead a one-period bond.

With five states for the interest rate, the long-term rate can take values of 3.08%, 3.27%, 3.44%, 3.61%, and 3.78% per annum.

Retirees receive 40% of the labor income from their last period of work as a pension. The pension replacement rate is set at 0.4. Utility function parameters are $\beta = 0.9962$, $\gamma = 4$, $\nu = 0.5$, and $\rho = 1.5^{-1}$. This gives an annualized rate of time preference of 1.54% and an intertemporal elasticity of substitution of 1.5.[29] The bequest function parameter is $b = 2.5$ as in Gomes and Michaelides (2005).

7.2 Model Impulse Responses

We simulate the economy for 300 periods (quarters). After 248 periods, the economy becomes populated by a full complement of cohorts. Each cohort consists of 6,000 people. The impulse event is a decline in the long-term bond rate generated by a decline in the federal funds rate.

The transmission mechanism starts with the monetary policy shock that lowers the interest rate and affects consumption decisions. In the model, we want the interest rate dynamics driving the model's impulse response to look as it does in the data. To illustrate how interest rates respond to monetary policy shocks in the data, Figure 10 shows the impulse responses of the real federal funds rate to the four monetary policy shocks used in Section 3.

As can be seen, the shocks (except perhaps HFI-CMO) have persistent effects on the real federal funds rate. To conform to these empirics, we model the expansionary interest rate shock as a persistent decline. Four periods before the shock, the long-term interest is set at its mean value (3.44%). In the shock period, it falls to its lowest value (3.08%) for seven quarters, and then rises to the next lowest value (3.27%) for the next six quarters before resuming random evolution.

We simulate unnormalized responses of log consumption, log labor supply, asset quantities, and asset values for each individual to the negative interest rate shock.[30] We then take the mean within each age cohort, and then the mean within the young, middle, and old age groups.

Figure 11 shows the unnormalized *relative* responses of mean log consumption, mean asset holdings, mean asset value, and mean log labor supply across age groups to the expansionary interest rate shock. If the shock occurs at $t*$, the relative responses are $\ln(C_t/C_{t*})$ for consumption, $\ln(L_t/L_{t*})$ for labor, A_t/A_{t*} for asset holdings, and $(P_t^a A_t)/(P_{t*}^a A_{t*})$ for asset value. Panel A shows that old consumption is the most responsive to the negative interest rate shock. The middle response is mildly positive, while the young response is basically nil.

29. With infinitely lived agents, a value of $\nu = 0.36$ typically gives a steady-state choice of time worked at one-third of the time endowment. We set ν at a slightly higher value.

30. Assets are not logged since young and middle households can borrow, resulting in negative values for assets.

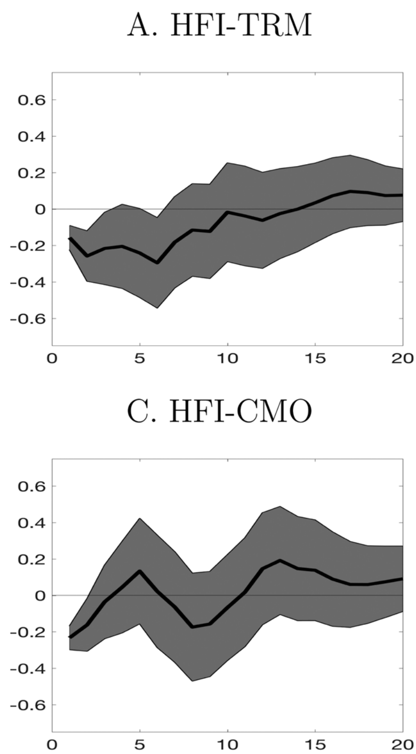

Fig 10. Real Federal Funds Rate Impulse Response to Expansionary Monetary Policy Shock.

Overall, the life-cycle model qualitatively replicates our main empirical finding based on the CEX data—namely, that old consumption is most responsive to monetary policy shocks. Quantitatively, the response for the middle age is smaller than in some of our empirical estimates. Looking back at Figures 2 and 3 and Table 2, the estimated response for the old is about twice the size of the middle-aged in many (but not all) of the specifications and time horizons. In contrast, Figure 11 shows the model response among the old to be four or five times larger over the first 2 years following a shock. We leave it to future research to uncover why middle-aged households might respond more than that implied by the model (short-term assets interacting with credit constraints are one possibility that we abstract from). In the remainder of the paper, we discuss the aspects of our model that qualitatively deliver the ranking of consumption responses observed in the data.

The model mechanism works through the wealth effects and labor-supply margins that differ over the life cycle. The persistent consumption response follows from the persistent reduction in the interest rate. Panel A shows that the model qualitatively explains our main empirical result—that the old have the biggest consumption response to an interest rate cut. In Panel B, the interest rate decline is seen to cause

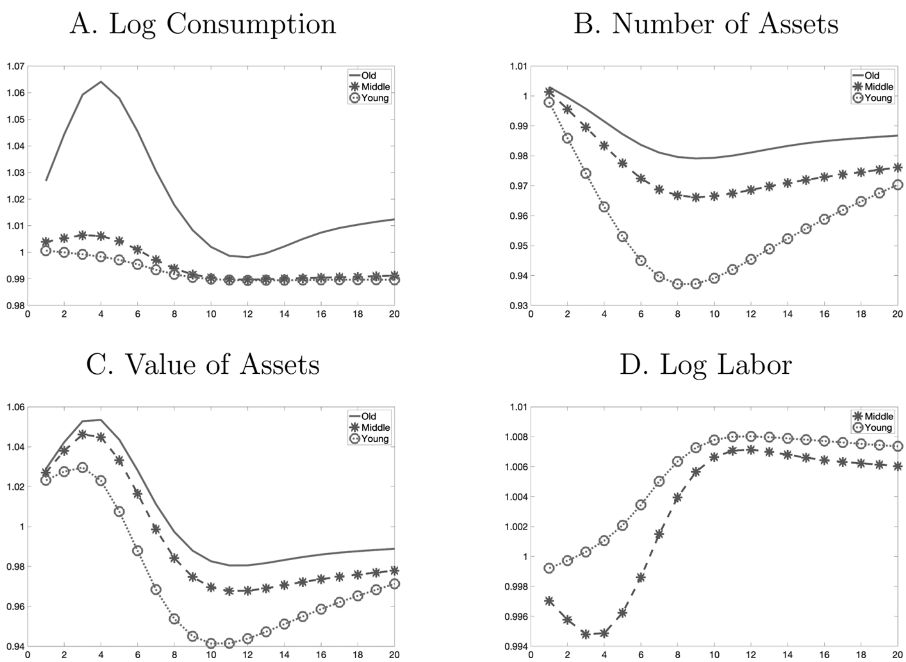

Fig 11. Relative Mean Response to Negative Interest Rate Shock.

NOTES: The figure shows the simulated unnormalized relative mean responses by age group to a decline in the long-term bond rate. If the shock occurs at time $t*$, the relative responses are $\ln(C_t/C_{t*})$ for consumption, $\ln(L_t/L_{t*})$ for labor, A_t/A_{t*} for asset holdings, and $(P_t^a A_t)/(P_{t*}^a A_{t*})$ for asset values. The horizontal axis indicates the number of quarters for up to 5 years after the shock.

asset decumulation (by numbers of assets) by all age groups. Relative decumulation is greatest by the young, who also have the lowest asset levels. Panel C shows that the old realize the largest capital gains on their assets. While the old sell about 2% of their assets, this reduction is more than offset by the increased value of their portfolio. Panel D shows that the interest rate shock leaves labor supply largely unchanged, and hence, labor income largely unchanged. After 10 quarters, the increase in young labor supply is about 8/10 of a percent. The young do not hold many assets and finance consumption primarily out of labor income, which, in the model, is not affected by the interest rate.

The online Appendix reports on a number of additional findings from the model, which we summarize here. We find that old wealthy households have the highest consumption response. Middle-aged households have a smaller response, whether they are wealthy or not. This small response is because most middle-aged households would like to accumulate assets; they even increase their labor supply (modestly) to do so. The youngest group behaves similarly, although the labor response difference between the wealthy and poor is trivial. Instead of adjusting their labor, the poor young cut their consumption.

The online Appendix also shows that the model generates realistic distributions of asset holdings across the three age groups. As in the data, younger households accumulate wealth, but older households hold much more. The wealth distribution within each age group is also highly skewed. A few lucky people accumulate massive wealth, leading to large capital gains. In the periods before retirement, the median household has accumulated only six quarters of consumption in bond wealth. Overall, consumption has the familiar hump shape over the life cycle, although a few rich retirees go on a consumption binge in the last few periods of their life.

To summarize, the model qualitatively explains key features of the data. In response to an exogenous interest rate cut, in both the data and the model, (i) consumption by the old increases by more than the middle and young, (ii) consumption by the wealthy old increases by more than the poor old, (iii) consumption by wealthy young increases slightly but consumption by poor young decreases, and (iv) consumption responses by middle wealthy and poor do not differ by much.

The essential feature of the model is recursive utility with high intertemporal elasticity of substitution, $\rho^{-1} = 1.5$, along with the use of a long-term asset. Other parameter settings yield counterfactual predictions. Those we investigated include the following:

1. When the asset is a one-period discount bond, the highest consumption response is by the middle, followed by the old, followed by the young.
2. Eliminating the labor-leisure choice results in the highest consumption response by the young, followed by the old, followed by the middle.
3. Under constant relative risk aversion utility (risk aversion coefficient = 4), working-aged people all go into debt; the interest rate cut generates virtually no consumption response by the old and middle, while consumption of the young declines.
4. When $\gamma = 12$, the poor young increase consumption more and take more leisure than the wealthy young.
5. Low IES ($\rho^{-1} = 0.5$) induces virtually all working-aged people to go into debt.

The online Appendix shows these model impulse responses under the alternative parameter settings.

8. CONCLUSION

The weight of the evidence presented across alternative monetary policy shocks, empirical methods, and consumption measures is that aggregate consumption of old households reacts more to monetary policy shocks than do middle and young households. We conjectured four potential features of life-cycle heterogeneity, which together form the underlying mechanism driving the observed consumption response patterns. They are life-cycle heterogeneity in portfolio composition, discounting and planning horizons, labor supply, and wealth. Sensibly, we find that households who rely on and hold the most wealth react strongly to shocks that will likely impact asset values. Several recent papers, e.g., Glover et al. (2020), have begun to document similar facts in other contexts.

We investigate the explanatory power of these ideas with a life-cycle model where households, who face uncertain labor income, death, and interest rates, make consumption, saving, and labor supply decisions. The model is able to replicate the most salient feature of the data, which is that consumption of old households is more responsive to monetary policy shocks than younger households.

Understanding potential heterogeneous responses to monetary policy is an interesting topic in its own right. Additionally, as the U.S. population continues to age, our results suggest a potential change in the effectiveness of monetary policy.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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