1 Online Appendix

1.1 Robustness on consumption elasticities

In this section, I show that the estimated impulse response functions in Section 4 are robust to the age definitions, and to clustering by age.

First, I consider alternative definitions of the age groups. I consider a higher cut-off for the young and an earlier cut-off for the old. The young are defined as aged between 25-40, the middle-aged are defined as aged between 40-60, and the old are those aged over 60. Figure 1 shows the impulse response functions of total consumption to a one standard deviation expansionary shock for the young, middle and old. This shows that the point estimates are very similar to the base estimates in Section 4, and the confidence intervals are tighter.

Second, I consider defining the young between 25-45, middle between 45-65, and the old 65+. Figure 2 shows shows the impulse response functions of total consumption to a one standard deviation expansionary shock for the young, middle and old. This shows that the point estimates are very similar to the base estimates in Section 4, and the confidence intervals are tighter.

Lastly, the estimated consumption elasticities are robust to clustering assumptions. I consider two different forms of clustering: by time and by age. Clustering the standard errors takes into account the possibility that the consumption of the households may be correlated within the time period, since the shock is common across households, or correlated within the age group. Figures 3 and 4 show the estimated impulse response functions of total consumption for each of the age groups, clustering by age and by time, respectively. The standard errors are larger than the base result. However, consistent with the main results in the paper, the response of the young is statistically significant, and larger than the middle and old. Moreover, the differences between the responses of the young and the middle-aged, and the young and old are also statistically significant (Figure 5).
Notes: This figure depicts the impulse response functions of consumption for the young (ages 25-40), middle-aged (40-60), and the old (60+). The dashed lines plot the 90% confidence interval.

Notes: This figure depicts the impulse response functions of consumption for the young (ages 25-45), middle-aged (45-65), and the old (65+). The dashed lines plot the 90% confidence interval.
Figure 3: Impulse response functions of consumption

Notes: This figure depicts the impulse response function of consumption to a one standard deviation expansionary monetary policy shock for each age group. The standard errors are clustered by age.

Figure 4: Impulse response functions of consumption

Notes: This figure depicts the impulse response function of consumption to a one standard deviation expansionary monetary policy shock for each age group. The standard errors are clustered by time.
Figure 5: Impulse response functions of consumption

Notes: This figure depicts the difference in consumption responses between the young and middle-aged (left panel), young and old (middle panel), and the middle-aged and old (right panel). The standard errors are clustered by time.

1.2 A comparison of micro and macro consumption elasticities

In order to see how the consumption elasticities may change depending on the sample period, shock type and the data source, I re-estimate Equation 2 under different samples. Figure 6 highlights the fact that the sample period matters for measuring the effects of the shock. First, that expansionary shocks have large effects on consumption, primarily in the recent time period (1992-2007), particularly when estimated using the micro data. This coincides with the period in which refinancing becomes more important, and is consistent with the refinancing channel playing a role in the transmission of monetary policy to the economy.

Figure 6A is based on micro consumption data from the U.S. CEX Survey. The time period is from 1992-2007, due to the time period in which the Federal Funds futures (and lagged values of the futures) is available. Given the shorter time horizon, the micro data is useful for identification purposes, since it provides a larger number of observations and variation across households to identify the consumption elasticities than under the aggregate data. Expansionary shocks have a large and significant effect on consumption, which increases by 1.7 percentage points over the year. In comparison, contractionary shocks do not have a
statistically significant effect. This is in part because there are fewer contractionary shocks
over this sample period to precisely identify the elasticities.

Figure 6B shows the estimated consumption elasticities over the same sample period
as (I), but uses instead aggregate data from the National Income and Product Accounts
(NIPA). The point estimates are consistent the estimates based on the micro data. However,
the standard errors are unsurprisingly large, given the short time horizon. Figure 6C shows
that results based on the Romer and Romer shocks. The estimates based on the Romer
and Romer shocks are statistically indistinguishable from the estimates based on the Federal
Funds futures shocks over this sample period.

Second, the results differ if I look over a longer time horizon. The micro CEX data and
the Fed Funds futures shocks are not available going back to 1969, so it is not possible to
examine long-run heterogeneity. Therefore, I focus on the aggregate consumption data and
the Romer and Romer shocks when comparing the pre-1990 periods to the post 1990 periods.

The point estimates in Figure 6 D and E imply that over the long time horizon of
1979-2007 and 1969-2007, contractionary effects have larger effects on consumption than
expansionary shocks. This is consistent with studies such as Delong and Summers (1988)
Cover (1992), Karras (1996) and more recently, Angrist, Jordà and Kuersteiner (2013) and
Tenreyro and Thwaites (2013). However, it is worth noting that the standard errors are
large and so the results should be interpreted with this in mind.

There are a number of reasons for the difference in results over the sample period. First, a
number of studies have argued that there have been regime shifts in the setting of monetary
policy since the 1960s. Second, refinancing volumes were much lower in the pre 1990s period.
The importance of the refinancing channel post 1990 is consistent with the stronger measured
expansionary effects, given that consumers can choose to refinance when interest rates decline
and not refinance when rates rises.
Figure 6: Impulse response functions of consumption

**Notes:** This figure depicts the impulse response functions of real consumption to a one standard deviation expansionary monetary policy shock. The consumption data used in figure (I) is from the U.S. CEX Survey. The consumption data used in figures (II)-(V) is from the National Income and Product Accounts (NIPA).
1.3 Computational Appendix

In this section, I describe the solution to the model described in the body of the text. In order to implement the solution to this model numerically, I proceed as follows.

First, I reformulate the choice variables to rectangularize the problem and simplify computational issues that arise from the endogenous mortgage constraint. I reformulate the problem in terms of the leverage ratio, defined as

\[ q_{jat} = b_{jat}/p_t h_{jat} \geq 0. \]

I substitute the budget constraint into the utility function to eliminate consumption as a choice variable. The choices variables are therefore \( s_{jat}, h_{jat}, 1(\text{rent})_{jat}, 1(\text{adjust})_{jat}, q_{jat} \). I then discretize the problem so it can be solved on the computer. I discretize the idiosyncratic income variable \( y_{jat} \) and multivariate aggregate state vector \( S_t = [y_t, \log p_t, r_t] \) using the algorithm of Tauchen (1986). I then simulate the quarter process of \( S_t \) to get the annual probability transition matrix for \( S_t \). I use 18 grids for \( S_t \) and four grids for \( y_{jat} \). I approximate the value functions \( V_j^{\text{own} \& \text{noadj}}(z_{jat}), V_j^{\text{own} \& \text{adj}}(z_{jat}) \) and \( V_j^{\text{rent}}(z_{jat}) \) as multilinear functions in the states, where \( z_{jat} = [S_t, y_{jat}, \text{assets}_{jat}] \). There are four endogenous states \( \text{assets}_{jat} = [s_{jat}, h^o_{jat}, b_{jat}, r_{jat}] \). I use 20 knots for \( h^o_{jat} \) and \( b_{jat} \) and 10 knots \( s_{jat} \) and \( r_{jat} \). The knots are spaced more closely together near the constraints for \( b_{jat} \) and \( s_{jat} \). I assume multilinear interpolation of the value functions between the knots.

I solve the model by backward induction from the final period of life. At each age and each case, I compute optimal policies using a Nelder-Meade algorithm. I compare the value functions for each of the three cases (to rent, to own a home and adjust the mortgage, to own a home and not adjust the mortgage) to generate the overall policy function. In order to compute the impulse response functions and the life-cycle moments, I simulate a panel of 10,000 households (100 cohorts) over their life-times.

To compute the impulse response functions of consumption to a monetary policy shock, I first simulate the consumption and asset profiles decisions for 100 different cohorts, with 1000 households in each cohort. Each cohort faces a different historical path for the state variables. Second, for each cohort, I compute the consumption choice for each household following a monetary policy shock. This involves feeding in the aggregate dynamics following the shock for house prices, rental rates, interest rates, mortgage rates, and income, and computing the consumption choices. Third, I compare the consumption response under the monetary policy shock to the consumption choice that would have occurred if the households faced
the aggregate dynamics under no monetary policy shock. Fourth, I aggregate up across households within the same cohort, assuming the demographic profile of the economy, to compute the aggregate consumption response and take the average across cohorts.

1.4 Mortgage Rate, House Prices and Rental Rates

In the model, I specify linear approximations of the mortgage yield curve, house prices and rental rates as a function of aggregate state variables. The mortgage yield curve is a function of the short-term interest rate, and aggregate employment. House prices and the house price to rent ratios are a function of prior period house price, short-term interest rates, and aggregate employment. One advantage of specifying these processes in this way is that it generates plausible time series and impulse response function dynamics, without adding additional state variables to the computation.

In this section, I provide evidence that the linear specifications are indeed good approximations of actual dynamics. Figure 7 shows that the predicted 30- and 15-year real mortgage rates closely fit the actual mortgage rates over time. Figure 8 also show that the predicted and actual log house price to rent ratios are similar over time.

Figure 7: Predicted and actual 30-year mortgage rate

Notes: This figure depicts the model predicted and actual 30- and 15-year real mortgage rates.
Figure 8: Predicted and actual log house price to rent ratio

Notes: This figure depicts the model predicted and actual log house price to rent ratio. The latter is from the St Louis Federal Bank.

References


