Revisiting the Effect of Monetary Policy on Household Consumption: A Functional Approach *

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Abstract

This paper uses a novel methodology (the functional local projection (FLP) approach developed by Inoue and Rossi (2021)) and US household survey data to investigate the heterogeneous response of household consumption to monetary policy. Measuring shocks as shifts in the entire term structure of interest rates reveals significant heterogeneity in the response of consumption during conventional and unconventional times. We find that consumption by outright owners is more sensitive to unconventional shocks than that of mortgagors and renters. In addition, we show that the consumption of younger households is more responsive to shocks that affect medium- and long-term interest rates than that of middle-age and older households. Our study provides empirical support in favor of theories that underline the importance of wealth and life cycle effects on the responsiveness of households to unconventional policy.

Keywords: Monetary Policy, Interest Rates, Consumption, EIS, Functional local projections

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1 Introduction

How do monetary policy shocks affect households' consumption expenditure? Do households with different levels of debt or at different points in the life cycle respond in a heterogeneous way? These questions have long been at the core of economic research and policy discussions. However, our understanding of how monetary policy shocks affect consumption is largely based on studies that focus on changes in short-term interest rates during conventional times. Earlier empirical studies have found that differences in households' balance sheets and differences in life cycle stages play a key role in the transmission of conventional monetary policy shocks (see, e.g., Cloyne et al. (2020) and Berg et al. (2020) among others). Moreover, since the Great Recession, academics and policy makers have recognized the importance of accounting for heterogeneous agents when studying business cycles.[1]

Despite the large empirical literature on the transmission of conventional monetary policy, less is known about the heterogeneous effects of unconventional monetary policy on consumption. However, both during the Great Recession and the Covid-19 pandemic -when short-term interest rates hit the zero lower bound - unconventional measures such as large asset purchases and forward guidance were used by the Federal Reserve and other central banks to moderate the consumer crunch. This paper employs the novel *functional* local projection (FLP) approach from Inoue and Rossi (2021) and data from US household surveys to investigate the heterogeneous response of household consumption to unconventional monetary policy and revisits empirical findings regarding transmission mechanisms of conventional monetary policy. Specifically, following Nelson and Siegel (1987) and Diebold and Li (2006), we first model yields as a function of their maturity and compute functional monetary policy shocks as movements in the term structure on FOMC announcement days. We then use the three extracted latent factors (level, slope, and curvature) to estimate the effect of monetary policy on consumption expenditure.

The FLP approach is well suited to study the heterogeneous effect of monetary policy for several reasons. It provides a unified framework for investigating the impact of conventional and unconventional monetary policy shocks, and thus allows us to circumvent the issue of having only a short estimation sample for the unconventional period. Moreover, the functional approach enables us to examine whether unconventional policies impact households differently based on their debt levels or life cycle stages. Exploring this aspect is crucial for developed countries like the US, where the percentage of the population aged 65 or older is increasing and where the effectiveness of monetary policy may depend on its ability to

[1]See Yellen (2016) for a discussion on the importance of shifting away from the representative agent paradigm after the Great Recession.

alter this group's consumption. Lastly, the conduct of monetary policy changed considerably during unconventional times. Although short-term interest rates remained close to zero, the Federal Reserve managed to tilt the yield curve by taking actions that targeted medium- and long-term interest rates. The effects of two tools that became common during the financial crisis, forward guidance and quantitative easing, are likely to be better captured via functional shocks. Moreover, identifying monetary policy shocks as scalar changes in short-term interest rates may underplay a source of heterogeneity in the consumption response to monetary policy: the diverse nature of monetary policy shocks.

As in Cloyne et al. (2020) and Berg et al. (2020), we employ household expenditure and income data from the US Consumer Expenditure Survey (CEX) to construct pseudo-cohorts based on housing tenure (outright owners–hereafter owners–, mortgagors, and renters) or age of the head of household (old, middle-aged, and young). The first set of pseudo-cohorts serves in studying heterogeneity across balance sheet positions, whereas the second enables us to investigate heterogeneity across the life cycle. As noted by other researchers, an advantage of the CEX is that it spans a long period and contains information on household expenditure, income, assets, liabilities, and age, allowing us to revisit the heterogeneous effect of various monetary policy shocks.

Three important insights are derived from our study. First, while reductions in consumption expenditure constitute an important transmission channel of contractionary monetary policy, heterogeneity across functional shocks in conventional and unconventional times is translated into quite diverse responses of durable and nondurable consumption across households with different levels of debt or age. Second, during unconventional times, the burden of the contraction shifts to wealthy households (outright owners), especially through curtailed expenditure on durable goods. The impact on renters and mortgagors is limited. Lastly, shocks that simultaneously reduce short-term interest rates and increase long-term interest rates–common during unconventional times– lead young households to reduce consumption while they have insignificant or slightly positive effects for middle-aged and old households. These results stand in contrast to Cloyne et al. (2020) and Berg et al. (2020), who find that outright owners and middle-aged and young households do not respond significantly to conventional scalar monetary policy shocks.

What transmission channels account for the heterogeneity in the transmission of monetary policy to consumption? While the vast majority of the theoretical literature treats short-term nominal interest rates as the primary monetary policy instrument (Kaplan et al., 2018), and does not model changes in the whole structure of interest rates, it provides a solid theoretical guide for our investigation. A recent survey of heterogeneous-agent incomplete market models by Kaplan and Violante (2022) notes that heterogeneity in the marginal

propensity to consume (MPC) of households could stem from the presence of hand-to-mouth households, precautionary savings, or ex-ante heterogeneity, which may be linked to a household's life cycle stage and debt holdings.

To inquire about the transmission channels, we estimate the effect of *functional* monetary policy shocks on disposable income, total household assets, and rental and mortgage payments, which directly affect the cash flow of renters and wealthy hand-to-mouth mortgagors. Since housing is the largest household asset, we also examine how housing prices respond to monetary policy shocks.[2] We find that, both in conventional and unconventional times, heterogeneity in the income response cannot fully explain the heterogeneity in the response of consumption expenditure. Instead, we find that during unconventional times, monetary policy has a large wealth effect, as it puts pressure on medium- and long-term interest rates and, in turn, affects durable consumption by outright owners. In addition, the interaction between more stringent liquidity constraints and longer planning horizons accounts for the increased responsiveness of young households to unconventional policies.

Two potentially important implications for the conduct of monetary policy stem from our analysis. First, because conventional contractionary policies tend to impose a higher burden on young and liquidity-constrained households, they could exacerbate consumption inequality. Second, the greater sensitivity of durable consumption by outright owners to unconventional monetary policies suggests that, as the fraction of the older population increases, monetary policies that target medium- and long-term interest rates could become increasingly useful in stimulating consumption and economic activity.

Our work is related to several strands of literature. First, our paper is related to articles investigating the effects of monetary policy shocks during conventional and unconventional times, such as Lakdawala (2019) and Jarociński and Karadi (2020), and to the literature that studies the effects of unconventional monetary policy actions –such as forward guidance and quantitative easing– using high-frequency identification (see, e.g., Swanson (2021), Gürkaynak et al. (2005)). We depart from their approach, as we employ a functional monetary policy shock. Our methodology follows Inoue and Rossi (2019, 2021), who study the effect of monetary policy on economic activity, inflation, and exchange rates.

Second, this article is closely related to research that uses aggregate consumption data to investigate the mechanisms that account for heterogeneity in the dynamic response of aggregate consumption to monetary policy shocks. We build on the work of Cloyne et al. (2020) and Berg et al. (2020), who investigated whether the transmission of conventional monetary policy shock is influenced by differences in liquidity and age, respectively.[3] A

[2]Work by Mian et al. (2013), Mian et al. (2017), and Kaplan et al. (2018), among others, suggest that heterogeneity in household debt plays a key role in the transmission of macroeconomic shocks.

[3]Related work by Leahy and Thapar (2022) finds that the share of the population under 35 years of age

key difference is that we revisit the heterogeneous effect of monetary policy on consumption using a unified framework to study the effects of *conventional* and *unconventional* policies, while digging deeper into the transmission mechanisms during unconventional times.

Third, our article is related to the theoretical and empirical literature investigating the role of household characteristics such as age, credit restrictions, balance sheet positions, and wealth in the transmission of macroeconomic shocks. Kaplan et al. (2018), Kaplan and Violante (2022), McKay and Wieland (2022), Bilbiie (2020), Mian et al. (2013), Mian and Sufi (2014), and Mian et al. (2017), among others, highlight the importance of household balance sheets in the transmission of shocks. On the empirical front, Di Maggio et al. (2020) explore the effect of large-scale asset purchases on the real economy and consumption, while Flodén et al. (2020) and Di Maggio et al. (2017) exploit adjustable-rate mortgages in different contexts to illustrate the importance of balance sheets in the cash flow channel. Our study provides empirical support in favor of theories that underline the role of wealth and household life cycle in explaining the response of consumption to unconventional monetary policy.

Finally, our study is connected to empirical research that investigates the effect of income changes on consumption expenditure.[4] Although early research focused on aggregate data, the vast majority of empirical studies rely on micro-level data. In contrast, we build aggregate data from the household survey and are interested in estimating the dynamic response of consumption to unconventional (and conventional) monetary policy.

This paper is structured as follows. Section 2 reviews the *functional local projection* approach developed by Inoue and Rossi (2021). We describe the data in Section 3 and discuss the empirical specification in Section 4. Sections 5 and 6 discuss the results by housing tenure and age, respectively. We explore the relevance of alternative transmission channels in Section 7 and describe the results of a battery of robustness checks in Section 8. Section 9 concludes.

2 Measuring Monetary Policy Shocks

2.1 High-frequency Identification, Functional and Scalar Monetary Policy Shocks

As mentioned above, we use the FLP approach proposed by Inoue and Rossi (2021) to study the effect of conventional and unconventional monetary policy on household consumption.

(between 40 and 65) attenuates (exacerbates) the effect of the interest rate increase on private employment and personal income.

[4]See Jappelli and Pistaferri (2010) for an excellent survey.

The novelty of the functional shock approach lies not in the identification of the shock but rather in how monetary policy shocks are measured. To gain some insight as to how this method differs from the conventional scalar approach, consider the case, as in this paper, where a high-frequency identification (HFI) scheme is used. HFI defines a scalar shock as the change in a yield at a given maturity within a short window around the FOMC announcement.[5] Studies that use HFI of monetary policy shocks have employed different measures of interest rates and short window lengths.[6] HFI has the advantage of estimating a well-identified average effect of changes in short-term rates, yet it ignores useful information regarding the impact of such announcements on longer-term interest rates during the same window of time, which may bias estimates of impulse responses to monetary policy shocks (Jarociński and Karadi (2020) Miranda-Agrippino and Ricco (2021)). In addition, FOMC announcements may lead to similar changes in short-term interest rates (especially when they are close to the zero lower bound, ZLB), but dissimilar changes in long-term yields.[7] A monetary policy shock identified by changes only in short-term maturities could miss this important difference, whereas the functional shock approach addresses these shortcomings.

In contrast, the *functional* shock simultaneously captures the change at each maturity in the yield curve around the time of the FOMC announcement. The change in the entire term structure matters; roughly a third of the 1990s monetary policy shocks caused asset prices to appreciate (depreciate) when the short-term shock was contractionary (expansionary), despite the Federal Reserve targeting a short-term rate (the federal funds rate).[8] Since the onset of the ZLB, central banks have intentionally targeted other parts of the yield curve via quantitative easing and forward guidance. Indeed, as we shall see in the following sections, these actions sometimes led short- and long-term interest rates to move in the opposite direction.[9] The functional approach enables us to estimate the impact of different monetary policies on household consumption using a unified framework during conventional and unconventional times.

[5]See the top panel of Figure 1 for an illustration.

[6]Gertler and Karadi (2015) measure a monetary policy shock as the change in the 3-month-forward future prices of federal funds within a 30-minute window of Federal Open Market Committee (FOMC) announcements; Gorodnichenko and Weber (2016) employs changes in federal funds futures within a 60-minute window; Jayawickrema and Swanson (2021) uses intradaily interest rate changes using a window that starts 10 minutes before each FOMC announcement and ends 20 minutes after it. Others have applied factor models to capture changes in several contracts (Barakchian and Crowe, 2013).

[7]See the bottom panel of Figure 1 for an illustration.

[8]See (Jarociński and Karadi, 2020).

[9]Gürkaynak et al. (2005) and Rogers et al. (2014) show that unconventional policy affects the term structure of the yield curve.

2.2 Why Does the Distinction Between Scalar and Functional Shocks Matter for Consumption

The functional shock approach is well suited to investigate the effect of monetary policy on aggregate consumption for several reasons. First, while the effect of wealth changes induced by monetary policy shocks has long been understood as a transmission channel of monetary policy (Modigliani and Brumberg (1954), Modigliani and Brumberg (1980), Ando and Modigliani (1963)), less is known about how unconventional policies affect wealth and thus aggregate consumption expenditure. Investigating such questions is particularly important during periods such as the ZLB when unconventional monetary policy tools are heavily utilized.

Second, many empirical investigations into the transmission of monetary policy shocks identify the direct effect of the policy via changes in a single short-run interest rate (i.e. a scalar shock); the effect of the policy on long-term interest rates is captured via their response to this shock. Instead, the functional approach measures the shift in the whole yield curve around the time to the FOMC announcement, and thus simultaneously incorporates information about future expected interest rates in the estimation of the impulse responses of interest. This is key when exploring whether the response to monetary policy shocks differs between households with different characteristics, such as the composition of their assets or the stage in their life cycle. For instance, households who are wealthy hand-to-mouth (mortgagors) may have a different response to shocks that decrease the slope of the yield curve (thus reflecting lower long-term interest rates and possible gains of refinancing) than households who do not have a mortgage (outright owners). Furthermore, younger households have a longer planning horizon and could therefore be more sensitive to expected changes in long-term interest rates induced by forward guidance or quantitative easing.

In summary, using a scalar monetary policy shock might lead the researcher to miss heterogeneity in the response of consumption expenditure across households, especially during ZLB periods. Given that consumption is the largest component of GDP and that previous work has found that traditional identification methods could miss important monetary policy effects on output and inflation (see Inoue and Rossi (2021)), we believe that it is important to revisit its impact on consumption.

3 Household Consumption Expenditure Data

To investigate the effect of monetary policy on consumption, we use data from the Consumption Expenditure Survey (CEX) from the first week of January 1984 to the last week

of December 2019.[10] One advantage of CEX is that it contains detailed expenditure data on durable and non-durable goods; a key distinction given that recent theoretical and empirical literature suggests demand for the former is more sensitive to current interest rate changes than to forward guidance (McKay and Wieland, 2022). An additional advantage is that it provides information on household characteristics such as household size, demographics, mortgage, and rent payments, allowing us to investigate heterogeneity in the transmission of monetary policy across different groups. In addition, data on housing tenure status serves as a proxy for a household's balance sheet position (Cloyne, Ferreira and Surico (2020)): (a) mortgagors are characterized by having wealth largely composed of equity in housing and a high level of debt; (b) the wealth of homeowners is composed of both housing and other financial assets. Although there may be concerns about endogenous changes in tenure status due to a monetary policy shock, Cloyne, Ferreira and Surico (2020) provide descriptive and formal evidence that composition changes are slow-moving, while monetary policy decisions take place at a significantly higher frequency. Indeed, Figure A.2 illustrates a rather stable tenure composition between 1983 and 2019 in the CEX.

Another concern is how well the survey data match national consumption expenditure estimates. Figure A.3 compares total, durable and non-durable expenditure per capita across tenures using data from the National Income and Product Accounts (NIPA). Each figure shows the corresponding trends in the CEX and the NIPA. Table A.1 shows that the CEX series and the NIPA series are highly correlated. Note that the evolution of the CEX time series for mortgagors and owners closely follows that of the NIPA; the correlations for all

[10]The survey comprises five interviews conducted three months apart and the expenditure data –collected in the last four interviews– covers a twelve-month period. Our object of interest is the change in per capita consumption expenditure for the average household in a particular group or pseudo-cohort. These groups are defined by housing tenure (i.e. outright owners, mortgagors, renters) or by age (i.e., old, middle-aged and young). Thus, we first divide a household's expenditure by the number of persons in the household to produce a measure of per capita expenditure. We then compute the average per capita expenditure for each group.

Our measure of average household expenditure by housing tenure and age is similar to that of Cloyne, Ferreira and Surico (2020) and Berg, Curtis, Lugauer and Mark (2020), respectively. Consumption by housing tenure is calculated based on the code that identifies the household as an outright owner, mortgagor, or renter. Consumption expenditure by age group is computed based on the age of the household's head; we divide households into young (25–34), middle (35–64), and old (65+)[11]. Because the timing of the interviews may not align with calendar quarters, we weigh the consumption of a given household by the number of months their interviews overlap with each calendar quarter (Berg, Curtis, Lugauer and Mark (2020)). These weighted consumption measures are deflated by the Consumer Price Index.

The motivation to use CEX data instead of the Panel Survey of Income Dynamics (PSID) is two-fold. Regular data collection for the CEX started in 1980 making it the most widely used data set to study consumption dynamics in the U.S. Data collection on expenditures other than food and housing did not start until 1999 for the PSID. Second, even for modern PSID, data collection takes place at a biannual frequency, which is not an ideal frequency given our interest in identifying the dynamic response to monetary policy shocks.

variables but nondurable consumption exceed 0.95 and equal 0.87 and 0.80 for mortgagors and owners, respectively. The data for renters are highly correlated with their NIPA counterparts, especially for total expenditure.[12].

4 Empirical Specification and Estimation Strategy

4.1 Functional Monetary Policy Shocks

Following Inoue and Rossi (2021) we identify monetary policy shocks as shifts in the yield curve, on the day of a Federal Open Market Committee (FOMC) meeting, using a parametric approach. That is, we first employ the widely-used Nelson and Siegel (1987) / Diebold and Li (2006) framework to fit the yield curve using the three-factor model,

$$y_t(M) = \beta_{l,t} + \beta_{s,t}\left(\frac{1-e^{-\lambda M}}{\lambda M}\right) + \beta_{c,t}\left(\frac{1-e^{-\lambda M}}{\lambda M} - e^{-\lambda M}\right) \tag{1}$$

where $y_t(M)$ denotes the yield for maturity M at time t, λ is a tuning parameter that governs the exponential decay rate (e.g., small values result in slow decay and better fit at longer maturities whereas large values result in fast decay and better fit at shorter maturities), and $\beta_{l,t}$, $\beta_{s,t}$, and $\beta_{c,t}$ represent three latent dynamic factors that govern the level, slope, and curvature of the yield curve, respectively. To estimate the yield before and after the FOMC announcement, we employ the US zero coupon yields from Gürkaynak, Sack and Swanson (2007),[13] and following Diebold and Li (2006) we fix the value of λ to 0.0609,[14] which maximizes the loading on the medium-term factor at 30 months.

Then, the functional monetary policy shock is defined as a change in the yield curve on the day of an FOMC announcement. Therefore, the shock is computed as follows:

$$\epsilon_{f,t}(M) \equiv \Delta y_t(M) \cdot d_t \tag{2}$$

where d_t is an indicator variable that takes the value of one when an FOMC announcement takes place at time t. From equations (1) and (2), we may rewrite the functional monetary

[12]The main specification includes quarterly dummies to deseasonalize the data. Following Cloyne, Ferreira and Surico (2020), the data are also smoothed using a four-quarter backward moving average

[13]As in Inoue and Rossi (2021) we employ yields at 3, 6, 12, 24, 36, 48, 60, 72, 84, 96 and 120 months to fit the yield curve at any time t.

[14]Estimation results not reported herein, but available from the authors upon requests, show that our findings are robust to setting $\lambda = 0.077$ as estimated by Diebold et al. (2006).

policy shock as

$$\epsilon_{f,t}(M) \equiv \Delta\beta^d_{l,t} + \Delta\beta^d_{s,t}\left(\frac{1-e^{-\lambda M}}{\lambda M}\right) + \Delta\beta^d_{c,t}\left(\frac{1-e^{-\lambda M}}{\lambda M} - e^{-\lambda M}\right) \tag{3}$$

where $\Delta\beta^d_{j,t} \equiv d_t \cdot \Delta\beta_{j,t}$ for $j = l, s, c$ capture changes in the level, slope, and curvature of the yield curve around the FOMC announcement. This equation makes it evident that each β embodies a different aspect of monetary policy.[15] For example, $\Delta\beta_{s,t}$ can be interpreted as a conventional monetary policy shock, as it reflects changes in short-term maturities. Instead, $\Delta\beta_{c,t}$ captures changes in monetary policy that affect medium-term yields. For example, unconventional monetary policy can target medium and long-term interest rates without having a significant impact on the short-term rate. This can be the case with forward guidance. In addition, $\Delta\beta_{l,t}$ corresponds to a policy that simultaneously changes all interest rates.

As noted by Inoue and Rossi (2021), linear combinations of the three terms provide a useful way to compare the differences between shocks. The combination $\Delta\beta_{l,t} + \Delta\beta_{s,t}$ produces the instantaneous change in yields, while $\Delta\beta_{c,t} - \Delta\beta_{l,t}$ expresses changes in the long run after accounting for any simultaneous changes. Table 2 illustrates how these parameters vary between shocks during conventional and unconventional times, respectively. For example, for the 1997: Q1 episode reported Table 2, $\Delta\beta_{l,t} + \Delta\beta_{s,t} = -0.001$ indicates that the change in instantaneous yield was small, while $\Delta\beta_{c,t} - \Delta\beta_{l,t} = 0.228$ reveals a considerably larger increase at longer maturities. This example illustrates how monetary policy may cause little or no change in the instantaneous rate, yet affect longer-term interest rates through changes in the long-term yield. Henceforth, we shall refer to $\Delta\beta_{l,t} + \Delta\beta_{s,t}$ as the *instantaneous yield* and $\Delta\beta_{c,t} - \Delta\beta_{l,t}$ as the *long-term yield*. Furthermore, the functional shock approach could allows us to decompose the effect of a historical shock into these three components and, thus, evaluate on how much of the effect is driven by changes in each of the latent factors.[16]

4.2 Estimation Strategy

To estimate the effect of monetary policy shocks on aggregate consumption by cohorts, we proceed in two steps. First, we aggregate daily *functional* monetary policy shocks (i.e. $\Delta\beta_{l,t}$, $\Delta\beta_{s,t}$. $\Delta\beta_{c,t}$) to match the quarterly frequency of the consumption data by attributing the daily shift on the day of the FOMC announcement (computed in Section 4.1) to a given

[15] Contrary Inoue and Rossi (2021) study, where monthly data is employed, we find little evidence of collinearity among the $\Delta\beta'_{it}s$ and, hence include the three terms in the FLP.

[16] To economizes space, decomposition of the contribution of each β to the impulse response functions are not reported within the paper. The results are available from the authors on request.

quarter. Each quarter contains at least one announcement; some quarters contain two. When more than one shock occurs in a quarter, we sum them.[17] As a result, we have three quarterly series corresponding to changes in the three factors that we denote by $\Delta\beta_{j,q}$, where $j = l, s, c$ (level, slope, and curvature) and q denotes the quarter. In the second step, we project the aggregate measure of consumption on these three quarterly shocks. That is, for each cohort (by age or tenure) and type of consumption (nondurable and durable), we estimate impulse response functions to a functional monetary policy shock, $\epsilon_{f,q}$, via FLP by estimating the following regressions for each horizon h:

$$C_{q+h} = \alpha_h + \Gamma_{1,h}\Delta\beta_{l,q} + \Gamma_{2,h}\Delta\beta_{s,q} + \Gamma_{3,h}\Delta\beta_{c,q} + A(L)C_{q-1} + u_{q+h} \tag{4}$$

where C_{q+h} denotes the logarithm of consumption expenditure for each household cohort at time $q + h$, $h = 0, 1, 2, ..., 12$, the vector α_h contains quarterly dummies, a constant, and a time trend, u_{q+h} is an error term.[18] Then, the effect of the functional shock on consumption at horizon h is computed as $\frac{dC_{q+h}}{d\epsilon_{f,q}} = \sum_{j=1}^{3} \hat{\Gamma}_{j,h}\Delta\beta_{j,q}$. Equation (4) implies that each monetary policy shock, $\epsilon_{f,q}$, at time q has a different impulse response function, since the $\Delta\beta_{j,q}$ are different for each quarter. We use Newey and West (1987) standard errors to account for serial correlation. To avoid excessive variation in the impulse response estimates, an issue common in LP estimates, we follow Inoue and Rossi (2019) in using a fourth-order polynomial. The estimates reported in the appendix show that the results are robust to using LP without smoothing.

Before discussing monetary policy's effects on household consumption, we address possible concerns regarding the predictability of the constructed monetary policy shocks concerning the cohort-level consumption data. To do so, we conducted pairwise and VAR-based Granger causality tests. The VAR-based tests rely on a VAR for each type of consumption (durable or nondurable) that includes lags of all $\Delta\beta$'s and lags of the durable (nondurable) consumption level for all cohorts (mortgagors, owners and renters for housing tenure and old, middle-aged and young for age). We fail to reject the null that consumption does not Granger-cause the monetary policy shocks at a 1% level.[19] These tests alleviate concerns about predictability of the monetary policy shocks.

[17] Estimation results reported in the Appendix reveal that our results are robust to aggregating the daily shocks in three different ways (i) by weighting each shock by the number of days left in the month after the shock, (ii) using a simple average, and (iii) summing all the shocks in the quarter.

[18] For ease of comparison with earlier studies, we control for a time trend and lags of the consumption level as in Cloyne et al. (2020); we select the lag length by minimizing the AICC.

[19] Only in the cases of durable consumption for the VAR-based test and durable consumption for mature and for old house holds are we able to reject at a 10% level.

5 Revisiting the effects of monetary policy when households have debt

This section reports the estimation results by housing tenure, which we interpret as a proxy for debt (Cloyne, Ferreira and Surico (2020)). To simplify the exposition and to gain some intuition as to how the responses differ across housing tenure, we first present estimation results for the conventional monetary policy period in Section 5.1. Then, in Section 5.2, we discuss the results for the period of unconventional monetary policy. For the sake of brevity and because each functional shock at a point in time results in an individual impulse response function, we initially focus on three selected events in each period (i.e., conventional and unconventional).

5.1 Conventional monetary policy

To take a first look at how functional monetary policy shocks differ across events, we follow Inoue and Rossi (2021) in reporting changes in the three factors of the yield curve (level, $\Delta\beta_{l,q}$, slope, $\Delta\beta_{s,q}$, and curvature, $\Delta\beta_{c,q}$) as well as changes in instantaneous yield ($\Delta\beta_{l,q}$+$\Delta\beta_{s,q}$) and the long run yield ($\Delta\beta_{c,q}$-$\Delta\beta_{l,q}$).[20] As Table 2 illustrates, all episodes represent distinct changes in the yield curve. For example, 1987Q1 corresponds to a decline in instantaneous yield and an increase in long-term yield with the decline in the former mainly driven by a decrease in $\beta_{l,q}$. In contrast, in 1997Q3, the long-term yield increases, while there is nearly no change in the instantaneous yield as the increase in $\beta_{s,q}$ (typically associated with conventional monetary policy) is offset by an increase in $\beta_{l,q}$ (due to the central bank's ability to simultaneously shift short- and long-term expectations).

As a first summary of the results, Table 3 reports the maximum response of consumption for five episodes of monetary policy. The table provides evidence of heterogeneity in the magnitude of the peak consumption response to conventional monetary policy shocks. Mortgagors and renters exhibit a stronger, albeit sometimes slower, response than owners to all monetary policy events. For example, in response to the 1987Q1 shock, which resulted in a 0.259% decrease in instantaneous yield and a 0.656% increase in long-term yield, mortgagors and renters cut their nondurable consumption by more than 2%, while owners reduced it by less than 1%. In turn, durable consumption decreased by -0.805%, -0.532%, and -0.906%, respectively, for mortgagors, owners, and renters. The greater decline in mortgagors and renters' consumption is consistent with the cash flow channel having a greater impact on

[20] Recall that while the frequency of their data is monthly, we aggregate the shocks to a quarterly frequency to match the frequency of the expenditure data.

households that face more stringent liquidity constraints (Cloyne et al., 2020).

A key difference in the response to *scalar* and *functional* monetary policy shocks across housing tenure is our finding of a statistically significant effect on durable consumption for outright owners. To better illustrate this point, Figure 2 plots the impulse responses for three episodes along with the 68% and 90% confidence intervals denoted by light blue and dark blue shaded areas, respectively. The last column in the figure depicts the shift in the yield curve (i.e., the functional shock).[21]

Consider first the response of durable consumption to the 1987Q1 shock (top panel), where the level and slope of the yield curve decline but the curvature increases, leading to a slight rise in the long-term yield and a somewhat larger increase in the short-term rates. In this case, the drop in durable consumption expenditure is greater for mortgagors and renters than for owners. The latter cut durable consumption, but the response is smaller and only marginally significant. On the contrary, for the 1997Q3 shock (middle panel), when the yield curve tilts downward, owners exhibit the largest increase in durable consumption. This suggests that owners' expenditure is more sensitive to monetary policy actions that target long-term interest rates. As a last example of a functional shock during the conventional monetary policy period, consider 1998Q4 (bottom panel), where the level and, especially, the curvature increase, but the slope declines. In particular, owners exhibit a significant decline in durable consumption that is similar (slightly larger) at the trough than the decline for mortgagors (renters) but recovers a bit faster.

Our response estimates for durable consumption stand in contrast with Cloyne, Ferreira and Surico (2020) who find no significant response of owners' consumption to *scalar* unanticipated cuts in interest rates. The difference in responses to scalar and functional shocks suggests that the former may not fully capture consumption responses that stem from changes in the slope and curvature of the yield curve and, thus, underestimate the responsiveness of wealthy households to changes in monetary policy that alter long-term interest rates. Although we further investigate the transmission mechanisms in Section 7, we conjecture that the wealth effect exerted by lower long-term interest rates on assets, stimulates purchases of durable goods by wealthy households.

Regarding the effect of functional monetary policy shocks on nondurable consumption, the heterogeneity found across housing tenure is consistent with recent estimates for scalar shocks (see, e.g. Cloyne, Ferreira and Surico (2020)). Nondurable expenditure by households with a higher level of debt (mortgagors) and, especially, by those more likely to live hand-to-mouth (renters) is more sensitive to changes in interest rates (see Figure 2). That the response for functional and scalar shocks are similar is perhaps not surprising, as nondurables

[21] For the sake of brevity, we relegate the impulse responses for total consumption to the Online Appendix.

goods are well known to be less interest rate sensitive, whereas durable goods are often financed (Mankiw (1985), Lerner (1959), Rampini (2019)).

To summarize, the effects of conventional *functional* monetary policy shocks on nondurables are consistent with those found in the earlier literature using *scalar* shocks. In contrast, our estimates underscore the importance of considering changes in the slope and curvature of the yield curve when estimating the response of durable consumption, especially for households with lower debt.[22]

5.2 Unconventional monetary policy

In the previous section, we showed that taking into account changes in the entire term structure is important for estimating the consumption response of owners to conventional monetary policy. Less is known about the transmission mechanisms of unconventional monetary policy on the average household's consumption expenditure. Previous studies have found that quantitative easing shifts the term structure towards the origin, implying decreases in short- and medium-term rates with larger changes in long-term rates (Inoue and Rossi, 2021). Furthermore, some investigations suggest that forward guidance may have an expansionary effect on output (see, e.g. Lakdawala (2019), Jarociński and Karadi (2020)). Such results highlight the importance of taking a comprehensive approach to modeling the effect of unconventional monetary policy on household expenditure.

Table 2 reports the values of the factors and key linear combinations for the selected episodes of unconventional monetary policy. For most episodes, the change in the long-term yield exceeds that of the instantaneous yield. The only exception being 2014Q2 where the magnitudes match. That unconventional monetary episodes exhibit larger changes in the long-term yield is to be expected, as longer maturities where the targeted instrument when the short-term interest rates hit the ZLB. It is important to note that for most events, monetary policy actions did not result in a parallel shift of the yield curve.

Table 3 reports the peak/trough response of durable, nondurable, and total consumption expenditures across housing tenures for the selected shocks. Interestingly, 2009Q1 saw increases in the short-term interest rate but decreases in the long term. In a conventional method where a shock is a scalar, this shock would be interpreted as monetary tightening; however, the functional shock method reveals a more nuanced picture. The opposite signs of changes in instantaneous and long-term yields for 2012Q3 and 2012Q2 are also to be noted.

Three patterns emerge from Table 3. First, owners' purchases of durable goods are more sensitive to unconventional monetary policy shocks than renters and mortgagors. Second,

[22]Responses for total consumption expenditure are reported in Figure A.1 of the Online Appendix.

purchases of durables by wealthy hand-to-mouth households (mortgagors) respond in the same direction but to a lesser degree than owners. Third, owners' purchases of nondurable goods are less sensitive than those of renters and mortgagors.

To better understand the variation in dynamic responses to unconventional monetary policy shocks, Figure 3 plots the responses of durable consumption expenditure for three episodes: 2009Q1, 2013Q2, and 2014Q2. The last column illustrates the shift in the yield curve associated with the corresponding monetary policy shock. Figure 3 depicts the responses of nondurable consumption expenditure for the same episodes.

Impulse responses clearly illustrate how shocks that tilted the yield curve downward (2009Q1 and 2014Q2) resulted in a significant increase in durable consumption for owners, a smaller and marginally significant increase for mortgagors, and a statistically insignificant increase for renters. In contrast, the 2013Q2 shock, which resulted in a considerably steeper yield curve, led to a large and significant decline in purchases of durable goods for owners, marginally significant decline in durables' expenditure for mortgagors, and no significant response for renters.

The response of nondurable expenditure stands in contrast to that of durables. For the three episodes highlighted in the paper, in which unconventional monetary policy mainly alters medium- and long-term interest rates, the direction of the response is consistent with that found for the episodes of conventional monetary policy, although estimated with a low degree of precision.

5.3 Unifying threads

As mentioned above, the functional approach provides a unifying framework for analyzing the response of consumption expenditure to conventional and unconventional shocks. However, to simplify the exposition, we followed Inoue and Rossi (2021) and focused on a few monetary policy shocks to illustrate the impact of these policies. However, the reader may wonder if our results would change had we picked a different set of events. Figure 4 illustrates the consumption responses across housing tenures for all events in the sample. The two top panels plot the impulse response functions, and the two bottom panels show a slice of the surfaces depicting the peak/trough response for each episode.

Two unifying threads connect the responses across different monetary policy events: the greater sensitivity of durable consumption by wealthier households (especially the less-liquidity-constrained outright owners) and the greater responsiveness of nondurable consumption by poorer, liquidity-constrained households.

There are three potentially important takeaways from our estimation results. The first

is that heterogeneity in the consumption response to monetary policy may stem not only from the micro-level characteristics of the households (e.g., the liquidity of their assets), but also from the way those characteristics interact with the type of policy implemented. In fact, Figure 4 reveals an important degree of variation in monetary policy shocks with some shocks being more persistent than others. Another key takeaway is that contractionary monetary policies–whether conventional or unconventional– exert a large burden on liquidity constrained households who, when faced with lower cash flows, are forced to curtail their nondurable consumption. Therefore, such policies may exacerbate consumption inequality during contractionary times. Lastly, because contractionary monetary policies that target long-term interest rates have a greater impact on wealthier, less liquidity-constrained households, the consequences of such policies on consumption inequality might be less detrimental.[23]

6 Revisiting the effects of monetary policy shocks across demographic groups

Berg, Curtis, Lugauer and Mark (2020) find that consumption expenditure by older households is more sensitive to conventional monetary policy shocks than that of young and middle-aged households. They conjecture that "life-cycle heterogeneity in wealth, portfolio composition, discounting and planning horizons, and labor supply" accounts for the heterogeneous response across age groups. This section investigates whether more nuanced effects of monetary policy on consumption across different age groups are found when using a *functional* approach.

6.1 Monetary policy and consumption over the life cycle

Figures 5 and 5, respectively, plot the response of durable and nondurable expenditure to conventional monetary policy shocks for the three age groups. The solid line denotes the impulse response, while the 68% and 90% confidence bands are denoted by the light and dark blue areas, respectively. The corresponding figures for unconventional times are reported in Figures 6 and 6. The magnitude of the peak/trough response, along with the horizon at which they occur, is summarized in Table 4.[24]

Three takeaways are gleaned from the estimation results. First, durable consumption

[23]Responses for total consumption expenditure are reported in Figure A.2 of the Online Appendix.

[24]For the sake of brevity, we focus on select episodes. Estimates for other dates are available from the authors on request.

expenditures by middle-aged and older households are rather unresponsive to monetary policy shocks during unconventional times. Second, monetary policy shocks that comprise larger drops in long-term than in short-term interest rates (e.g., 1997Q3, 2012Q3, 2013Q1) have a greater impact on durable purchases made by the young. Finally, unconventional monetary policy has heterogeneous effects on nondurable consumption by old and young households. More specifically, shocks that tilt the yield curve upward lead the young to cut their purchases of nondurables, whereas older households slightly increase their spending.

It is interesting to contrast our results with those of Berg, Curtis, Lugauer and Mark (2020) who study the effects of *scalar* monetary policy in these demographics during conventional times. They find that older households are more sensitive to monetary policy shocks identified as changes in short-term interest rates. Using Inoue and Rossi (2021)'s functional approach, we uncover an additional layer of heterogeneity: policy actions that affect the slope and curvature of the yield curve cause younger households to curtail their spending in nondurable goods while older households slightly increase their purchases. This response is consistent with young households facing more stringent liquidity constraints than middle-aged or old households. Durable consumption of young households is also more sensitive to these monetary policy shocks, suggesting that differences in wealth and portfolio composition could give rise to heterogeneous responses to shocks that tilt the yield curve.

6.2 Heterogeneity among the young

To further inquire what mechanism drives the response of young households, we divide the young into mortgagors, owners, and renters. The motivation to split the sample in this way is two-fold. First, recent literature has found heterogeneity in the response of consumption to conventional monetary policy across tenure, even after controlling for demographics (Campbell and Cocco (2007), Cloyne et al. (2020)). Therefore, differences in balance sheets could explain the response of young households. Second, for households that expect to work many years before retiring, monetary policy shocks that largely affect expected long-term interest rates might have a very heterogeneous effect depending on their debt profile.

Our results for conventional monetary episodes are consistent with Berg et al. (2020) who, using a sample that ends in 2007Q4, find that old households are more responsive to monetary policy shocks. However, for the unconventional period, our results stand in stark contrast to their findings. This begs the question of what drives the sensitivity of the young. Is it driven by households that are more liquidity constrained or by the rich young household that hold less debt? This brings us to our third motive for splitting the sample. As Figure **??** illustrates, there is a large degree of heterogeneity in household tenure across demographics.

Specifically, the majority of young households are renters or mortgagors (see Figure **??** in the appendix), but there is a non-negligible percentage of young households that are outright owners.

Thus, we zero in on the expenditure of durable consumption by young households and focus on four monetary policy shocks: 1997Q3, 1998Q4, 2009Q1, and 2012Q3. The first two shocks fall on conventional times, whereas the last two correspond to unconventional episodes. However, the 1997Q3 shock resembles the shocks during unconventional times in that it did not shift the yield curve in a parallel fashion but tilted it. Indeed, we find that the response to the three shocks that tilt the curve is similar. Figure 7 shows an increase (decrease) in durable consumption for young owners when the curve tilts downward (upward) and an insignificant response for young renters and mortgagors. Instead, for the almost parallel upward shift in 1998Q4, young mortgagors and renters exhibit a significant drop in consumption, whereas consumption of young owners initially increases and drops only twelve quarters after the shock.

Regarding nondurable expenditures, estimation results not reported herein show that young mortgagors and renters curtail their expenditures when short-term interest rates increase, but do not when the monetary policy mainly implies an increase in long-term interest rates. In summary, our estimation results suggest that liquidity constraints play a key role in the transmission of monetary policy shocks among the young but that there is a great degree of heterogeneity that stems from the type of monetary policy implemented.

6.3 Unifying threads

As we did when revisiting the response to monetary policy when households have debt, we end this section by taking a comprehensive look at the responses by household age. Figure 8 illustrates the consumption responses across age for all events in the sample. The two top panels depict the impulse response functions for all events, and the two bottom panels show a slice of the surfaces depicting the peak/trough response for each episode.

Two unifying threads across monetary policy events are the greater sensitivity of durable consumption expenditure by older households and the greater responsiveness of nondurable consumption by younger households. As in previous studies, we find a significant degree of heterogeneity in the response of consumption expenditure over the life cycle. Additionally, our results reveal an important degree of heterogeneity across different monetary policy events. In particular, we find a higher responsiveness of nondurable consumption expenditure to unconventional monetary policy for young households than for other age groups.

7 Revisiting the monetary transmission mechanisms

The previous sections revisited the effect of monetary policy shocks when households have debt and across demographics using the FLP approach. We observed notable differences in responses across housing tenure and demographic groups. In particular, unconventional monetary policy significantly affects homeowners, and young households respond to monetary policy changes that impact expected future interest rates. These consumption responses align with Inoue and Rossi (2021)'s findings on how the term structure of interest rates affects output. Our results highlight that monetary policy influences medium- and long-term interest rates, impacting durable consumption. We further explore transmission mechanisms by examining the effects of specific functional shocks on income, housing costs, prices, and asset holdings.

7.1 The Effect on Mortgage and Rental Payments

Expansionary monetary policy can increase the resources available to consumers by reducing mortgage and rental payments. Previous studies find that US rental (mortgage) payments increase (decrease) in response to a conventional expansionary monetary policy shock (e.g., Cloyne et al. (2020)). The increase in rental payments is attributed to the increase in housing prices offsetting the lower user cost of housing.

To investigate this transmission channel, we compute the average real per capita mortgage/rental payment by summing the payments and dividing by the number of adults in a household. Then, we estimate the impulse response functions using FLP. Figure 9 depicts the response of mortgage and rental payments to selected monetary policy shocks. Two results stand out. Parallel shifts in the yield curve (1987Q1, 1998Q4) appear to have little impact on mortgage payments. In contrast, unconventional monetary policies that result in larger drops in long-term than short-term interest rates lead to significant declines in mortgage payments in the medium and long run. This suggests that unconventional monetary policies that target long-term interest rates may stimulate expenditure by having a direct impact on mortgage payments.

Regarding rental payments, we find a statistically significant response for almost all selected episodes (see Figure 9). In general, we find that monetary policy that exerts downward pressure on long-term interest rates lowers the user cost of housing, and hypothesize that, by providing households with an incentive to purchase over renting, puts additional downward pressure on rental payments. An important takeaway is that monetary policy that results in lower interest rates in the short and long run relaxes the liquidity constraints of renters. The resources resulting from lower rental payments can then be used to purchase durable

and nondurable goods. These results provide evidence in support of the cash flow channel of monetary policy during conventional and unconventional times.

7.2 Wealth Effects

Changes in wealth have been long considered to have important effects on consumption. For instance, Chodorow-Reich et al. (2021) find "that for every dollar of increased stock market wealth, consumer spending increases by 2.8 cents per year", whereas Mian et al. (2013) and Kaplan et al. (2018) find significant effects of house price changes on consumption.

To inquire whether the heterogeneity we uncover in the response of consumption to functional monetary policy shocks could be driven by differences in the response of assets to diverse shocks, we take a two-pronged approach. First, we investigate the effect of shocks on household asset holdings by using data obtained from the Board of Governors of the Federal Reserve System Flow of Funds. We deflate the total household asset holdings by the CPI and compute the logged growth rates. Second, to complement the analysis of Section 7.1 and to gather additional insights into the housing wealth channel, we estimate the effect of select monetary policy shocks on housing prices. We measure housing prices as the purchase-only house price index for the U.S. computed by the U.S. Federal Housing Finance Agency and retrieved from FRED as in Mishkin (2007). We deflate this housing price by the CPI.

Figure 10 reports the response of total household assets. As the figure illustrates, for all the depicted episodes, we find that monetary policy actions that result in lower (higher) long-term interest rates lead to increases (decreases) in real asset holdings. Our results are broadly consistent with the seminal work of Bernanke and Kuttner (2005) who find that monetary tightening in the US leads to negative stock returns and recent work by Bekaert et al. (2021) which finds evidence of a negative effect of such policy on bond returns. An important takeaway from the functional framework is that the negative relationship between total asset holdings and interest rates is driven by changes in the long-term component of the yield curve. For example, real asset holdings decreased in 2013Q2 when short-term interest rates remained almost unchanged while the yield curve tilted upward. These results suggest that wealth effects play a key role in accounting for the response of owners' consumption during unconventional times.[25]

Figure 10 provides additional evidence in favor of a wealth channel that operates through housing and partially accounts for the heterogeneity found across housing tenure and age. More specifically, monetary policy shocks that exert downward pressure on long-term interest rates lead to increases in the average price of houses sold. Housing wealth for outright owners

[25] Gürkaynak, Sack and Swanson (2005) find that unconventional monetary policy actions and statements have a significant effect on asset prices.

and older households, who hold more housing assets, thus increases, allowing them to expand consumption expenditure.

7.3 The Effect on Income

As demonstrated by Inoue and Rossi (2021) monetary policy shocks that result in a rise (drop) in short-term interest rates, while exerting upward (downward) pressure on medium- and long-term interest rates have different effects on GDP than scalar shocks. This suggests that the general equilibrium effects of monetary policy on household income may differ between various functional shocks and could further explain the heterogeneity in the response by housing tenure or age.

Estimates of the response of total income net of taxes to selected functional monetary policy shocks are reported in Figures 11 to 12. Two results stand out. First, there is some evidence of heterogeneity in the response of disposable income by housing tenure and age during conventional times. In particular, shocks that cause short- and long-term interest rates to increase (1987Q1, 1998Q4) result in lower income for mortgagors and renters but have a slightly positive effect on owners' income in the long run. Moreover, young households are somewhat more responsive than middle-aged and old households to shocks that comprise larger movements at longer maturities (e.g., 1997Q3). Second, we do not find evidence of heterogeneity in the response of income during unconventional times.

Contrasting the response of income with that of expenditure suggests heterogeneity in the response of the latter, is not generally driven by heterogeneity in the effect of monetary policy on income across groups. In fact, for most shocks, the response of income is statistically insignificant. The only exception appears to be the 1987Q1 episode, where a typical conventional monetary policy shock comprised by larger increases in the short- than the long-run interest rates results in a significant decline in income for mortgagors and renters, but no immediate resource windfall for owners.

8 Robustness Checks

This section summarizes the results of a battery of robustness checks. As in the earlier sections, we restrict the discussion to select functional shocks and, for the sake of brevity, we relegate the figures to the Online Appendix.[26]

IV Estimation Our baseline results are obtained using FLPs estimated via OLS. How-

[26]Estimation results for all monetary policy events and alternative specifications are available from the authors upon request.

ever, the reader may wonder whether the shocks to the yield curve may be due to factors other than monetary policy. Thus, we reestimate the baseline models for consumption by housing tenure and age using the term structure of the Fed Funds rate as an instrument in an FLP-IV setup similar to Inoue and Rossi (2019). Because we use quarterly data, and hence a smaller sample, we do not split the sample into conventional and unconventional subsamples. While the estimation results reported in Figure B.1 reveals larger responses than in the previous section, they confirm our main findings: (1) The sensitivity of durable consumption to monetary policy shocks is greater for outright owners than for mortgagors or renters and for older households relative to young and middle-aged; (2) Nondurable consumption of households that face stricter liquidity constraints (i.e. renters and young households) are more responsive to monetary policy shocks. All in all, the estimation results confirm that there is important heterogeneity in the response of consumption to monetary policy shocks.

Alternative Measures of Consumption Figures B.5 and B.6 depict the response of consumption expenditure when alternative expenditure measures are used. For reference, we also plot the baseline response along with the 68% and 90% confidence intervals.

As mentioned above, we do not use the probability weights provided by the CEX to group households. Instead, we follow Berg et al. (2020) and Dynan et al. (2009) to compute the expenditure by groups. However, the reader may wonder whether our results are robust to the use of CEX weights or whether differences between our results and those of Cloyne et al. (2020) arise from using different weights. As the blue x-dashed line in Figures Figures B.5 and B.6 in the Appendix illustrates, the response by housing tenure is almost identical to the baseline estimates.

Given that housing constitutes a large expenditure for households, we also check whether our estimates are robust to computing average consumption spending after excluding housing expenses. The yellow line with the marker "+" in Figures B.5 and B.6 in the appendix shows that the responses retain their shape and significance; however, a decrease in the magnitude of the consumption response is evident at the peak / trough. This indicates that contractionary monetary policy -whether conventional or unconventional- has a negative effect on households' expenditure that is not completely accounted for by changes in rental and mortgage payments.

Alternative Estimation Strategies and Model Specification The estimation results presented in the previous sections were obtained using a fourth-order polynomial (Inoue and Rossi (2021)) to avoid excess variation that is common in local projection estimates of impulse responses. Such a strategy can be interpreted as a generalization of the Barnichon and Brownlees (2019) smooth local projections approach to the case of multidimensional shocks. To alleviate any concerns that the use of polynomial smoothing may provide a dif-

ferent story on the impact of monetary policy shocks, the red circle line in Figures B.5 and B.6 reports the responses computed using the common local projections in the dashed circle marker red line. As expected, there is more variation in the local projection estimates; yet, the qualitative results remain unchanged.

We also evaluate whether the results are robust to the estimation of the model in levels. Figures B.7 and B.8 plot the estimated impulse response functions. As can be seen, the level responses are very similar to the cumulative responses corresponding to the main specification.

Alternative time aggregation The last set of robustness checks explores alternative computations of quarterly *functional* monetary policy shocks. Specifically, we explore whether using a simple average of the shocks in the quarter or the sum of all of the shocks alters our results. We confirm that our results are robust to computing the shocks in these alternative ways. The red dashed line with the circle marker and the blue line with the diamond marker in Figures B.9 to B.12 report the mean and sum aggregation, respectively, and reveal no significant changes.

9 Conclusions

Using the FLP approach, this paper revisited the effect of monetary policy shocks on households' consumption expenditure and inquired into the sources of heterogeneity across two key dimensions: housing tenure and age. We found that heterogeneity across functional shocks constitutes an additional layer of heterogeneity, by which conventional and unconventional policies might have diverse effects on different population groups.

Our work provided new insights into the effects of monetary policy when households have debt. In particular, while previous work found outright owners to be rather insensitive to (scalar) conventional contractionary monetary policy, we showed they are more responsive than renters and mortgagors to unconventional policies. Furthermore, we provided evidence suggesting that changes in wealth constitute an important transmission channel for unconventional monetary policy.

We also found new empirical evidence of heterogeneity in the response of households across different age profiles. More specifically, policies that simultaneously reduce short-term interest rates and increase long-term interest rates, typical of unconventional times, led young households to reduce consumption while having insignificant or slightly positive effects for middle-aged and old households. We posited that differences in planning horizons could explain these differences.

Building on the work of Inoue and Rossi (2021), we found that monetary policy events

that comprise unambiguous increases (decreases) in the entire structure of interest rates have contractionary (expansionary) effects on consumption expenditure, the largest component of GDP. Nevertheless, even these events have heterogeneous effects in households with different levels of debt or at different points in the life cycle.

Two potentially important implications for the conduct of monetary policy stem from our analysis. First, because conventional contractionary policies tend to impose a higher burden on young liquidity constrained households, they could exacerbate consumption inequality. Second, the greater sensitivity of durable consumption by outright owners and older households to unconventional monetary policies suggests that, as the fraction of the population aged 65 years and older who have less need to borrow increases, monetary policies that target medium- and long-term interest rates might become increasingly useful in stimulating consumption, and thus economic activity, during recessionary times.

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Table 1: Quarterly Expenditure by Tenure

	Durable		**Non-Durable**		**Income**	
	Mean	Std	Mean	Std	Mean	Std
Housing Tenure						
Mortgage	4492.42	542.21	7471.83	619.71	42321.41	6488.73
Own	3608.40	535.10	7634.76	791.39	30909.07	5584.09
Rent	2823.20	347.61	5720.75	222.12	27048.46	2516.91

Table 1 above reports the average quarterly expenditure from January 1984 to December 2019 for each housing tenure in the Consumer Expenditure Survey in 2010 US Dollars. Each category of consumption follows the definitions detailed in Cloyne, Ferreira and Surico (2020) .

Table 2: Monetary Policy Shocks in Selected Episodes

Date	Level $\Delta\beta_{l,q}$	Slope $\Delta\beta_{s,q}$	Curvature $\Delta\beta_{c,q}$	Instantaneous Yield $\Delta\beta_{l,q} + \Delta\beta_{s,q}$	Long-term Yield $\Delta\beta_{c,q} - \Delta\beta_{l,q}$
Conventional					
1987 Q1	-0.243	-0.016	0.413	-0.259	0.656
1991 Q2	-0.068	-0.115	0.067	-0.183	0.135
1997 Q3	-0.216	0.215	0.012	-0.001	0.228
1998 Q4	0.022	-0.492	0.496	-0.470	0.474
2002 Q3	-0.161	0.064	0.752	-0.096	0.913
Unconventional					
2009 Q1	-0.326	0.348	0.268	0.022	0.594
2012 Q3	0.140	-0.137	-0.188	0.003	-0.329
2013 Q2	0.262	-0.310	-0.045	-0.048	-0.307
2014 Q2	-0.128	0.156	-0.101	0.028	0.028

Table 2 presents the factors that summarize each of the select conventional and unconventional monetary policy shock episodes. Instantaneous and long-term yield help describe changes in the latent factors of the yield curve.

Table 3: Peak/Trough Responses to Monetary Policy Shocks By Tenure

	Mortgagors		**Owners**		**Renters**	
	Magnitude (%)	Horizon	Magnitude (%)	Horizon	Magnitude (%)	Horizon
Durable						
1987 Q1	-0.805	8	-0.532	4	-0.906	12
1991 Q2	-0.680	8	-0.617	5	-0.643	9
1997 Q3	0.281	12	0.584	8	-0.213	12
1998 Q4	-1.951	8	-2.044	6	-1.702	9
2002 Q3	-0.226	8	0.158	10	-0.406	12
2009 Q1	0.492	12	0.970	7	-0.260	12
2012 Q3	-0.175	12	-0.370	8	0.146	12
2013 Q2	-0.484	12	-0.900	7	-0.247	8
2014 Q2	0.254	7	0.460	7	0.138	8
NonDurable						
1987 Q1	-2.033	6	-0.858	8	-2.917	5
1991 Q2	-1.429	6	-0.419	4	-1.868	5
1997 Q3	-1.498	12	-1.061	10	-1.569	12
1998 Q4	3.679	12	-1.023	4	-4.42	5
2002 Q3	-0.802	7	-0.662	10	-1.348	12
2009 Q1	-2.438	12	-1.634	10	-2.323	12
2012 Q3	0.953	12	0.686	10	1.025	12
2013 Q2	2.189	12	1.356	10	1.815	12
2014 Q2	-1.107	12	-0.670	10	-0.879	12
Total						
1987 Q1	-0.863	8	-0.332	5	-1.046	12
1991 Q2	-0.458	7	-0.342	4	-0.423	6
1997 Q3	-0.415	11	0.247	4	-0.887	12
1998 Q4	-0.911	7	-1.103	4	-0.758	5
2002 Q3	-0.432	9	-0.105	9	-0.679	12
2009 Q1	-0.631	12	0.427	4	-1.334	12
2012 Q3	0.271	11	-0.154	4	0.577	12
2013 Q2	0.519	12	-0.412	4	1.069	12
2014 Q2	-0.256	12	0.213	4	-0.522	12

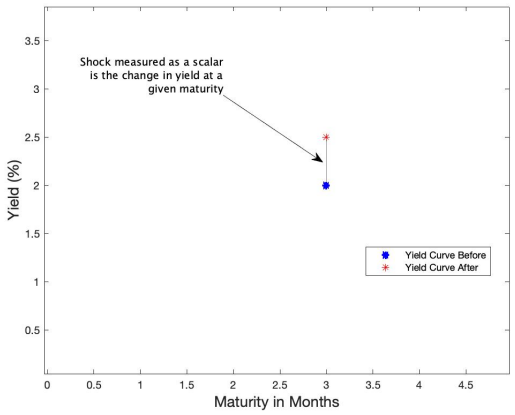
Table 3 reports the peak/trough magnitude and horizon of the consumption response to a select functional monetary policy shock. Each column corresponds to the percentage change and timing of the consumption response for a given group. Each row represents a given monetary policy shock episode. Durable and nondurable consumption are as defined as in Cloyne et al. (2020).

Table 4: Peak/Trough Responses to Monetary Policy Shocks by Age Group

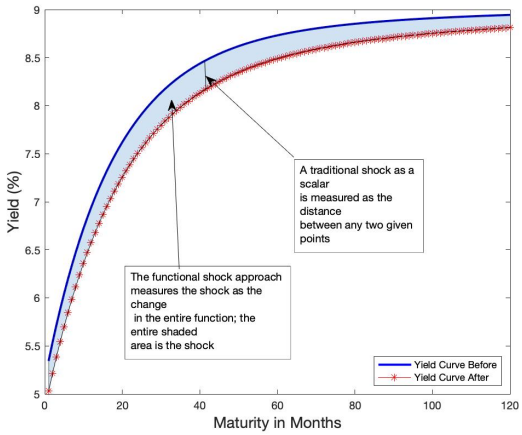
	Middle		**Older**		**Younger**	
Date	Magnitude(%)	Horizon	Magnitude(%)	Horizon	Magnitude(%)	Horizon
Durables						
1987 Q1	-0.956	6	-1.271	5	-0.805	8
1991 Q2	-1.180	7	-1.359	5	-1.371	7
1997 Q3	0.115	8	0.096	5	0.211	6
1998 Q4	0.088	3	0.083	6	-0.279	6
2002 Q3	-0.480	8	-0.438	5	-0.389	7
2009 Q1	-0.493	12	-0.862	12	1.339	6
2012 Q3	-0.038	7	-0.037	8	-0.135	6
2013 Q2	-0.171	7	0.320	12	-0.540	6
NonDurables						
1987 Q1	-2.603	7	-3.652	5	-1.587	3
1991 Q2	-2.149	7	-2.410	4	-2.897	4
1997 Q3	-0.252	12	-0.248	10	0.489	4
1998 Q4	0.690	5	1.088	5	-0.999	5
2002 Q3	-1.218	6	-1.565	4	0.94	12
2009 Q1	-2.981	5	-5.471	10	5.860	5
2012 Q3	0.209	12	0.312	10	-0.395	5
2013 Q2	0.758	5	1.764	10	-2.099	5
2014 Q2	-0.634	5	-1.315	10	1.505	5
Total						
1987 Q1	-0.695	7	-1.000	5	0.342	5
1991 Q2	-0.739	7	-0.720	5	-0.478	7
1997 Q3	0.051	7	-0.081	12	0.148	5
1998 Q4	0.194	5	0.252	6	-0.331	5
2002 Q3	-0.473	7	-0.410	5	-0.141	1
2009 Q1	-1.112	8	-1.424	11	1.280	6
2012 Q3	0.040	4	0.069	11	-0.120	5
2013 Q2	0.306	8	0.474	11	-0.429	6
2014 Q2	-0.237	8	-0.345	11	0.327	6

Table 4 depicts the peak expenditure responses to select monetary policy shocks. Each column corresponds to the percent deviation and timing of the consumption response for a given group. Each row represents a given monetary policy shock episode. The table is divided into three measures of expenditure: Durable, Non-Durable and Total Consumption. Durable and Non-Durable Consumption are as defined in Cloyne et al. (2020)

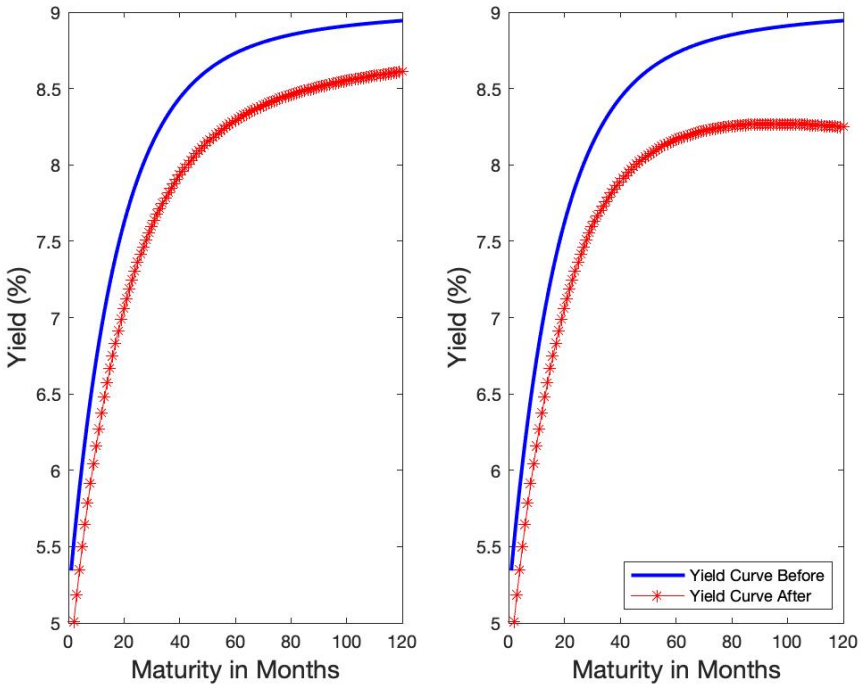
Figure 1: Functional Shock Example



(a) Traditional Shock



(b) Functional Shock



(c) Comparing Functional Shocks

Figure 1 illustrates hypothetical scalar and functional shocks. In the upper-left panel, the figure depicts how a traditional scalar shock is measured at a given maturity. The figure in the upper-right panel describes how a functional shock captures the change in an entire yield curve, not just a single maturity. The figure in the lower panel shows how two functional shocks can capture a similar change at short maturities but greatly differ at other maturities.

Figure 2: Consumption by Housing Tenure, Conventional Times

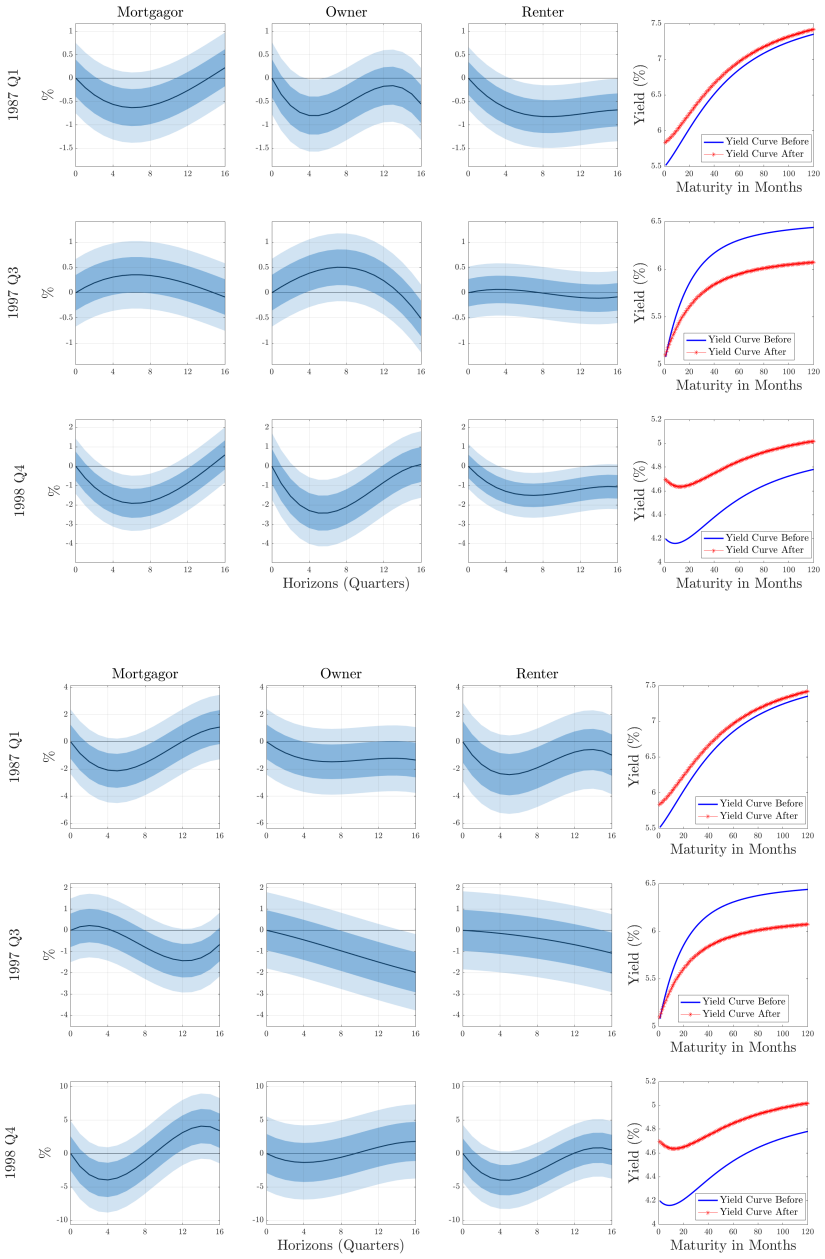


Figure 2 plots durable (top) and nondurable (bottom) consumption by housing tenure for selected conventional monetary policy shocks. The solid black line denotes the impulse response, and the light and dark shaded areas denote the 68 and 90% confidence intervals, respectively. The right panel also plots the functional monetary policy shock at each date.

Figure 3: Consumption by Housing Tenure, Unconventional Times

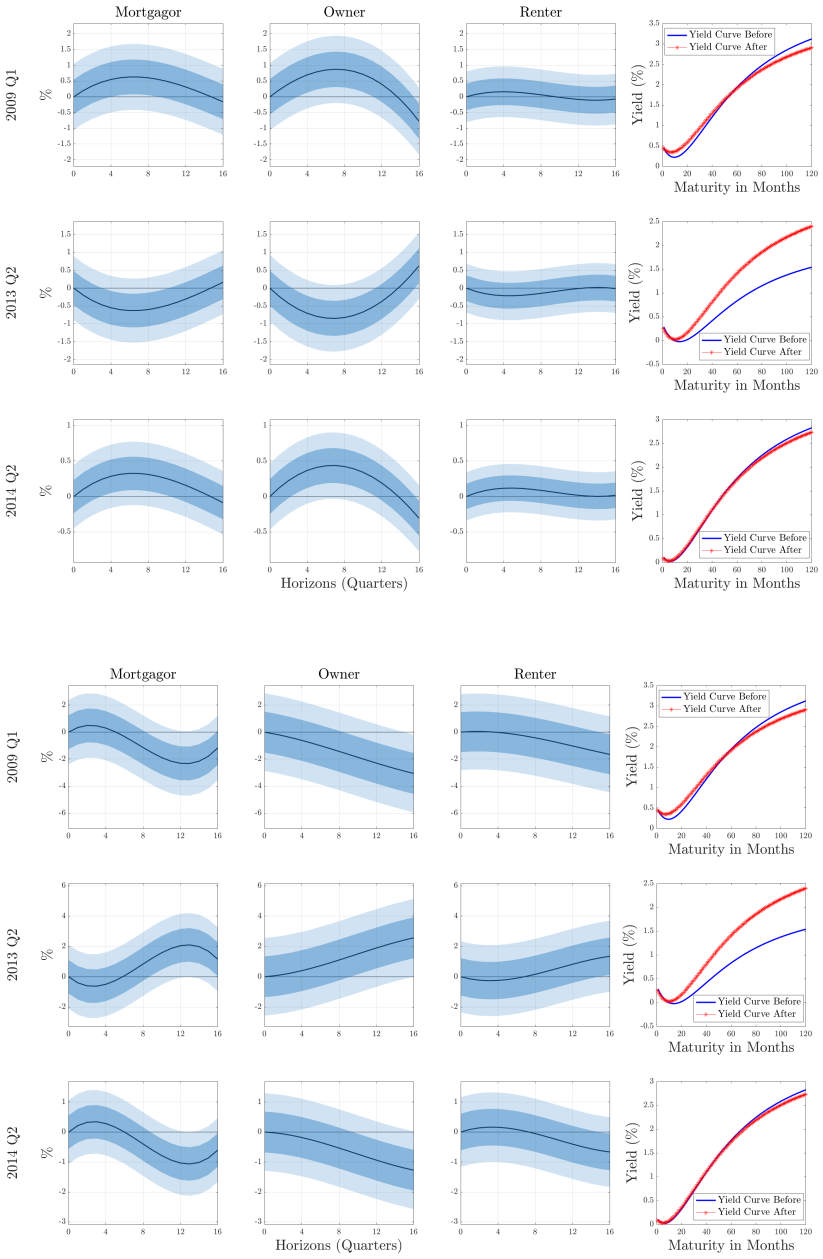


Figure 3 plots durable (top) and nondurable (bottom) consumption by housing tenure for selected conventional monetary policy shocks. The solid black line denotes the impulse response, and the light and dark shaded areas denote the 68 and 90% confidence intervals, respectively. The right panel also plots the functional monetary policy shock at each date.

Figure 4: Response to Functional Shocks, All Episodes - Housing Tenure

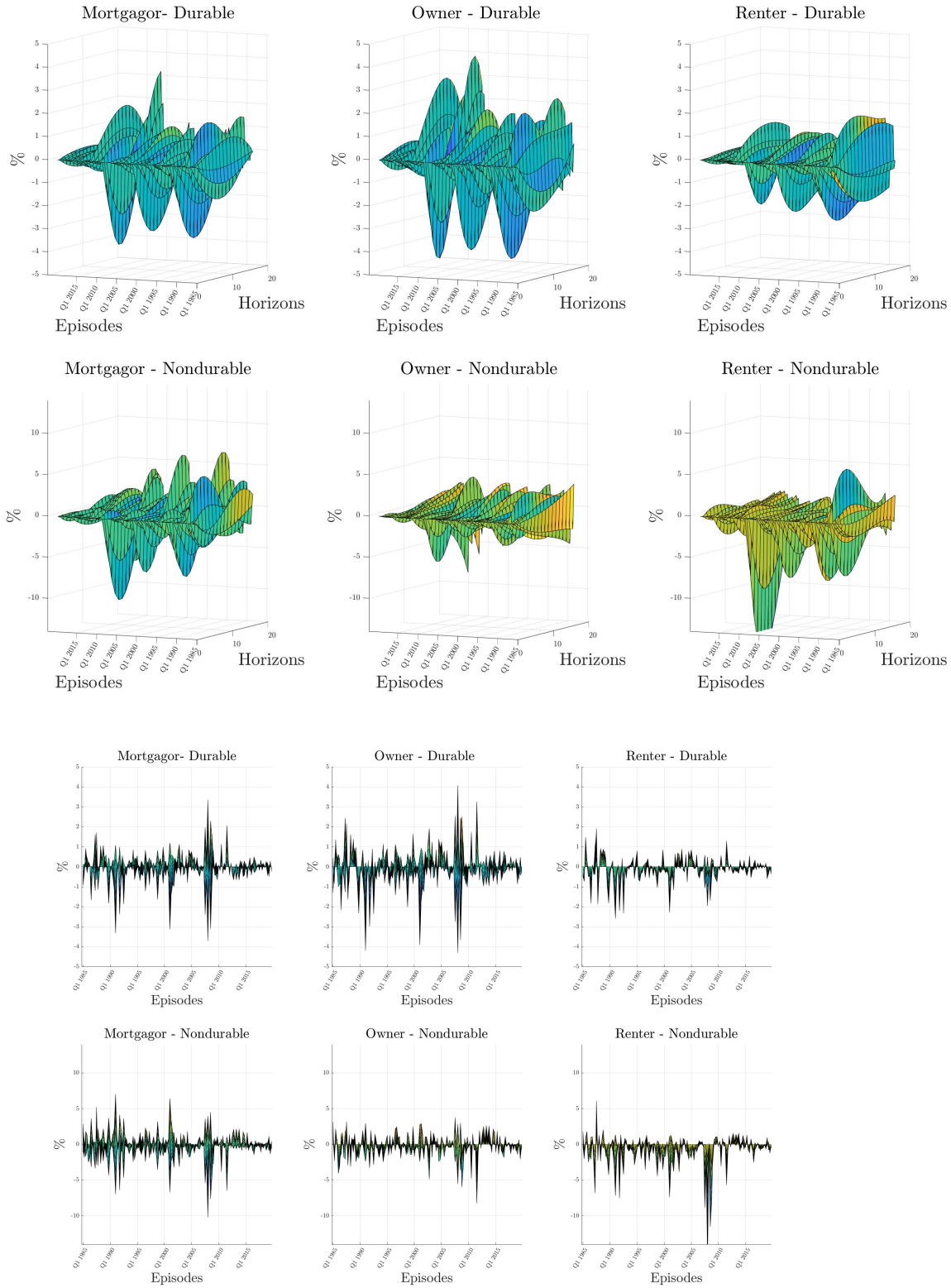


Figure 4 plots the response of consumption by housing tenure for each *functional* monetary policy shock. The first two rows plot the responses where the magnitude of the impulse response is measured in the z axis, the horizons are denoted in the y axis, and the x axis denotes the events. The two bottom rows show a slice of the above surfaces with the peak and trough responses for each event. The first and third rows present the response to durable consumption, whereas the second and fourth rows report the response of nondurable consumption.

Figure 5: Consumption by Age, Conventional Times

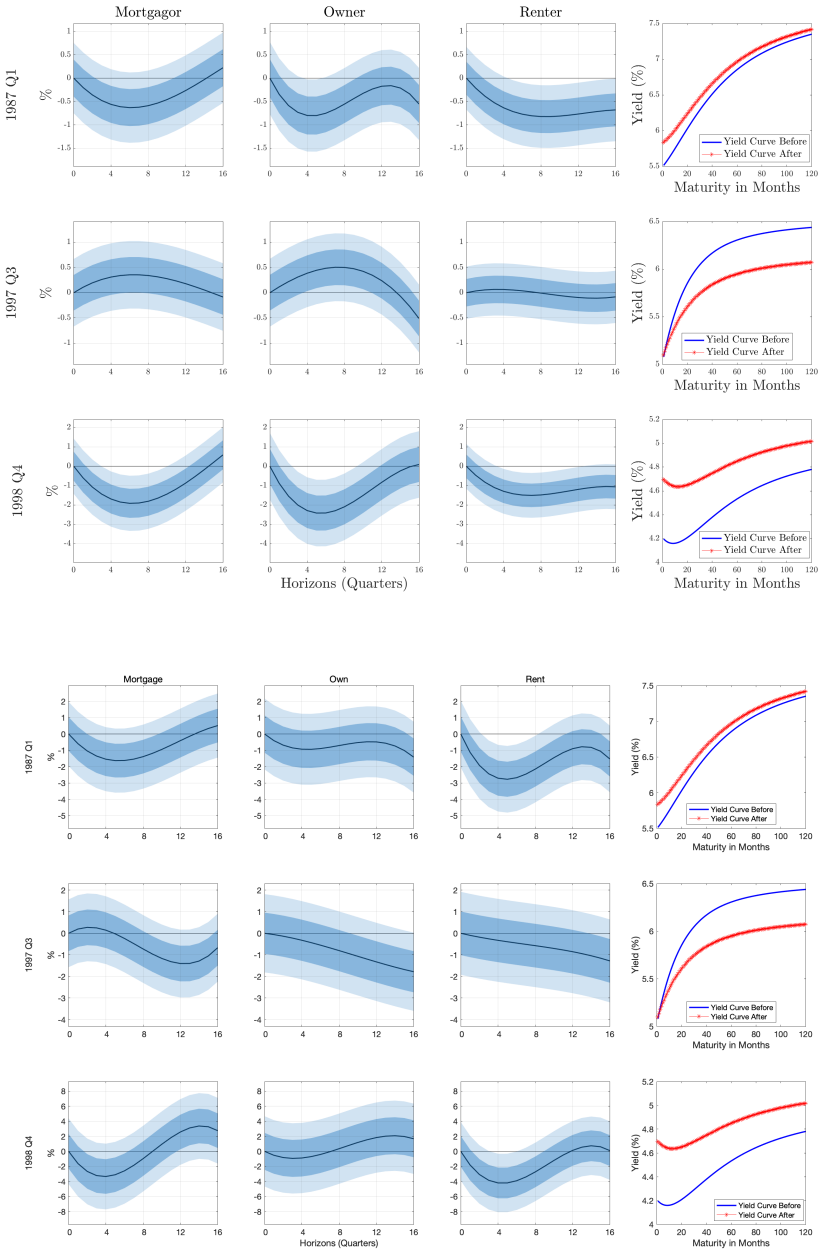


Figure 5 plots durable (top) and nondurable (bottom) consumption by age groups for selected conventional monetary policy shocks. The solid black line denotes the impulse response, and the light and dark shaded areas denote the 68 and 90% confidence intervals, respectively. The right panel also plots the functional monetary policy shock at each date.

Figure 6: Consumption by Age, Unconventional Times

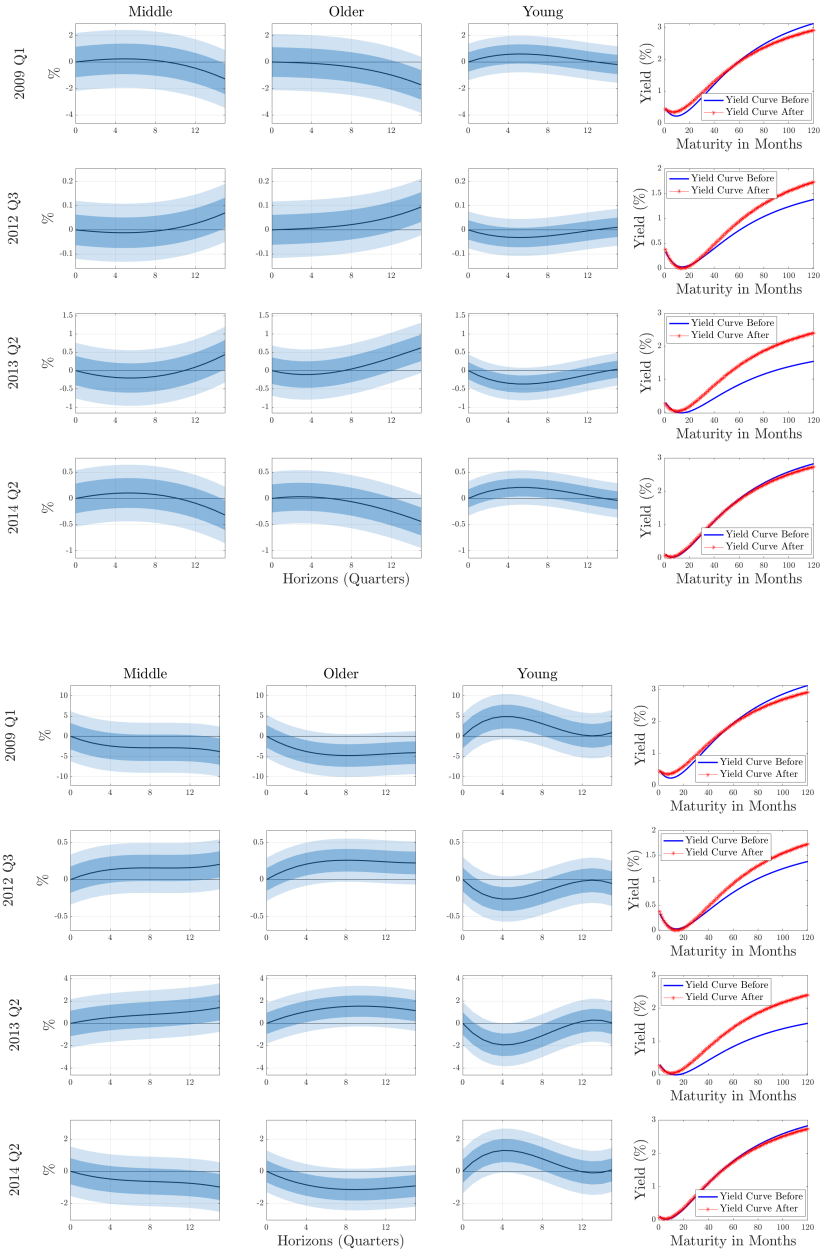


Figure 6 plots durable (top) and nondurable (bottom) consumption by age groups for selected unconventional monetary policy shocks. The solid black line denotes the impulse response, and the light and dark shaded areas denote the 68 and 90% confidence intervals, respectively. The right panel also plots the functional monetary policy shock at each date.

Figure 7: Durable Consumption Response Young by Tenure, Conventional Times

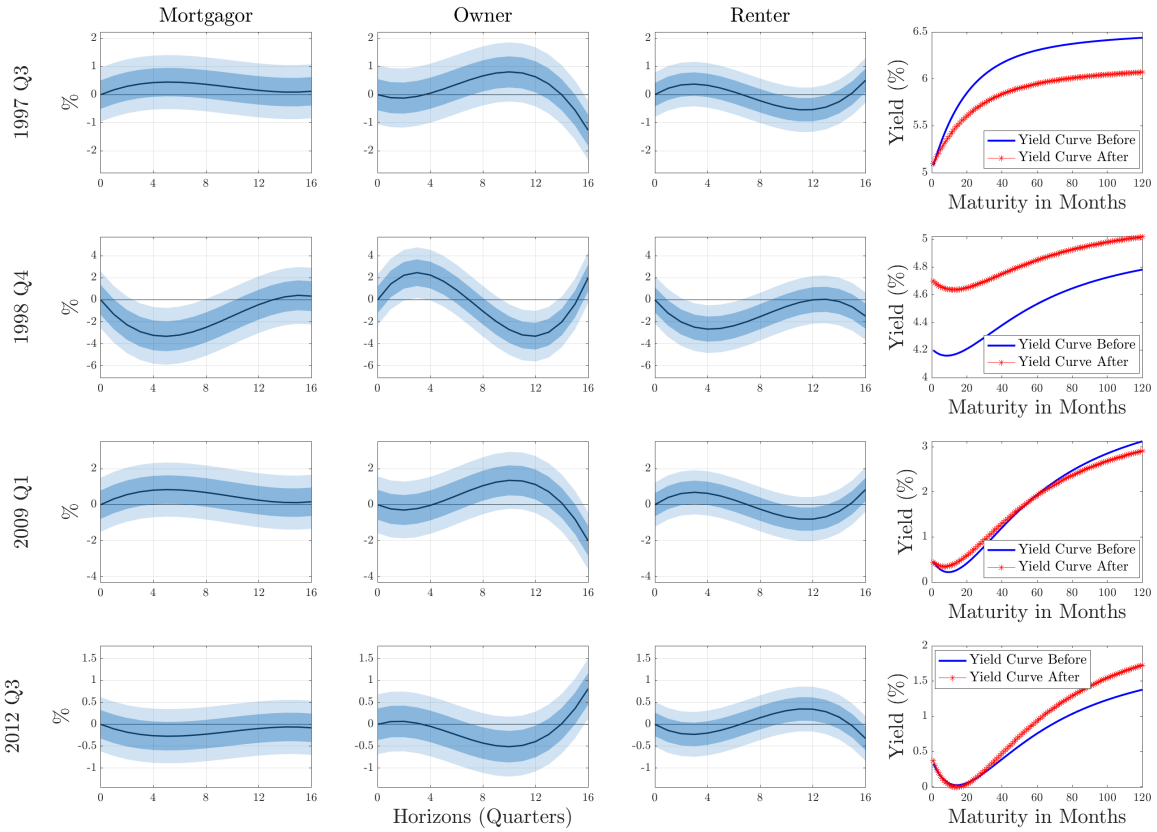


Figure 7 plots the response of durable consumption by the younger age group by tenure for selected conventional monetary policy shocks. The solid black line denotes the impulse response, the light and dark shaded areas denote the 68 and 90% confidence intervals, respectively.

Figure 8: Response to Functional Shocks, All Episodes - Age

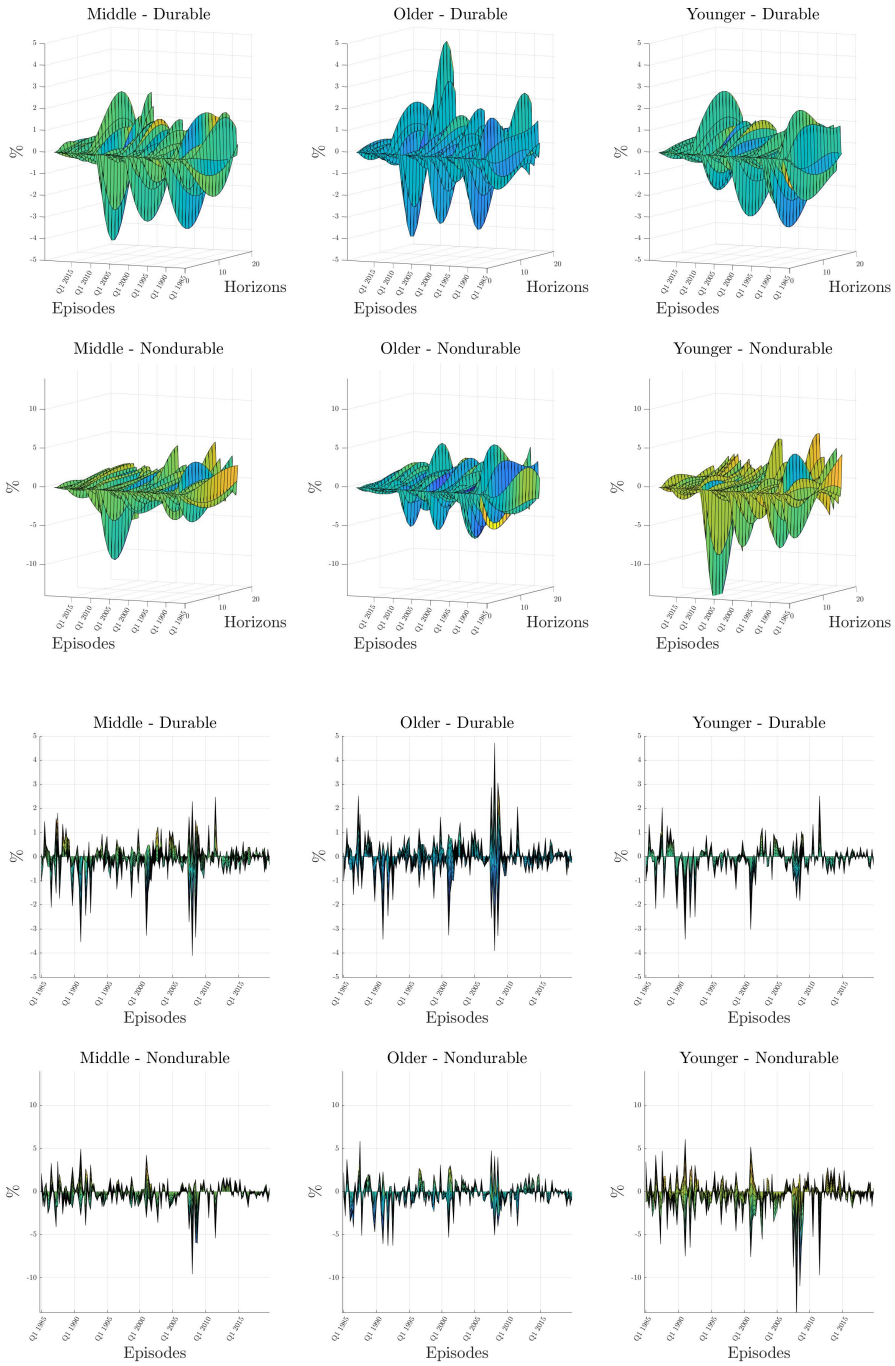


Figure 8 plots the response of consumption by housing tenure for each *functional* monetary policy shock. The first two rows plot the responses where the magnitude of the impulse response is measured in the z axis, the horizons are denoted in the y axis, and the x axis denotes the events. The two bottom rows show a slice of the above surfaces with the peak and trough responses for each event. The first and third row present the response of durable consumption whereas the second and fourth rows report the response of nondurable consumption.

Figure 9: Response of Mortgage and Rental Payments

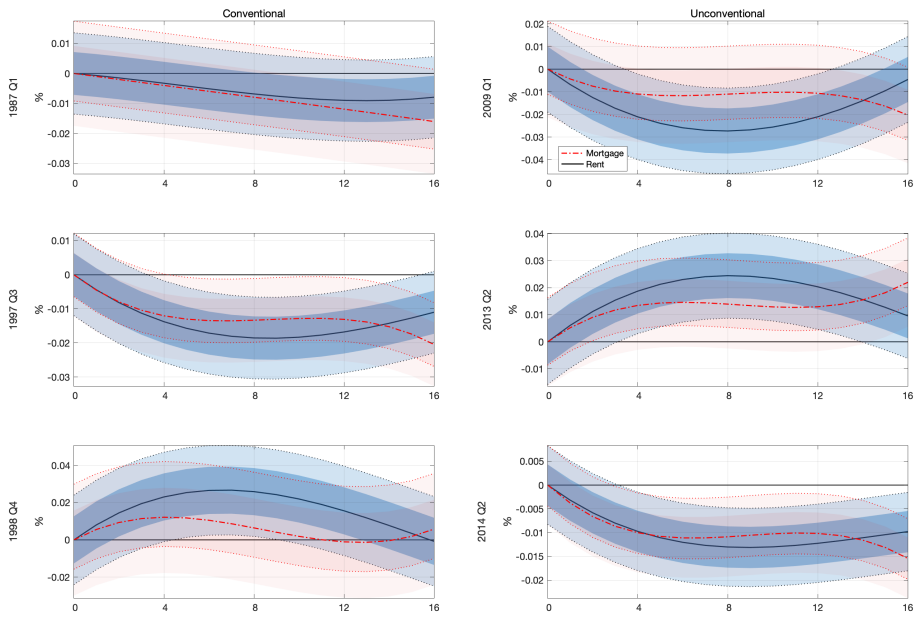


Figure 9 plots the response of rental and mortgage payments for selected monetary policy shocks. The solid black line denotes the impulse response, the light and dark shaded areas denote the 68 and 90% confidence intervals, respectively.

Figure 10: Response of the House Price Index and Household Assets

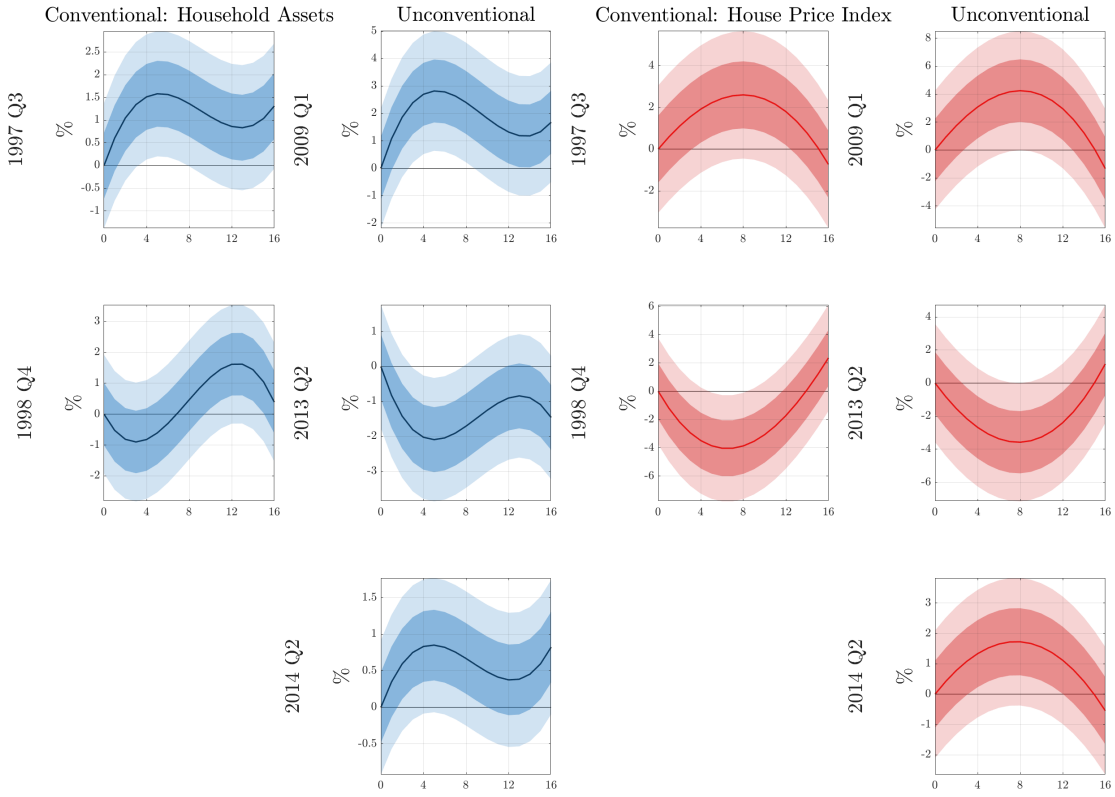


Figure 10 plots the response of Logged Real Purchase-only House Price index (red) and Logged Returns of Household Total Assets (blue) for selected monetary policy shocks. The solid black line denotes the impulse response, the light and dark shaded areas denote the 68 and 90% confidence intervals, respectively.

Figure 11: Income Response by Housing Tenure

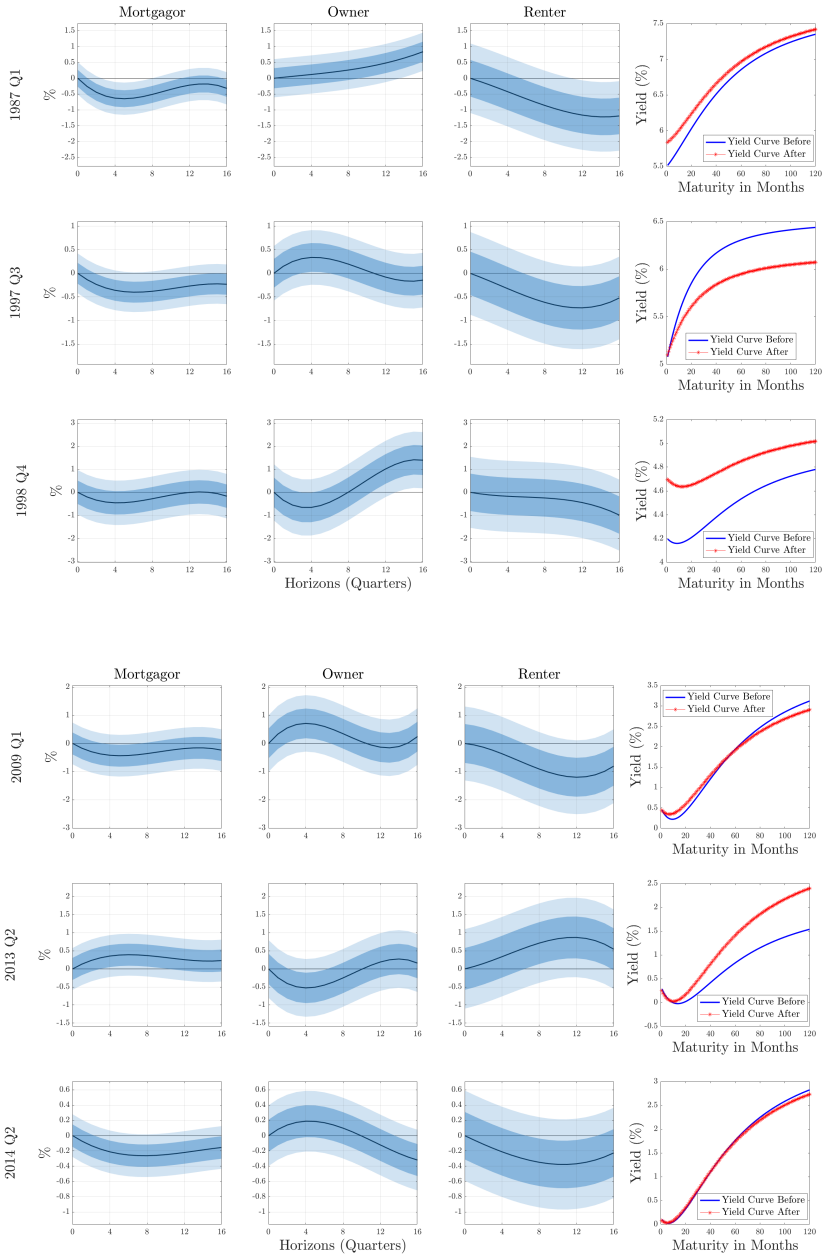


Figure 11 plots income responses by housing tenure for selected conventional (top) and unconventional (bottom) monetary policy shocks. The solid black line denotes the impulse response, and the light and dark shaded areas denote the 68 and 90% confidence intervals, respectively. The right panel also plots the functional monetary policy shock at each date.

Figure 12: Income Response by Age

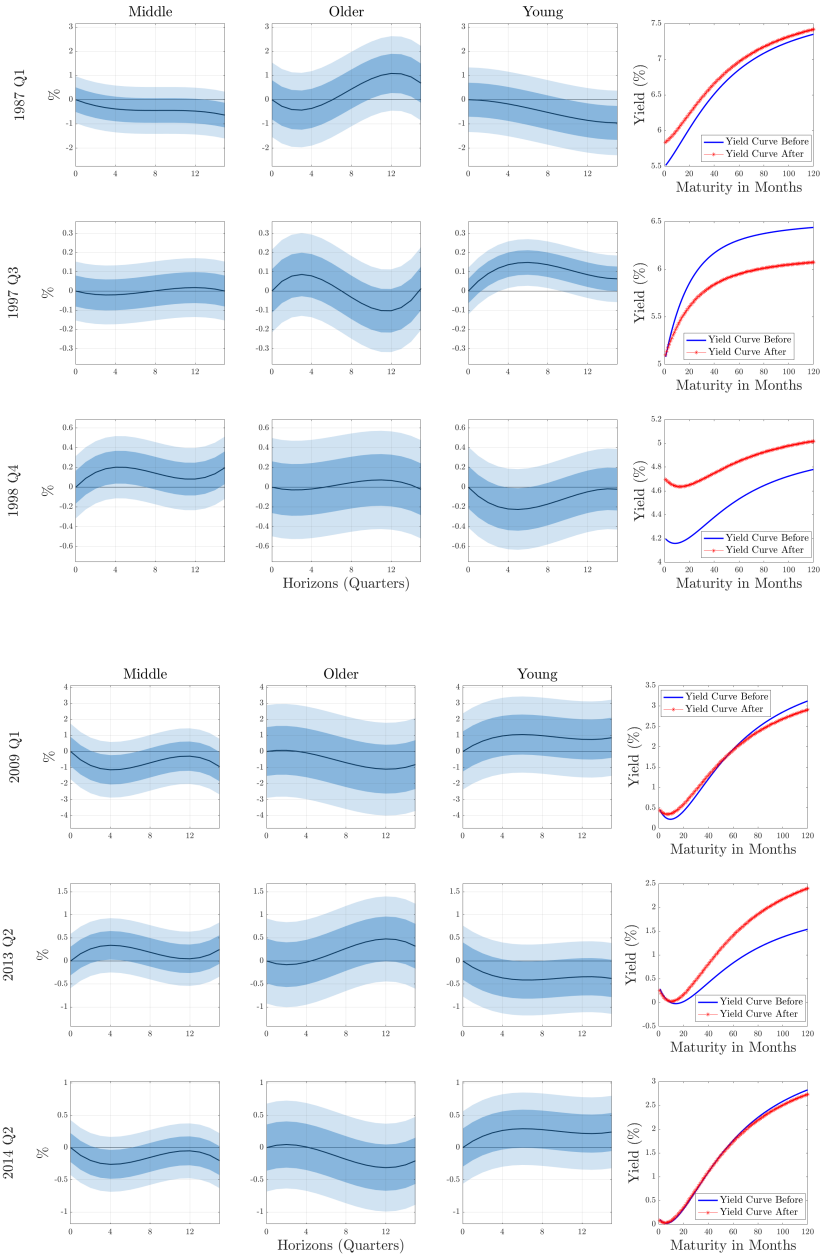


Figure 12 plots income responses by age groups for selected conventional (top) and unconventional (bottom) monetary policy shocks. The solid black line denotes the impulse response, and the light and dark shaded areas denote the 68 and 90% confidence intervals, respectively. The right panel also plots the functional monetary policy shock at each date.