Refinancing and The Transmission of Monetary Policy to Consumption*

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May, 2019

Abstract

This paper examines the role of refinancing channel and the mortgage market structure for the transmission of monetary policy to consumption. First, I document heterogeneous consumption responses to monetary policy shocks. I find a large consumption response for homeowners who refinance or enter new loans, which is concentrated among younger people. Second, I develop a life-cycle model with fixed rate mortgages that explains these facts. Moving from a fixed- to a variable-rate mortgage structure reduces the heterogeneous effects of monetary policy on consumption by age. At the same time, the aggregate effects of monetary policy on consumption is increased substantially.

Keywords: Consumption; monetary policy; refinancing; heterogeneous responses; age

*Earlier versions of the paper were previously circulated under the title "Population aging and the transmission of monetary policy to consumption". I thank Matthias Doepke, Martin Eichenbaum, Aviv Nevo, and Sergio Rebelo for their advice and feedback. I am very thankful to David Berger, Nir Jaimovich, Alejandro Justiniano, and Giorgio Primiceri for useful discussions. I also wish to thank Mark Aguiar, Adrien Auclert, Martin Beraja, Luigi Bocola, Michael Chu, Laura Doval, Yana Gallen, Erik Hurst, Guido Lorenzoni, Emi Nakamura, Joseph Vavra, and numerous seminar participants for helpful comments.

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1 Introduction

This paper studies the transmission of monetary policy to household consumption, the largest component of GDP. In standard macroeconomics models, changes in interest rates primarily affect household consumption directly through inter-temporal substitution. Recent literature has debated the role of the inter-temporal substitution effect, compared with other channels of monetary policy. Part of the debate has centered around the role of mortgage market and refinancing. In this paper, I examine the question: What is the role of the refinancing for the transmission of monetary policy to consumption in the aggregate and the cross-section?

The paper makes two contributions relative to the literature: (i) by quantifying the response of consumption to monetary policy shocks by age and by mortgage decisions, and (ii) by examining which channels can explain the heterogeneity and sensitive of consumption to changes in monetary policy, including the role played by refinancing. To do so, I document new cross-sectional patterns in consumption responses using household-level micro data. I then develop a model that accounts for these empirical patterns.

My empirical work combines monetary shocks, measured using the high-frequency event study approach, with micro consumption data from the U.S. Consumer Expenditure Survey (CEX) and the Nielsen Homescan data. I supplement the consumption analysis with Freddie Mac mortgage data to examine loan adjustment propensities.

I provide suggestive evidence on three key cross-sectional patterns in the data. First, I provide evidence of a larger semi-elasticity of consumption to monetary policy shocks for younger people. The response is roughly double the response of the average person in the economy.

Second, I show that the response of consumption is driven by homeowners. There is no statistically significant response for renters. The larger response of homeowners is predominately due to households who adjust their loans following interest rate shocks.

Third, younger households are more likely to adjust their loans after expansionary monetary policy shocks. Moreover, I find that the household's propensity to adjust their loan rises with loan size. In the data, young people have much larger loan sizes as individuals take out a mortgage to purchase their home, which is then paid down over time. Old people have lower balances as they have paid down more of their mortgages than young people.

These findings together suggest that young homeowners who adjust their loans are an important driver of the aggregate consumption response. I develop a household model of mortgages and housing, consistent with the suggestive empirical findings, in order to study the channels of monetary policy transmission. The features of model are: an uninsurable labor income risk, a life-cycle savings motive, and a fixed-rate mortgage structure. Individuals pay a transaction cost to adjust their long-term assets, which includes their housing and their fixed-rate mortgage. The interest rate on the mortgage is fixed unless the individual pays a cost to adjust their loan.

The model generates key life-cycle moments that closely match the corresponding moments in the data. These moments include the hump-shaped consumption profile, rising total wealth and homeownership rates, and declining debt holdings over the life-cycle. The model also generates aggregate and heterogeneous age-specific responses to a monetary policy shock that are statistically indistinguishable from the analog moments in the data.

The cross-sectional results by age provide insight into why the refinancing channel matters for the aggregate response. The fixed-rate mortgage structure generates heterogeneity in the pass-through of monetary policy to the mortgage balances and payments because individuals vary in their refinancing and new borrowing decisions. Individuals with larger loan sizes are more likely to adjust their loans when interest rates decline because interest savings rise with loan size, while some components of the adjustment costs remain fixed. In the model, consistent with the data, younger people have larger loans than older people, as they borrow against higher expected future income. Therefore, young people also have a higher propensity to adjust their loans when rates decline. At the same time, younger people are also more likely to be short-term liquidity constrained. As a result, there is a positive correlation between those who decide to refinance and short-term liquidity constraints, which can generate large consumption responses in the aggregate.

I use the model to show that the refinancing channel explains a sizable share of the cross-section patterns by age. I quantify the role of the refinancing channel by shutting down the refinancing decision and re-estimating the model under a variable rate mortgage structure, without any fixed costs. I find that the difference between the consumption response of young and old people declines by about 45 percent under the model with a variable mortgage structure. So according to my model, the refinancing channel accounts for 45 percent of the difference in the consumption response of younger and older people. I show that the effect of the refinancing channel on the consumption responses by age is at least as large as the effect from changes in aggregate income and changes in house prices following monetary policy shocks.

I also use the model to understand the role of refinancing and the mortgage market structure for the aggregate consumption response. How consumption changes when we move from having fixed to variable rate mortgages is theoretically ambiguous. On the one hand, there is a decline in the covariance between those who experience changes in their mortgage rates and those with short-term constraints, since interest rates change automatically and pass through to all mortgages under a variable mortgage structure. The decline in the covariance dampens the cross-sectional differences in consumption responses across households, as well as the aggregate response. On the other hand, there are more households that have lower mortgage payments after expansionary monetary policy shocks, bolstering aggregate consumption.

I use the model to examine this trade-off between the effect from lower covariance vs. a larger number of households experiencing interest rate changes when we move from fixed to variable rate structures. I find that quantitatively, the overall interest income effect from more households experiencing a change in rates dominates. As a result, aggregate consumption responds more under a variable rate structure (consistent with empirical research from Di Maggio et al. (2017)), while the cross-sectional heterogeneity is smaller.

A key implication of the quantitative exercises in my model is that the structure of the mortgage market is important for monetary policy, in terms of both the aggregate and cross-sectional effects on consumption. More generally, these calculations also suggest that the effect of the mortgage market structure on the transmission of monetary policy to consumption depends on the strength of the covariance term in refinancing. This covariance may vary across different countries or regions due to differences in, for instance, the population age composition.

Related literature

This paper contributes towards three main strands of literature. First, this paper adds to the literature that studies the relationship between consumption, mortgage refinancing and homeownership. Studies, such as Cochrane and Piazessi (2002), Hamilton (2008), Nakamura and Steinsson (2018) and others, show that monetary shocks can have significant effects on long-term yields through affecting market expectations about the future path of interest rates and/or affecting risk premia. These studies focus on asset price effects. In this paper, I showing that these changes in long-term rates can also affect real variables, in particular consumption, for households who differ in their mortgage decisions.

Recent empirical studies have focused on the consumption response, taking as given a change in the individual's mortgage rate. For instance, Di Maggio et al. (2017) exploit the change in the outstanding auto loan balance following anticipated rate resets on adjustable rate mortgages. Cloyne, Ferreira and Surico (forthcoming) examine consumption responses in the U.S. and the U.K. of outright homeowners and mortgagees. In this paper, I show that there is heterogeneity, not only in the consumption response, but also in the decision to adjust a loan or not. This highlights a novel feature of transmission mechanism: large responses can occur if those who choose to adjust their loans are also those who spend a larger portion of the savings. I show that this decision is related to the age of the household – younger individuals are simultaneously more likely to be short-term liquidity constrained, and more likely to adjust their loans when rates decline. The correlation between spending coefficients and refinancing decisions is a specific form of the correlation explored in Auclert (forthcoming). His analysis abstracts from refinancing. In this paper, I show that refinancing decisions over the life-cycle can matter for the aggregate consumption response.

On the theoretical front, papers such as Garriga, Kydland and Sustek (2017), Greenwald (2018), and Hedlund et al. (2017) also study monetary transmission to the mortgage market. However, these papers assume a representative borrower and generally abstract from life-cycle features of borrowers. Beraja et al. (2019) use a model closer to this paper. Their paper highlights the role of collateralized borrowing across regions, while I explore the implications of the mortgage market structure for the cross-sectional and aggregate consumption responses. My findings complement Guren, Krishnamurthy and McQuade (2018), who study the optimal design of mortgages to reduce household consumption volatility and default.

The model developed in this paper is most closely related to the transaction cost models in the literature that distinguish between liquid and illiquid assets. In these models, the presence of fixed costs of adjustment for illiquid assets generates lumpy adjustments of asset portfolios. Recent examples are Alvarez, Guiso and Lippi (2012), Alvarez and Lippi (2009), Kaplan and Violante (2014), and others. My framework builds on these models with liquid and illiquid assets by incorporating a number of additional features, which are important for generating the heterogenous age-specific consumption responses to interest rate shocks. These features include a uninsurable labor income risk, a life-cycle savings motive, and a fixed-rate mortgage structure.

Structure of the paper. The rest of the paper is structured as follows. Section 2 describes the data. Sections 3 discusses the empirical methodology and the empirical results. Sections 4 and 5 sets up the model, and Section 6 discusses the model results. Section 7 concludes. The Appendix contains some further results and robustness exercises.

2 Data Description

My sample combines monetary policy shocks with quarterly data on household consumption and mortgage decisions from the Consumer Expenditure Survey and Freddie Mac.

Monetary policy shocks I measure monetary shocks using the high-frequency movements in the Federal Funds futures rate in a small window of time around Federal Open Market Committee (FOMC) announcements. Following Gürkaynak, Sack and Swanson (2005), Gorodnichenko and Weber (2016) and Nakamura and Steinsson (2018), I construct the monetary policy shock as

$$\epsilon_t = \frac{D}{D-t}\left(ff^0_{t+\triangle^+} - ff^0_{t-\triangle^-}\right). \tag{1}$$

where t is the time of the monetary announcement, $ff^0_{t+\triangle^+}$ is the Federal Funds futures rate shortly after t, $ff^0_{t-\triangle^-}$ is the Federal Funds futures rate just before t, and D is the number of days in the month. The $D/(D-t)$ term adjusts for the fact that the Federal Funds futures settle on the average effective overnight Federal Funds rate. I consider a 60 minute time window around the announcement that starts $\triangle^- = 15$ minutes before the announcement. This narrow window makes it highly likely that the only relevant shock during that time period (if any) is the monetary policy shock. My shock series begins in 1989 and ends in 2007, before the financial crisis.[1]

Following Cochrane and Piazessi (2002) and others, I aggregate the identified shocks to a quarterly frequency if there is more than one shock in the quarter, in order to merge with the consumption data. Table 1 shows that the moments of the aggregated shocks is similar to the raw data.[2]

Table 1: Summary statistics of monetary policy shocks

	Raw shocks	Quarterly shocks
Median	0.000	-0.005
Mean	-0.019	-0.042
Standard deviation	0.086	0.124
Min	-0.463	-0.479
Max	0.152	0.261
Number	164	72

Notes: Summary statistics of the monetary policy shocks. "High frequency" shocks are estimated using equation 1. "Aggregated" shocks are based on summing the shocks within the quarter.

The time aggregation relies on the assumption that shocks are orthogonal to economic variables in that quarter. This assumption is analogous to the literature that identifies monetary policy shocks using vector auto-regressions (VAR) assuming that the monetary policy shock is orthogonal to movements in other real variables within that quarter (Christiano, Eichenbaum and Evans (1999)). However, the high-frequency approach is more general than the VAR literature, because it does not need to be identified conditional on a specific set of variables in the VAR. The Federal Funds futures contracts incorporate any (broader) information the market has access to. Another advantage of using high-frequency identification, relative to specifying a linear VAR, is that we can estimate the responses to monetary shocks without imposing linearity or invertibility of the specification, since the variables can be regressed directly on the identified shocks (Jordà (2005)).

Table 1 shows that the aggregated shocks have similar features to the raw high-frequency shocks. There are 72 quarterly monetary policy shocks over 1990-2007. The median is approximately 0.

[1] I stop the sample in December 2007 in order to study a period of conventional monetary policy, which is the focus of the economic model.

[2] As noted in Ottonello and Winberry (2018), the shocks have very similar properties if they are instead weighted by the number of days in the quarter after the shock occurs.

Two standard deviations of the quarterly shock is 25-29 basis points. The largest expansionary shock is 46 basis points, in the fourth quarter of 1991. 15 percent of expansionary shocks occur during recession periods, compared with 8 percent of contractionary shocks. The expansionary shocks occur earlier in the sample, 1990-1994. There is no evidence of serial correlation in the shocks. The times series of the shocks are depicted in Appendix A, Figure 3.

The small size and transitory nature of the shocks make it challenging to obtain tight standard errors for estimated responses of real variables to the shocks, particularly for the aggregate variables. There is, however, greater precision for estimates of the *differential* responses across household groups. Identification comes from variations across households in their responses to the relatively large shocks. The differential responses are useful for understanding the transmission mechanisms of monetary policy.

In the Appendix E, I redo the empirical analysis for an alternative measure of monetary policy shock based on the "path" of interest rates. Specifically, the policy indicator is based on the second component of the unanticipated change over the 60-minute windows discussed above. Gürkaynak, Sack and Swanson (2005) (GSS) decompose the shock into two orthogonal components: (i) surprises in the current monthly rate, and (ii) surprises in the path of the futures rate. The second component, which GSS refer to as the "path" factor, is interpreted as the forward guidance shock. The estimation uses a principal components analysis to extract two factors from changes in the 3, 6, 9 and 12 month ahead futures on 3-month Eurodollar deposits and OIS rates.[3]

Consumption data I use data from the Consumer Expenditure Survey (CEX) interview sample. The CEX interview survey is a rotating panel of households that are selected to be representative of the U.S. population. Each household is interviewed about their expenditures for up to four consecutive quarters. Expenditures on detailed categories over the preceding three months are recorded at each interview. Expenditure categories encompass durable goods, non-durable goods and services. I deflate the expenditure using the inflation index from the BLS and the National Income and Product Accounts (NIPA) separately for each category. Demographic variables, including family status, earnings, income and age of family members, are also recorded. My analysis sample contains 235,933 households over the period 1989-2007 which overlaps with the sample period of my monetary policy shocks. See Appendix B.1 for details on the construction of the categories, and discussion of robustness around measurement issues.

Housing and Mortgage data The CEX survey also provides information on mortgages and homeownership. I use the CEX detailed expenditure files on owned living quarters and other owned real estate, and mortgages, over the sample period of 1990-2007.

[3]I thank Alejandro Justiniano for sharing with me the shocks estimated in Justiniano et al. (2012).

Table 2 summarizes some well-known key mortgage and homeownership decisions in the data. For instance, homeownership rises with age, while mortgage balance and duration declines with age. In the data, young people have larger loan sizes, longer durations and are more leveraged (higher loan-to-valuation ratios). Many older households have lower loan balances, as part or all of the loan has already been repaid.

Table 2: Mortgage Statistics

	Young 25-34	**Middle** 35-64	**Old** 65+
Homeownership rate	46%	72%	79%
Fraction with mortgages	42%	55%	23%
Median loan size	110,328	98,061	65,497
Median loan duration (years)	27.25	22.25	17.25
Median credit utilization rate	36%	25%	13%
Average fraction of loans at fixed rates	78%	80%	83%

Notes: This table shows homeownership and mortgage statistics for each age group. The statistics are based on the CEX data for the mortgage statistics and Equifax data for the credit utilization rates.

Using the CEX data, I examine loan adjustments, which include households that entered into a new mortgage due to refinancing or home purchase. I supplement the analysis using loan-level panel data of 30-year mortgages from the Freddie Mac Single Family Loan-Level dataset. In total, there are approximately 17 million loans in the sample period 2000-2007.

The Freddie Mac data differs from the CEX data in a number of ways. It has less information about the household (for example, it does not have the family size or age of the head(s) of households), and does not link to consumption. However, it has more information about the loan, including the FICO credit score, delinquency status, and interest rates. The loan balance can also be observed continuously since it is a loan-level panel, which is not possible in the CEX data. These extra dimensions allow me to examine the relationship between loan adjustment decisions and loan size, and to control for loan-specific characteristics.

While there is insufficient information in the CEX to separate loan adjustments in refinances vs. new housing purchases, it is possible to examine the responses of these two margins in the Freddie Mac loan-level data. In Appendix B.2 Table 22, I provide some evidence that suggests that the majority of loan adjustments to monetary policy shocks are refinances. The responses of refinances to monetary policy shocks are statistically significant at a 1 percent level.

In Appendix B.2 Table 21, I compare the unconditional share of loans that adjust each quarter and the propensity to adjust loans following monetary shocks implied by different datasets: the CEX data, Freddie Mac data, and Core Logic loan data. Table 21 shows that these moments are consistent across the different data sets.

Mortgage rates I obtain mortgage rate information from the Federal Reserve Bank of St. Louis. These are deflated based on expected inflation from the Federal Reserve Bank of Cleveland.

Consistent with the literature, I find that these long-term interest rates respond to the monetary shocks described earlier. Table 3 shows the OLS estimate of the contemporaneous change in the 30- and 15-year mortgage rates after a one percentage point monetary policy shock. I obtain a point estimate of about 56 basis points with a standard error of about 25 basis points, so the estimates are significant at a 5 percent level. Taking sampling uncertainty into account, the estimates are consistent with the literature: Gertler and Karadi (2015) find pass-through ranging from 17 to 48 basis points, and Gilchrist, López-Salido and Zakrajšek (2015) find pass-through of 0.68.

Table 3: Response of Mortgage Rates to Monetary Policy Shocks

Change in mortgage rate	30-year	15-year
	(I)	(II)
Coefficient	0.564	0.562
Standard error	(0.286)	(0.255)
P-value	0.054	0.032

Notes: This table shows change in the mortgage rates to a 1 percentage point monetary policy shock. The mortgage rates are obtained from the Federal Reserve Bank of St. Louis. The rates are deflated using inflation expectations from the Federal Reserve Bank of Cleveland.

3 Heterogeneous Responses to Monetary Policy

This section documents heterogeneity in the impact of monetary policy on consumption by age and mortgage decisions. First, I provide suggestive evidence that young households increase their consumption by relatively more than old households when interest rates decline. Second, I show that households that change their home-loan status have a relatively larger consumption response to monetary policy shocks than renters and those who do adjust their loans. Finally, I show that younger households are more likely to adjust their loans when rates decline. These findings together suggest that mortgage decisions by young households are important for understanding the transmission of monetary policy to consumption.

3.1 Heterogeneous consumption responses by age

I begin by estimating the differential response of consumption by age groups to interest rate shocks using the following baseline regression:

$$\triangle \ln C_{ht} = b_0 + \sum_k \beta_k^a \cdot \epsilon_{t-k} \cdot \text{Age}_{h,t-k} + \alpha_1 \text{Age}_{h,t-k} + \alpha_2 X_{ht} + \lambda_{s(t)} + \lambda_h + \nu_{ht}. \quad (2)$$

for household h in quarter t. The regressions are estimated using the CEX household weights so that the sample can be representative of the population.

$\triangle \ln C_{ht}$ denotes the change in real consumption for household h over the quarter t. X_{ht} denotes household-level controls, which include changes over the quarter in number of children and total number of family members, and fixed effects for the calendar month that the household's survey is conducted. $\lambda_{s(t)}$ denotes fixed effects for quarterly seasonality and NBER recession dates. λ_h denotes household fixed effects. The monetary policy shocks at date t are denoted by ϵ_t.[4] The residual is denoted by ν_{ht}. In the specifications, I include 9 lags based on standard lag-length selection criteria.

Age_{ht} is a vector of age-group dummies referring to the average age of the head(s) of household. In the base results, I define young individuals as those aged 25-34 years, as this is the primary age range for first-time home purchases. Middle-aged is defined as 35-64 years, and old individuals are those between ages 65 and 75. Defining age groups in this way captures any differential consumption response to interest rate shocks that may be related to homeownership decisions. The broad age ranges also ensures that there is a sufficient number of households to reliably estimate age-specific responses using the CEX data set.

The semi-elasticity of consumption to a contractionary monetary policy shock that occurred k periods ago is given by the sum of the β coefficients for age group a from period 1 to k. The standard errors are clustered by time to capture potential correlations across households' consumption responses to the aggregate monetary policy shocks. The standard errors are computed using the Delta method.

Table 4 reports the differences between the age groups in their average consumption response over the year after a monetary policy shock.[5] The coefficients are normalized to report the response to an expansionary monetary policy shock (i.e. a decline in rates).[6] The p-values for the test of

[4] Similar to many existing studies in the literature, Equation 2 does not condition on the sign of the shock as there is not sufficient power in the sample of shocks to statistically distinguish between the responses to expansionary shocks from the responses to contractionary shocks.

[5] I report the average response over the year, as these moments map naturally to the model-equivalent moments in Section 4. However, the results are qualitatively robust to computing year-end semi-elasticities instead.

[6] I.e., the response to a 1 sd expansionary monetary policy shock multiplies the coefficients by -1 and the standard deviation of monetary policy shocks.

equality between the responses of the group are computed using the Delta method. For example, a p-value less than 0.1 reject the null of equal consumption between age groups at a 10 percent significance level.

Table 4: Heterogeneous responses to expansionary monetary policy shocks, by age

	(I)	(II)	(III)
Young-Middle			
Coefficient	2.29	2.53	2.64
Standard error	(1.25)	(1.28)	(1.32)
P-value	0.07	0.05	0.05
Young-Old			
Coefficient	2.42	2.66	4.21
Standard error	(1.80)	(1.79)	(2.06)
P-value	0.18	0.14	0.05
Middle-Old			
Coefficient	0.12	0.13	1.56
Standard error	(1.52)	(1.54)	(1.74)
P-value	0.94	0.93	0.37
Recession fixed effects	Yes		
Time fixed effects		Yes	Yes
Income interactions			Yes
Education interactions			Yes

Notes: This table shows the differences between age groups in their average semi-elasticities of consumption over the year, in response to a 1 sd expansionary monetary policy shock. The estimates are based on Equation 2. The standard errors and corresponding p-values for the coefficients are computed using the Delta method. See text for more detail.

The estimates suggest that young people adjust their consumption more than middle-aged and older households. Specifically, the young increase consumption by about 2.3-2.6 percentage points more than middle-age, which is statistically significant at a 5-10 percent level. In contrast, the difference in consumption responses of the middle-aged relative to older households is statistically insignificant at a 10 percent level.

Table 5 computes the contribution of each age group to the aggregate consumption response. Column (I) depicts the average annual responses, and column (II) gives the unconditional share of the level of non-durable expenditure for each age group, based on the CEX data. The product of columns (I) and (II) gives the percentage point contribution of the group to the aggregate response in column (III). The standard errors and p-values are computed based on the Delta method. The contribution as a share of the overall response is given in column (IV).

Table 5 suggests that young households increase their consumption by about 2.4 percent over the year, following a monetary policy shock. This accounts for about 80 percent of the aggregate consumption response. The contribution is statistically significant at a 10 percent level. The estimates of responses in levels are less precise than the estimates of differential responses between groups. Nonetheless, the estimates are consistent with the idea that young contribute more to the overall response than older age groups.

Table 5: Contribution by Age-group to Aggregate Consumption Response

	Annual Response	Share of Consumption	Contribution to total	
			in ppts	share of total
	(I)	(II)	(III)	(IV)
Young				
Coefficient	**2.36**	**0.32**	**0.75**	**0.83**
Standard error	(1.08)		(0.35)	(0.45)
P-value	0.03		0.03	0.07
Middle				
Coefficient	**0.25**	**0.57**	**0.14**	**0.15**
Standard error	(0.81)		(0.46)	(0.42)
P-value	0.76		0.76	0.72
Old				
Coefficient	**0.17**	**0.11**	**0.02**	**0.02**
Standard error	(1.38)		(0.15)	(0.16)
P-value	0.90		0.90	0.90

Notes: This table shows the average semi-elasticities of consumption over the year, by age group, to a 1 sd expansionary monetary policy shock. Column (I) is based on Equation 2. Column (II) shows each age group's share of overall consumption within the consumption category. Column (III) and (IV) give the contribution of each age group to the total response in percentage points and percent of total, respectively. Column (III) is computed based on the product of (I) and (II). (IV) is computed based on (III) divided by the semi-elasticity within each consumption category. The standard errors and corresponding p-values for the coefficients are computed using the Delta method. See text for more detail.

One potential concern is that the regressions may be picking up responses related to recessions, when expansionary shocks are more likely to occur. I consider these aggregate factors in two ways. First, the estimation of Table 4 column (I) includes recession fixed effects (similar to Tenreyro and Thwaites (2016)). Second, in column (II), I include time fixed effects to capture any confounding aggregate factors. The results are little changed, suggesting that the timing of the shocks is not driving the differential results.

The estimates are also robust to including controls for income and an indicator for college education attainment, both interacted with monetary policy shocks (Table 4, column (III)). Although we cannot completely rule out all income factors, the estimates provide suggestive evidence that there may be other factors, in addition to income, that could explain consumption differences by age. Sections 3.2 and 3.3 explore the role of mortgages and loan adjustments for the heterogeneous transmission of monetary policy.

3.2 Heterogeneous consumption responses by mortgage decisions

The second dimension of heterogeneity that I study is the variation in consumption responses conditional on households' mortgage and homeownership decisions.

In the U.S., most mortgages have fixed rates. This means that changes in interest rates only affect the household's mortgage rates if they decide to adjust their loan by entering a new mortgage or refinancing an existing loan. Households could also increase the amount borrowed without changing their mortgage payments when interest rates decline, if they are not against their mortgage borrowing constraints. The increase in balance is also known as "cash-out" refinancing, and is one way that households can extract equity from their housing.

I study the heterogeneity by mortgage and homeownership decisions by dividing the CEX sample into three groups g: (i) households that own a home and adjust their loan, (ii) households that own a home and do not adjust their loan, and (iii) households that are renters. I define a loan adjustment as a new mortgage transaction, due to refinancing of existing loans or new loan contract which arises when a household buys a new home. A household belongs to the first group if they had a mortgage loan adjustment over the past year. For robustness, I show that the results are qualitatively robust to considering different horizons for defining a change in loan status in Appendix D Table 24.

I estimate the following specification to explore the heterogeneity by mortgage and homeownership decisions.

$$\triangle \ln C_{ht} = b_0 + \sum_k \beta_k \epsilon_{t-k} \cdot M_{h,t-k} + \alpha_1 M_{h,t-k} + \alpha_2^g X_{ht} + \lambda_{s(t)} + \lambda_h + \nu_{ht}^g. \tag{3}$$

where $\triangle \ln C_{ht}$ denotes the change in real consumption for household h over the quarter t. X_{ht} denotes household-level controls, which include changes over the quarter in number of children and total number of family members, and fixed effects for the calendar month that the household's survey is conducted. $\lambda_{s(t)}$ denotes fixed effects for quarterly seasonality. λ_h denotes household fixed effects. The monetary policy shocks are denoted by ϵ_{t-k}. The residual is denoted by ν_{ht}. $M_{h,t-k}$ denotes the indicator variables for each of the three groups described above (own home and adjust loan, own home and not adjust loan, and renting).

Table 6 reports the average consumption response over the year following a monetary policy shock across the three mortgage and homeownership groups. Table 7 gives the difference between the groups. The coefficients are normalized to report the response to an expansionary monetary policy shock (i.e. a decline in rates). The p-values for the test of equality between the responses of the group are computed using the Delta method. For example, a p-value less than 0.1 would reject the null of equal consumption between age groups at a 10 percent significance level.

Home owners that adjust their mortgage Tables 6 and 7 provide some suggestive evidence that the response of consumption is driven by those who change their home-loan status (i.e. they refinanced an existing loan, or purchased a home). The consumption effect is statistically insignificant for household who do not have a change in their home-loan status, and for renters.

Households who adjust their loans increase their consumption by 4 percent, which is statistically significant at a 10 percent level (Table 6 column (I)). These findings are robust to including income and education controls in the regression specifications (columns (II) and (III)). For the average household in the CEX sample, who has an annual expenditure of \$50,000, a 4 percent increase in consumption is equivalent to about \$2,000. Across all households that hold a mortgage (i.e. averaging across those who adjust as well as those who do not adjust), consumption increases by 0.3 percent, which is equivalent to about \$153 for the average household.

Table 6: Consumption Responses by Housing and Mortgage Decisions

	(I)	(II)	(III)
Adjust Loan			
Coefficient	4.02	4.07	4.26
Standard error	(2.18)	(2.13)	(2.06)
P-value	0.07	0.06	0.04
Do not adjust loan			
Coefficient	0.08	0.06	0.21
Standard error	(0.49)	(0.56)	(0.67)
P-value	0.88	0.92	0.76
Renters			
Coefficient	0.44	0.39	0.52
Standard error	(0.39)	(0.42)	(0.44)
P-value	0.26	0.36	0.24
Recession fixed effects	Yes	Yes	Yes
Income interactions		Yes	Yes
Education interctions			Yes

Notes: This table shows the average semi-elasticity of consumption responses to a 1 standard deviation expansionary monetary policy shock over the year, based on Equation 3. The standard errors and corresponding p-values for the coefficients are computed using the Delta method. See text for more detail.

Table 7: Differential Consumption Responses by Housing and Mortgage Decisions

	(I)	(II)	(III)
Adjust loan vs Do not adjust loan			
Coefficient	3.95	4.01	4.05
Standard error	(2.45)	(2.42)	(2.43)
P-value	0.1	0.1	0.1
Adjust loan vs Renters			
Coefficient	3.59	3.69	3.74
Standard error	(2.02)	(2.15)	(2.16)
P-value	0.08	0.09	0.09
Do not adjust loan vs Renters			
Coefficient	-0.36	-0.33	-0.32
Standard error	(0.71)	(0.45)	(0.46)
P-value	0.61	0.47	0.49
Recession fixed effects	Yes	Yes	Yes
Income interactions		Yes	Yes
Education interctions			Yes

Notes: This table shows the difference in the average semi-elasticity of consumption responses to a 1 standard deviation expansionary monetary policy shock over the year, based on Equation 3. The standard errors and corresponding p-values for the coefficients are computed using the Delta method. See text for more detail.

To interpret the magnitudes of the consumption responses, one useful benchmark is the change in mortgage payments and balances. Consider a mortgage rate decline from 6 to 5.9 percent. In 2007, the median mortgage was about \$200,000. For homeowners who adjust their existing mortgage, the decline in mortgage rates results in a reduction of \$155 in payments each year, which is equivalent to \$2,158 over the life of a 30-year mortgage (comparable to the magnitudes of the consumption responses of homeowners that adjust their loans). This means that the homeowner can extract the savings in payments upfront today by increasing their balance by up \$2,158 at the lower mortgage rate without raising their existing payments. If the households' change in mortgage rates is even larger than 0.1 percent, then the potential home equity extraction may be even greater.

There is evidence that homeowners extract home equity following monetary policy shocks. For instance, Bhutta and Keys (2016) finds evidence in Equifax data of home equity extraction of around \$1,700 when rates decline. Eichenbaum, Rebelo and Wong (2018) estimate that for households who adjust their loans, their balance increases by about 1.15 percent in response to a 1 standard deviation monetary policy shock, which is equivalent to \$2,300 for a household with a \$200,000 median loan size. Studies such as Di Maggio et al. (2017) and Mian and Sufi (2014) estimate that most of the home equity extraction is used towards consumption. These studies highlight the potential role of equity extraction for generating large consumption responses, which is consistent with the consumption estimates in this paper.

Of course there may be other potential factors, besides changes in mortgage balances, that could also underlie the differences in consumption responses in Tables 6 and 7. In Section 4, I develop a quantitative model to isolate the role of this mechanism for generating the heterogeneous responses to monetary policy shocks, relative to other potential channels such as aggregate income and house price effects.

Renters and homeowners who do not adjust their mortgage Table 7 also shows that renters have on average a slightly larger consumption response than homeowners who do not adjust their loans. However, the response is not statistically significant. On the one hand, homeowners may experience a positive wealth effect relative to renters, associated with any increases in house prices when interest rates decline. However, it is not obvious this will translate to large differences in consumption responses between the two groups if the household does not withdraw equity from their home. The overall consumption responses depend on their marginal propensity to consume out of wealth. The finding that renters do not differ that much from homeowners that do not have a loan status change suggests that equity extraction may be important for generating sizable consumption responses to changes in interest rates.

These findings are consistent with Cloyne, Ferreira and Surico (forthcoming), who find that homeowners with mortgages respond more than outright owners and renters. In this paper, I split the homeowners with mortgages further into those who adjust and those who do not adjust their mortgages (the latter group includes current outright owners). The further split of homeowners with mortgages provides new suggestive evidence of the importance of loan adjustments for understanding the transmission of monetary policy. The dynamic loan adjustment decision is relevant in countries with fixed rate mortgage structures such as the U.S.

Further decompositions by mortgage decisions and age It is possible to further split the three housing and mortgage categories into young and middle-aged groups.[7] Once we condition on the housing and mortgage groups, there is less difference in consumption responses between the young and middle-aged group, both in terms of point estimates and significance (Table 8). This is broadly consistent with the idea that loan adjustment decisions matters for the heterogeneous consumption responses across age groups.

[7] There are not enough observations to examine loan adjustment decisions for old households since the majority of old homeowners have paid off their mortgages and therefore fall in the classification of owning a home and not adjusting their loan.

Table 8: Differential Consumption Responses by Age, Housing and Mortgage Decisions

Young vs Middle	All	Subset of households		
		Adjust loan	No adjust	Renters
Coefficient	2.62	0.81	1.33	-3.25
Standard error	(1.32)	(9.42)	(1.73)	(2.14)
P-value	0.05	0.93	0.45	0.14
Recession fixed effects	Yes	Yes	Yes	Yes
Income interactions	Yes	Yes	Yes	Yes
Education interctions	Yes	Yes	Yes	Yes

Notes: This table shows the differential consumption responses to a 1 standard deviation expansionary monetary policy shock, based on Equation 3. The standard errors and corresponding p-values for the coefficients are computed using the Delta method. See text for more detail.

These estimates are robust to including controls for income and an indicator for college education attainment, both interacted with monetary policy shocks. While these controls do not rule out all potential income factors, such as change in income expectations by age, it provides some suggestive evidence that the consumption differences by age are not only driven by income differences alone between the housing and mortgage groups.

3.3 Heterogeneous loan adjustment decisions by age

Given that loan adjustment decision is important for the consumption response, I now examine how the adjustment decision varies with age.

First, I document the average share of households in different demographic groups, without conditioning on any shocks. Table 9 shows the unconditional average share of households in the three groups: own a home and adjusted their loan in the past year, own a home and did not adjust their loan in the past year, and those that continuously rented during the year.

The summary statistics in Table 9 show that on average young households are more likely to change loan status in the past year than middle age and older households. About 31 percent (0.19/(0.19+0.4)) of young homeowners had a loan status change in the past year. These magnitudes are also broadly consistent with existing literature on refinancing. For instance, using Danish data, Andersen et al. (2015) find that about 22.5 percent of households refinanced in 2010. Inattention is lower for young households, as refinancing probabilities are 30-40 percentage points higher for young households relative to older households. While the paper has a different sample period and country, these magnitudes are broadly in line with the average fractions in this paper.

Keys, Pope and Pope (2016) also examine refinancing behavior using a sample of U.S. households in 2010-2012. They estimate that between 20-40 percent of homeowners fail to refinance, despite potential interest savings from doing so. This implies that 60-80 percent of homeowners do respond to lower interest rates over 2010-2012, equivalent to an average of 20-27 percent of homeowners refinancing each year. The magnitudes are broadly in line with those described in this paper.

Table 9: Average Mortgage and Housing Decisions by Age

Average fraction of households	**Young** (I)	**Middle** (II)	**Old** (III)
Own house and adjust loan	0.19	0.04	0.04
Own house and do not adjust loan	0.40	0.76	0.81
Renters	0.41	0.20	0.15

Notes: This table shows the average share of households that had a loan-status change in the past year, households that did not have a loan-status change in the past year, and households who remained renters continuously over the past year. The averages are baseline shares, unconditional on any shocks.

Second, I examine the marginal increase in loan adjustment over the year after a 1 ppt shock. The marginal refinancing responses are estimated based on the following regression:

$$P_{ht} = b_0 + \sum_{k=1}^{K} \beta_k^a \epsilon_{t-k} \cdot \text{Age}_{h,t-k} + \alpha_1 \text{Age}_{h,t-k} + \alpha_2 X_{ht} + \lambda_{s(t)} + \lambda_h + \nu_{ht}. \tag{4}$$

P_{ht} is an indicator equal to one if household h adjusts their loan in quarter t. X_{ht} denotes household-level controls, which include changes over the quarter in number of children and total number of family members, age of the head of household, and fixed effects for the calendar month that the household's survey is conducted. $\lambda_{s(t)}$ and λ_h denote denotes quarterly seasonality and household fixed effects, respectively. The monetary policy shocks are denoted by ϵ_{t-k}. The residual is denoted by ν_{ht}.

Table 10 Panel A reports the marginal responses in loan adjustment over the year to a 1 ppt monetary policy shock. Panel B reports the differential response between the age groups. Standard errors are computed based on the Delta method. The estimates in the first column of Table 10 imply that a 25 basis point monetary policy shock leads to an additional 2.5 percentage point increase in young households entering a new loan (estimate of 0.1 times 0.25). This is roughly equivalent to an additional 4 percent of young homeowners (marginal effect of 0.025 divided by the average share of homeowners (1-0.41) from Table of 9). In comparison, less than 1 percent of middle-age and old households change their loan status when rates decline. The marginal response of the young is statistically different from that of the response of the old at a 5 percent level (column 1 of Table 10 Panel B). The marginal response of the middle-age is also statistically different from that of the response of the old at a 10 percent level (column 3 of Table 10 Panel B). Overall, across all homeowners of all age groups, the marginal response is around 1.3 percent in response to a 25 bp expansionary monetary shock. These magnitudes are broadly consistent with Bhutta and Keys (2016), Table 3, who use Equifax data to consider cash-out refinancing propensities in response to short-term interest rate movements.

Table 10: Marginal Propensities to Change Loan Status, conditional on an Expansionary Shock

Panel A: Extra propensity to adjust loan over the year after a shock	**Young**	**Middle**	**Old**
Coefficient	0.10	0.02	-0.03
Standard error	(0.01)	(0.02)	(0.02)
P-value	0.01	0.42	0.21
Panel B: Differential response	**Young - Middle**	**Young-Old**	**Middle-Old**
Coefficient	0.08	0.13	0.05
Standard error	(0.03)	(0.03)	(0.02)
P-value	0.1	0.04	0.08

Notes: Panel A shows the marginal propensities of households to have a loan-status change over the past year following an expansionary monetary policy shock. Panel B shows the differential responses. The standard errors and p-values are computed based on the Delta method.

Given Tables 9-10, we can compute the overall share of *homeowners* that adjust their loans after a monetary policy shock. This is given by the unconditional share of homeowners who adjust, plus the additional propensity to adjust when there is an expansionary monetary policy shock. Table 11 shows that 33 percent of young homeowners adjust their loans after a 1 standard deviation monetary policy shock.[8] In comparison, around 5 percent of middle-aged homeowners and old homeowners adjust their loans.

[8] This is computed as $(0.19 + \sigma_\epsilon \times 0.1)/(1 - 0.41)$, The coefficient 0.19 is the baseline share of young homeowners that adjust, 0.1 is the young's marginal propensity to adjust after a 1 ppt monetary shock, $(1 - 0.41)$ is the share of homeowners, and σ_ϵ denotes the standard deviation of monetary policy shocks.

Table 11: Total Share of Homeowners who Adjust after an Expansionary Monetary Policy Shock

Share of homeowners with loan adjustment after a 1sd shock	**Young**	**Middle**	**Old**
Coefficient	0.33	0.05	0.05
Standard error	(0.05)	(0.02)	(0.004)
P-value	0.02	0.11	0.01

Notes: The table gives the total share of homeowners that have a loan status change in the past year (either via refinancing or entering a new loan when making a home purchase), following an expansionary monetary policy shock. This is the total share of homeowners, which is given by the baseline average plus the marginal propensity to adjust after the shock. See text for more detail. The standard errors and p-values are computed based on the Delta method.

For robustness, I also consider different time horizons for defining a change in loan status, ranging from 2 to 4 quarters after a monetary shock has occurred. The results are not statistically different across the different time horizons (Appendix D Table 24).

Loan size and propensity to adjust One potential reason why young households are more likely to adjust their loans when rates decline is because they have larger loan sizes. In the presence of fixed transaction costs, agents with larger loan sizes are more likely to adjust their loans when rates decline since their interest savings are greater relative to the fixed costs. In the data, individuals take out a mortgage to purchase their home and pay down the mortgage over time. So naturally, older people have lower loan balances since part or all of the loan has already been paid down (as seen in Table 2), which may reduce their incentive to refinance relative to younger households when interest rates fall.

To examine the role of loan size, I re-estimate equation 4, controlling for the log of the loan size interacted with the monetary policy shocks. Table 12 Panel B shows the differences in responses by age after controlling for loan size. Panel A gives the baseline estimates, without controlling for loan size, for comparison to Panel B. We can see that the differences in the propensities to adjust loans between the age groups becomes smaller in magnitude and is statistically insignificant, after controlling for the loan size effect. The change in these coefficients from Panel A to B provides suggestive evidence that the life-cycle profile of mortgages size may explain part of why the young are more likely to adjust their loans after monetary shocks.

Table 12: Marginal Propensities to Change Loan Status

Panel A: Baseline estimates, not controlling for (loan size)*shock	Young - Middle	Young-Old	Middle-Old
Coefficient	0.08	0.13	0.05
Standard error	(0.03)	(0.03)	(0.02)
P-value	0.12	0.04	0.08

Panel B: Differential response, controlling for (loan size)*shock	Young - Middle	Young-Old	Middle-Old
Coefficient	0.03	0.07	0.04
Standard error	(0.08)	(0.09)	(0.01)
P-value	0.76	0.49	0.07

Notes: This table shows the differential marginal propensities of households to have loan-status change in the past year, given an expansionary monetary policy shock. Panel A does not condition on loan size and its interaction with the monetary policy shocks. Panel B shows the differential responses in a specification that does condition on loan size and its interaction with the monetary policy shocks. The standard errors and p-values are computed based on the Delta method.

In Appendix Table 23, I provide further evidence that loan adjustment propensities rise with loan size. The large number of observations in the Freddie Mac data allows me to split the loan size into finer decile bins. The relationship is roughly linear with loan size.

Summary Taken together, these empirical results contribute to the literature that highlights an important role of mortgages for the monetary transmission to consumption (e.g. Di Maggio et al. (2017), Cloyne, Ferreira and Surico (forthcoming), and Beraja et al. (2019)). While Di Maggio et al. (2017) examine the response to an given anticipated rate change, I highlight the importance of the loan adjustment decision for the transmission of monetary policy. I show that younger individuals (who have higher propensities to spend than older individuals) are more likely to adjust their loans when rates decline, which can generate large consumption responses in the aggregate. My results also suggest that the mortgage channel depends critically on the decision and ability of homeowners, particularly the young, to adjust their loans.

4 Model

I now build a household model of housing and mortgage decisions in order to interpret the cross-sectional evidence in Section 3 and understand the transmission mechanism of monetary policy.

Households in the model face exogenous idiosyncratic and aggregate shocks. The shock processes generate dynamics that resemble business cycle fluctuations in the data. This allows me to examine the household's policy decisions in an environment with realistic dynamics in prices and aggregate variables, while preserving the household heterogeneity in income and mortgages.

The model contains two key features. First, following recent work such as Kaplan and Violante (2014), Kaplan, Moll and Violante (2018), and Berger et al. (2018), I assume that households pay a transaction cost to adjust their long-term assets. Transaction costs are paid when entering a new loan or refinancing an existing mortgage. Second, I model a fixed-rate mortgage structure. The mortgage rate is fixed unless the individual refinances their loan.

The key intuition of the model is as follows. The fixed costs and fixed-rate mortgage structure generate heterogeneity in the pass-through of monetary policy to the interest rate payments of households, because individuals can vary in their refinancing and new borrowing decisions. Individuals with larger loan sizes and with longer durations are more likely to refinance or enter a new loan when interest rates decline because the interest savings rise with loan size and duration, while some components of the adjustment costs remain fixed. In the model, young people have larger loan sizes and longer durations, and therefore have a higher propensity to refinance and enter new loans.

Moreover, the young are more likely to be against their short-term liquidity constraints, as they are more likely to borrow against higher expected future income growth. As a result, refinancing leads to interest savings and home equity extraction that relieves them from their short-term constraints. In the presence of transaction costs, there exists individuals, who are against their short-term constraints but have not yet adjusted their long-term mortgage assets by refinancing because the benefit of doing so may be less than the fixed cost of adjustment. This is similar to the hand-to-mouth individuals in Kaplan and Violante (2014). When interest rates fall sufficiently, this increases the incentive to refinance. For these individuals, it leads to large consumption responses because it can relieve them from their short-term constraints.

I use the model to quantify the relative importance of the mechanisms that generate the heterogenous responses. The structural model is useful for separating the refinancing channel from other potential mechanisms, such as income volatility and liquidity constraints, which may be correlated with the household's loan adjustment decisions. I also use to the model to study how the aggregate and heterogeneous effects of monetary policy shocks differ between fixed and variable rate mortgage systems.

4.1 Setup

Environment The economy is populated by a continuum of households indexed by j. Agents live for a maximum of T periods. Each period, an agent who is aged a survives to the next period with probability π_a. They work for the first T_y periods, and retire thereafter.

Assets Agents can choose to hold three types of assets: (i) saving via a one-period assets s_{jat} at an interest rate of r_t, with a short-term borrowing constraint $s_{jat} \geq -\underline{s}$, (ii) holding a long-term mortgage b_{jat} at a fixed rate of R_{jat}, and (iii) purchasing a unit of housing at price p_t. Housing can be either owned, or rented at price p_t^r. Owned housing stock depreciates at a rate of δ each period.

Following Campbell and Cocco (2003) and Kaplan, Moll and Violante (2018), I assume the mortgage is amortized over the life of the agent.[9] The duration of a new loan for an agent aged a is $d(a) = T - a$. $R_{ja0} = r_t^{d(a)}$ denotes the current market mortgage rate with a $d(a)$ duration. The loan balance b evolves as follows:

$$b_{j,a+1,t+1} = b_{jat}(1 + R_{ja0}) - M_{ja0}$$

where the initial amount borrowed b_{ja0} and the mortgage payment M_{ja0} satisfies:[10]

$$b_{ja0} = M_{ja0} \left[\sum_{k=1}^{d(a)} \frac{1}{(1 + R_{ja0})^k} \right]. \tag{5}$$

Following the literature, I assume that households pay transaction costs when they purchase a new home or when they refinance an existing mortgage, denoted by F^{new} and F^{refi}, respectively. When a household moves or refinances, they enter into a new mortgage contract. This means that the mortgage rate is reset to the current market rate. The mortgage rate can be expressed recursively as:

$$R_{j,a+1,t+1} = r_{t+1}^{d(a+1)} \cdot 1(\text{refi})_{t+1} + R_{jat} \cdot [1 - 1(\text{refi})_{t+1}] \tag{6}$$

[9] This assumption is motivated by the empirical observation that the loan durations decline with age (as seen in Table 2). In addition, the assumption significantly reduces the computational burden, because I do not need an extra state variable to track loan duration separately from age.

[10] Note, at each point in time, the duration of the loan is known given the age of the person, since the loan is amortized over their life. Thus, the constant mortgage payment M_{jat} is known, given the balance and mortgage rate. It can be computed, based on Equation 5, as:

$$M_{jat} = b_{jat} \left[\sum_{k=1}^{d(a)} \frac{1}{(1 + R_{jat})^k} \right]^{-1}$$

where the variable $1(\text{refi})_{t+1}$ equals one if the agent refinances in period $t+1$ and zero otherwise.[11] The household also has the option of choosing a new mortgage balance, subject to a minimum equity requirement:

$$b_{jat} \leq (1-\phi)p_t h_{jat}$$

where ϕ is the minimum down payment or equity that must be held in the house.

Similar to the approach taken by papers in the literature (e.g. Hurst et al. (2016), Kaplan, Moll and Violante (2018), Chen, Michaux and Roussanov (Forthcoming)) and others), I abstract from other durable goods besides housing. This decision reduces the computational burden of the model, while still capturing the largest component of households' durable assets holdings (housing assets). Other non-housing durables include items such as auto purchases and furniture. In the CEX data, these other durable goods account for a larger share of younger households' consumption basket, while services account for a larger share of older households' expenditure. If these additional durables are modeled, I would expect the heterogeneity in consumption response to monetary shocks by age to be even more pronounced in the model, given durables are more responsive to interest rate changes than non-durables (Cloyne, Ferreira, and Surico (forthcoming)) and these are mostly consumed by younger households.

Income Each period t, a working agent of age a receives an exogenous income y_{jat}, where:

$$\log(y_{jat}) = \chi_a + \eta_{jat} + \phi_a(y_t) \tag{7}$$

where χ_a is deterministic; η_{jat} is idiosyncratic, with $\eta_{jat} = \rho_\eta \eta_{j,a-1,t-1} + \psi_{jt}$ where ψ_{jt} is an i.i.d. shock drawn each period from $N(0, \sigma_\eta^2)$; and $\phi_a(y_t)$ captures age-specific fluctuations to income that arise from aggregate shocks to the aggregate income in the economy (the y_t process is described below). When the household is retired, income is given by a social security transfer, which is a function of income in the last working-age period, as modeled in Guvenen and Smith (2014).

The idiosyncratic income shocks are important for at least two reasons. First, the idiosyncratic shocks generate a dispersion of households income within age groups. This makes it is possible to compare, across age groups, their different propensities to refinance existing loans, as well as the extensive margin of switching from renting into owning a home, after interest rate shocks. Second, the idiosyncratic shocks are important for generating the life-cycle savings patterns in the data by creating a precautionary savings motive. As shown in a number of papers, including Krueger and Perri (2006), the idiosyncratic income component creates a precautionary savings motive, which

[11] If I include a mortgage payment-to-income constraint, as in Greenwald (2018), this would amplify the heterogeneous results even more. This is because income changes more for the young following interest rate shocks and they are the ones who are more likely to be against their payment-to-income constraint.

helps to more closely match the rising profile of savings (decline in debt holdings) over the life that is observed in the data. Both of these factors are important for generating the heterogeneous consumption responses by age following interest rate shocks (discussed further in Section 6).

Aggregate shocks to the economy In addition to idiosyncratic income shocks, households also face exogenous aggregate shocks. The vector S_t of aggregate variables includes log of real aggregate income $\log y_t$, log of real house prices $\log p_t$, and the one-period interest rate r_t. I assume the dynamics of S_t are given by

$$S_t = A_0 + A_1 S_{t-1} + u_t \tag{8}$$

where u_t is the residual, which is normally-distributed with mean 0 and variance-covariance V. The specification of the aggregate process follows the approach in Hurst et al. (2016), Kaplan, Moll and Violante (2018), Chen, Michaux and Roussanov (Forthcoming)) and others.

The aggregate state variables affect the mortgage rates and rental rates. The current market mortgage rate with a duration of d periods is modeled as a function of the aggregate state variables:

$$r_t^d = f^d(S_t) \tag{9}$$

The function f^d is duration-specific. This captures, in a reduced-form way, changes in term-premia and risk-premia that arise from shocks to the aggregate state of the economy. The rental rate is modeled as a function of the aggregate state of the economy:

$$\log(p_t^r) = f^{pr}(S_t) \tag{10}$$

4.2 Recursive formulation

For notational clarity, I drop the agent and age indices when describing the household's problem below.

I assume agents derive per-period utility from consumption and housing services:[12]

$$u(c,h) = \frac{\left(c^\alpha \cdot h^{1-\alpha}\right)^{1-\sigma} - 1}{1-\sigma}.$$

Housing can be rented or owned. Each period, households choose whether (i) to rent, (ii) to purchase new home, (iii) to own a home and refinance their existing mortgage, or (iv) to own a home and

[12]This specification of utility between housing and non-durable consumption is common in the literature. See, for example, Piazzesi, Schneider and Tuzel (2007) and Davis and Van Nieuwerburgh (2015). Using data from the consumer expenditure survey, Aguiar and Hurst (2013) find that the share of expenditure households allocate to housing out of total expenditure is roughly invariant with either the level of household income or the level of household expenditure.

not refinance their existing mortgage. Households also choose their consumption, savings in liquid one-period bonds, and mortgage debt. The household problem is solved recursively (Appendix section G describes the model computation).

Denote the household's state variables by $z = \{a, S, y, \text{assets}\}$, where a denotes age, S and y are the aggregate state and idiosyncratic labor income realizations, respectively, and assets is a vector of start-of-period holdings of short-term assets (s), housing owned (h^{own}), mortgage balance (b) and the fixed rate on any existing mortgage (R). The value function can be written as

$$V(z) = \max \left\{ V(z)^{\text{rent}}, V(z)^{\text{purchase}}, V(z)^{\text{own \& refi}}, V(z)^{\text{own \& no refi}} \right\} \tag{11}$$

If the household decides to rent, they face the following value function:

$$\begin{aligned} V(z)^{\text{rent}} &= \max_{c, h^{\text{rent}}, s'} u\left(c, h^{\text{rent}}\right) + E\left[V(z')\right] \\ \text{s.t. } c + s' + p^r h^{\text{rent}} &= y + (1-\delta) p h^{\text{own}} + (1+r)s - b(1+R) \\ h'^{\text{own}} &= b' = 0, \quad s' \geq -\underline{s} \end{aligned} \tag{12}$$

and Equations 7-10 for income and aggregate state processes, mortgage yields and rental rate.

If the household decides to purchase a new home, they face the following value function:

$$\begin{aligned} V(z)^{\text{purchase}} &= \max_{c, s', h'^{\text{own}}, b'} u\left(c, h'^{\text{own}}\right) + E\left[V(z')\right] \\ \text{s.t. } c + s' + p h'^{\text{own}} - b' &= y + (1-\delta) p h^{\text{own}} + (1+r)s - b(1+R) - F^{\text{new}} \\ b' &\leq (1-\phi) p h'^{\text{own}}, \quad s' \geq -\underline{s}, \quad R' = r^d \end{aligned} \tag{13}$$

and Equations 7-10 for income and aggregate state processes, mortgage yields and rental rate. F^{new} is the transaction cost of purchasing a new home, which is a function of the size of the home. In section 4.3, I describe the functional form and calibration of F^{new} in more detail.

If the household decides to refinance an existing mortgage and not move, they solve:

$$\begin{aligned} V(z)^{\text{own \& refi}} &= \max_{c, s', b'} u\left(c, h'^{\text{own}}\right) + E\left[V(z')\right] \\ \text{s.t. } c + s' - b' &= y + (1+r)s - b(1+R) - F^{\text{refi}} \\ b' &\leq (1-\phi) p h'^{\text{own}}, \quad s' \geq -\underline{s}, \quad R' = r^d \\ h'^{\text{own}} &= h^{\text{own}}(1-\delta) \end{aligned} \tag{14}$$

and Equations 7-10 for income and aggregate state processes, mortgage yields and rental rate. F^{refi} is the transaction cost of refinancing. I describe the functional form and calibration of F^{refi} in more detail in section 4.3.

If the household decides to not move and not refinance an existing mortgage, they solve:

$$\begin{aligned} V(z)^{\text{own \& no refi}} &= \max_{c,s'} u\left(c, h^{\text{own}}(1-\delta)\right) + E\left[V(z')\right] \\ \text{s.t. } c + s' &= y + (1+r)s - M \\ b' &= b(1+R) - M, \quad s' \geq -\underline{s}, \quad R' = R \end{aligned} \tag{15}$$

and Equations 7-10 for income and aggregate state processes, mortgage yields and rental rate. The mortgage payment M follows Equation 5.

The problem for a retired household is identical, except that social security benefits replace labor earnings. Upon death, the agent bequeathes total net wealth $W = (1-\delta)ph^{\text{own}} + (1+r)s$ which gives utility $B\left(W_{jat} - 1\right)^{1-\sigma}/(1-\sigma)$. B is the bequest utility parameter.

In deciding to rent or own a home, households consider the user cost of housing relative to rental costs (see Diaz and Luengo-Prado (2012) for a review of the literature on the user cost of owning a home). The user cost of owning a home depends on the savings from not paying rent, the expected real rate of housing appreciation net of depreciation, and the opportunity cost of down payment. Households are more likely to own a home if: (i) house prices are expected to appreciate in the future; (ii) rental costs rise relative to current house prices; and (iii) the interest rate declines, because the cost of financing and the opportunity cost of the down payment is lower.

4.3 Model Calibration

Demographics and preferences The model period is annual. Households work for 40 years and are retired for up to 20 years. Agents face age-dependent survival probabilities, given by the U.S. actuarial life-expectancy tables and assume a maximum age of $T = 85$.[13] I interpret the first period of life as 25 years of age and initialize the model by these agents assets and income to match the distribution of ages 20 to 29 households in the 2004 SCF.

The discount rate β, the utility parameter α, and the bequest paramater B are calibrated to target key moments of the savings and asset-holding profiles. These moments include the average homeownership rate of 70 per cent, liquid wealth to income ratio for the working age, and the share of wealth held by older households (aged 65+) of 20 percent from the SCF data in 2007. These targets yield $\beta = 0.962$, $\alpha = 0.88$, and a bequest motive of B around 2 (comparable to Cocco, Gomes and Maenhout (2005)).

[13] I use the male survival probabilities from the 2000 Social Security Administration actuarial life tables. The share of the population aged over 85 was less than 1.5 percent in 2000.

Transaction costs The household pays transaction costs if they make a home purchase or if they refinance. I consider different transaction costs for these two decisions.

For refinancing costs, I consider $F^{\text{refi}} = F_f^{\text{refi}} + F_v^{\text{refi}} \cdot b'$, where F_v^{refi} is the variable cost that scales with the size of the mortgage and F_f^{refi} denotes the fixed costs. In reality, refinancing costs typically contains a fixed component of around \$2,000, comprised of appraisal, inspection and attorney review and closing fees (Federal Reserve Board online refinancing guide, 2018). In addition, there may also be a component that scales with the size of the mortgage, where this variable component can range from 0 to 3 per cent of the loan principal for the origination fee. However, for many lenders, it is not uncommon to waive the variable fees i.e. set to be 0 per cent. Besides these fees to lenders, there may also be other costs such as time costs associated with appraisal of the home and filing the application, which may not necessarily scale with the size of the mortgage.

I calibrate the fixed and variable refinancing costs to match the average annual refinancing rate of 5 per cent, and the correlation between refinancing probability and the size of the mortgage balance. The use of fixed costs to match refinancing patterns is not new to this paper (e.g. this approach is also taken in Berger et al. (2018)). The calibrated fixed cost of refinancing is about \$2,100, which is in line with the range of costs described in the Federal Reserve Board's article on refinancing. The calibrated variable component turns out to be small, close to 0.005 per cent (equivalent to \$10 for a \$200K loan). Given this, for simplicity I set the variable component to zero for my baseline results. The small size of the variable cost suggests that the fixed costs are the predominant source of refinancing cost. Intuitively, one reason for the small size is that it proxies not just for lender-related costs, but also other pecuniary and non-pecuniary expenses which do not necessarily scale with the size of the mortgage. The small size of the variable coefficient is also consistent with the fact that it is not uncommon for lenders to waive these variable fees. [14]

For new purchases, I follow Dìaz and Luengo-Prado (2012), Berger et al. (2018), and Berger and Vavra (Forthcoming) in setting the transaction cost as a function of the value of the home. Specifically, I assume $F^{\text{new}} = 0.05 \cdot ph^{\text{own}}$. The typical fee charged by real estate brokers in the U.S. economy is around 2-5 per cent (Zillow home guide (2018)).

In section 5, I show that given these transaction costs and the rest of the calibration, the model generates distributions of total wealth and liquid wealth holdings across households that resemble the empirical distributions.

[14] I have also experimented with alternative transaction costs. These alternative specifications include: (i) a common fixed adjustment cost for both moving and refinancing of around \$5,000 (to match the average loan adjustment rate, in previous versions of this paper), and (ii) small variable cost component of 0.005 per cent for refinancing. Both approaches give the qualitative result that refinancing propensities and consumption semi-elasticities decline with age.

Income I follow Floden and Lindé (2001) in exogenously setting the idiosyncratic income process terms $\rho_\eta = 0.91$ and $\sigma_\eta = 0.21$ to match the annual persistence and standard deviation of residual earnings in the PSID. The process is discretized with two states using the Tauchen method. I set the deterministic age-specific vector χ_a equal to the average log earnings for each age from Guvenen et al. (2015).[15] I set the parameter ϕ_a based on the correlation between real aggregate income per capita and age-specific earnings in the CPS. Table 13 shows that the earnings of young workers fluctuate more with aggregate income than middle-aged workers, consistent with the literature (e.g. Jaimovich and Siu (2009), Ríos-Rull (1996) and others).

Table 13: Income Exposure to Aggregate Activity by Age

Age group	25-34	35-44	45-54	55-64
ϕ_a	4.582	1.603	3.574	0.307

Notes: This table shows the estimated coefficient obtained from a regression of the log earnings growth of each group on log growth in aggregate income per capita interacted with an indicator function for the 10-year age ranges, controlling for age-education-gender fixed effects, quarterly seasonality and a linear time trend. The regression is based on quarterly CPS data over 1982-2007.

Aggregate variables The parameters on the aggregate variables (income, house prices and short-term interest rate) in Equation 8 are exogenously set based on estimated coefficients from a reduced-form quarterly VAR of these variables over the period 1984-2007. The data on income and interest rates are obtained from the Federal Reserve Board. Table 14 gives the coefficients for the aggregate processes. The aggregate processes are then discretized with 18 states using the Tauchen method.

Table 14: Coefficients for the Aggregate Processes

Variables	$\log y_t$	$\log p_t$	r_t
$\log y_{t-1}$	0.9200	0.2857	-0.6344
$\log p_{t-1}$	0.002	0.9827	0.9629
r_{t-1}	-0.0001	-0.0013	0.9173
constant	-0.0097	-4.5682	0.0930

Notes: This table shows the estimated coefficients for Equation 8. The variables $\log y_t$, $\log p_t$, and r_t denote the log income per capita, log house prices and the 3-month interest rate, respectively. See text for more detail.

[15] See Table 4 of Guvenen et al. (2015), which are estimated from a regression of earnings of individuals on a full set of age and cohort dummies using a long panel of administrative data.

I model the mortgage yield curve as a linear function of the current aggregate short-term interest rate and aggregate economic activity. This specification allows me to capture, in a reduced form way, changes in term premia and risk premia arising from shocks to the aggregate economy, without introducing additional states into the computation of the model. Formally, I specify:

$$r_t^d = a_0^d + a_1^d r_t + a_2^d \log y_t \tag{16}$$

where r_t^d denotes the mortgage rate of duration d, r_t denotes the short-term interest rate, and y_t denotes real per-capita aggregate income. I estimate Equation 16 for the 30-year, 15-year and 1-year real mortgage rates. I deflate the nominal mortgage rate using the break-even inflation rate implied from Treasury inflation protected bonds.[16] I then interpolate the mortgage rates with durations between 30, 15 and 1 year. Coefficients are in Table 15.

I set the housing depreciation rate δ to 3 percent to match the average ratio of residential investment to the residential stock in BEA data. I set $\phi = 0.2$ so that households are required to have a minimum 20 percent down-payment, in line with Landvoigt, Piazzesi and Schneider (2015) and others. The short-term asset borrowing constraint is set to 0.

The rental rate is assumed to depend on the aggregate state of the economy, as follows.

$$\log(p_t^r) = \alpha_0 + \alpha_1 r_t + \alpha_2 \log y_t + \alpha_3 \log p_t \tag{17}$$

I estimate Equation 17 using the national house price and rent indices obtained from the Dallas Federal Reserve. See Column (IV) of Table 15 for the regression coefficients.

Table 15: Real Mortgage Rates, House Prices and Rental Rates

Variables	30-year rate (I)	15-year rate (II)	1-year rate (III)	$\log\left(p_t^R\right)$ (IV)
$\log(y_t)$	-3.475	-2.272	3.093	0.843
r_t	0.334	0.392	0.415	-0.002
$\log(p_t)$				-0.022
constant	-0.030	-0.029	0.027	3.187

Notes: This table shows the estimated processes for real mortgage rates and rental rates from Equations 16-17. The 1988-2007 data are from the Federal Reserve Board, St. Louis Federal Reserve Bank and Freddie Mac.

An alternative approach to modeling the dynamics of the interest rates, house prices and rental rates would be to define a term structure that relates the mortgage yield curve to expectations

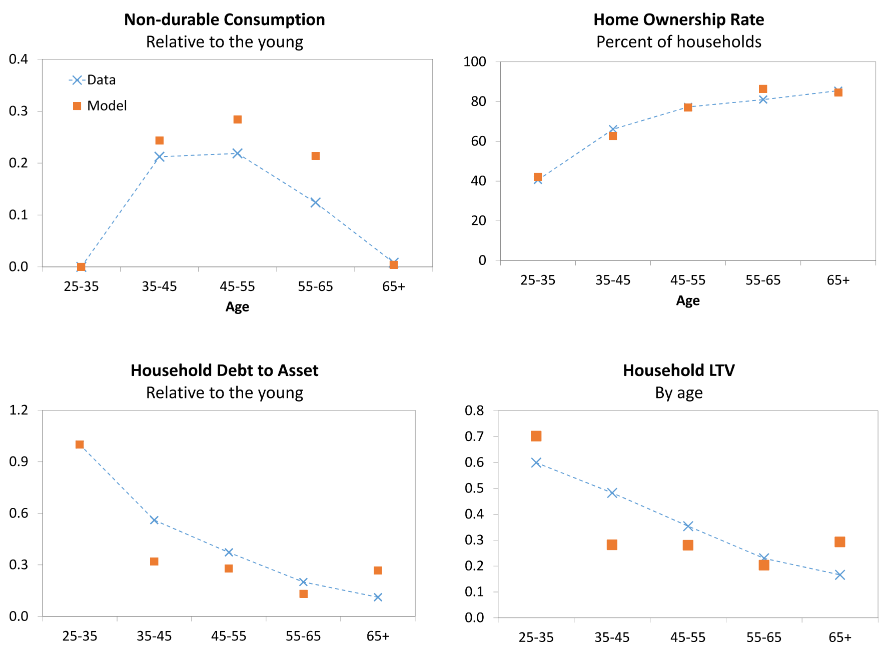
[16] These data are available from the Federal Reserve Bank. TIPS were first issued in 1997, but the market was initially illiquid (as discussed in Nakamura and Steinsson (2018)). Therefore I use data from 2003 onwards to avoid relying on data from the period when TIPS liquidity was limited.

about the paths of both the nominal interest rates and inflation, and a no-arbitrage condition within the housing market. I find that the dynamics over time and the impulse response functions of interest rates to monetary policy shocks match better under the current approach, and therefore define the relationship based on empirically estimation of Equation 16. In Appendix Section H, I provide evidence that the specification in Equations 16 and 17 generate good approximations of the actual mortgage rate, house prices and rental dynamics in the data.

5 Model Fit

The estimated model matches various key non-targeted life-cycle moments in the data. Figure 1 shows the life-cycle profiles in the model compared to the data from the 2004 U.S. Survey of Consumer Finances (SCF) asset profiles and consumption profiles. The model captures the hump-shaped profile of non-durable consumption, the rise in homeownership rate, decline debt-to-asset and loan-to-valuation ratios over the life-cycle.

Figure 1: Life-cycle Consumption and Asset Profiles: Model vs Data



Notes: This figure depicts four key life-cycle moments by age group. Each panel plots both the model implied average moments (in orange) and the empirical moments (in blue) from the CEX and the SCF.

In addition, the model generates the distribution of net wealth and distribution of liquid assets. Table 16 shows the distributions by age groups. The rows with the title "aggregate" gives the share of total wealth held by the young, middle and old households. I further split households in terms of the bottom quartile (p0-25), the middle-group (p25-75), and top quartile (p75-100) of the distribution of net wealth. For instance, Column 1 of Table 16 shows that old households hold about 24 per cent of aggregate net wealth. Old households who are in 25th-75th percentile of the wealth distribution hold about 13 percent of aggregate net wealth in total. Old households who are in top quartile (p75-100) of the wealth distribution hold about 11 percent of aggregate net wealth in total.

Similarly, Column 3 of Table 16 shows that old households hold about 36 per cent of liquid assets in aggregate. Old households who are in bottom quartile (p0-25) of the wealth distribution hold about 3 percent of liquid assets in total, while those in 25th-75th percentile of the wealth distribution hold about 2 percent of liquid assets in total. Old households who are in top quartile (p75-100) of the wealth distribution hold about 31 percent of liquid assets in total.

Comparing Columns 1 to 2 and Columns 3 to 4 of Table 16, we can see that the distribution of both total net wealth and liquid asset holdings by age and wealth distribution are broadly consistent with the empirical SCF estimates. Net wealth in the SCF is defined as the difference between assets and liabilities of the household. Net liquid assets in the SCF includes transaction accounts and deposits less any credit card balances and other lines of credit.

Table 16: Wealth Distribution by Age and Percentiles of Wealth

		Share of aggregate net wealth		Share of aggregate liquid assets	
		Model	Data	Model	Data
Young	**Aggregate**	**0.04**	**0.05**	**0.03**	**0.03**
	p0-25	0.00	0.00	0.02	0.00
	p25-75	0.01	0.01	0.01	0.00
	p75-100	0.03	0.03	0.00	0.05
Middle	**Aggregate**	**0.72**	**0.76**	**0.62**	**0.68**
	p0-25	0.01	0.00	0.05	-0.01
	p25-75	0.27	0.43	0.01	0.41
	p75-100	0.43	0.33	0.56	0.34
Old	**Aggregate**	**0.24**	**0.20**	**0.36**	**0.29**
	p0-25	0.00	0.00	0.03	0.00
	p25-75	0.13	0.13	0.02	0.10
	p75-100	0.11	0.07	0.31	0.11

Notes: This table shows the distribution of net wealth and distribution of liquid assets by age, and in terms of the bottom quartile (p0-25), the middle-group (p25-75), and top quartile (p75-100) of the distribution of net wealth. Columns 3 and 5 are derived from the model. Columns 4 and 6 are from the Survey of Consumer Finances.

6 Monetary Policy Experiment

I use the model to interpret the heterogeneous empirical findings in Section 3 and to understand the transmission mechanism of monetary policy to consumption.

Recall the aggregate state variables were $S_t = [\log y_t, \log p_t, r_t]$, which followed the process $S_t = A_0 + A_1 \cdot S_{t-1} + u_t$. A monetary policy shock ϵ_t affects the residuals u_t in the following way: $u_t = \Gamma(\epsilon_t) + \psi_t$ where ψ_t denotes all other non-monetary policy shocks (i.e. house price and aggregate income shocks). Consistent with the data estimation described in Section 3, I regress the residuals u_t on the Federal Funds futures shocks (identified in Section 2).[17] The parameter coefficients are presented in Table 17.

Given the coefficients on the VAR, Figure 2 shows the pass-through to the short-term interest rate, aggregate income, and prices after a 1 ppt expansionary monetary policy shock. The short-term interest rate declines upon impact, aggregate income while house price growth and the price to rent ratio rise over the first year. Since the parameters on the aggregate variables were set based on empirically estimated processes, the dynamics resemble the time series and impulse response functions to monetary policy shocks observed in the data. This allows me to then examine the consumption, refinancing and homeownership responses to a realistic monetary policy shock.

Table 17: Monetary policy shock coefficients

	$u_t^{\log y_t}$	$u_t^{\log p_t}$	$u_t^{r_t}$
Γ	0.006	0.004	0.648
	(0.003)	(0.008)	(0.393)

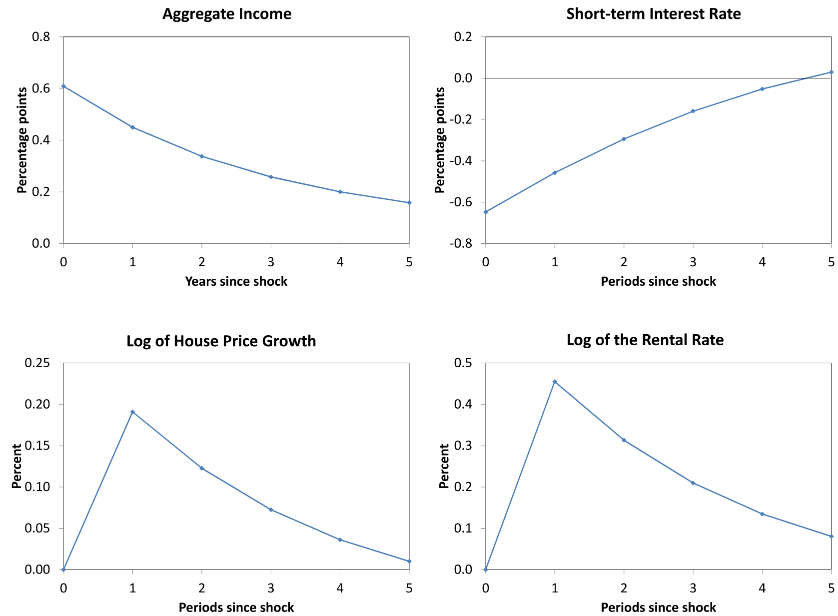
Notes: This table shows the contemporaneous effect of monetary policy shocks on the aggregate variables. The variables $u_t^{\log y_t}$, $u_t^{\log p_t}$, and $u_t^{r_t}$ denote the residuals from the regression corresponding to the equation with the dependent variables of log income per capita, log house prices and the 3-month interest rate, respectively. The Γ coefficients are estimated using high-frequency Federal Funds futures shocks. Standard errors are given in parentheses.

6.1 Heterogeneity Response to Monetary Policy

I now show that the heterogeneous consumption and loan adjustment responses in the model are consistent with the data.

[17] Empirically, the Federal Funds futures shocks give a measure of the true monetary policy shock plus some measurement noise $\epsilon_t^{\text{true}} + \text{noise}_t$. Under the assumption that the noise component is uncorrelated with non-monetary policy shocks, then the regression will give consistent estimates of the coefficients in $\mathrm{E}u_t = \Gamma(\epsilon_t) + \psi_t$. As in Gertler and Karadi (2015), this structure does not impose any timing restrictions on the effects of monetary policy and non-monetary policy shocks.

Figure 2: Response to an Expansionary Monetary Policy Shock



Notes: This figure depicts the annual impulse response functions for aggregate income, the short-term interest rate, log of house price growth, and log of house price to rent ratio.

Model-Implied Heterogeneous Responses to Monetary Policy In order to directly compare the model to the data, I simulate a panel of households in response to the monetary shock. I then estimate the change in log consumption over the year after the shock and the share of loans that adjusted over the year. This is comparable to the regression specification 2, which controls for features outside of the model (such as family structure formation, which are less likely to be relevant at high-frequencies).

Table 18 shows that the model implies that young households respond more to monetary policy shocks than middle age and older households. The model-implied response (column II) is consistent with the suggestive evidence from the section 3.1 (reproduced in column I).

The model also implies that young homeowners are more likely to adjust their loans after a monetary shock than old homeowners. The total share that adjust their loan is broadly consistent (column IV) with the suggestive evidence from the empirical patterns documented in section 3.3 (reproduced in column III). In the model, refinancing is the predominant driver of loan adjustments after monetary policy shocks, rather than new home purchases. This is consistent with suggestive evidence from the responsiveness of refinancing and purchases in Freddie Mac (Appendix B.2 Table 22).

One important reason why young people have a higher propensity to refinance is the presence

Table 18: Heterogeneous responses to monetary policy by age

	Consumption response		Share of home-owners that adjusted	
	Data (I)	Model (II)	Data (III)	Model (IV)
Young				
Coefficient	**2.36**	**1.22**	**0.33**	**0.26**
Standard error	(1.08)		(0.05)	
P-value	0.03		0.02	
Middle				
Coefficient	**0.25**	**0.85**	**0.05**	**0.10**
Standard error	(0.81)		(0.02)	
P-value	0.76		0.11	
Old				
Coefficient	**0.17**	**0.23**	**0.05**	**0.05**
Standard error	(1.38)		(0.00)	
P-value	0.90		0.01	

Notes: Columns (I) and (II) show the differences between age groups in their average semi-elasticities of consumption with respect to a 1 sd monetary policy shock. Column I gives the empirical estimates from Table 5. Columns (III) and (IV) show the total share of homeowners that adjusted over the year (baseline share plus the marginal response to the monetary policy shock). Column (III) gives the empirical estimates from Table 11. See text for more detail.

of fixed costs for refinancing. In deciding to adjust an existing mortgage or not, the household compares the extra utility that they gain from lower interest payments net of paying a fixed cost of adjustment, relative to their existing utility (formalized in Equation 11 in the model.) The benefit of adjusting the loan, in the form of lower interest payments, rises with loan size and duration, while the costs remain fixed. The refinancing channel does not exist in standard models with variable mortgages. In these models, interest rate shocks pass-through to all mortgages.

The model provides insight into the large consumption responses of younger people. In the presence of fixed transaction costs, there are individuals who do not always choose to refinance their mortgage to access their home equity despite being against their short-term constraints (as in Kaplan and Violante (2014)). However, when there is a large enough monetary policy shock, they have an additional incentive to pay the transaction cost to adjust their assets and liabilities because they can reset their mortgage to a lower rate. These individuals would be classified as "wealthy hand-to-mouth" households (as in Kaplan, Violante and Weidner (2014) and Kaplan and Violante (2014)). In the model, there is a larger portion of young homeowners who are short-term liquidity constrained, but not against their long-term mortgage constraint. 87 percent of young homeowners were short-term constrained but were not against the long-term mortgage loan-to-valuation ratio (LTV) (Table 19). This compares to 17 percent of old homeowners.[18]

[18] I split households in terms of LTV greater than or less than 70% in order to consider ranges where households

Table 19: Share of households by short-term constraints and LTVs

	Not LT constrained		LT constrained		Total
	ST constrained	Not ST constrained	ST constrained	Not ST constrained	
Young	87.3%	7.1%	5.7%	0.0%	100.0%
Middle	55.5%	44.0%	0.2%	0.4%	100.0%
Old	16.8%	82.6%	0.0%	0.6%	100.0%

Notes: This table reports the joint distribution of homeowners in terms of their short-term liquidity constraint status and low and high loan-to-valuation ratios, within each age group.

Since the young are more likely to refinance and they are more likely to be against their short-term constraints, there is a positive correlation between those who adjust their loans and those with low liquidity of 0.3. The decision to refinance leads to additional available cash in terms of lower interest payments and higher mortgage balance (home equity extraction). The correlation between those who are short-term constrained and the decision to extract home equity is 0.3. The average increase in mortgage balance is around $1,100 after an expansionary monetary policy shock, above a baseline average extraction of $6,600 when refinancing (broadly consistent with Bhutta and Keys (2016)). Those who are against their short-term liquidity constraints spend all of their additional cash (i.e. MPC of 1). As a result, the correlation between those who adjust their loans and those with liquidity constraints leads to larger consumption responses in the aggregate, and in the cross-sectional heterogeneity by age. This result relates to Auclert (forthcoming), who highlights the importance of the correlation between unhedged interest exposures and marginal propensities to consume for understanding aggregate consumption responses. The analysis here differs in that it highlights the loan adjustment decisions by age.

Prepayment penalties can potentially undo the refinancing incentives for fixed rate loans if they are large enough. This is because it reduces the net savings from lower interest payments. In the U.S., however, it is relatively uncommon for lenders to have prepayment penalties. Less than 2 percent of prime borrowers have prepayment penalties (Mayer, Piskorski and Tchistyi (2013)). Moreover, under the 2010 Dodd-Frank Wall Street Reform and Consumer Protection Act, prepayment penalties have become prohibited for most residential mortgage loans. From 2002 onward, Freddie Mac also placed restrictions on the purchases on prime and subprime loans with prepayments. This differs from other counties, such as Australia, where prepayment penalties on fixed rate mortgages are common and sizable.[19]

can withdraw non-negligible home-equity up to the maximum LTV limit of 80%.

[19]See Freddie Mac perspectives article (2017) for a discussion of prepayment penalties in the U.S.

Role of the Refinancing Channel for the Transmission of Monetary Policy How important is the refinancing channel for explaining the cross-sectional and aggregate consumption responses to monetary policy shocks, relative to other channels? To quantify the importance of the refinancing channel, I shut down the refinancing decision by re-estimating the model under a variable rate mortgage structure, while keeping the calibrated parameters on the utility functions the same. This means that the mortgage rates changes for all households following an interest rate shock. Table 20 Panel A Column (IV) shows the consumption responses under a variable rate mortgage structure. Column (I) reproduces the baseline results from Table 18, which assumes a fixed rate mortgage structure. Panel B gives the percentage difference between columns (IV) and (I).

Table 20: Decomposition of Semi-Elasticity of Consumption to Monetary Policy Shocks

	Fixed rate mortgage			Variable rate
	Overall	No Δ income	No Δ house prices	mortgage
	(I)	(II)	(III)	(IV)
Panel A: Consumption response				
Young	1.22	0.84	1.15	1.82
Middle	0.85	0.31	0.75	1.77
Old	0.23	0.24	0.41	1.28
Aggregate	**0.72**	**0.33**	**0.62**	**1.75**
Young-Old	0.99	0.60	0.75	0.54
Middle-Old	0.62	0.07	0.34	0.49
Young-Middle	0.37	0.53	0.40	0.05
Average difference	**0.66**	**0.40**	**0.50**	**0.36**
Panel B: % relative to (I)				
Aggregate level		-0.54	-0.14	1.43
Average difference		-0.40	-0.25	-0.46

Notes: This table reports the consumption responses for different specifications. Column (I) shows the baseline overall results. Column (II) assumes that aggregate income remains unchanged after the monetary policy shock. Column (III) assumes that house prices remain unchanged after the monetary policy shock. Column (IV) assumes that mortgage rates changes pass through automatically to existing mortgages. The bottom panel gives the percentage difference of the results relative to the baseline results in column (I). See text for more detail.

I find that the difference between the consumption response of young and old people declines by about 45 percent under the model with a variable mortgage structure (Panel B, column IV). So according to my model, the refinancing channel accounts for 45 percent of the difference in the consumption response of younger and older people. The decline in heterogeneity by age is consistent with the fact that there is uneven pass-through of mortgage rates by age in a fixed rate structure, with younger households more likely to refinance than older households after a monetary policy shock. In contrast, in a variable mortgage rate structure, the rate changes automatically and passes through to all households.

At the same time, the aggregate consumption response is about 1.5 times larger under a variable rate structure than a fixed rate structure (consistent with theoretical studies such as Auclert (forthcoming) and Garriga, Kydland and Sustek (2017)), and empirical work in Di Maggio et al. (2017)). How consumption changes when we move from having fixed to variable-rate mortgages is a priori ambiguous. On the one hand, the covariance between those who experience changes in their mortgage rates and those with short-term constraints naturally declines when we move from a fixed-rate to a variable-rate mortgage structure, since interest rate changes automatically and passes through to all mortgages. This decline in the covariance dampens the cross-sectional differences in consumption responses across households as well as the aggregate response. On the other hand, there is now a larger number of households that have lower mortgage payments following expansionary monetary policy shocks. Quantitatively, the latter effect dominates and we can see in panel B, column (IV) that the aggregate consumption response is larger under a variable rate structure.

I show that the effect of the refinancing channel on the consumption responses by age is at least as large as the effect from changes in aggregate income and changes in house prices following monetary policy shocks. Changes in aggregate income after monetary shocks boost the response of consumption. In addition, the income effect can also vary in terms of their effects on consumption by age, because young and old workers have different exposures to fluctuations in aggregate income (described in section 4.3). In order to explore the role of changes in aggregate income, I recompute the consumption responses assuming that the monetary shock has no effect on aggregate income (Table 20 column II). In Panel B, comparing columns (II) and the baseline results in (I) shows that aggregate consumption response declines by about 54 percent and age-specific heterogeneity declines by 40 percent. This implies that income effects are an important channel, accounting for almost half of the transmission of monetary consumption in the aggregate and cross-section (consistent with Kaplan, Moll and Violante (2018) and Cloyne, Ferreira and Surico (forthcoming)).

Column (III) also considers the effects of changes in house prices after monetary policy shocks. The wealth of an individual increases when house prices appreciate. Households can choose to consume out of that wealth (see for instance, Berger et al. (2018), Stroebel and Vavra (forthcoming), Mian and Sufi (2014)). For instance, households may also extract equity from their home by increasing their mortgage balance (see, e.g., Mian and Sufi (2014) and Bhutta and Keys (2016)). Column (III) shows the consumption responses if house prices do not change in response to monetary policy shocks. This differs from column (I) where house prices rise slightly (Figure 2). When house prices do not change, aggregate consumption is about 15 percent lower and heterogeneity by age declines by 25 percent (Panel B, column III). This implies that the effect of changes in aggregate house prices after monetary shocks on consumption declines with age (consistent with declining elasticities in Berger et al (2017)).

Overall, these results imply that refinancing response generates heterogeneity in consumption responses, similar to the effects from the income channel and at least as important as wealth effects from changes in house prices. These results imply that the mortgage structure is an important channel for generating large aggregate consumption effects, as well as for understanding the cross-sectional dispersion in consumption responses to changes in monetary policy.

7 Conclusion

What is the role of the refinancing and mortgage market structure for the transmission of monetary policy to consumption in the aggregate and the cross-section? This paper first provides new suggestive evidence using micro household-level data, that young people are more responsive than old individuals to interest rate shocks. The consumption elasticities of young people are larger than that of the average person, and matter for the aggregate response. The consumption responses are driven by homeowners with mortgage transactions. I find that young people have a higher propensity to adjust their loans following interest rate declines, which can account for their higher consumption elasticities.

The second contribution of this paper is to develop a life-cycle model with fixed transaction costs and a fixed-rate mortgage structure that is able to generate the empirical heterogeneity. The fixed-rate mortgage structure is key to generating heterogeneity in the transmission of monetary policy to interest income, because there is variation across households in their decision to refinance their mortgage. In the model, individuals with larger loan sizes have a higher propensity to adjust their loans after interest rate declines, because the benefit of refinancing rises with loan size and duration but some costs of adjustment are fixed. These individuals are disproportionately younger, reflecting life-cycle incentives to hold larger sized loans when young in order to borrow against higher expected future income.

I use the model to quantify the importance of the mortgage channel for explaining the consumption responses of the young-old to interest rate shocks. I find that it explains a sizable fraction of the total age-specific heterogeneity and highlights the role of refinancing for monetary transmission. These results imply that the structure of the mortgage market is important for understanding monetary policy transmission.

The cross-sectional results by age provide insight into why the refinancing channel matters for the aggregate response. The fixed-rate mortgage structure generates heterogeneity in the pass-through of monetary policy to the mortgage balances and payments because individuals vary in their refinancing and new borrowing decisions. Individuals with larger loan sizes are more likely to adjust their loans when interest rates decline because interest savings rise with loan size, while the cost of adjustment is fixed. In the model, consistent with the data, younger people have larger loans than older people, as they borrow against higher expected future income. Therefore, young people also have a higher propensity to adjust their loans when rates decline. At the same time, younger people are also more likely to be short-term liquidity constrained. As a result, there is a positive correlation between those who decide to refinance and short-term liquidity constraints, which can generate large consumption responses in the aggregate.

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