Monetary policy when households have debt:
New evidence on the transmission mechanism

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The views expressed are those of the authors and do not necessarily reflect the views of the Bank of England, MPC, FPC or PRA.

Monetary transmission and the mortgage market

- Are households with debt more sensitive to rate changes?
- Is this just a direct effect from interest payments?
- Or is there also an amplification via HHs' balance sheet?

Empirical challenges and our approach

1. Household survey data on income, expenditure and wealth.
   - → *UK: LCFS; US: CEX.*
   - → *Group by housing tenure to elicit debt positions.*
2. And a series of monetary policy shocks.
   - → *US: Romer & Romer (2004); UK: Cloyne & Huertgen (2014).*

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Main empirical findings

- Homeowners with mortgage debt exhibit large and significant responses (especially for durables).
- Outright homeowners do not adjust their spending at all.
- After-tax income changes for all housing tenure groups.

(I) HOUSEHOLDS WITH DEBT ARE LIQUIDITY-CONSTRAINED.

Main empirical findings cont'd

- Mortgage repayments change significantly (especially in the UK) ***but*** change far less than expenditure.
- Changes in income and spending are similar across US and UK...
- and so are changes in house prices and housing equity extracted.

(II) FINANCIAL ACCELERATOR AT WORK IN BOTH COUNTRIES.

Related literature

- **Consumption and mortgage repayments**: Di Maggio et al. (2015), Keys et al. (2015), Auclert (2015).
- **Debt, house prices & collateral constraints**: Iacoviello (2005), Mian & Sufi (2014), Calza et al. (2013), Jorda & Taylor (2014).
- **Monetary policy and heterogeneity**: Coibion et al. (2012), Gornemann et al. (2012), Sterk & Tenreyro (2014).
- **Debt-constrained households**: Kaplan & Violante (2014), Eggertsson & Krugman (2012), Cloyne & Surico (2013).

Outline

1. Data and approach
2. Expenditure and income
3. Households' balance sheets
4. Theoretical insights
5. Concluding remarks

Household expenditure survey data

- UK Living Costs and Food Survey 1975-2007,
  US Consumer Expenditure Survey 1981-2007.
- Quarterly non-durable and durable expenditure;
  after-tax gross income and mortgage repayments.
- UK: repeated cross-section; US: short panel $\rightarrow$ **grouping estimator**.
- Explore asset positions via **housing tenure**:
  Mortgagors (40%), Outright owners (30%), Renters (30%). ▸ Shares
- Separate time series for mortgagor/owner/renter variables.

Monetary policy shocks

- ▸ RESIDUALS from a Taylor Rule-type regression:

  $\rightarrow$ *target interest rate changes regressed on real-time data and forecasts available to policymakers at the time of the decision.*

- Romer & Romer (2004) for the U.S.;
  Applied to the U.K. by Cloyne & Huertgen (2014).

Empirical specification

$$X_{i,t} = \alpha_0^i + \alpha_1^i t + B^i(L)X_{i,t-1} + C^i(L)S_{t-1} + u_{i,t}$$

- $X_{i,t}$: real p.c. non-durable, durable expenditure, after-tax income;
- $i \in$ *Mortgagors*, *Outright Owners*, *Renters*;
- X_t: mortgage repayments, house price index, housing equity withdrawal;
- S: monetary policy shocks;
- Optimal lag length selection.

Robust to using a vector of X variables and different trends.

Outline

1 Data and approach

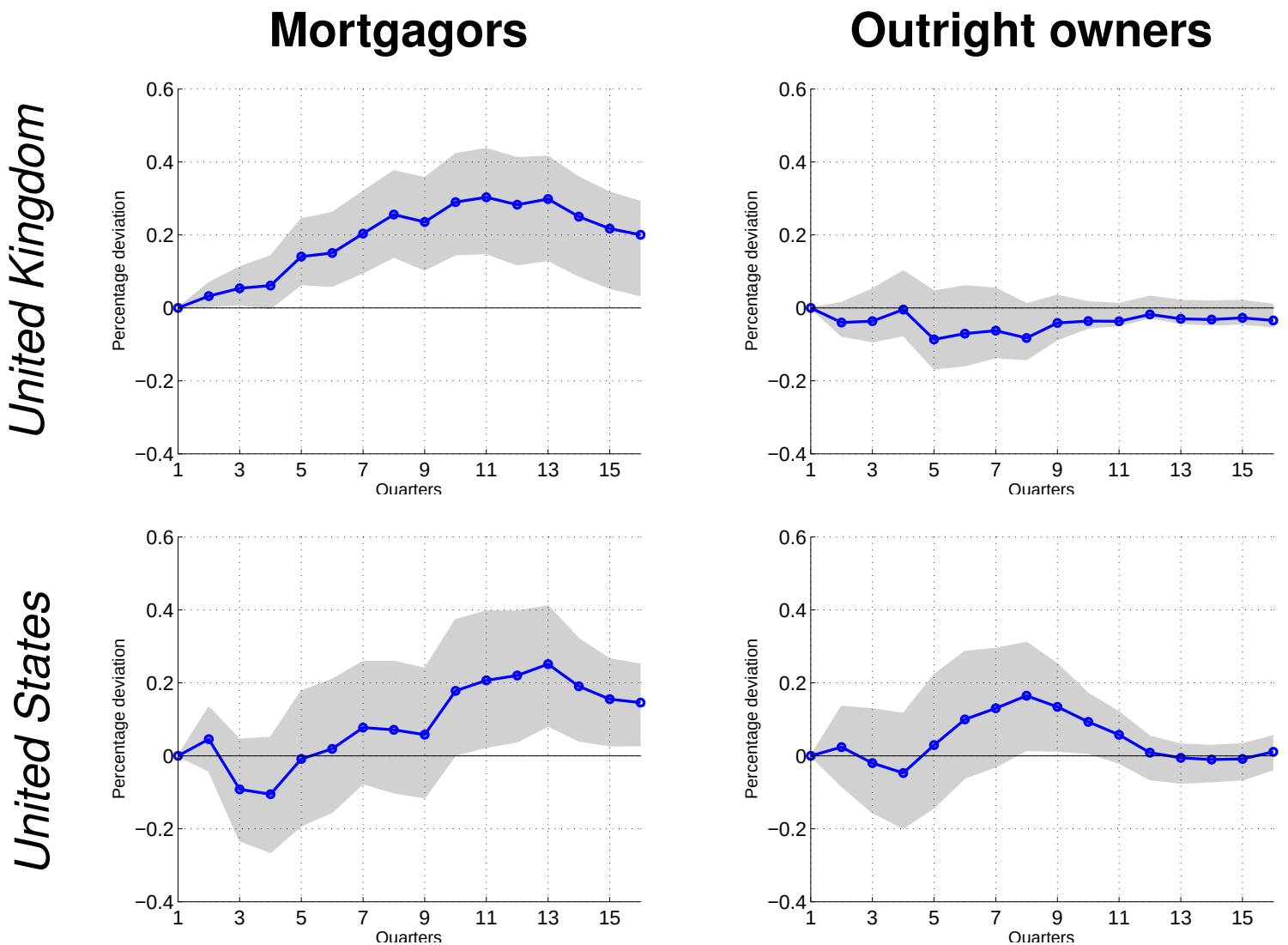
2 Expenditure and income

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4 Theoretical insights

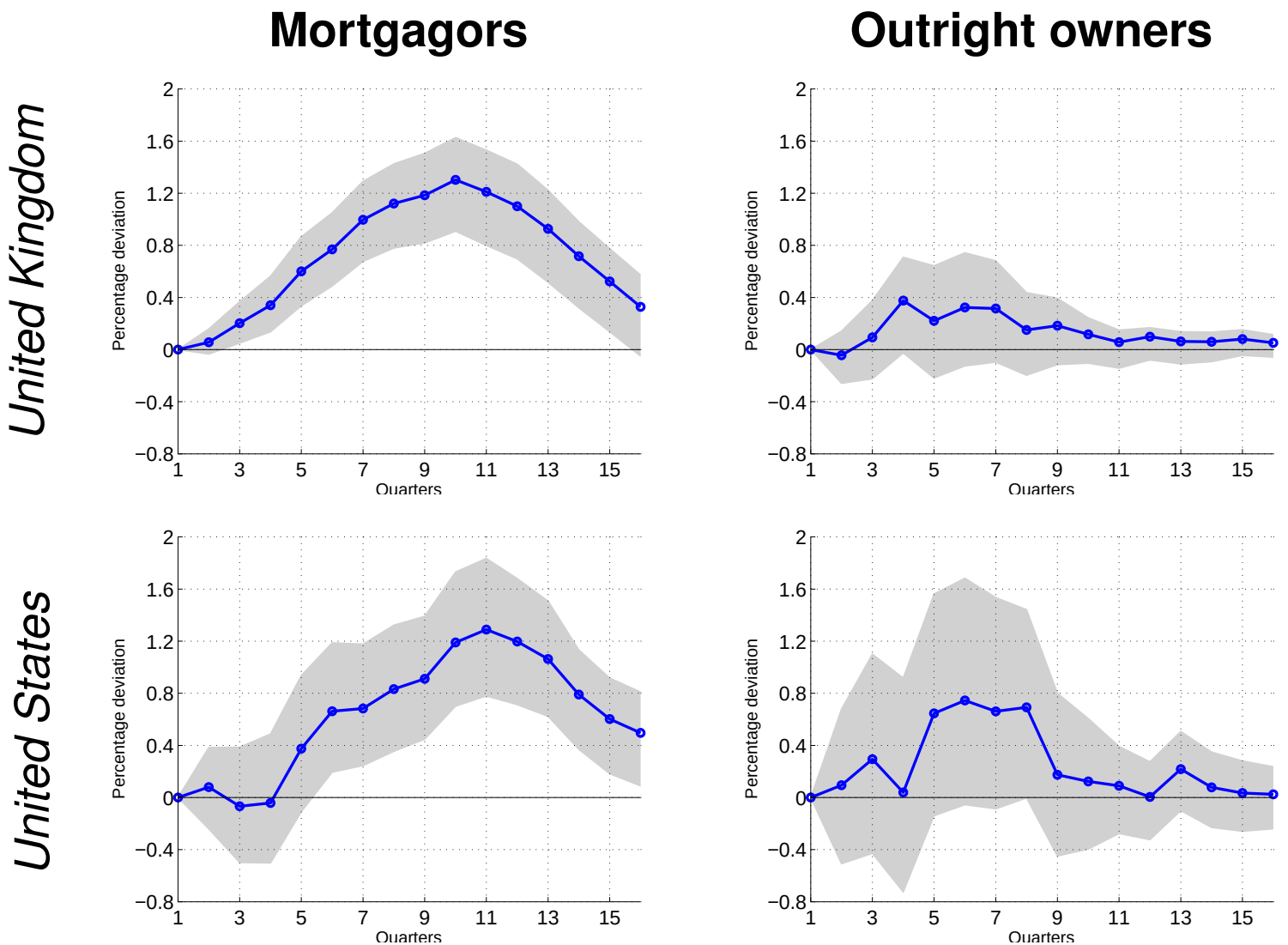
5 Concluding remarks

Non-durable goods and services consumption



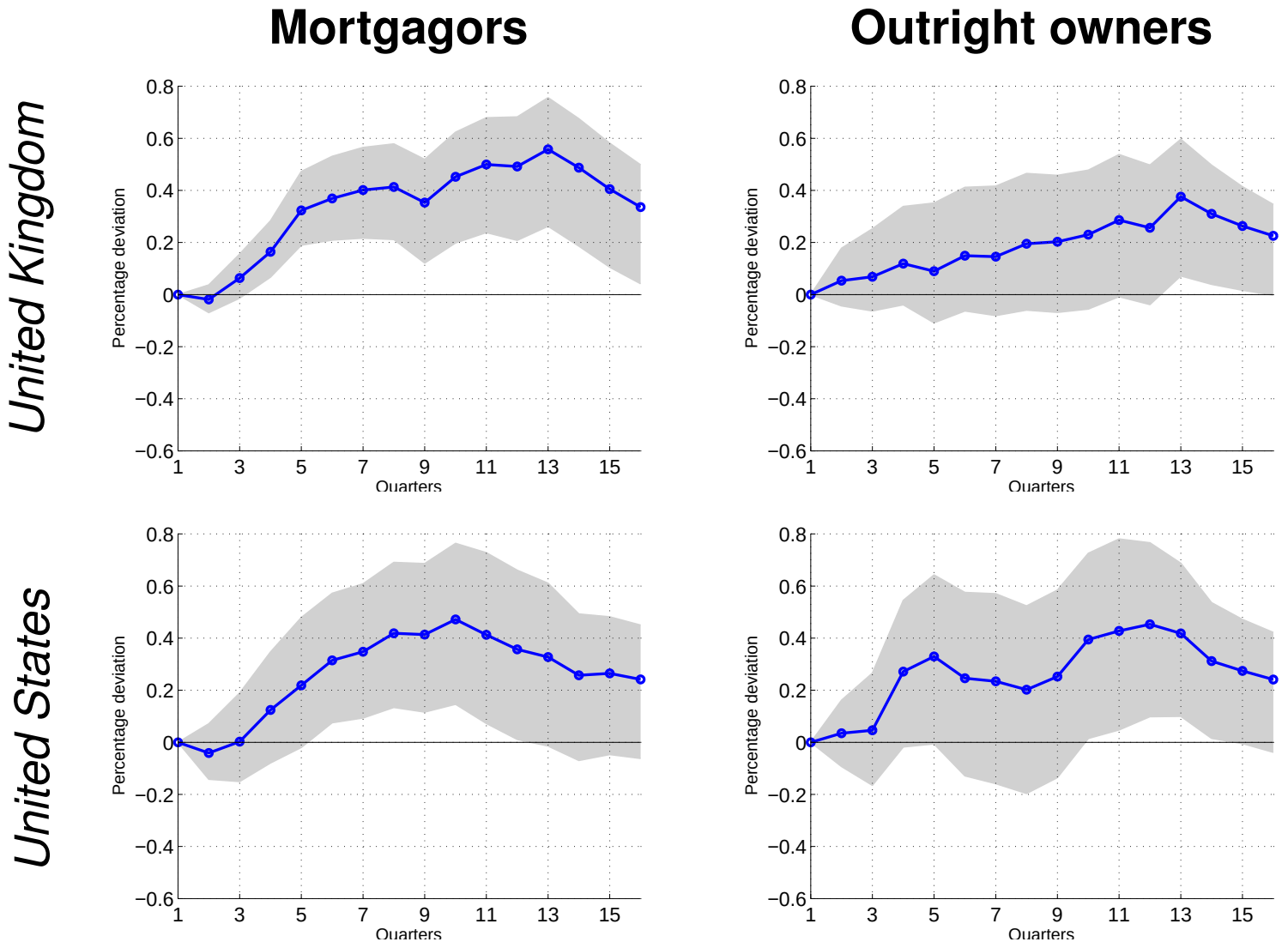
Monetary policy shock: 25 basis points interest rate cut; Confidence bands: 90%.

Durable goods expenditure



Monetary policy shock: 25 basis points interest rate cut; Confidence bands: 90%.

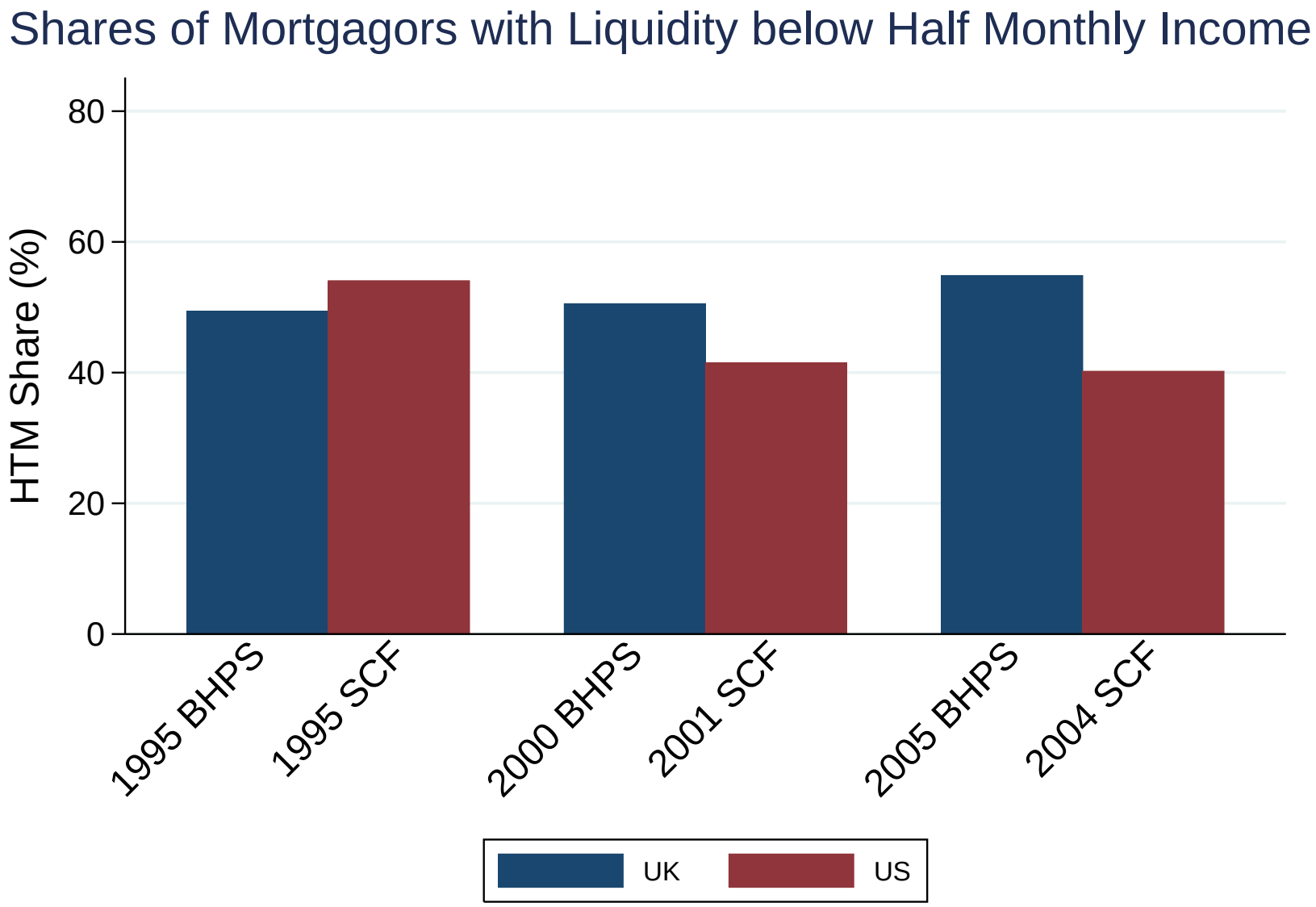
Income increases significantly for both groups!



Monetary policy shock: 25 basis points interest rate cut; Confidence bands: 90%.

▸ AGGREGATE RESPONSES USING NATIONAL STATISTICS ▸ RENTERS

The 'Wealthy' Hand-to-Mouth (HTM)



Confounding factors

1. It's not driven by demographics:

   → Homogeneity ▸ ACROSS mortgagors (young and middle-aged).

   → Heterogeneity ▸ ACROSS middle-aged (mortgagors and owners).

2. Results similar when excluding ▸ HOUSEHOLDS WITH RETIRED HEAD

3. No evidence of ▸ SELECTION INTO TREATMENT

Interim summary

- Following a monetary policy shock, mortgagors' spending responds significantly more than outright owners' (and renters').
- Income changes significantly for all groups.
- Between 40% and 50% of mortgagors are hand-to-mouth.

Outline

1 Data and approach

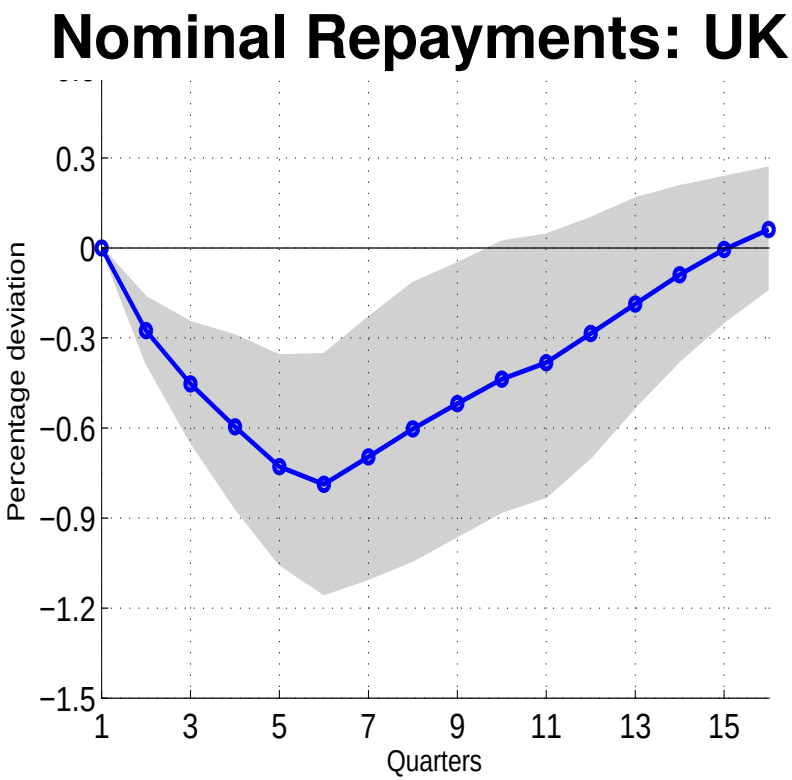
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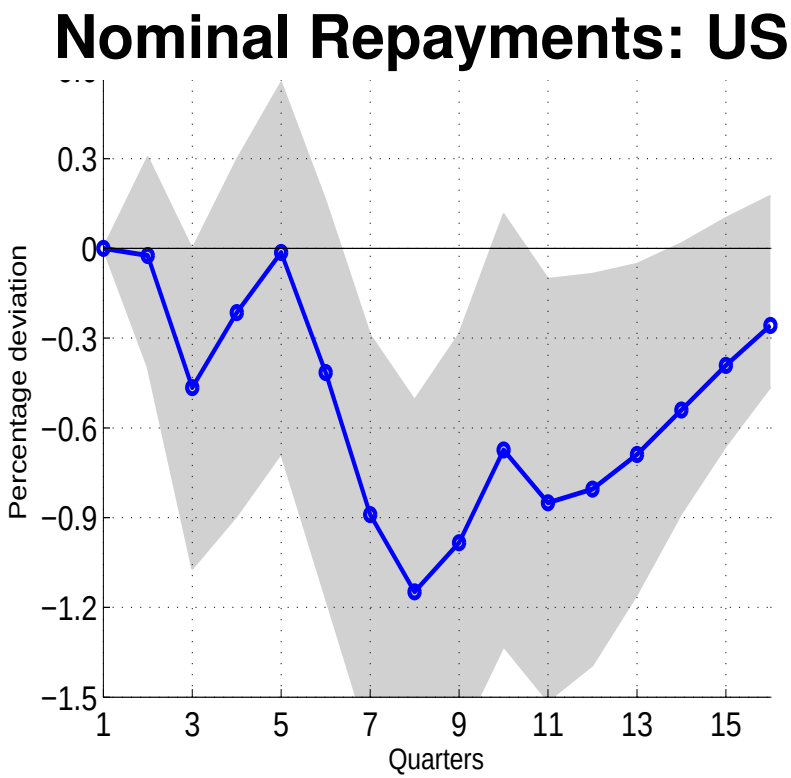
3 Households' balance sheets

4 Theoretical insights

5 Concluding remarks

Mortgage repayments respond significantly...





Monetary policy shock: 25 basis points interest rate cut; Confidence bands: 90%.

... but not as much as expenditure in the U.K.

Table 1: Cumulative Currency Changes Measured in US$ 2007

Panel A: United Kingdom

	non-durable expenditure	*durable expenditure*	*mortgage repayments*	*after-tax income*
Mortgagors	79.1	74.5	-61.6	272.7
	[28.3 , 126.4]	[46.1 , 94.8]	[-104.9 , -20.5]	[128.3 , 369.4]
Outright Owners	-26.5	20.6		143.3
	[-38.2 , 13.0]	[-2.9 , 36.4]		[9.6 , 263.4]
Renters	39.0	18.3		145.3
	[2.3 , 68.8]	[1.0 , 33.3]		[48.8 , 226.0]

▸ AVERAGE VALUES

... and also not as much as expenditure in the U.S.

Panel B: United States

	non-durable expenditure	*durables expenditure*	*mortgage repayments*	*after-tax income*
Mortgagors	83.8	100.1	-36.9	271.3
	[-20.0 , 187.7]	[55.7 , 148.3]	[-61.0 , -8.5]	[44.3 , 492.6]
Outright Owners	35.3	28.3		200.6
	[-15.2 , 84.8]	[-0.0 , 58.5]		[17.1 , 368.7]
Renters	73.2	34.3		151.3
	[-17.2 , 169.8]	[-1.3 , 70.8]		[55.6 , 238.7]

▸ AVERAGE VALUES

Housing equity extraction

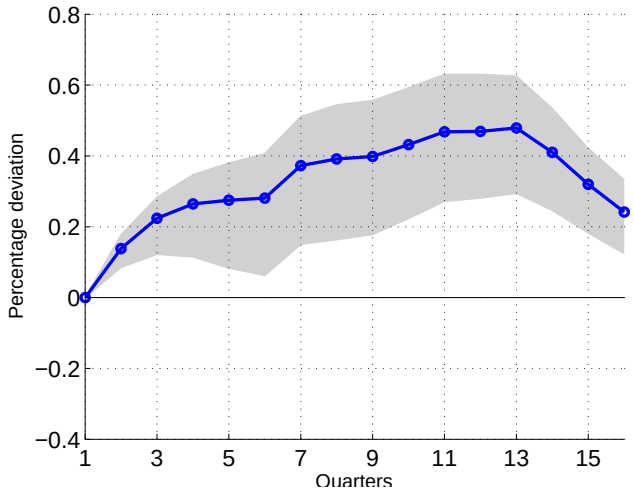
Real house price

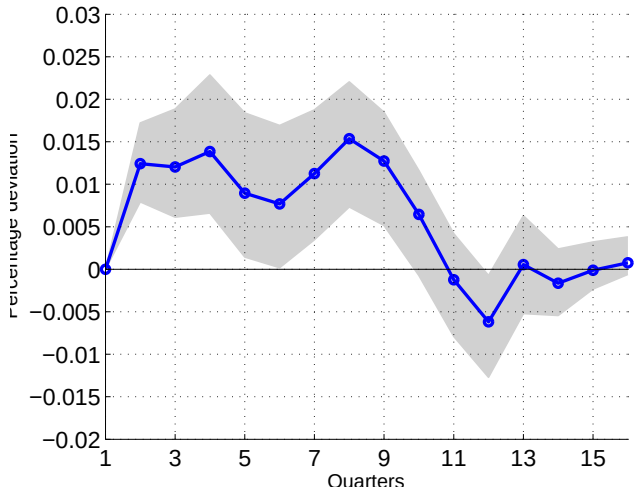
▸ INDEX

Mortgage equity withdrawal as share of net housing wealth

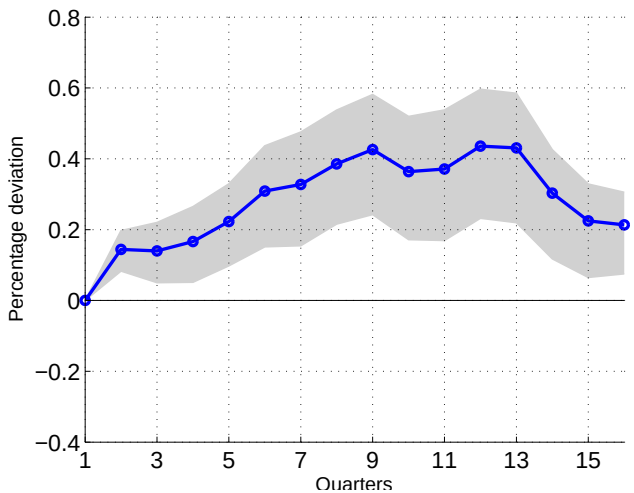
▸ MEW

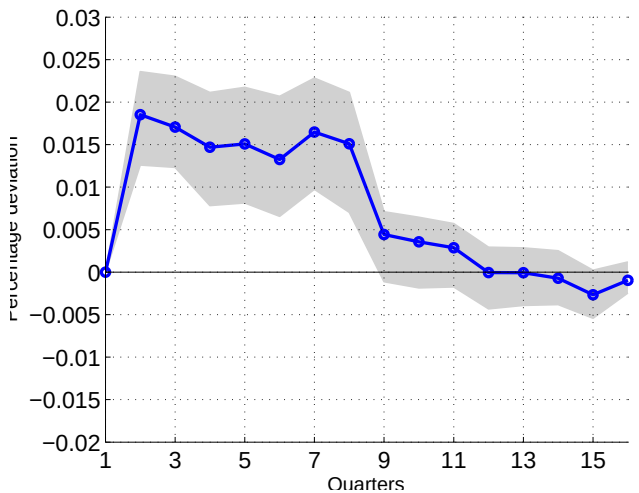
United Kingdom





United States





Monetary policy shock: 25 basis points interest rate cut; Confidence bands: 90%.

▸ LTI and LTV

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A stylised model with constrained borrowers

Households:

1. Patient and impatient households.
2. Housing tenure choice: rent, buy with mortgage or own outright.
3. Some impatient have a preference for renting.

Endogenously generate empirically-relevant housing tenure groups. ▸ SS

Firms: two final aggregators and two intermediate sectors.

1. Competitive final sectors aggregate varieties of durable and ND goods.
2. Monopolistically competitive intermediate sectors face nominal rigidities.

Monetary policy follows a Taylor-type rule.

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Impatient Households

$$\max E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t, V_t, \tilde{h}_t, L_t\right) \tag{1}$$

where

$$\tilde{h}_t = h_t + \gamma^{i} s_t^{+} - s_t^{-} \qquad \gamma^{r} = 1 \quad \gamma^{m} = \gamma \in (0,1) \tag{2}$$

subject to

$$C_t + q_t^d D_t + q_t^h \Delta h_t + \frac{R_{t-1}}{\pi_{c,t}} b_{t-1} = w_t L_t + b_t + p_t \left(s_t^{-} - s_t^{+}\right) \tag{3}$$

equations for durable purchases and the collateral constraint

$$b_t \leq m^{LTV} E\left(\frac{q_{t+1}^h h_t \pi_{c,t+1}}{R_t}\right) \tag{4}$$

and constraints $s^{+} \geq 0$, $s^{-} \geq 0$ and $h - s^{-} \geq 0$.

Patient Households

$$\max E_0 \sum_{t=0}^{\infty} \beta'^t U\left(C_t, V_t, \tilde{h}_t, L_t\right) \tag{5}$$

where

$$\tilde{h}'_t = h'_t + \gamma s_t^{+'} - s_t^{-'} \tag{6}$$

subject to the budget

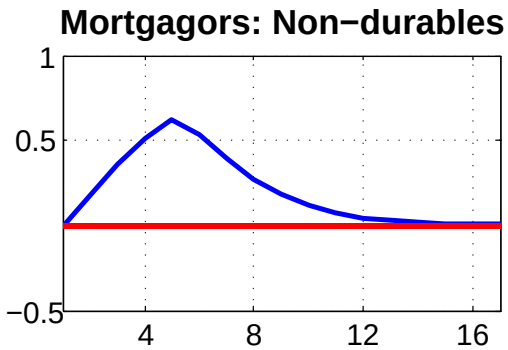
$$C'_t + q_t^d D'_t + q_t^h \Delta h'_t + \frac{R_{t-1}}{\pi_{c,t}} b'_{t-1} = w_t L'_t + b'_t + p_t \left(s_t^{-'} - s_t^{+'}\right) + \Pi_{C,t} + \Pi_{D,c} \tag{7}$$

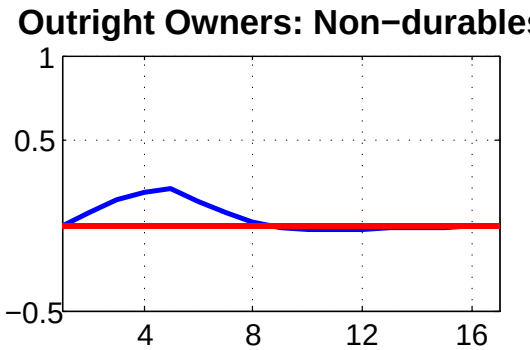
and with constraints $s^{+'} \geq 0$, $s^{-'} \geq 0$, $h' - s^{-'} \geq 0$

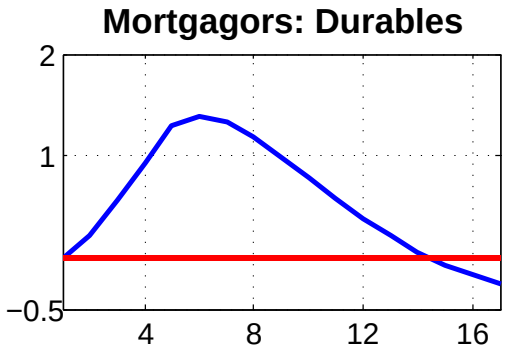
Calibration

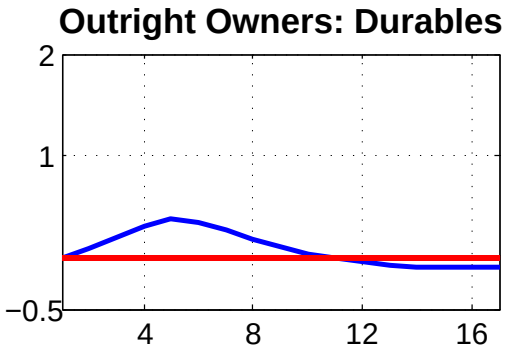
Parameter	Description	Value
$\theta/(1-\theta)$	elasticity of substitution between ND and D stock	4
σ	elasticity of intertemporal substitution	1
$\beta, \beta^{'}$	discount factor: mortgagors, outright owners	0.95, 0.99
$1/(\eta-1)$	Frisch elasticity of labour supply	3
μ	habits parameter	0.5
$\varepsilon_{C,D}$	elasticity varieties	7
$\vartheta_{C,D}$	price adjustment cost	50
m	max LTV (baseline)	0.60
ω_{IH}	share of mortgagors	40%
ω_{PH}	share outright owners	30%
r_π, r_Y, r_R	Taylor rule: CPI, output, smoothing	1.5,.05,.8

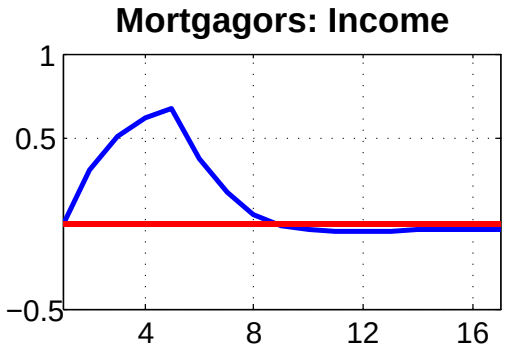
Is the model consistent with the empirical evidence?

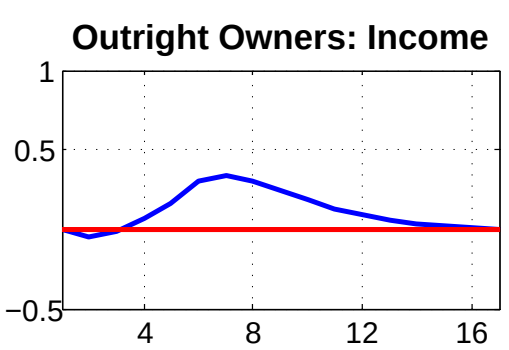












▸ Renters

Concluding remarks

1. Households with debt are the most sensitive to interest rate changes (both in U.K. and U.S) because they are constrained;

2. their mortgage repayments change with monetary policy...
   ...but they also change their housing equity extraction.
   General equilibrium effects dominate the cash-flow effect.

3. Stylized model of housing collateral consistent with our evidence: household indebtedness plays an important role in the MTM.

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Monetary policy when households have debt: new evidence on the transmission mechanism*

James Cloyne Clodomiro Ferreira Paolo Surico

March 2015

Preliminary: an updated version will be posted in due course. Note: the empirical results in the July 2015 slides, enclosed above, include new results for the United States and supersede the results in this older version of the paper.

Abstract

In response to an unanticipated change in interest rates, households with mortgage debt adjust their expenditure significantly, especially on durable goods, renters react to a lesser extent and outright home-owners do not react at all. All housing tenure groups experience a significant change in disposable income (over and above the direct impact on mortgage repayments). The response of house prices is sizable, driving a significant adjustment in loan-to-income ratios but little change in loan-to-value ratios. A simple collateral constraint model augmented with durable goods and a renting decision generates predictions consistent with these novel empirical findings and suggests that heterogeneity in housing debt positions plays an important role in the transmission of monetary policy.

JEL classification: E21, D91, H31, E62.

Key words: mortgage debt, household expenditure, monetary transmission.

*We are grateful to comments and advice from Joao Cocco, Mark Gertler, Matteo Iacoviello, Andrew Levin, Michael McMahon, Ricardo Reis and seminar and conference participants at the London Business School, the NBER Mid-Year Meetings Chicago 2014, Science-Po, Banque de France and Bank of England. We kindly thank the FCA for mortgage data from the Product Sales Database. The views in this paper are those of the authors and do not necessarily reflect the views of the Bank of England, the Monetary Policy Committee, the Financial Policy Committee or the PRA. Surico gratefully acknowledges financial support from the European Research Council (Starting Independent Grant 263429). The graphs in this paper are best viewed in color. Address for correspondence: James Cloyne (Bank of England) james.cloyne@bankofengland.co.uk; Clodomiro Ferreira (London Business School) cferreira@london.edu; Paolo Surico (London Business School and CEPR) psurico@london.edu.

1 Introduction

The recent financial crisis has brought household debt and the mortgage market to center stage. Understanding the way economic policies, and monetary policy in particular, can stabilize macroeconomic fluctuations through the direct and indirect effects on the housing market is therefore of paramount importance for policymakers and academics alike. By affecting interest rates and access to credit, monetary policy inherently alters the incentives between borrowers and savers to smooth consumption over time. Furthermore, the sizable number of mortgaged households in modern economies makes mortgage debt a key element of the monetary transmission mechanism.

Whilst these issues are much debated in policy and academic circles, little is known empirically about the specific channel(s) through which monetary policy affects different households and whether any heterogeneous response is related to housing debt. We fill this gap by providing new estimates of the effect of monetary policy on households with different balance sheet positions. Exploring the impact of macroeconomic shocks across groups with diverse exposure to the credit market, however, requires high quality micro-data over a sufficiently long period of time. To this end, we use a novel grouping strategy based on households' housing market status — their housing tenure — to explore the response of expenditure and income using data from the U.K.'s rich Living Costs and Food Survey (LCFS). Estimation makes use of a time series of monetary policy shocks derived for the U.K. by Cloyne and Huertgen (2014) in the spirit of Romer and Romer (2004).

The focus on the U.K. is motivated by two considerations. First, the prevalence of variable rate mortgage products, together with the availability of data on mortgage repayments, makes it a natural laboratory to evaluate the effects of an unanticipated change in interest rates (over and above the mechanical impact on mortgage repayments). Second, the availability of a unique dataset on mortgage originations from

1975 to the recent financial crisis will allow us to explore at an unprecedentedly detailed level the response of house prices, loan-to-value and loan-to-income ratios to a monetary policy shock. This will allow us to explore how the indebtedness and leverage of mortgagors is affected by monetary policy and assess the transmission mechanism.

A considerable challenge in analyzing the impact of monetary policy across agents with different mortgage debt positions is the lack of detailed information on households' wealth and balance sheets in surveys that also feature high quality expenditure and income data. While we are not aware of any data source that contains this information consistently and over a sufficiently long period of time, most widely used surveys, such as the UK's Living Cost and Food Survey, do allow us to proxy a household's debt position using housing tenure. Our analysis builds on a long standing tradition in microeconometrics which emphasizes demographics (especially birth cohorts) and educational attainments as significant predictors of the presence of liquidity constraints at the household level. We contribute to this important literature by arguing that housing tenure — and in particular the distinction between households with mortgage debt, outright home-owners and renters — can provide novel insights into the transmission of macroeconomic shocks to the real economy.

This paper has three main empirical findings. First, the expenditure response of mortgagors to an unanticipated movement in interest rates is large and significant, the response of outright owners is not statistically different from zero and the renters' is in-between the other two groups. This heterogeneity is far more pronounced for durable goods. Monetary contractions therefore have a much larger negative effect on mortgagors' expenditure. Second, the income responses for all tenure cohorts are significant but statistically indistinguishable from each other, even after netting-out the direct impact of the interest rate change on mortgage repayments. Third, changes in monetary policy trigger variations in house prices and loan sizes of a similar magnitude but, in contrast, loan-to-income ratios fall significantly following a

monetary contraction. Monetary policy therefore has important effects on household debt and leverage.

Motivated by these empirical findings, we explore the extent to which a financial accelerator mechanism (which generates heterogeneous affects on different households) can account for our results and the transmission of monetary policy. Our model features a housing collateral constraint, as proposed by Kiyotaki and Moore (1997) and applied to housing by Iacoviello (2005), but also novel features which capture the key elements of our empirical findings. Specifically, our model includes durable goods and a set-up where households *endogenously* choose whether to rent or own housing. The model is kept deliberately simple, allowing us to elicit the role played by housing debt and mortgage market-related credit constraints. We show that heterogeneity in the discount factor coupled with the presence of a housing collateral constraint can generate heterogeneous responses in household expenditure, income and mortgage debt to a monetary policy shock which are qualitatively and quantitatively consistent with our empirical evidence.

Related Literature. This work relates to at least three strands of the existing literature. First, we contribute to the large body of results on the relationship between housing finance and real activity. This includes the earlier work by Kiyotaki and Moore (1997) and Iacoviello (2005) as well the more recent studies by Mian et al. (2013), Mian and Sufi (2014), Calza et al. (2013), Guerrieri and Iacoviello (2013), Justiniano et al. (2014) and Aladangady (2014). We share an emphasis on developments in the mortgage market but, unlike these studies, we use survey data to evaluate the role played by housing debt and heterogeneity in the monetary transmission mechanism.

Our results also provide empirical support for the role of debt-constrained agents put forward by a (mostly theoretical) literature, such as Eggertsson and Krugman (2012), Ragot (2014), Kaplan and Violante (2014) and Cloyne and Surico (2013).

Although, those studies consider the household response to fiscal policy whereas we focus on monetary policy.

Finally, the findings in this paper complements the evidence from an increasing number of studies, including Coibion et al. (2012), Gornemann, Kuester and Nakajima (2012), Sterk and Tenreyro (2014), Wong (2014) and Auclert (2014), which analyze the redistributive effects of monetary policy focusing on differences across demographics (rather than household debt positions as we do here).

Structure of the Paper. The rest of the paper is structured as follows. Section 2 presents the datasets used in the empirical analysis while Section 3 discusses the identification of monetary policy shocks and the grouping strategy for households with heterogeneous debt positions. The baseline estimates are reported in Section 4. Further empirical results are presented in Section 5, where we evaluate some potential interpretations of our findings. In Section 6, we examine the extent to which the predictions of a collateral constraint model, designed to confront key features of our data, are consistent with our novel empirical findings.

2 Data

2.1 Household Expenditure and Income

In order to measure how different households respond to monetary policy, we use individual household data from the UK's rich Living Costs and Food Survey (LCFS), previously known as the Family Expenditure Survey (FES).[1]

There are few datasets that *both* (i) contain information about the balance sheet position of households and (ii) which have detailed consumption and income micro data over a sufficiently long period of time. One significant advantage of the LCFS is

[1]From 1957 to 2001, the FES together with the National Food Survey (NFS) where the surveys providing information on household food consumption and expenditure patterns in the UK. In April 2001, these two surveys were combined into one single survey, the Expenditure and Food Survey (EFS). The EFS then, in 2008, become known as the LCFS module of the Integrated Household Survey (IHS) of the UK.

that it has detailed expenditure and income data that, among other things, forms the basis for National Accounts as well as information on the households' housing tenure positions. We make use of detailed information on weekly non-durable and durable consumption expenditures separately (excluding housing and rental-related costs), as well as on disposable income. The latter is composed of labor income (wages and salaries) and non-labor income (income from investments and social security payments), net of taxes paid.[2] In addition, the survey provides information on other two sets of variables which will be useful for our main empirical estimation: (i) several demographic variables, including the year of birth of the head of the household and education attainment and (ii) housing tenure as well as information on mortgage repayments for households with outstanding mortgage debt. These latter data will allow us to examine to what degree direct interest payment effects can explain our results.

We convert weekly data into a quarterly time series using the date of interview, as is common in the micro-econometrics literature. The resulting series is then scaled by the Retail Prices Index to convert the data into real series. Our sample covers 1975 to 2007. The key variables of interest are available in the FES from the mid-1970s and we deliberately stop just prior to the financial crisis, excluding the period of "unconventional" monetary policy in the UK.

[2] As it has been recently documented in the household consumption literature (such as Aguiar and Hurst (2005) and Attanasio et al. (2006) using the Consumer Expenditure Survey (CEX) for the US; Crossley et al. (2012) and Brewer and O'Dea (2012) using the LCFS for the UK.), the non-durable and durable expenditures reported by households fall short, when aggregated appropriately, from the aggregate figures in the United Kingdom Economic Accounts (UKEA). Following this literature, we adjust the household data in the following way: in each quarter and *for each* household, we gross-up the reported expenditure categories using the inverse of the ratio of the aggregate expenditure implied by the LCFS to the aggregate expenditure in the UKEA.

2.2 Grouping into Cohorts

Unfortunately the LCFS only features repeated cross-sections rather than a genuine panel of households followed through time.[3] In keeping with the tradition of Browning et al. (1985), we employ a grouping estimator to aggregate individual observations into pseudo-cohorts.

The LCFS, while having excellent micro data on consumption and income, does not — in common with other surveys — have detailed information about household balance sheets. We do, however, observe whether the household has mortgage debt or not. Specifically, we observe whether the household owns their home outright or with a mortgage. We therefore group households according to their housing tenure status.

To illustrate why housing tenure is an appealing group strategy, Table 1 presents some key statistics from the distribution of households' net liquid and housing assets in one wave of the British Household Panel Survey.[4] The mortgagor group tends to have few liquid assets. In contrast, the owner group tends to have sizable net savings. The housing tenure groups — essentially borrowers with housing debt and net savers — therefore have a close parallel in a range of theoretical models. For example, these groups emerge in *equilibrium* in a (by now) standard class of models, such as Iacoviello (2005). These papers have followed Kiyotaki and Moore (1997) in constructing heterogeneous agent frameworks which feature patient and impatient households. Differences in discount factors lead some agents to be borrowers and some to be savers. Impatient households are credit constrained but can increase their

[3]Panel datasets such as the British Household Panel Survey, in contrast, have the well-known issue of lacking detailed and broader expenditure data.

[4]The BHPS collected information on wealth and asset positions of households only in the years 1995, 2000 and 2005. However, and as the case of other household panel surveys such as the SCF in the US or the EFF in Spain, these do not collect detailed information on different consumption items. As in Cloyne and Surico (2013), net financial (liquid) wealth is defined as the value of savings and investments net of outstanding non-mortgage debt, while net housing wealth is defined as the household's estimate of the property value net of any outstanding mortgage.

borrowing capacity by exploiting the collateral value of their housing assets.[5] Since it is hard to identify credit constrained households in the data, our mortgagor group has a close, and very useful, mapping to the constrained households in these models.

We also have information on the final group of households in the sample, renters. These are a relatively heterogeneous group comprising of social renters (those renting from local authorities and housing associations) and private renters (who are only around 10 % of the population). That said, the balance sheet information presented in table 1 suggests that renters are likely to be an interesting proxy for the traditionally liquidity constrained households in society. While our main distinction is therefore between homeowners with and without mortgage debt, the results for renters are also of interest as one might expect the responses to be more similar to those of mortgagors than outright owners.

One potential issue of grouping by housing tenure is possible changes from one tenure status to another over time, specifically selection into treatment and other compositional change. To tackle this issue head-on we employ the propensity score method developed by Attanasio et al. (2002) which is specifically designed to deal with issues of selection, as well as compositional change, for grouping strategies like ours (their paper estimates Euler equations for shareholders and non-shareholders). In main results section below we discuss the details of this method and show that it produces very similar results to grouping by actual housing tenure.

2.3 House Prices and Mortgage Market Data

To investigate the various channels explaining the heterogeneous response of different households to monetary policy shocks, we use a range of housing market variables, including household mortgage payments, loan to value, loan to income ratios and aggregate house prices.

[5] In addition, recent work by Kaplan and Violante (2014), using a different mechanism, has argued that many households could still be 'wealthy hand to mouth' in the sense that they own illiquid assets but are still liquidity constrained.

House Price Indices. Two sets of house price indices are available in the UK which provide information for the period we are interested in. These are compiled by the mortgage providers Halifax and Nationwide. Both provide national as well as regional indices at a monthly and quarterly frequency. These series track a "representative" house price derived from a monthly sample of its mortgage transactions (at the approval stage, rather than at completion) and are constructed using similar statistical techniques.[6] Although Halifax has a larger market share for approved mortgages, and therefore a potentially broader coverage of prices, both indices follow a similar pattern across time. Figure 2 plots Halifax and Nationwide indices at the national level for a representative transaction, as well as the Halifax indices for first-time-buyers (FTB) and non-FTB transactions. Both the 1986-1992 and the 2001-2008 boom in the housing market are apparent. The former coincided with an expansion in the availability of interest-only mortgages[7], and the latter with a steep increase in the loan-to-income ratios.

In our benchmark estimations, we use the UK "All Properties" (old and new) index constructed by Nationwide at quarterly frequency, as it allows us to go a bit further back in time.[8] We deflate the series using the Retail Prices Index.

Loan-to-Value, Loan-to-Income Ratios and Repayments To understand the relative response of mortgagors to a monetary policy shock we would also like to know how monetary policy affects mortgage debt, mortgage repayments and on households' balance sheets. As discussed above, the LCFS does not include detailed individual household level balance sheet information. But one of the advantages of studying the UK is that we can make use of a different, novel, micro dataset to explore the

[6]For a more detail description of the indices construction, see Nationwide House Price Index and Halifax House Price Index.

[7]The increase in the share of such mortgagors is also apparent from the LCFS data, as explained below.

[8] Nationwide has been publishing quarterly property price reports since 1952, while Halifax House Price index starts in 1983. Another advantage is that Nationwide definition of the 'typical' house is revised every year, and the building society revises its regional weighting in accordance with rolling averages from HM Land Registry, Department of Communities and Local Government.

response of mortgage debt.

We exploit data on *individual* loan-to-value (LTV) and loan-to-income (LTI) ratios at origination. These data come from the UK Council of Mortgage Lenders (CML) until 2005 and then the UK Financial Conduct Authority's Product Sales Database from 2005 to 2007. Up to 2005, we have access to a representative sample comprising 10% of all mortgages originated; after 2005, we have access to the whole population of originations.[9] The two dataset have information on *first-time-buyers*, i.e. households that get a mortgage for the first time, and *non-first-time-buyers*. We can also analyze the evolution of different moments of the distribution, as well as the response of such moments to an exogenous monetary policy shock. Figures 3 and 4 present the evolution of the mean and 90th percentile of the LTV and LTI distributions, for all buyers as well as for both for first-time buyers and non-first-time buyers. It is interesting that average LTV ratios have not moved all that much over the sample, while there has been a sharp rise in LTI ratios, particularly in more recent decades.

As documented by Calza et al. (2013), almost 75% of mortgages in the U.K. are of adjustable-rate type, meaning that the monthly mortgage payments faced by the majority of mortgagors can rapidly change when there is a change in the policy rate. One variable we do observe in the LCFS is household-level information on the last (monthly) mortgage repayment, and identifies mortgagors according to whether they have an interest-only or interest-plus-capital mortgage. In terms of repayments relative to income, the median is around 20 %, with a gentle upward trend over time, mirroring the rise in LTI ratios.

3 Identification and Empirical Strategy

As discussed above, we examine the effect of monetary policy on the consumption and income of different *groups* of households and on variables such as mortgagors' debt

[9]To do, we first merge the pre- and post-2005 datasets using the *growth rates* from the latter one to extrapolate forward the former one.

and aggregate house prices. We therefore face the usual macroeconomic identification problem that monetary policy responds countercyclically but also affects the economy. To identify movements in monetary policy we need a monetary policy shock series which can be used for estimation.

There is a vast literature on the identification of monetary policy changes, although the majority of research has focused on the United States. Older approaches relied on timing restrictions and a Choleski decomposition of the variance-covariance matrix of a Vector Autoregression, such as Christiano et al. (1996, 1999). But when applied to the U.K. this method produces a large rise in inflation following a monetary contraction, the so-called price puzzle, as shown by Cloyne and Huertgen (2014).[10] Another, very popular, approach for the U.S. was introduced by Romer and Romer (2004). This method first constructs a measure of the target policy rate (since the effective Federal Funds Rate is moved around by other factors than just policy decisions) and then regresses the change in the target rate around the policy decision on a proxy for the information set available to the policymaker just prior to that decision. This information set includes a range of real time indicators (such as GDP) and forecasts to reflect the forward-looking nature of monetary policy. Cloyne and Huertgen (2014) construct a measure for the U.K. employing this methodology and show that it improves on conventional VAR methods. Rather than constructing a new measure of monetary policy changes, we therefore use the Cloyne and Huertgen (2014) shock series directly.

The shock series matches our micro-data sample period. This means we use shocks from 1975 to 2007. The shock series deliberately stops just prior to the recent financial crisis when the policy rate hit the zero lower bound. The original shock series is monthly but our micro-data are quarterly. Following Romer and Romer (2004) and Coibion (2012) we sum up the monthly innovations to get a quarterly shock to the target rate. The construction of the series also allows for a break in regime in 1993

[10]This is true even after controlling for variables shown to ameliorate this issue for the U.S.

when the U.K. adopted inflation targeting. The monetary policy series from Cloyne and Huertgen (2014) is shown in Figure 5.

Armed with a series of monetary policy shocks, the most natural empirical specification is to follow Romer and Romer (2004). We therefore regress the variable of interest on a distributed lag of the monetary policy shocks. As in Romer and Romer (2004) we also control for the lagged endogenous variable as is common in exercises with relatively small samples. Specifically we estimate for the following:

$$X_{i,t} = \alpha_0^i + \alpha_1^i t + B^i(L)X_{i,t-1} + C^i(L)S_{t-1} + D^i(L)Z_{i,t-1} + u_{i,t} \tag{1}$$

where X is real non-durable consumption, durable consumption or income[11], S are the monetary policy shocks, Z is vector of additional controls, including quarterly dummies, the α terms are constants and time trends, with breaks in 1993. $i \in Mortgagors, Outright\ owners, Renters$. The order of the lag polynomials are chosen using optimal lag length criteria.[12] Standard errors are bootstrapped using a recursive wild bootstrap.

4 Empirical Results

In this section, we present the results from estimating our benchmark specification (1) with both aggregate and cohort level data. In order to make results comparable with the previous literature, all the impulse response functions (IRFs) are computed by simulating a 25 basis points (bp) *increase* in the policy rate. Finally, all the figures present point estimates together with bootstrapped 90% confidence bands generated from 5000 resamples.

[11] When estimating (1) with cohort level data from the LCFS, in order to eliminate some of the noise inherent in survey data, $X_{i,t}$ is smoothed with a backward-looking (current and previous three quarters) moving average filter.

[12] Specifically, the corrected AIC. We have also explored a generalized specification where X is a vector, but with similar results. In addition, we have experimented with including and excluding the contemporaneous value of the shock and with the type of trend assumed. In all cases our results are robust.

4.1 Aggregate Variables from National Accounts

Before exploring the response of different household groups, it is useful to examine the aggregate response of non-durable expenditure, durable expenditure and household income from the UK National Accounts. These results are presented in Figure 6. We find that a contractionary increase in the policy rate lowers durable expenditure, non-durable expenditure and disposable income. Concretely, a 25 basis point monetary policy contraction lead to a persistent fall in non-durable consumption, which peaks at -0.36% after 10 quarters; a larger *percentage* fall in durable expenditure peaking at -1.6% after 10 quarters; and fall in household income that peaks at -0.4% after 12 quarters. Two points are worth mentioning: (i) these magnitudes are very similar to the overall effects found in Romer and Romer (2004) and Cloyne and Huertgen (2014).[13]; and (ii) the relative response of durable and non-durable expenditure is in line with the recent macro literature, such as Barsky et al. (2007), Monacelli (2009) and Sterk and Tenreyro (2014).

4.2 Household Variables from Survey Responses

We next explore the heterogeneous response by housing tenure status.[14] The results comparing mortgagors and outright owners can be seen in Figures 7 to 9, while Figure 10 presents responses for the renters group.

Considering the relative responses of mortgagors and outright owners, two main results stand out. First, we find that consumption expenditures (non-durable and durable) fall significantly after a shock *only* for the mortgagor group. For outright owners, the expenditure responses are not significantly different from zero (with

[13]For a discussion of these magnitudes relative to the VAR literature, see Coibion (2012) and Cloyne and Huertgen (2014).

[14]Before proceeding, we confirm that these aggregate results are broadly consistent with those obtained using aggregated micro data from the Living Cost and Food Survey (LCFS), formerly the Family Expenditure Survey, for the UK. We estimate equation (1) using *aggregate* variables constructed from the LCFS household level data and find results in line with the ones using aggregate data from national accounts. Results are available upon request.

slightly positive point estimates for non-durable expenditure). Second, the heterogeneity is much more stark for the fall in durable expenditure. For mortgagors the peak effect on durable expenditure is at -1.6% from trend 10 quarters after the shock and the response is fast and persistent. The corresponding peak effect for non-durable expenditure is -0.35%, although with a similar persistence. Given these numbers, and that durables expenditures represent around 15% of mortgagors' total quarterly expenditure, the *share* of durable expenditure falls to approximately 15% after 10 quarters. This relative response of durable and non durable expenditure is in line with the results we obtained using aggregate data.

Turning to the responses of renters, Figure 10 shows that the response of non-durable and durable expenditure is somewhere in-between the response of mortgagors and outright owners, and is less significant than the responses of mortgagors (which may reflect the heterogeneous nature of the group). The response of renters' non-durable and durable expenditure is about half that of the mortgagors' at around 0.15 and 0.8 percent at peak (respectively). That said, this is still much larger than the response of outright owners: the peak response of durables being twice that of the point estimate for outright owners.

As seen in Figures 9 and 10, we find that household disposable income (net of taxes) tends to fall for *all three groups*, i.e. mortgagors, outright owners and renters, although the income of mortgagors responds a bit more strongly and we discuss this further below. The income fall across all groups is consistent with a general-equilibrium response of labor earnings following a monetary contraction. However, it is also important to take into account the heterogeneous composition of income for the three housing-tenure cohorts. On average, quarterly real earnings (labor income) represents 82%, 50% and 30% of total income for mortgagors, renters and outright owners respectively. Even though the outright owners have a higher proportion of non-labor income, it is noteworthy that their income still declines overall.

Consumption Relative to Income. One possibility is that the expenditure responses of mortgages can be solely explained by differential movements in income across groups, rather than differences in their propensity to consume. To evaluate this hypothesis, Table 2 computes the change in the level of consumption (cumulated over the impulse response horizon) relative to the overall change in income. It is tempting to think of this as a marginal propensity to consume, although it is a mere descriptive statistic rather than a structural parameter. That said, the proportions for mortgagors are sizable and significant, while those for the owners are insignificant and much smaller. This means that the expenditure responses for mortgagors are much larger *even relative to the movement in income* (and taking into account the different levels of expenditure and income across groups). Our findings therefore do not simply reflect heterogeneity in the cyclical sensitivity of mortgagors, for example if their income were more responsive or if monetary contractions cause a larger number of mortgagors to become unemployed. While these mechanisms could still be at work in producing the fall in mortgagor income, that expenditure responds so much more than income suggests something else must explain the sensitivity of expenditure of the mortgagor group, such as some form of borrowing constraint. We examine this in detail in Section 5.

4.3 Selection and compositional change

To interpret our estimates as the causal effect of monetary policy on the expenditure and income for a representative mortgagor, we need that the monetary policy change does not cause households to move from one housing tenure status to another. This assumption is like assuming there is no 'selection into treatment'. From a household perspective, we are implicitly relying on the notion that the housing tenure status is independent of the *timing* and the *size* of the shock. But this assumption of no 'selection into treatment' is a much less stringent requirement than housing tenure be exogenous (in the way that, for example, age is exogenous), which would seem hard

to entertain given that different households select themselves into different tenure groups over their life-cycle. We simply require that the monetary policy shocks we consider did not trigger a change in housing tenure. While certainly a possibility, we can test this assumption to ensure that the results presented above are robust and this is the focus of the current section.

One simple way of examining whether the monetary policy shock triggered changes in house tenure is to look at the response of group shares. As can be seen in Figure 1, the very gradual rate at which home ownership has changes in the United Kingdom, relative to the high frequency movements in the monetary policy series, already suggests the response of the shares may be limited. Figure 11 shows this formally. Each panel shows the response of the group shares for mortgagors, outright owners and renters. It is clear from Figure 11 that none of the shares respond significantly, indicating that changes in monetary policy do not seem to trigger significant selection into treatment.[15]

A more rigorous way of addressing possible selection and composition effects is to employ the propensity score method of Attanasio et al. (2002). The key idea is that in each pair of adjacent time periods the household groups are formed on the basis of the same criterion: the probability of ownership at the beginning of the two periods over which the rate of consumption growth is then computed. It is then important that the variables used to predict group membership are either fully predictable or constant over time. This ensures that there are no group changes as a result of the monetary policy shock. To predict the probability of being a mortgagor rather than an owner over two consecutive periods, we therefore run a probit for actual housing tenure over the full-sample (for mortgagors and outright owners) using as regressors the same high order polynomials in age and educational attainment of the household head, time trends and their interactions used in Attanasio et al. (2002).

[15]While it may be theoretically possible that the inflows into one group might be almost perfectly compensated by its outflows, it would seem difficult to think that *at the same time*, for example, some renters become mortgagors and other households with debt become renters.

Following their method, the estimated coefficients from the probit model are then used together with actual values for the regressors in the previous period to generate predicted probability of being in the same group over two subsequent observations in time. This will ultimately produce time series for expenditure and income growth over time for each group we consider.

Once we obtain a predicted probability, we then need to choose a cutoff above (below) which households are classified as 'likely' ('unlikely') members. As noted in Attanasio et al. (2002), in addition to selection effects, we may also be concerned about compositional change in the characteristics of the likely (unlikely) mortgagor group over time. Our inference would be blurred if households which a higher sensitivity to interest rate changes were becoming mortgagors over time and this occurred coincidentally with the monetary policy shock but had nothing to do with actually being a mortgagor. In using exogenous characteristics like birth cohort and education to produce predicted probabilities, the Attanasio et al. (2002) method has the additional advantage that it ameliorates concerns about compositional change in the likely mortgagor group. Attanasio et al. (2002) argue that any bias from compositional change can be minimized by choosing a fixed cutoff above which households are classified as 'likely' ('unlikely') mortgagors. We therefore define likely mortgagors as those with a predicted probability greater than 40%, the sample average group share (although results are robust to variations in this precise number).

The results are shown in Figure 12. The results for 'likely' mortgagors' expenditure and income are very similar to the responses based on actual tenure. This suggests there is little bias associated with using the mortgagor group directly. The responses of 'unlikely' mortgagors are also similar: income again falls to around 0.2 percent, non-durable expenditure hardly responds and is insignificant. The durable response is a bit larger but remains half the response of the 'likely' mortgagors and insignificant. We therefore conclude that our previous results using actual housing tenure are not driven by possible selection and compositional issues.

5 Interpreting the Housing Tenure Heterogeneity

In the previous section we showed that mortgagor households, on average, alter their expenditure far more than outright owners in response to changes in monetary policy. The purpose of this section is to explore what might be driving these results. One possibility is that mortgagors face constraints specifically related to their debt and mortgage market positions. But one may be concerned that our housing tenure distinction is simply picking up another characteristic and that the ultimate explanation for our results it not driven by mortgage related constraints. In this section we explore the issue further, showing that a collateral constraint facing mortgagors seems the most plausible explanation. In the next section we explore this further using a theoretical model where its predictions are in line with all our empirical findings.

5.1 Demographics

It could be that our housing tenure distinction is simply picking-up life cycle effects and or that our results simply reflect differences in age. For example, mortgagors are often younger and owners older. To explore this issue we follow the micro-econometrics literature and group our micro data according to birth cohort. One might be tempted to group households by age directly but, as discussed extensively in the micro-econometrics literature, this would be incorrect. The grouping estimator relies on constructing a sample for a representative household whose characteristics are predictable over time. If we were to construct a time series for someone who was, for example 25, we would end up with the change in consumption over time for a household who was always that age. Instead, we consider older households born before 1930, middle-aged households born between 1930 and 1955 and younger households born after 1955. Figure 13 shows the breakdown of our tenure groups by birth cohort. As expected, younger households tend to be dominated by mortgagors and older households by owners but, importantly, not all younger households are

mortgagors.

We consider three experiments to explore whether age or life cycle considerations could be driving our results, rather than mortgage debt per se. First, if this were the case it should be that younger mortgagors respond differently to older mortgagors. Second, we consider owners and mortgagors at the same point in their life cycle. Third, we exclude all retired households from the analysis.

Turning to the comparison between younger and older mortgagors. Unfortunately there are not enough mortgagors in the older birth cohort but we can explore this issue for the two younger cohorts. Interestingly, the first two columns of Figure 14 shows that younger and middle-aged mortgagors respond in a very similar way. This is true of the non-durable, durable and income responses.

As noted above, we can go further by exploring the response of mortgagors vs. outright owners *controlling* for their position in the life cycle.[16] Again, we need to consider a point in the life cycle where we have enough outright owners and mortgagors and, as can be seen from Figure 13, this is only possible for the middle-aged cohort. The middle and final column of Figure 14 therefore shows the expenditure responses for outright owners and mortgagors controlling for their stage in the life cycle. It is clear from these columns that our main results remain, with mortgagors adjusting significantly and the outright owners responses being small and statistically indistinguishable from zero.

Finally, we consider a reduced sample from the LCFS where we exclude retired households. Again the results are very similar to our baseline, as can be seen in Figure 15.

Given all the results in this section, we therefore conclude that life cycle considerations do not seem to explain our heterogeneity.

[16]Note that given the grouping strategy it is not possible to *control* for age or birth cohort by including regressors in the main regressions.

5.2 Cash Flows and Redistribution Effects

A monetary contraction should lead to an increase in interest payments for borrowers and a rise in interest income for savers. It is therefore possible that mortgagors' expenditure is more sensitive because their mortgage payments are directly affected by higher interest rates, lowering their disposable income. This 'cash-flow' channel would also imply a redistribution effect with an increase in interest income for the owner group. Any aggregate effect of this transfer, however, still requires that the borrowers (our mortgagor group) are credit constrained, such that the effects do not net-out in the aggregate. But it is still instructive to ask whether the mechanical change in mortgage payments can explain the larger response of mortgagors. This is particularly important as, historically, most UK mortgages have been on a variable rate.

As discussed earlier, we construct household mortgage payments from the LCFS. Figure 16 shows the impulse response function for mortgage payments following an increase in policy rate. As can be seen in the figure, mortgage payments rise following a monetary contraction, as expected. But the question is whether this is large enough to explain our empirical findings for mortgagors' expenditure. The response of mortgage payments is not particularly large, especially relative to the overall fall in income. So while there may be an effect from the direct movement in repayments, this channel cannot explain the large responses found in the previous section. To see this, Table 2 recomputes the response of expenditure relative to income *net of mortgage payments*. If the movement in mortgage payments is sufficient to explain the expenditure response, we should see considerable differences between the last two columns. Instead, we see the results are again significant, not that different from the previous results using overall income, and, once again, remain much larger than owners.

5.3 House Prices and the Collateral Channel

Given the role of mortgagors in explaining the aggregate effects of monetary policy, the response of the housing market and mortgage debt is likely to play a crucial role in the transmission mechanism. To explore this we first show that a 25 basis point increase in interest rates lowers house prices, shown in Figure 17. The effect on house prices is significant and sizable, and the dynamics look very much like the dynamics of consumption and income presented earlier.

Next we consider the response of mortgage debt itself. For the UK we have detailed information on mortgage debt from two novel datasets of mortgage originations. While we are unable to study the response of debt at a household level we can still, in the spirit of our empirical strategy, study the response of key debt variables for the mortgagor group as a whole (and moments of the distribution). Specifically we now consider how loan to income ratios and loan to value ratios respond, two key measures of household leverage.

We find that loan to income ratios fall quickly and significantly, as shown in Figure 18. This means that monetary contractions *reduce* household leverage. In contrast, over the first few years the response of loan to value ratios is not statistically different from zero (and even start rising later on), as shown in Figure 19. House prices therefore fall by more than loan values, but loan values fall by more income over the contractionary period. Secured debt and leverage therefore clearly responds to monetary policy contractions. These are stylized facts we would like any theoretical model to replicate.

6 Insights from a model with housing tenure and collateral constraints

Our empirical results appear consistent with mortgagors facing constraints that produce larger expenditure responses than for outright owners, even relative to income.

In addition, renters seem to fit the traditional description of hand-to-mouth consumers and this is also evident in the larger responses for renters than owners. Finally, we showed that monetary policy affects mortgage debt and that house prices fall significantly after a monetary contraction.

In this section we interpret these findings using a relatively stylized heterogeneous agent housing market model with mortgagors, owners and renters. Specifically, we investigate how well a model featuring collateral constraints — in the spirit of Iacoviello (2005), Guerrieri and Iacoviello (2013) and Calza et al. (2013) — and endogenous housing tenure choices can account for the empirical evidence presented in the previous section. Our goal is to examine how well this particular collateral constraint mechanism can, on its own, rationalize our empirical results.

6.1 Theoretical Framework

In this section we sketch the main features of the model, we leave the full details for the appendix. The model is a simple heterogeneous agent New Keynesian model in the spirit of Iacoviello (2005). But, motivated by our empirical findings, we incorporate two features which have not been considered jointly in the macro literature. First, the choice of owning or renting housing is endogenous and the relative prices of housing and renting are determined in equilibrium. Second, all households consume *long-lived* durable goods.

The model features patient and impatient households. Both can choose to own housing, consume non-durable goods and accumulate durable goods, but the impatient households have a lower discount factor and this leads them to want to borrow in equilibrium. In contrast, the patient households are net savers. The borrowing capacity of the impatient households is limited by a collateral constraint linked to the value their their housing assets. Importantly, and unlike typical housing market models, households decide how much housing to own and rent, with relative prices determined endogenously. Our set-up will lead to three groups in equilibrium: the

traditional patient households who will own housing for themselves but also some rent out, impatient mortgagors who hold housing, do not rent, and borrow against their housing as in Iacoviello (2005) and, finally, a group of renters who own no housing of their own and, as such, cannot borrow. These three groups therefore have close parallels with housing tenure categories in the previous sections and accord well with the evidence on the distribution of wealth across groups shown in Table (1).

Formally, we model two types of impatient household who differ in their preferences for renting versus owning housing. For both groups (as well as the patient households) utility is derived from housing, but unlike the standard Iacoviello (2005) housing model, the housing variable that enters the utility function, for household type i, is defined as the sum of owned housing ($h_{i,t}$), rented housing $s^{+}_{i,t}$ and net of housing stock rented out to others ($s^{-}_{i,t}$). Specifically,

$$\tilde{h}_{i,t} = h_{i,t} + \gamma s^{+}_{i,t} - s^{-}_{i,t}. \tag{2}$$

The coefficient γ governs the household's preference for renting relative to owning houses h. Specifically, we assume that for impatient "renters" $\gamma = 1$ and for impatient "mortgagors" (as well as the patient households) $\gamma < \bar{\gamma}$.

As is common in the wider literature there is a fixed stock of houses H and the price of housing is q_t. But in our setup there is also a rental market, through which households can rent a house for one period at a rate p_t. All households face an individual housing feasibility constraint

$$h_{t,i} - s^{-}_{t,i} \geq 0 \tag{3}$$

meaning that they cannot rent out to other households more than they currently own, and they cannot sub-let. In equilibrium, it will also need to be the case that both markets clear such that

$$H = h_{t,m} + h_{t,r} + h_{t,o} \tag{4}$$

$$s^{+}_{t,r} + s^{+}_{t,m} + s^{+}_{t,o} = s^{-}_{t,r} + s^{-}_{t,m} + s^{-}_{t,o}. \tag{5}$$

We cover the detailed setup in the appendix but, to make things concrete, it is useful to briefly consider the balance sheets of the three household groups. For impatient mortgagors and renters, their real budget constraint (in terms of the price of non-durable goods) features real non-durables C, real durable *expenditures* D (where q^d is the relative price of durables investment goods) and the accumulation of housing h (where q^h is the relative price of housing) which is in fixed supply (aggregate H is fixed). Mortgagors and renters may also, in principle, borrow b from the patient outright owners and pay interest on the loans R. They may also rent (s^+) or rent out (s^-) housing at price p. Households earn a real wage w and supply L hours of work. The labor market is competitive and the real wage w will be the same across all households.

$$C_t + q_t^d D_t + q_t^h \Delta h_t + \frac{R_{t-1}}{\pi_{c,t}} b_{t-1} = w_t L_t + b_t + p_t \left(s_t^- - s_t^+ \right) \tag{6}$$

The impatient mortgagors and renters also face a collateral constraint where the amount repayable in period $t+1$ ($R_t b_t$) is constrained by the expected value of housing assets in $t+1$.

$$b_t \leq m^{LTV} E_t \left(\frac{q_{t+1}^h h_t \pi_{c,t+1}}{R_t} \right) \tag{7}$$

The patient households also consume and accumulate housing (the owners' variables are denoted with a $'$) but have positive net assets b' in equilibrium.

$$C_t^{'} + q_t^d D_t^{'} + q_t^h \Delta h_t^{'} + \frac{R_{t-1}}{\pi_{c,t}} b_{t-1}^{'} = w_t L_t^{'} + b_t^{'} + p_t \left(s_t^- - s_t^+ \right) + \Pi_{C,t} + \Pi_{D,c} \tag{8}$$

This means the patient households are the net savers in the economy. $\Pi_{j,t}$ are the profits from monopolistically competitive intermediate goods firms (j refers to durable or non-durable producers) and ω^{PH} is the number of outright owners (patient households) in the population. The owners, in addition to labor income, therefore also earn income from savings (at rate R) and receive dividends from firms.

As shown in the model appendix, patient and impatient households maximizes

utility

$$W = \max_{\{C_t, D_t, V_{t+1}, h_t, s_t^+, s_t^-, L_t, b_t\}} E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{x_t^{1-\sigma}}{1-\sigma} + j \log \tilde{h}_t - \frac{L_t^{\eta}}{\eta} \right) \tag{9}$$

with $\tilde{h}$ defined as above and subject to their budget constraint, the law of motion for durable purchases, the collateral constraint (for impatient households) and a series of inequalities governing the stocks of s^+, s^- and h.

Durable goods are specified in a similar way to Barsky et al. (2007) and Mertens and Ravn (2011) where consumers derive utility from the *stock* of durable goods and non-durable goods, weighted together using a Cobb-Douglas aggregator. Households then make choices about new durable purchases each period although importantly, and unlike in Monacelli (2009) or Sterk (2010), durable goods *cannot* be used as collateral for borrowing. In other words, we distinguish durable goods from housing; we think about the former as capturing goods that are used less often as collateral for borrowing to fund other consumption, such as furniture and electronic/electrical appliances.[17]

As noted above, the key calibration is to set γ such that some impatient households have a preference for renting. These assumptions, combined with the usual Iacoviello (2005) type assumptions on the discount factors of patient and impatient households such that the collateral constraint binds, allows us to solve the model by linearizing first order conditions and applying conventional solution techniques.

Given the calibration, we linearize around a "separation" steady state which, as we discuss in the appendix, has the following properties: (i) Patient households own housing stock ($h_o > 0$) and rent out part of it ($s_o^- > 0$). (ii) Impatient renters do not own housing ($h_r = 0$) which means they cannot borrow ($b_r = 0$) or rent to others ($s_r = 0$). Instead, they rent housing services from patient households ($s_r^+ > 0$). (iii) Impatient mortgagors own housing ($h_m > 0$) but do not participate in the rental

[17] While it is common for households to acquire furniture and cars on hire-purchase or secured credit, the same good is used as collateral for that particular transaction. It is much less common to use such goods as collateral for *other* purchases/contracts.

market ($s_m^- = s_m^+ = 0$). (iv) We can derive the endogenous threshold $\bar{\gamma}$. These properties are particularly novel and appealing because the characteristics of the three different households groups match the evidence in Table (1) *endogenously.*[18]

The total population is normalized to one, which means the shares of each household are also the number of households in each group. ω^{PH}, ω^{IH}, $(1 - \omega^{PH} - \omega^{IH})$ refer to the shares of mortgagors, owners and renters and are calibrated using our LCFS microdata.

The production side of the economy is relatively standard in the New Keynesian literature. There are monopolistically competitive intermediate goods firms producing different varieties of intermediate inputs using labor supplied by each of the three household groups. Housing is not used in production. These firms are subject to price adjustment costs. The labor market is competitive so the real wage w is the same across households and firms. Final goods firms then package-up the intermediate goods and sell them in a competitive market to consumers.

The main difference with the typical New Keynesian set-up is that we have two types of producers and final goods firms. Specifically we have intermediate and final durable and non-durable goods firms. In principle this leads to a different evolution of prices between durable and non-durable goods and the model features two price Phillips Curves leading to movements in the relative price of durables q_t^d, as in Monacelli (2009).

Monetary policy follows a conventional Taylor rule where the policy rate responds to expected inflation, the output gap and is subject to shocks. The response of the economy and the household groups to these monetary policy shocks will be compared with our empirical results from the previous sections.

[18] In linearizing around this steady state we assuming that the conditions above also hold within the region of this steady state. This means we are assuming that the monetary policy shocks are not sufficiently large to trigger households to change group. Of course, this is not a trivial assumption and, essentially, requires that the wedge between the rental rate p_t and the house price q_t^h not to diverge *too much* from its value in steady state. This seems empirically reasonable given the empirical results in Figure 11, where we showed that the shares of different housing tenure did not respond significantly to our monetary policy changes.

6.2 Main Findings

The model is linearized around a deterministic steady state and solved using conventional first order perturbation methods. The model's deep parameters are calibrated to be in line with common parameter values found in the literature. The precise calibration can be found in Table (3). The elasticity of substitution between durables and non-durables is in line with the calibration used in Mertens and Ravn (2011). Discount factors are chosen as in Iacoviello (2005). Estimates of the degree of habit persistence vary in the literature from relatively low (for example around 0.3), to high (such as 0.7). We therefore choose 0.5 for the baseline case. The adjustment costs and mark-up parameters map into an average reset price reset time of around a year. In our baseline case, steady state debt is calibrated so that the steady state loan to value ratio is 60 %. The shares of the different groups comes from the Living Cost and Food Survey.

We now consider a 25 basis point shock to the policy rate in the model, to be consistent with our empirical results presented earlier. We consider the effect on non-durable and durable consumption across the three groups of households. For the response of mortgagors relative to owners, the impulse response functions are shown in Figure (20) and the responses for renters and shown in Figure (21). The responses are shown for real variables deflated using the aggregate price index to match our empirical specification.

In a representative agent model with durable and non-durable goods monetary policy would have real effects on both types of expenditure (and GDP) via the usual New Keynesian transmission channels. Monetary policy induces households to alter their consumption decisions over time and, in the face of sticky prices, real outcomes respond. For representative agent New Keynesian models with durable purchases see Monacelli (2009), Barsky et al. (2007) and Sterk (2010).

The heterogeneity in the housing market in our model adds a key financial ac-

celerator to the standard framework.[19] A rise in the interest rate lowers inflation increasing the real service cost of debt. The second channel works via the collateral constraint where a rise in the interest rate increases the shadow value of borrowing which induces a fall in consumption. Finally, movements in asset prices alter the collateral value of housing which changes the tightness of the collateral constraint itself.

As can be seen in Figure (20) both types of expenditure move considerably more for the constrained mortgagor households. The response of durables is also much larger (in percentage deviations from steady state) than for non-durable, as we find empirically. One interesting feature of the effect on owners is that the overall general equilibrium effects dominate (as must be the case in our empirical results). While owners may benefit directly from higher interest payments on their savings and lower inflation raising the real value of their assets, overall their total income falls, as does their consumption. Savers are therefore also adversely affected by an increase in interest rates, although less so than borrowers. In addition, Figure (21) shows that renters who are, in a sense, endogenously borrowing constrained behave qualitatively similar to the mortgagor group with sizable decreases in both types of expenditure. Furthermore, as in our empirical results income falls for all groups.

Figures (20) and (21) show that the model, despite being simple and stylized does a remarkably good job replicating the heterogeneity we find in the data. The model lacks some of the extra amplification mechanisms found in larger scale DSGE models, so the responses lack some of the persistence found in our empirical section, but this is a well-known issue with DSGE models in general. What is striking is the significant heterogeneity and that the empirical magnitudes mirrors our empirical IRFs for consumption across owners and mortgagors. The model is also able to replicate the fall in house prices and loan to income ratios. Defined in terms of expected house value, loan to value ratios rise slightly, although the m parameter is

[19] See Calza et al. (2013) for a fuller discussion.

clearly constant by construction. The model therefore matches all the salient features of our empirical results, suggesting that a even a simple collateral constraint story is highly consistent with all our empirical findings.

7 Conclusions

This paper has explored empirically the interactions between monetary policy, household indebtedness and the housing market. Many have argued that household debt and the mortgage market played a key role in the recent financial crisis, and understanding how monetary policy affects different groups, as well as whether this matters for the aggregate effects, remains a key issue facing academics and policymakers. But, as we have argued, little is known empirically about whether monetary policy has heterogeneous effects according to a household's debt position, and whether this heterogeneity has first-order implications.

To overcome a number of empirical challenges, we have exploited a series of novel UK datasets and proxied the household's balance sheet position using housing tenure. Specifically, we have examined whether homeowners with mortgage debt respond differently to monetary policy than outright home-owners. Since these grouping have natural counterparts in many housing market models, this is a novel way to explore whether indebted households react disproportionately more than savers following monetary policy changes.

We find that monetary policy has sizable heterogeneous effects across household groups. Most importantly, we showed that this heterogeneity is highly correlated with mortgage debt and the household's housing market position. Mortgagors change their consumption significantly whereas outright owners do not. And this heterogeneity is much more stark for durable expenditure. Furthermore, income falls for all groups following a monetary contraction but we showed that the response of consumption for mortgagors remains significantly larger, even relative to their change in income. We also showed that our results do not seem to be simply driven by demographics or

due to the direct interest 'cash-flow' effects associated with higher policy rates.

Our results are consistent with a housing collateral constraint story and we showed that house prices and — in exploiting a unique UK dataset on mortgage originations — we found that mortgage debt responds significantly, with leverage (loan to income ratios) falling following a monetary contraction. Loan to value ratios, in contrast, do not move, at least in the short term.

A relatively simple housing market model, in the spirit of Iacoviello (2005), does a remarkably good job, both qualitatively and quantitatively, in accounting for our empirical results. Our model features a novel endogenous renting decision, as well as durable expenditures. The congruence between the simulations from our simple model and the empirical results are striking and suggest that the collateral and housing market channels play a key role in explaining the heterogeneity we find, but also in the aggregate transmission of monetary policy.

Figures

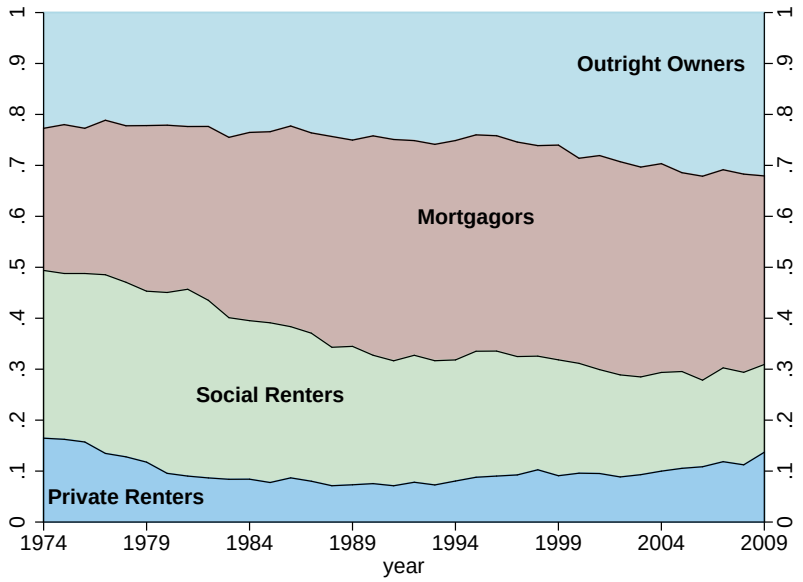


Figure 1: Evolution of Housing Tenure Shares

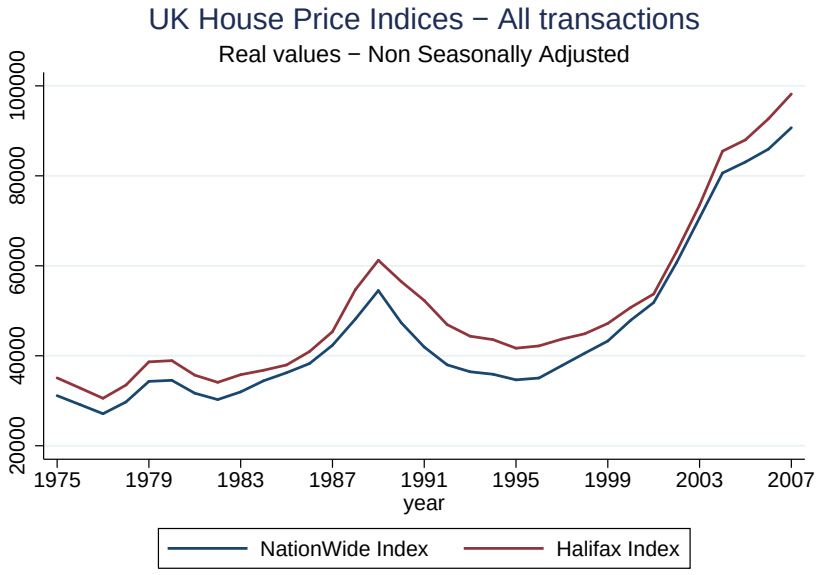


Figure 2: House Price Indexes for the UK. The 1975-1983 data for the Halifax is constructed by backward-extrapolation, using the growth rates from the Nationwide Index.

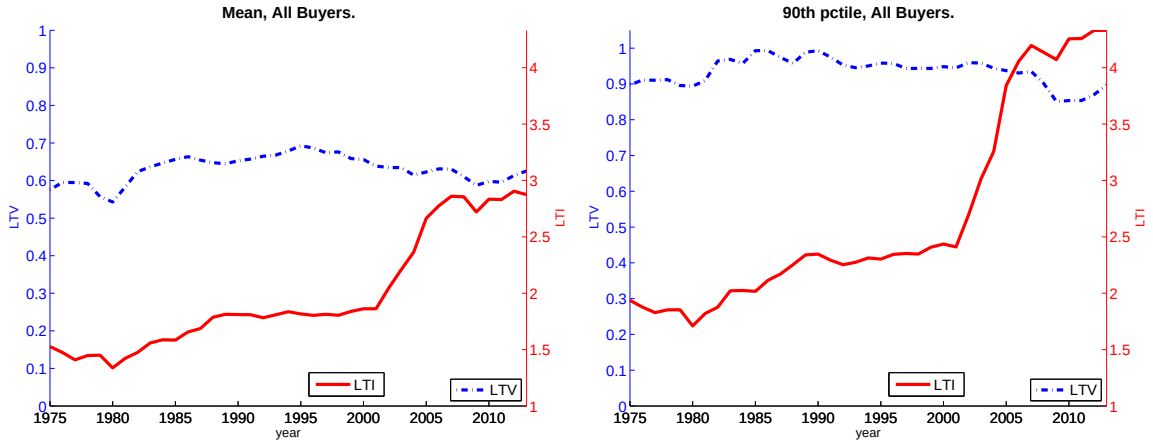


Figure 3: LTV ratios over time (using CML data up to 2005 and data kindly provided by the FCA after)

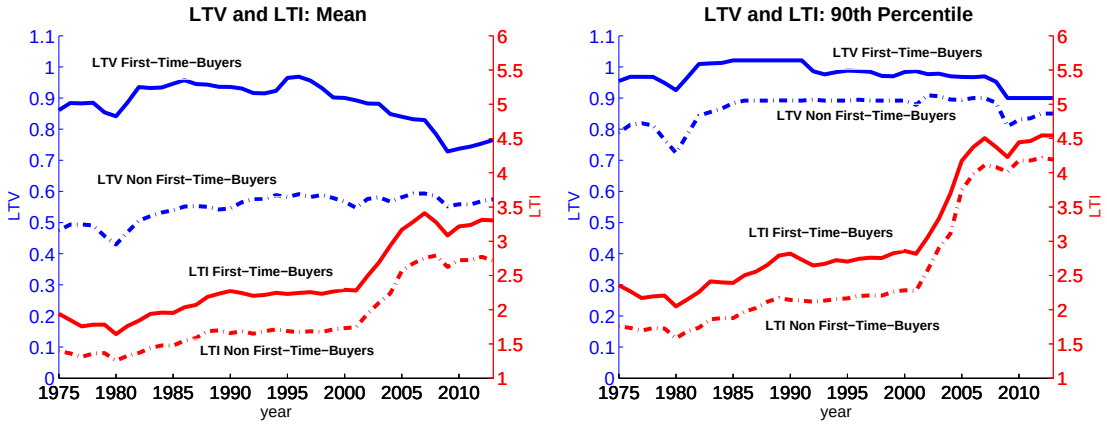


Figure 4: Loan-to-Value (LTV) and Loan-to-Income (LTI): mean (left) and 90th percentile (right) (using CML data up to 2005 and data kindly provided by the FCA after)

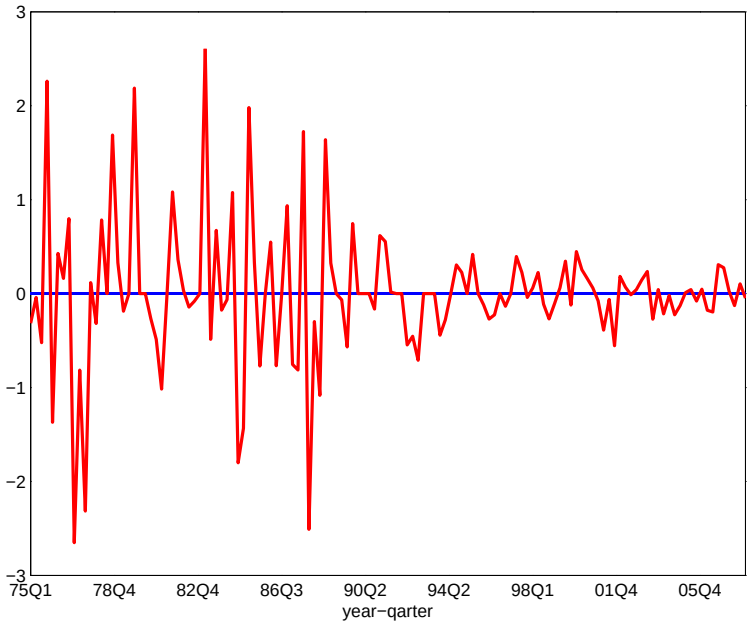


Figure 5: UK monetary policy shocks: Cloyne and Huertgen (2014)

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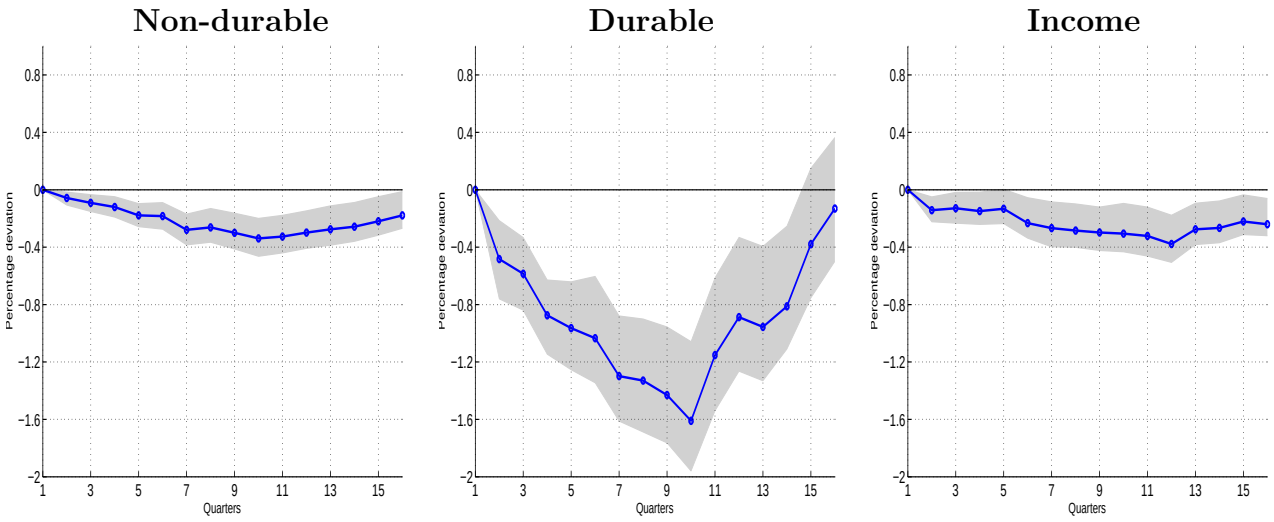


Figure 6: Response of consumption and income using aggregate ONS data.
Grey areas are 90% confidence intervals.

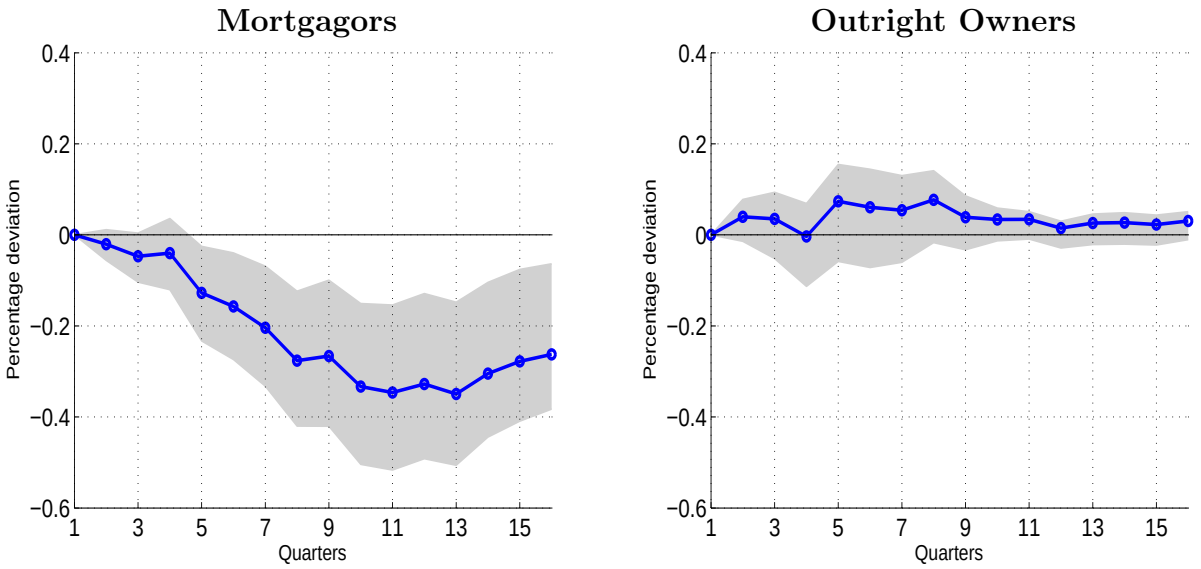


Figure 7: Response of non-durable consumption by housing tenure.

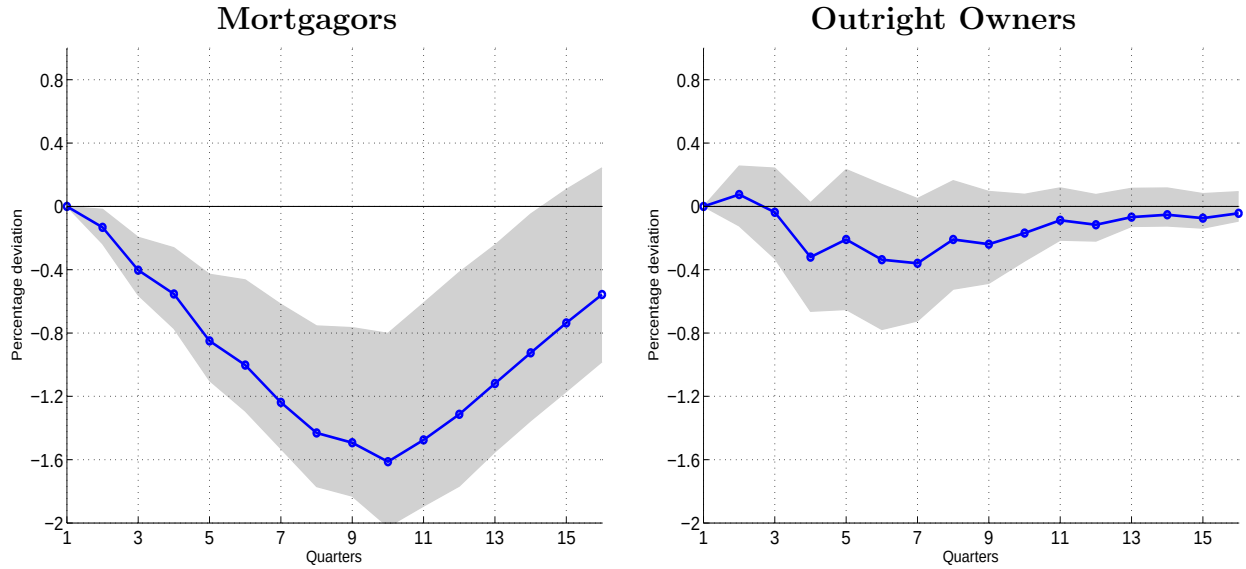


Figure 8: Response of durable consumption by housing tenure.

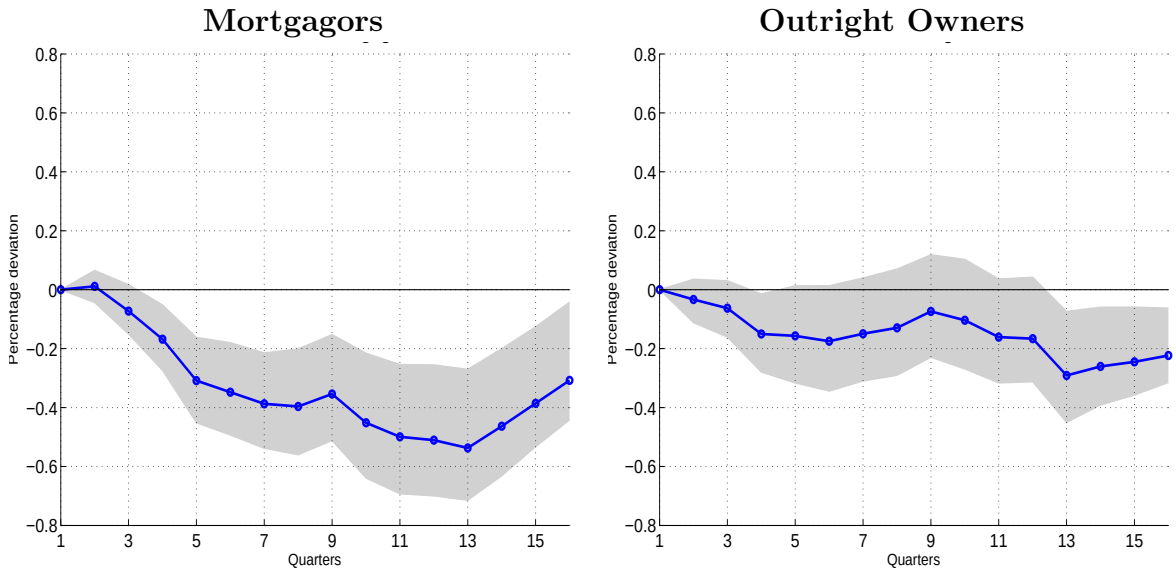


Figure 9: Response of net income by housing tenure.

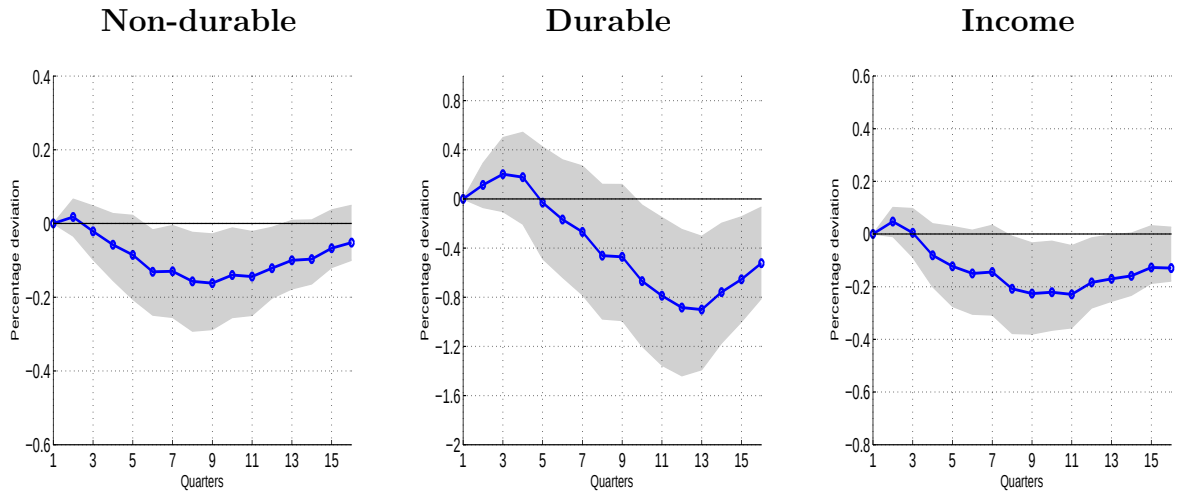


Figure 10: Response of consumption and income for renters

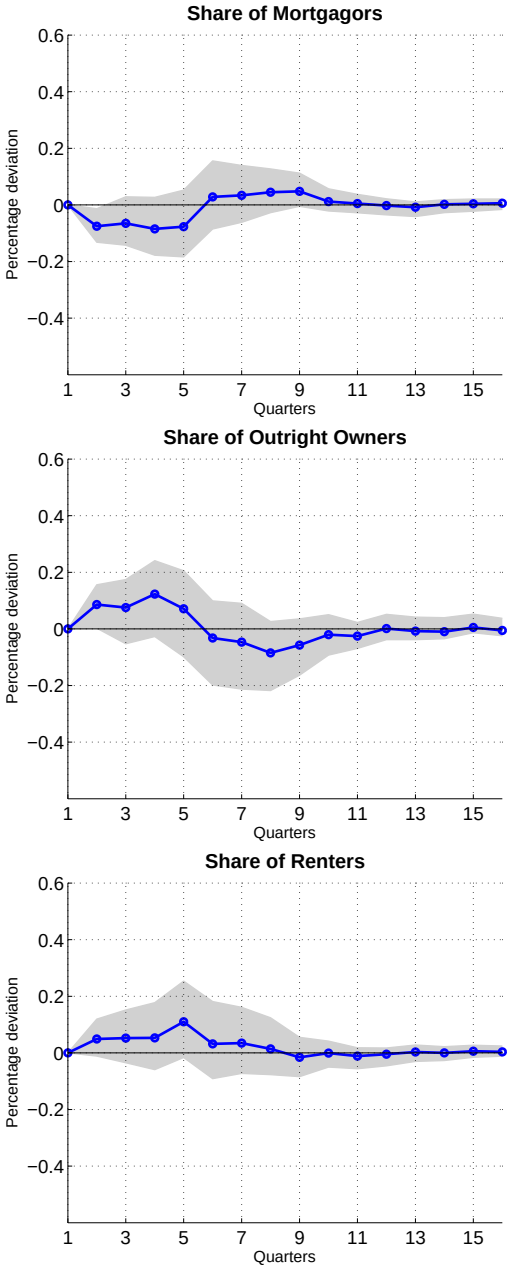


Figure 11: Response of the group shares

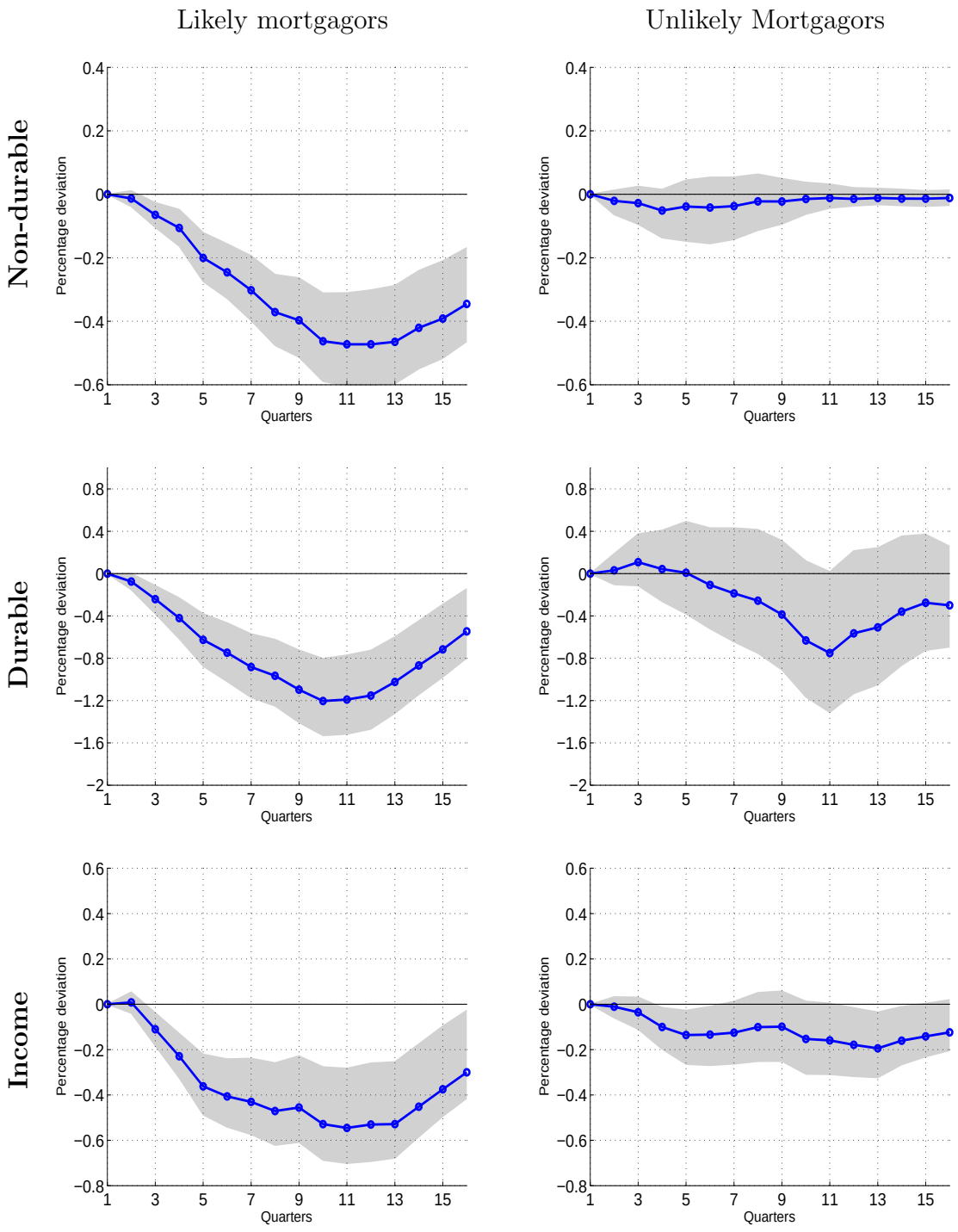


Figure 12: Response of non-durable, durable and income for likely and unlikely mortgagors

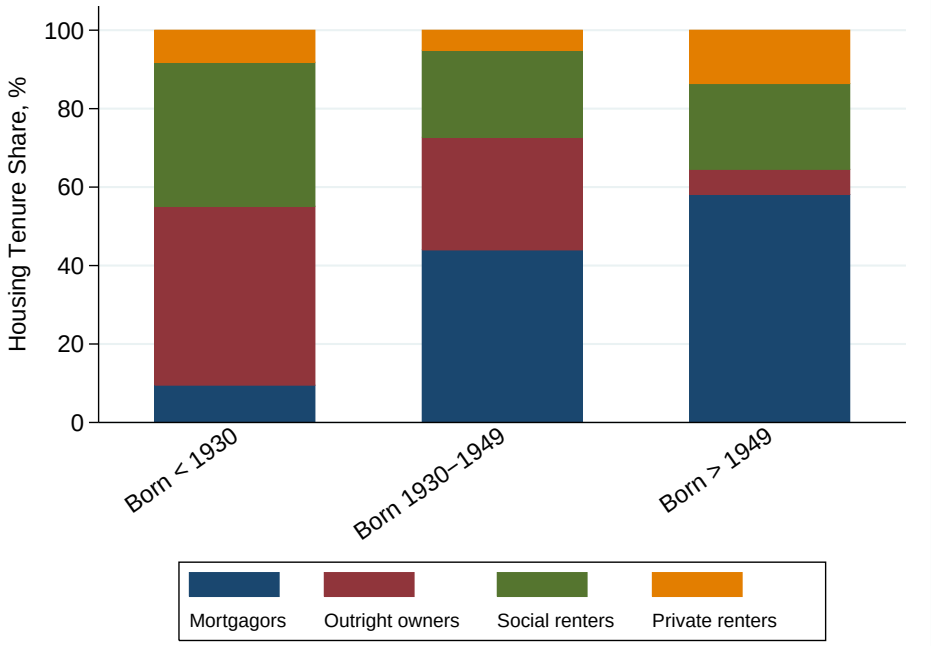


Figure 13: Housing tenure by birth cohort.

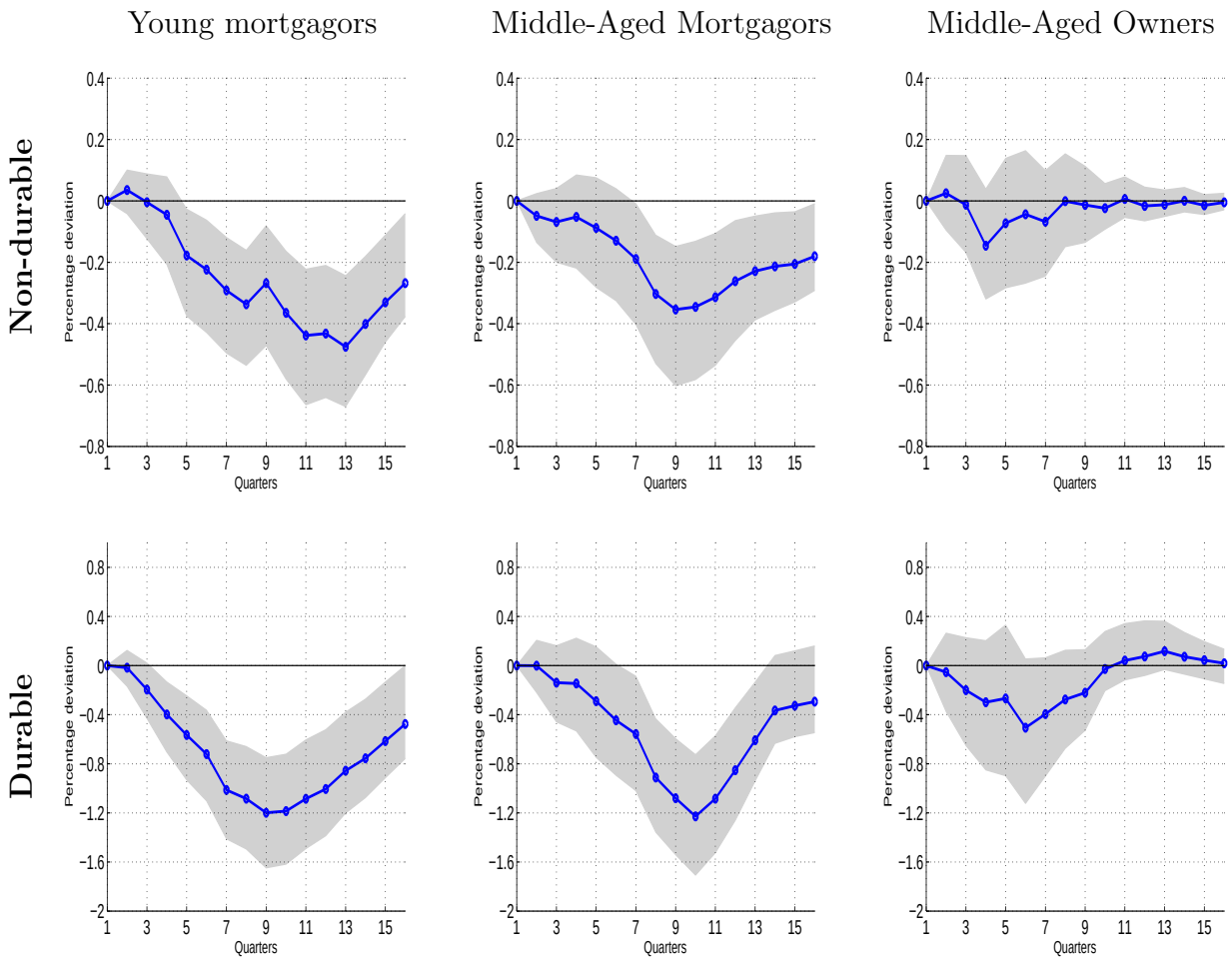


Figure 14: Response of different tenure groups by birth cohort. First row non-durable, second row durable. Left and middle column compares younger and middle aged mortgagors (born after 1949; born 1930-1949). Middle and right column compares middle-aged mortgagors with middle-aged owners.

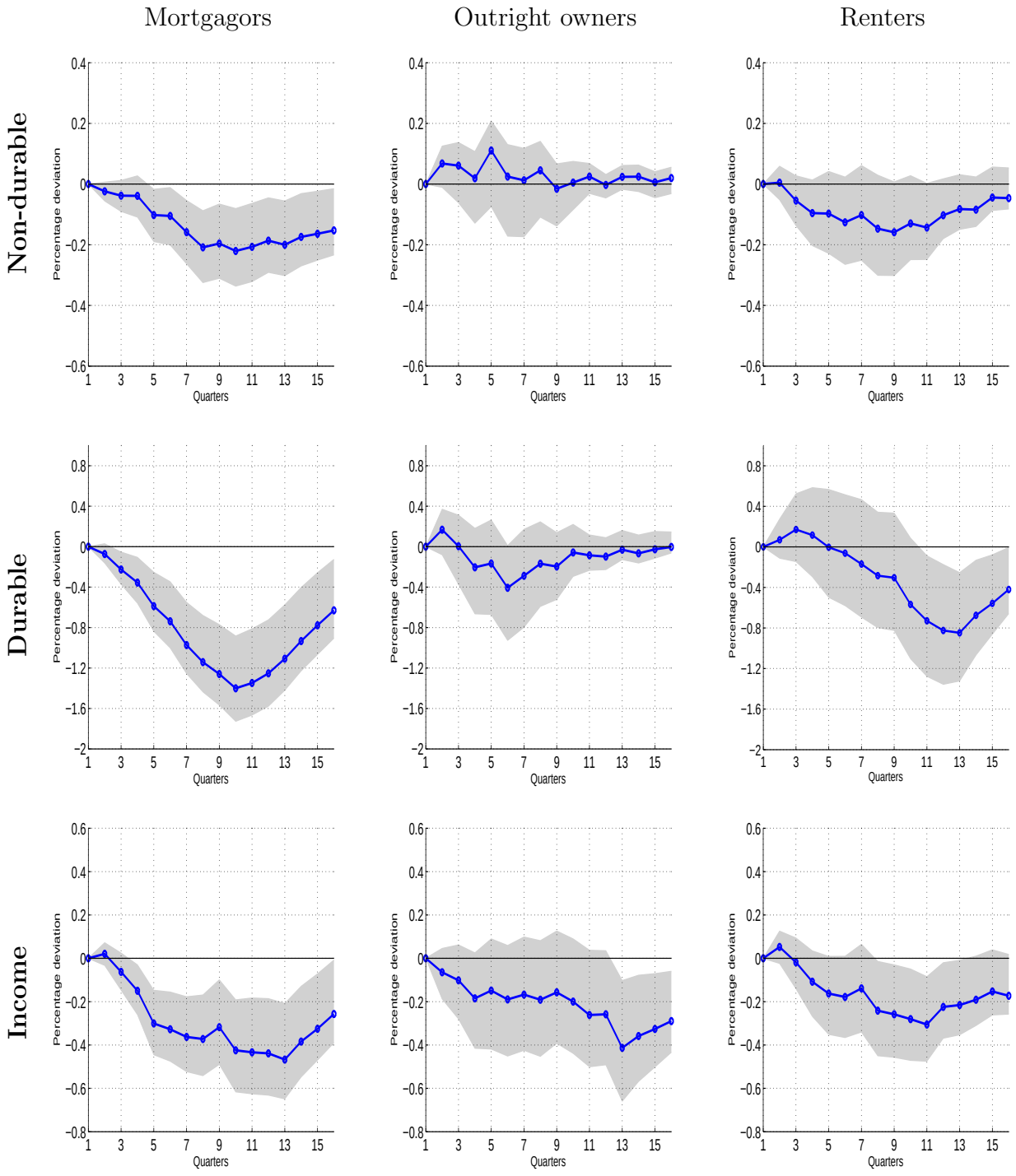


Figure 15: Response of non-durable, durable and income **excluding retired households**.

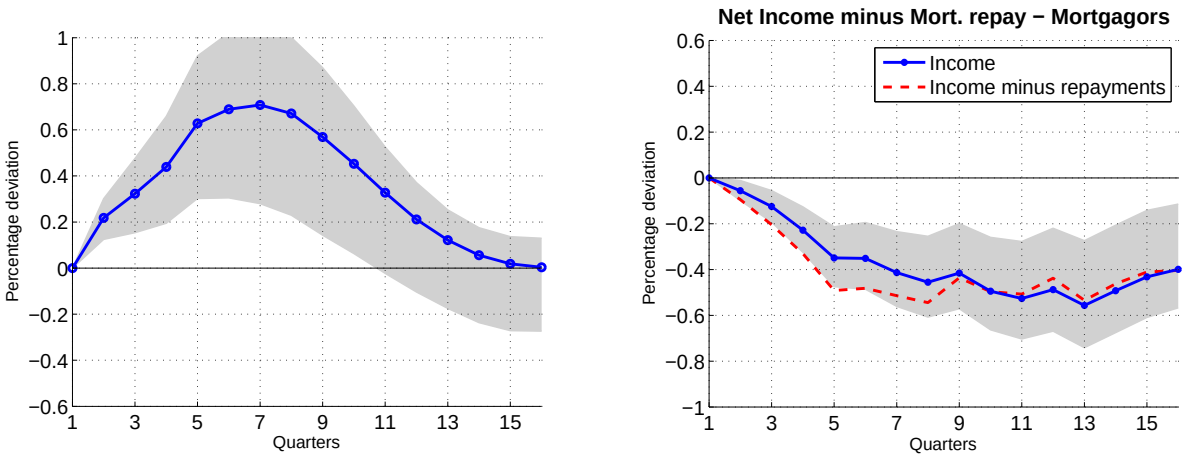


Figure 16: Impulse responses of the level of the average level of mortgage repayment (left) and the disposable income net of mortgage repayments (right). Computed using data from the Living Costs and Food Survey (LCFS).

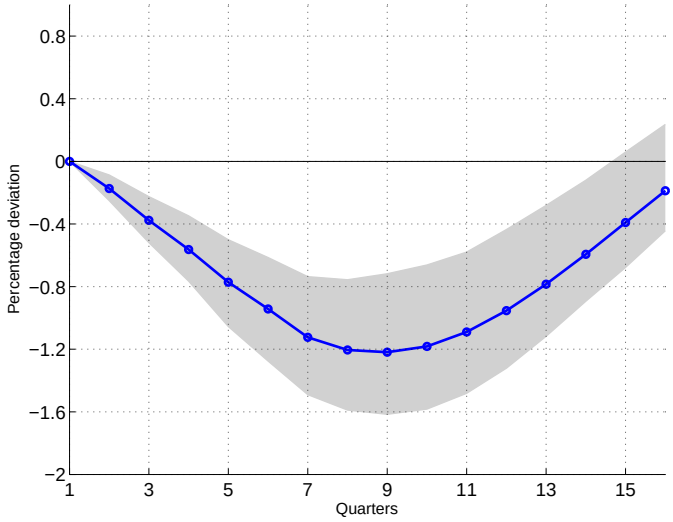


Figure 17: Response of real house prices

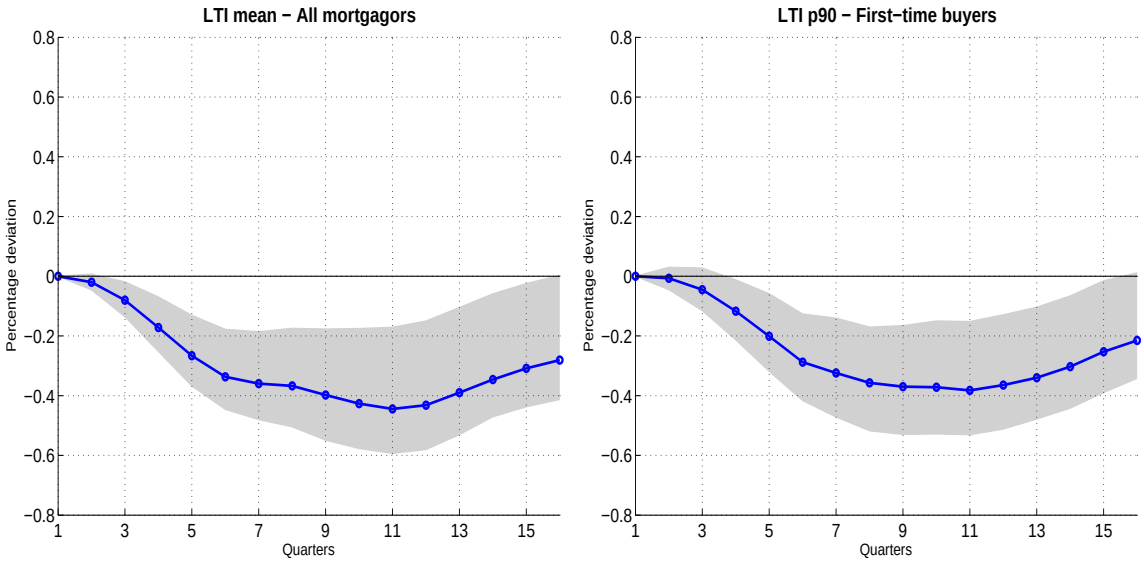


Figure 18: Response of loan to income ratios (mean, left; p90, right).

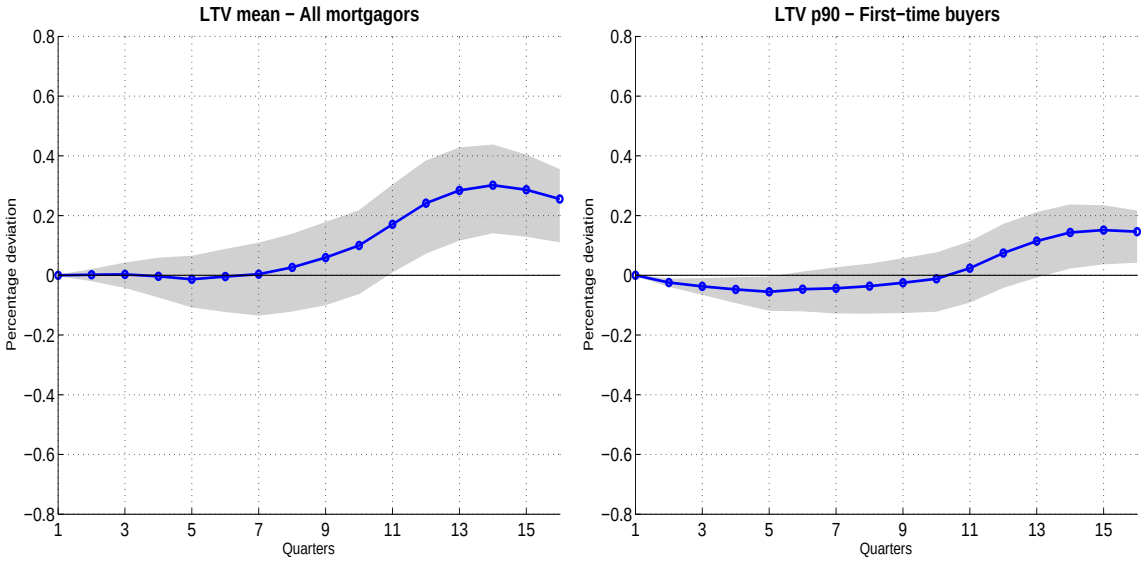


Figure 19: Response of loan to value ratios (mean, left; p90, right).

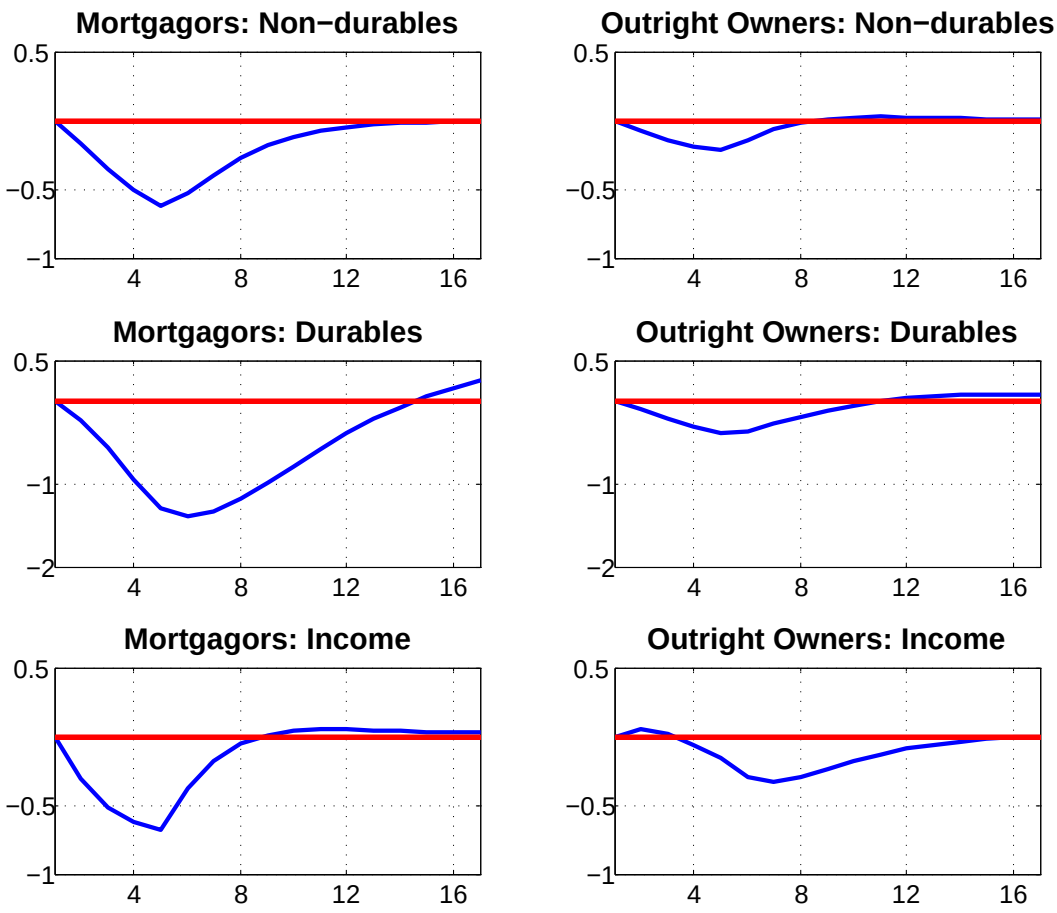


Figure 20: Model response of expenditure and income: mortgagors vs. outright owners.

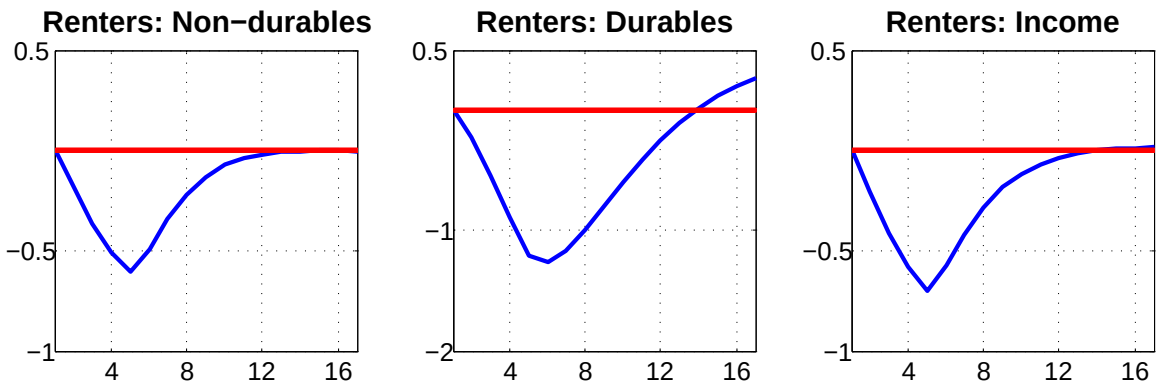


Figure 21: Model response of expenditure and income: renters.

Table 1: Some moments from the wealth distribution in 2005

	Net financial wealth[1]			**Net housing wealth**[2]			
	p25	***Median***	*p75*	*p25*	***Median***	*p75*	*Obs.*
Renters	-400	**0**	150	0	**0**	0	1,337
Mortgagors	-3,250	**0**	4,600	55,000	**95,000**	150,000	3,179
Outright owners	0	**3,000**	21,100	100,000	**150,000**	230,000	2,385

Note: Computed from the 2005 wave of the British Household Panel Survey (BHPS). Values in 2005 £. [1] **Net financial wealth** is defined as the value of savings and investments net of outstanding non-mortgage debt. [2] **Net housing wealth** is defined as the household's estimate of the property value net of any outstanding mortgage.

Table 2: Expenditures Relative to Income.

	Outright Owners	Mortgagors	
		Inc gross of repay	Inc net of repay
ND consum	0.143	**0.568**	**0.435**
D consum	0.168	**0.483**	**0.346**

Note: **Bold** figures represent statistical significance using 90% confidence intervals constructed from a non-parametric bootstrap with 5000 repetitions. Numbers are computed by cumulating the impulse response functions for 15 periods post shock. For details, see formula in the main text.

Parameter	Description	Value
$\theta/(1-\theta)$	elasticity of substitution between ND and D stock	4
σ	elasticity of intertemporal substitution	1
$\beta, \beta^{'}$	discount factor: mortgagors, outright owners	0.95, 0.99
$1/(\eta-1)$	Frisch elasticity of labor supply	3
μ	habits parameter	0.5
$\varepsilon_{C,D}$	elasticity varieties	7
$\vartheta_{C,D}$	price adjustment cost	50
m	max LTV (baseline)	0.60
ω_{IH}	share of mortgagors	40%
ω_{PH}	share outright owners	30%
r_π, r_Y, r_R	Taylor rule: CPI, output, smoothing	1.5,.05,.8

Table 3: Calibration of the model.

Appendices

Details of the model

The model can be seen as a stripped down version of Iacoviello (2005) but including durables as in Mertens and Ravn (2011) and two types of impatient households, one who has a preference for renting. Unlike in Monacelli (2009) households do not face a collateral constraint on their purchase of durables but instead face a collateral constraint according to their housing assets (as in Iacoviello (2005)). These extra features are important as they allow us to investigate key aspects of our empirical findings. There is a continuum of households, measure one, with each of the population shares calibrated to match our microdata.

7.1 Types of Households

There are three type of households defined in the following way. All households in the economy are either *patient households* (PH) or *impatient households* (IH) and differentiated by their discount factors β' and β respectively, with $0 < \beta < \beta' < 1$. Within the impatient households, there is a share ω_r of impatient renters and a share $\omega_m = 1 - \omega_r$ of impatient mortgagors. Below, variables for the patient households have no subscript, while variables for the impatient renters have a subscript r and variables for the impatient mortgagors have subscript m.

All households all derive utility from the consumption bundle x_t, housing (stock and / or services) $\tilde{h}_t$ and labor L_t. The period-utility for group i is given by

$$u\left(x_t, h_t, l_t\right) = \frac{x_t^{1-\sigma}}{1-\sigma} + j \log \tilde{h}_t - \frac{L_t^{\eta}}{\eta} \tag{10}$$

where $\sigma > 0$ is a curvature parameter, j is a housing demand parameter, and $\eta > 0$ is related to the Frisch elasticity of labor supply

The consumption bundle x_t is defined as

$$x_t \equiv C_t^{\theta} V_t^{1-\theta} - \mu C_{t-1}^{\theta} V_{t-1}^{1-\theta} \tag{11}$$

with C_t and V_t being non-durable consumption and the stock of durables, respectively; $\theta \in [0,1]$ is a share parameter and $\mu \in [0,1)$ captures habit persistence. We will allow η to differ across households. The stock of durables for a household evolves according to the following:

$$V_{t+1} = \left(1 - \Phi\left(\frac{D_t}{D_{t-1}}\right)\right) D_t + (1-\delta) V_t \tag{12}$$

where D_t denotes purchases of new durables, $\Phi\left(\frac{D_t}{D_{t-1}}\right) = \frac{\phi_d}{2}\left(\frac{D_t}{D_{t-1}}\right)^2$ captures the costs of adjusting durables, and δ is the rate of depreciation of consumer durables.

Households differ in their utility derived from housing. Define

$$\begin{aligned} h_t \in \mathbb{R}^+ &\equiv \text{housing } \textit{stock owned} \\ s_t^- \in \mathbb{R}^+ &\equiv \text{housing } \textit{services rented to others} \\ s_t^+ \in \mathbb{R}^+ &\equiv \text{housing } \textit{services rented from others} \end{aligned}$$

We assume that patient and impatient mortgagor households derive a higher marginal utility from their own stock of housing h_t than from rented housing s_t^+, such that

$$\tilde{h}_{t,i} = h_{t,i} + \gamma s_{t,i}^+ - s_{t,i}^- \quad i \in \{\text{o, m}\} \tag{13}$$

with $\gamma \in [0,1]$ capturing different reasons why households might prefer to own rather than to rent. For impatient renters, on the other hand, the marginal utility is equal whether its owned or rented,

$$\tilde{h}_{t,i} = h_{t,i} + s_{t,i}^+ - s_{t,i}^- \quad i = \text{r} \tag{14}$$

Households face an adjustment cost when adjusting the housing stock, given by

$$\xi_{h,t} = \phi_h \left(\frac{\Delta h_t}{h_{t-1}}\right)^2 \frac{q_t^h h_{t-1}}{2} \tag{15}$$

7.2 Residential housing and rental market

There is a fixed stock of housing H which is bought and sold at a price q_t. There is also a rental market through which households can rent a house for one period at a rate p_t.

All households face an individual housing *feasibility* constraint

$$h_{t,i} - s^-_{t,i} \geq 0 \tag{16}$$

meaning that they can not rent out to other households more than what they currently own, and they cannot sub-let. Note that restriction (16) together with the non-negativity of $s^-_{t,i}$ already imply that $h_{t,i} \geq 0$.

In equilibrium, it will also need to be the case that both markets clear

$$H = h_{t,m} + h_{t,r} + h_t \tag{17}$$

$$s^+_{t,r} + s^+_{t,m} + s^+_t = s^-_{t,r} + s^-_{t,m} + s^-_t \tag{18}$$

Equality (18) simply represents rental market clearing.

7.3 The impatient household's problem

The impatient households (borrowers in equilibrium) solves the following program

$$W = \max_{\{C_t, D_t, V_{t+1}, h_t, s^+_t, s^-_t, L_t, b_t\}} E_0 \sum_{t=0}^{\infty} \beta^t u\left(x_t, \tilde{h}_t, L_t\right)$$

subject to

$$C_t + q^d_t D_t + q^h_t \Delta h_t + \frac{R_{t-1}}{\pi_{c,t}} b_{t-1} + \xi_{h,t} = w_t L_t + b_t + p_t\left(s^-_t - s^+_t\right) + T_t \quad (\lambda_t) \tag{19}$$

$$V_{t+1} = \left(1 - \Phi\left(\frac{D_t}{D_{t-1}}\right)\right) D_t + (1-\delta) V_t \quad (\lambda^2_t) \tag{20}$$

$$\tilde{h}_t = \begin{cases} h_{t,i} + \gamma s^+_{t,i} - s^-_{t,i} & \text{if } i = IHm \\ h_{t,i} + s^+_{t,i} - s^-_{t,i} & \text{if } i = IHr \end{cases} \quad (\lambda^3_t) \tag{21}$$

$$h_t \geq 0 \quad (\lambda^4_t) \tag{22}$$

$$h_t - s^-_t \geq 0 \quad (\lambda^5_t) \tag{23}$$

$$s^-_t \geq 0 \quad (\lambda^6_t) \tag{24}$$

$$s^+_t \geq 0 \quad (\lambda^7_t) \tag{25}$$

and a collateral constraint as in Iacoviello (2005), steming from Kiyotaki & Moore (1997)

$$b_t \leq m^{LTV} E\left(\frac{q^h_{t+1} h_t \pi_{c,t+1}}{R_t}\right) \quad (\lambda^{BC}_t) \tag{26}$$

where $q^h \equiv \frac{P_h}{P_c}$ is the price of housing in terms of non-durables (the numeraire), $w_t \equiv \frac{W_t}{P_c}$ is the real wage and m^{LTV} is the steady state loan-to-value ratio; the associated Lagrange multipliers are between parenthesis. As mentioned above, the constraint (22) is redundant once constraints (23) and (24) are imposed. Therefore, in the optimization problems below, we will ignore it.

7.3.1 Impatient mortgagors

The optimality conditions for impatient mortgagors ($\gamma = 1$) are given by

$$
\begin{aligned}
C_t: \quad \lambda_t &= \frac{\partial u}{\partial x_t}\cdot\frac{\partial x_t}{\partial C_t}+\beta E_t\left(\frac{\partial u}{\partial x_{t+1}}\cdot\frac{\partial x_{t+1}}{\partial C_t}\right) && (27)\\
&= \theta\left(\frac{C_t}{V_t}\right)^{\theta-1}\left(x_t^{-\sigma}-\mu\beta E_t\left(x_{t+1}^{-\sigma}\right)\right)\\
D_t: \quad q_t^d &= q_t^v\left(1-\Phi\left(\frac{D_t}{D_{t-1}}\right)-\frac{\partial\Phi\left(\frac{D_t}{D_{t-1}}\right)}{\partial D_t}D_t\right)+\\
&\quad +\beta E_t\left(\frac{\lambda_{t+1}q_{t+1}^v}{\lambda_t}\frac{\partial\Phi\left(\frac{D_{t+1}}{D_t}\right)}{\partial D_t}D_{t+1}\right) && (28)\\
V_{t+1}: \quad \lambda_t q_t^v &= \beta E_t\left(\frac{\partial u}{\partial x_{t+1}}\cdot\frac{\partial x_{t+1}}{\partial V_{t+1}}+\beta\left(\frac{\partial u}{\partial x_{t+2}}\cdot\frac{\partial x_{t+2}}{\partial V_{t+1}}\right)+(1-\delta)\lambda_{t+1}q_{t+1}^v\right) && (29)\\
&= \beta E_t\left(\lambda_{t+1}\left(\frac{1-\theta}{\theta}\frac{C_{t+1}}{V_{t+1}}+(1-\delta)q_{t+1}^v\right)\right) && (30)\\
b_t: \quad \lambda_t &= \beta E_t\left(\lambda_{t+1}\frac{R_t}{\pi_{c,t+1}}\right)+\lambda_{BC,t}R_t && (31)\\
L_t: \quad L_t^{\eta-1} &= \lambda_t w_t && (32)\\
h_t: \quad \lambda_t\left(q_t^h+\frac{\partial\xi_{h,t}}{\partial h_t}\right) &= \frac{\partial u}{\partial h_t}+\beta E_t\left(\lambda_{t+1}\left(q_{t+1}^h+\frac{\partial\xi_{h,t+1}}{\partial h_t}\right)+m\lambda_{BC,t}q_{t+1}^h\pi_{c,t+1}\right)+\lambda_t^5 && (33)\\
&\Leftrightarrow\\
\lambda_t q_t^h\left(1+\phi_h\frac{\Delta h_t}{h_{t-1}}\right) &= \frac{j_t}{\tilde{h}_t}+E_t\left(\beta\lambda_{t+1}q_{t+1}^h\left(1+\phi_h\frac{\Delta h_{t+1}}{h_t}\right)+m\lambda_{BC,t}q_{t+1}^h\pi_{c,t+1}\right)+\lambda_t^5\\
s_t^+: \quad p_t\lambda_t &= \frac{j\gamma}{\tilde{h}_t}+\lambda_t^7 && (34)\\
s_t^-: \quad p_t\lambda_t &= \frac{j}{\tilde{h}_t}+\lambda_t^5-\lambda_t^6 && (35)
\end{aligned}
$$

together with the Kuhn-Tucker conditions

$$
\begin{aligned}
\lambda_t, \lambda_t q_t^v, \lambda_t^3, \lambda_t^5, \lambda_t^6, \lambda_t^7, \lambda_t^{BC} &\geq 0 && (36)\\
\lambda_t^{BC}\left(b_t R_t - mE_t\left(q_{t+1}^h h_t \pi_{t+1}\right)\right) &= 0 && (37)\\
\lambda_t^5\left(h_t - s_t^-\right) &= 0 && (38)\\
\lambda_t^6 s_t^- &= 0 && (39)\\
\lambda_t^7 s_t^+ &= 0 && (40)
\end{aligned}
$$

7.3.2 Impatient renters

The optimality conditions for impatient renters are given by

$$C_t^{''}: \quad \lambda_t^{''} = \frac{\partial u}{\partial x_t^{''}} \cdot \frac{\partial x_t^{''}}{\partial C_t^{''}} + \beta^{''} E_t \left(\frac{\partial u}{\partial x_{t+1}^{'}} \cdot \frac{\partial x_{t+1}^{'}}{\partial C_t^{'}} \right) \tag{41}$$

$$= \theta \left(\frac{C_t^{''}}{V_t^{''}} \right)^{\theta-1} \left(x_t^{''-\sigma} - \mu\beta^{''} E_t \left(x_{t+1}^{''-\sigma} \right) \right) \tag{42}$$

$$D_t^{''}: \quad q_t^d = q_t^v \left(1 - \Phi \left(\frac{D_t^{''}}{D_{t-1}^{''}} \right) - \frac{\partial \Phi \left(\frac{D_t^{''}}{D_{t-1}^{''}} \right)}{\partial D_t^{''}} D_t^{''} \right) +$$

$$+\beta^{''} E_t \left(\frac{\lambda_{t+1}^{''} q_{t+1}^v}{\lambda_t^{''}} D_{t+1}^{''} \frac{\partial \Phi \left(\frac{D_{t+1}^{''}}{D_t^{''}} \right)}{\partial D_t^{''}} \right) \tag{43}$$

$$V_{t+1}^{''}: \quad \lambda_t^{''} q_t^v = \beta^{''} E_t \left(\frac{\partial u}{\partial x_{t+1}^{''}} \cdot \frac{\partial x_{t+1}^{''}}{\partial V_{t+1}^{''}} + \beta^{''} \left(\frac{\partial u}{\partial x_{t+2}^{''}} \cdot \frac{\partial x_{t+2}^{''}}{\partial V_{t+1}^{''}} \right) + (1-\delta)\lambda_{t+1}^{''} q_{t+1}^v \right) \tag{44}$$

$$= \beta^{''} E_t \left(\lambda_{t+1}^{''} \left(\frac{1-\theta}{\theta} \frac{C_{t+1}^{''}}{V_{t+1}^{''}} + (1-\delta) q_{t+1}^{v''} \right) \right) \tag{45}$$

$$b_t^{''}: \quad \lambda_t^{''} = \beta E_t \left(\lambda_{t+1}^{''} \frac{R_t}{\pi_{c,t+1}} \right) + \lambda_{BC,t}^{''} R_t \tag{46}$$

$$L_t^{''}: \quad w_t \lambda_t^{''} = L_t^{''\eta^{''}-1} \tag{47}$$

$$h_t^{''}: \quad \lambda_t^{''} \left(q_t^h + \frac{\partial \xi_{h,t}}{\partial h_t^{''}} \right) = \frac{\partial u}{\partial h_t^{''}} + \beta E_t \left(\lambda_{t+1}^{''} \left(q_{t+1}^h + \frac{\partial \xi_{h,t+1}}{\partial h_t^{''}} \right) + m\lambda_{BC,t}^{''} q_{t+1}^h \pi_{c,t+1} \right) + \lambda_t^{5''} \tag{48}$$

$$\Leftrightarrow$$

$$\lambda_t^{''} q_t^h \left(1 + \phi_h \frac{\Delta h_t^{''}}{h_{t-1}^{''}} \right) = \frac{j_t}{\tilde{h}_t^{''}} + \beta E_t \left(\lambda_{t+1}^{''} q_{t+1}^h \left(1 + \phi_h \frac{\Delta h_{t+1}^{''}}{h_t^{''}} \right) + m\lambda_{BC,t}^{''} q_{t+1}^h \pi_{c,t+1} \right) + \lambda_t^{5''}$$

$$s_t^{+''}: \quad p_t \lambda_t^{''} = \frac{j}{\tilde{h}_t^{''}} + \lambda_t^{7''} \tag{49}$$

$$s_t^{-''}: \quad p_t \lambda_t^{''} = \frac{j}{\tilde{h}_t^{''}} + \lambda_t^{5''} - \lambda_t^{6''} \tag{50}$$

together with the Kuhn-Tucker conditions

$$\begin{aligned}
\lambda_t^{''}, \lambda_t^{''} q_t^v, \lambda_t^{3''}, \lambda_t^{5''}, \lambda_t^{6''}, \lambda_t^{7''}, \lambda_t^{BC''} &\geq 0 && (51)\\
\lambda_t^{BC''} \left(b_t^{''} R_t - mE_t \left(q_{t+1}^h h_t^{''} \pi_{t+1} \right) \right) &= 0 && (52)\\
\lambda_t^{5''} \left(h_t^{''} - s_t^{-''} \right) &= 0 && (53)\\
\lambda_t^{6''} s_t^{-''} &= 0 && (54)\\
\lambda_t^{7''} s_t^{+''} &= 0 && (55)
\end{aligned}$$

7.4 The patient household's problem

We assume there is a share ω_{PH} of patient households. We will denote the variables for the patient household with " $'$ ". The patient household (saver in equilibrium) has a discount factor $\beta^{'} > \beta$ and solves the following program

$$W^{'} = \max_{\left\{C_t^{'}, D_t^{'}, V_{t+1}^{'}, h_t^{'}, s_t^{+'}, s_t^{-'} L_t^{'}, b_t^{'}\right\}} E_0 \sum_{t=0}^{\infty} \beta^{'t} u \left(x_t^{'}, \tilde{h}_t^{'}, L_t^{'} \right)$$

subject to

$$\begin{aligned}
C_t^{'} + q_t^d D_t^{'} + q_t^h \Delta h_t^{'} + \frac{R_{t-1}}{\pi_{c,t}} b_{t-1}^{'} + \xi_{h,t} &= w_t L_t^{'} + b_t^{'} + p_t \left(s_t^{-} - s_t^{+} \right) + \Pi_{C,t} + \Pi_{D,c} + T_t^{'} \quad (\lambda_t^{'}) && (56)\\
V_{t+1}^{'} &= \left(1 - \Phi \left(\frac{D_t^{'}}{D_{t-1}^{'}} \right) \right) D_t^{'} + (1-\delta) V_t^{'} \quad (\lambda_t^{'} q_t^v) && (57)\\
\tilde{h}_t^{'} &= h_t^{'} + \gamma s_t^{+'} - s_t^{-'} \quad \left(\lambda_t^{3'} \right) && (58)\\
h_t^{'} &\geq 0 \quad \left(\lambda_t^{4'} \right) && (59)\\
h_t^{'} - s_t^{-'} &\geq 0 \quad \left(\lambda_t^{5'} \right) && (60)\\
s_t^{-'} &\geq 0 \quad \left(\lambda_t^{6'} \right) && (61)\\
s_t^{+'} &\geq 0 \quad \left(\lambda_t^{7'} \right) && (62)
\end{aligned}$$

where Π_C and Π_D are aggregate profits from the non-durable and durable sectors. The optimality conditions are given by

$$C_t: \quad \lambda_t^{'} = \frac{\partial u}{\partial x_t^{'}} \cdot \frac{\partial x_t^{'}}{\partial C_t^{'}} + \beta^{'} E_t \left(\frac{\partial u}{\partial x_{t+1}^{'}} \cdot \frac{\partial x_{t+1}^{'}}{\partial C_t^{'}} \right) \tag{63}$$

$$= \theta \left(\frac{C_t^{'}}{V_t^{'}} \right)^{\theta-1} \left(x_t^{'-\sigma} - \mu \beta^{'} E_t \left(x_{t+1}^{'-\sigma} \right) \right) \tag{64}$$

$$D_t: \quad q_t^d = q_t^v \left(1 - \Phi \left(\frac{D_t^{'}}{D_{t-1}^{'}} \right) - \frac{\partial \Phi \left(\frac{D_t^{'}}{D_{t-1}^{'}} \right)}{\partial D_t^{'}} D_t^{'} \right) +$$

$$+ \beta^{'} E_t \left(\frac{\lambda_{t+1}^{'} q_{t+1}^v}{\lambda_t^{'}} D_{t+1}^{'} \frac{\partial \Phi \left(\frac{D_{t+1}^{'}}{D_t^{'}} \right)}{\partial D_t^{'}} \right) \tag{65}$$

$$V_{t+1}: \quad \lambda_t^{'} q_t^v = \beta^{'} E_t \left(\frac{\partial u}{\partial x_{t+1}^{'}} \cdot \frac{\partial x_{t+1}^{'}}{\partial V_{t+1}^{'}} + \beta^{'} \left(\frac{\partial u}{\partial x_{t+2}^{'}} \cdot \frac{\partial x_{t+2}^{'}}{\partial V_{t+1}^{'}} \right) + (1-\delta) \lambda_{t+1}^{'} q_{t+1}^v \right) \tag{66}$$

$$= \beta^{'} E_t \left(\lambda_{t+1}^{'} \left(\frac{1-\theta}{\theta} \frac{C_{t+1}^{'}}{V_{t+1}^{'}} + (1-\delta) q_{t+1}^v \right) \right) \tag{67}$$

$$b_t: \quad \lambda_t^{'} = \beta^{'} E_t \left(\lambda_{t+1}^{'} \frac{R_t}{\pi_{c,t+1}} \right) \tag{68}$$

$$L_t: \quad L_t^{'\eta^{'}-1} = \lambda_t^{'} w_t \tag{69}$$

$$h_t: \quad \lambda_t^{'} \left(q_t^h + \frac{\partial \xi_{h,t}}{\partial h_t^{'}} \right) = \frac{\partial u}{\partial h_t^{'}} + \beta^{'} E \left(\lambda_{t+1}^{'} \left(q_{t+1}^h + \frac{\partial \xi_{h,t+1}}{\partial h_t^{'}} \right) \right) + \lambda_t^{5'} \tag{70}$$

$$\Leftrightarrow$$

$$\lambda_t^{'} q_t^h \left(1 + \phi_h \frac{\Delta h_t^{'}}{h_{t-1}^{'}} \right) = \frac{j_t}{\tilde{h}_t^{'}} + \beta^{'} E_t \left(\lambda_{t+1}^{'} q_{t+1}^h \left(1 + \phi_h \frac{\Delta h_{t+1}^{'}}{h_t^{'}} \right) \right) + \lambda_t^{5'}$$

$$s_t^{+'}: \quad p_t \lambda_t^{'} = \frac{j\gamma}{\tilde{h}_t^{'}} + \lambda_t^{7'} \tag{71}$$

$$s_t^{-'}: \quad p_t \lambda_t^{'} = \frac{j}{\tilde{h}_t^{'}} + \lambda_t^{5'} - \lambda_t^{6'} \tag{72}$$

7.5 Intermediate Firms

On the production side there are two types of intermediate goods firms producing a distinct durable or non-durable intermediate good. These firms face price adjustment costs as in Monacelli (2009) and this leads to movements in the relative price of durable goods relative to non-durables. In keeping with the standard New Keynesian

set-up, these firms are monopolistically competitive and produce output using labor:

$$Y_{j,t}(i) = L_{j,t}(i) \tag{73}$$

Subject to price adjustment costs:

$$AC_{j,t}(i) = \frac{\vartheta_j}{2}\Big(\frac{P_{j,t}(i)}{P_{j,t-1}(i)} - 1\Big)^2 Y_{j,t} \tag{74}$$

$\vartheta_j \geq 0$ measures price-stickiness.

7.6 Final goods firms

Competitive final good producers combined intermediate goods to produce a durable and non-durable final consumption good ($j = C, D$):

$$Y_{j,t} = \Big(\int_0^1 Y_{j,t}(i)^{\frac{\epsilon_j - 1}{\epsilon_j}} di\Big)^{\frac{\epsilon_j}{\epsilon_j - 1}} \tag{75}$$

Profit maximization imply a demand for variety i

$$Y^*_{j,t}(i) = \Big(\frac{P_{j,t}(i)}{P_{j,t}}\Big)^{-\epsilon_j} Y_{j,t} \tag{76}$$

and the sector-price index then is:

$$P_{j,t} \equiv \Big(\int_0^1 P_{j,t}(i)^{1-\epsilon_j} di\Big)^{\frac{1}{1-\epsilon_j}} \tag{77}$$

7.7 Price dynamics

Standard linearization of the intermediate goods firms' equilibrium conditions lead to two sectoral Phillips curves describing the evolution of durable and non-durable goods prices.

$$\hat{\pi}_{D,t} = \tilde{\beta} E_t\left(\hat{\pi}_{D,t+1}\right) + \left(\frac{\epsilon_D - 1}{\vartheta_D}\right) \hat{mc}_{D,t} \tag{78}$$

$$\hat{\pi}_{C,t} = \tilde{\beta} E_t\left(\hat{\pi}_{C,t+1}\right) + \left(\frac{\epsilon_C - 1}{\vartheta_C}\right) \hat{mc}_{C,t} \tag{79}$$

7.8 Monetary policy

Monetary policy is conducted by means of a simple Taylor rule,

$$R_t = (R_{t-1})^{r_R} E\left(\pi_{t+1}(1+r_\pi)\left(\frac{Y_{t+1}}{Y}\right)^{r_Y} \bar{rr}\right)^{1-r_R} \epsilon_{R,t} \tag{80}$$

7.9 Market Clearing

We abstract from fiscal transfers, and therefore set $T_t = T_t^{'} = T_t^{''} = 0$. The rest of the market clearing conditions are

$$\begin{aligned}
Y_{C,t} &= \omega_{IH}\left(C_t + \xi_{h,t}\right) + \omega_{PH}\left(C_t^{'} + \xi_{h,t}^{'}\right) + \left(1-\omega_{IH}-\omega_{PH}\right) C_t^{''} + \frac{\vartheta_C}{2}\left(\pi_{C,t}-1\right)^2 Y_{Ct} \\
Y_{D,t} &= \omega_{IH} D_t + \omega_{PH} D_t^{'} + \left(1-\omega_{IH}-\omega_{PH}\right) D_t^{''} + \frac{\vartheta_D}{2}\left(\pi_{D,t}-1\right)^2 Y_{Dt} \\
0 &= \omega_{IH} b_t + \omega_{PH} b_t^{'} + \left(1-\omega_{IH}-\omega_{PH}\right) b_t^{''} \\
H &= \omega_{IH} h_t + \omega_{PH} h_t^{'} + \left(1-\omega_{IH}-\omega_{PH}\right) h_t^{''} \\
s_t^{+''} + s_t^{+'} + s_t^{+} &= s_t^{-''} + s_t^{-'} + s_t^{-} \\
L_{C,t} + L_{D,t} &= \omega_{IH} L_t + \omega_{PH} L_t^{'} + \left(1-\omega_{IH}-\omega_{PH}\right) L_t^{''}
\end{aligned}$$

7.10 The steady state

In what follows, we linearize the main equilibrium conditions around a 0-inflation steady state ($SS^{\pi=0}$) in which:

1. Patient households own housing stock ($h^{'} > 0$) and rent out part of it ($s^{-'} > 0$)
2. Impatient renters do not own housing ($h^{''} = 0$) which means they cannot: (i) borrow ($b^{''} = 0$), and (ii) rent to others ($s^{-''} = 0$). They instead rent housing services from others ($s^{+''} > 0$)
3. Impatient mortgagors own housing ($h > 0$) but do not participate in the renting market ($s^{-} = s^{+} = 0$)

In such a steady state, therefore, the following must hold:

1. $\lambda^{5'} = \lambda^{6'} = 0$; $\lambda^{7'} \geq 0$

2. $\lambda^{5''} \geq 0$; $\lambda^{6''} \geq 0$; $\lambda^{7''} = 0$

3. $\lambda^{5} = 0$; $\lambda^{6} \geq 0$; $\lambda^{7} \geq 0$

Below, we show that such SS exists for an owning-preference $\gamma < \bar{\gamma}$. We assume that the conditions above also hold for states near the steady state. This is not a trivial assumption and essentially requires the wedge between the rental rate p_t and the house price q_t^h not to diverge too much from its value in the steady state $SS^{\pi=0}$ described above. As we will show, the wedge in steady state is

$$p = \left(1 - \beta^{'}\right) q^h.$$

Sketch proof of "Separation" In Steady State

At the SS interest rate $R = \frac{1}{\beta'}$, both mortgagors and renters households want to borrow in order to shift consumption from the future to the current period. To do so, due to frictions in credit markets, they need to own housing stock to use as collateral. A crucial element is the LTV being <1, or the "haircut" on the value of the collateral being >0. This will imply that an increase in the amount of collateralizable asset (in this case housing stock) they own, translates into a less than proportional increase in the resources available to borrow. The SS relative rental rate $\frac{p}{q^h} = 1 - \beta^{'}$ (determined such that assets have the same returns) implies that, given the perfect substitutability between renting and owning in terms of utility, a positive down-payment (m<1) will make it suboptimal for the renter to own (i.e. invest) in *any* amount housing stock. For the mortgagor, however, a sufficiently high "bias for owning", reflected in a sufficiently low γ, implies they can overcome the relatively high $\frac{q^h}{p}$ by buying a house "smaller" than the one they would otherwise rent, and using it to get a collateralized loan (a mortgage).

What the above means is that the collateral value of a house *per se* is not enough incentive for the impatient households to invest / buy a house. What we are adding in our set-up is the assumption that, for some households, the services provided by a rented house are less valuable in terms of utility than the services provided by an own house.

The arguments above make use of the fact that owning a house and renting are substitutes in terms of the utility generated. This implies that an increase of Δ units of housing stock h generates the *same* increase in utility as an increase of $\frac{1}{\gamma}\Delta$ units of rented housing s^+ (with $\gamma = 1$ in the case of impatient renter households):

$$u\left(h + \Delta + \gamma s^+ - s^-\right) = u\left(h + \gamma\left(s^+ + \frac{1}{\gamma}\Delta\right) - s^-\right) \tag{81}$$

The proof shows that, in a SS equilibrium with active mortgage markets, the relative rental rate needs to be

$$p = q^h\left(1 - \beta^{'}\right)$$

in which case the patient households will be indifferent between lending and buy-to-rent, and under which impatient mortgagors will want to own for a sufficiently low γ. For $p > q^h\left(1 - \beta^{'}\right)$, the patient households would prefer not to lend funds through the mortgage market, but to buy-to-let as much as possible. For such relative prices, we will see that the return of a buy-to-let strategy is such that $R^{buy-to-let} > R$. This would imply a collapse of the mortgage market and unbounded consumption growth, unless it bring the housing price up and back to $p = q^h\left(1 - \beta^{'}\right)$. For $p < q^h\left(1 - \beta^{'}\right)$, it will be the case that neither patient nor impatient mortgagors will be willing to engage in buy-to-let, and therefore no household will be willing to rent to renters.

Descriptive statistics

Table 4: Descriptive Statistics for Birth Cohorts, 1975q1 - 2007q4

	Older[1]	**Middle Aged**[2]	**Younger**[3]	**Mortgagors**	**Owners**
Educated	0.28	0.39	0.49	0.51	0.41
Employed	0.17	0.63	0.79	0.87	0.34
Earnings	170.51	675.23	944.98	1107.62	365.62
Net Income	967.17	1184.50	1183.91	1387.53	1167.25
Soc. Renters	0.32	0.21	0.21	-	-
Priv. Renters	0.06	0.05	0.16	-	-
Mortgagors	0.07	0.40	0.52	-	-
O. Owners	0.48	0.28	0.05	-	-

[1] **Older:** born before 1930. [2] **Middle Aged:** born bewteen 1930 and 1949.
[3] **Younger:** born after 1949.

Table 5: Descriptive Statistics for Housing Tenure Cohorts, 1975q1 - 2007q4

	Social Renters			
	Mean	**St. Dev.**	**Min**	**Max**
Educated	0.20	0.04	0.11	0.35
Employed	0.37	0.12	0.24	0.67
Earnings	322.60	79.18	169.73	511.98
Net Income	762.44	94.44	625.47	972.14

	Private Renters			
	Mean	**St. Dev.**	**Min**	**Max**
Educated	0.49	0.09	0.28	0.74
Employed	0.57	0.08	0.41	0.76
Earnings	710.22	210.01	375.15	1240.06
Net Income	1091.87	234.15	721.32	1591.83

	Mortgagors			
	Mean	**St. Dev.**	**Min**	**Max**
Educated	0.51	0.03	0.45	0.58
Employed	0.87	0.03	0.81	0.94
Earnings	1107.62	233.57	719.40	1512.60
Net Income	1387.53	325.78	851.86	1948.60

	Outright Owners			
	Mean	**St. Dev.**	**Min**	**Max**
Educated	0.41	0.06	0.27	0.55
Employed	0.34	0.07	0.23	0.54
Earnings	365.62	70.17	247.10	588.54
Net Income	1167.25	262.99	726.94	1663.21

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