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

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Abstract

In response to an interest rate change, mortgagors in the United Kingdom and United States adjust their spending significantly (especially on durable goods) but outright home-owners do not. While the dollar change in mortgage payments is nearly three times larger in the United Kingdom than in the United States, these magnitudes are much smaller than the overall change in expenditure. In contrast, the income change is sizable and similar across both household groups and countries. Consistent with the predictions of a simple heterogeneous agents model with credit-constrained households and multi-period fixed-rate debt contracts, our evidence suggests that the general equilibrium effect of monetary policy on income is quantitatively more important than the direct effect on cash flows.

Key words: Monetary policy, mortgage debt, liquidity constraints.

JEL classification: E21, E32, E52.

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1 Introduction

How monetary policy affects the real economy is one of the oldest and most intensively investigated topics in macroeconomics. In many of the models with nominal rigidities that are widely used in academic and policy circles, interest rate changes primarily affect the price of consumption today relative to the price of consumption tomorrow — the so-called intertemporal substitution channel. But the recent financial crisis has sparked renewed interest in whether other, less explored, mechanisms might complement, amplify or even dominate the quantitative effects implied by intertemporal substitution alone.

Two often discussed examples relate to the household balance sheet. In particular, the impact of interest rates on households, and the economy more generally, could be significantly affected by (i) the structure of the mortgage market, especially the prevalence of adjustable rate versus fixed rate contracts, (ii) the possibility that households with mortgage debt face some form of liquidity constraints. While a number of important recent theoretical and empirical contributions have improved our understanding of how the transmission mechanism may work, a detailed empirical analysis of which channels are quantitatively more important is still lacking. Furthermore, despite all the recent attention paid to the role of household indebtedness in shaping business cycle fluctuations, we are not aware of empirical studies that quantitatively examine the ways in which mortgage debt may affect the transmission of monetary policy. This paper attempts to fill the gap by providing evidence using household survey data for the United States and the United Kingdom.

In an important dimension, the U.S. and U.K. mortgage markets are often described as polar opposites. The majority of British products are characterized by relatively adjustable rates and shorter durations whilst most American products tend to have fixed rates and longer durations. If these structural differences in the mortgage markets play a significant role in the transmission of monetary policy we should observe two things. First, the direct interest rate effect on mortgage repayments should be significantly larger in the U.K. than in the U.S. We find evidence that this

is indeed the case. Second, if this direct effect is the most quantitatively important channel, the difference between the expenditure of home-owners with a mortgage and home-owners without a mortgage should be significantly larger in the U.K. than in the U.S. In other words, the expenditure differences between these housing tenure groups should largely reflect the magnitude of the effect on mortgage repayments. However, our evidence does not support this second prediction.

On the other hand, if households with debt cannot easily smooth consumption (because, for instance, additional equity extraction is constrained by collateral values or by transaction costs associated with accessing illiquid wealth), the change in mortgagors' spending should be significantly larger than that of outright owners in both countries. Furthermore, in general equilibrium, there should be an effect on household income for all groups, implying a higher marginal propensity to consume for households with debt. If this mechanism is quantitatively more important than the direct cash flow effect, there should be similar expenditure differences between mortgagors and outright owners in two relatively different mortgage markets like the U.S. and U.K. Our evidence is indeed consistent with this hypothesis.

In looking at the disaggregated effects of monetary policy, we face a number of empirical and econometric challenges. Specifically, we need good quality micro data on expenditures and income, together with information on household balance sheets over a long period of time. Few, if any, datasets include this information. We therefore use rich micro data from the Living Costs and Food Survey (for the U.K.) and the Consumer Expenditure Survey (for the U.S.) and focus on a household's housing tenure status — specifically whether they own their home with or without a mortgage — as a proxy for their balance sheet position. Housing tenure status is then used to aggregate individual households into a group with debt (mortgagors) and a group without debt (outright home-owners). To tackle the reverse causality problem between interest rates and consumption, we measure monetary policy shocks using the identification strategy of Romer and Romer (2004) for the United States and applied to the United Kingdom by Cloyne and Huertgen (2015).

Our main empirical findings can be summarized as follows. Following a change in monetary policy, in both countries households with mortgage debt adjust their expenditure considerably more than outright owners without debt. The heterogeneity is far more pronounced for durable goods than for non-durable goods and services. The direct effect on mortgage repayments in dollars is nearly three times larger in the U.K. than in the U.S. (for a cumulative interest rate change of the same size). But, even for the U.K., the repayment effect in dollars is still much smaller (both statistically and economically) than the dollar change in total expenditure. The income of *all* housing tenure groups, however, responds significantly following a monetary policy shock, and these income changes are of the same order of magnitude as the mortgagors' expenditure response.

We interpret the similar and sizable response of expenditure relative to income for mortgagors in both countries as suggestive evidence that (i) households with mortgage debt tend to be liquidity constrained and (ii) the general equilibrium effect of monetary policy on income seems quantitatively more important than the direct effect of interest rate changes on cash-flows. We also show that, in both countries, between 40% and 50% of households with mortgage debt tend to live with net liquid wealth below half of their monthly income. This group therefore seems to feature a significant proportion of households who are liquidity constrained despite possessing sizable illiquid assets (i.e. they are 'wealthy' hand-to-mouth in the definition proposed by Kaplan and Violante (2014)).

To corroborate the interpretation of our empirical findings, we lay out a simple heterogeneous agent model featuring a liquidity constraint and multi-period debt (where we can vary a single parameter to reflect the different average fixed-rate contract durations in two mortgage markets like the U.S. and U.K.). We first employ an exogenous credit limit. This demonstrates the quantitative importance of a simple liquidity constraint in a world where two economies are subject to a different mix of adjustable rate and fixed rate contracts. We then extend the framework to include a constraint tied to the collateral value of a mortgagor's housing assets and

an endogenous housing tenure decision between buying a property with a mortgage and renting. Both models are able to replicate qualitatively our empirical findings. The performance of the extended model, however, appears quantitatively superior, suggesting that additional amplification mechanisms — whether in the form of a (housing) collateral constraint as in Iacoviello (2005) and Kiyotaki and Moore (1997) or in the form of some transaction costs associated with accessing illiquid wealth as in Kaplan and Violante (2014) — play an important role in fully accounting for the aggregate and heterogeneous effects of monetary policy on the real economy.

Related literature. This work relates to four strands of the literature. First, we provide empirical support for theoretical mechanisms that emphasize the role of debt-constrained agents in the transmission of economic shocks. Prominent examples include Kaplan and Violante (2014), Kaplan et al. (2015), Bayer et al. (2015), Ragot (2014), Eggertsson and Krugman (2012) and Iacoviello (2005).

Second, we contribute to the large body of evidence on the relationship between the housing market, credit and real activity, with Mian et al. (2013), Mian et al. (2015), Guerrieri and Iacoviello (2014), Aladangady (2014), Jorda et al. (2014), Justiniano et al. (2015, 2014) and Cloyne and Surico (2015) being recent examples. While we share an emphasis on developments in the mortgage market, unlike most of these contributions we use expenditure survey data to explore interesting dimensions of heterogeneity which can be used to identify the groups that are most likely to drive the aggregate effects of monetary policy.

Third, we relate to a growing literature studying how the structure of the mortgage market (and repayments in particular) affects the transmission of monetary policy. On the theoretical side, this includes Calza et al. (2013) (who also explore this empirically using aggregate data), Garriga et al. (2013) and Auclert (2015). More recent empirical work using micro data includes Keys et al. (2015) and Di Maggio et al. (2015). While we also consider the response of mortgage payments, our empirical analysis focuses on the joint response of income, non-durable consumption and

durable expenditure. We show that considering all these responses is important for assessing the relative merits of competing views of the monetary transmission.

Finally, our findings complement the evidence from an increasing number of studies, including Coibion et al. (2012), Gornemann et al. (2012), Sterk and Tenreyro (2015) and Wong (2015), which report some heterogeneity in the consumption response to monetary policy across demographic groups. In contrast, we focus on household debt positions and find strong evidence of heterogeneity over and above any possible heterogeneity arising from demographic factors alone.

Structure of the paper. The rest of the paper is structured as follows. Section 2 presents the datasets, discusses the identification of the monetary policy shocks and the strategy of grouping households by their heterogeneous debt positions. The baseline estimates are reported in Section 3, together with evidence that a significant portion of mortgagors are 'wealthy' hand-to-mouth. We also show that the general equilibrium effect on income is quantitatively more important that the direct effect of interest rate changes on interest cash-flows. Further empirical results are presented in Section 4, where we assess whether other traits such as demographics or compositional changes in the housing tenure groups may be responsible for our findings. In Section 5, we examine the extent to which the predictions of a class of heterogeneous agent models with a liquidity constraint and multi-period debt are consistent with our novel empirical findings on the transmission of monetary policy. The Appendices provide some additional results, detail the derivation of the theoretical models and report the response of house prices and housing equity withdrawal to a monetary policy shock.

2 Data and empirical framework

In this section, we describe our main sources of household survey data and the variables we use. We then lay out the strategy to group individual observations into pseudo-cohorts using housing tenure status to proxy a household's debt position and

discuss the identification of the monetary policy shocks. Finally, we present the empirical specification that we use.

2.1 Household survey data

In order to measure how different types of consumers respond to monetary policy across spending categories, we use household survey data with rich coverage of expenditure variables. For the U.K., this is the Living Costs and Food Survey (LCFS), previously known as the Family Expenditure Survey (FES). For the U.S., we use the Consumer Expenditure Survey (CEX).

We make use of detailed information on weekly expenditures both on non-durable goods and services, and on durable goods (excluding housing and rental-related costs), as well as on household income.[1] The latter is defined as labor income (wages and salaries) plus non-labor income (income from investments and social security payments), net of taxes paid by each household. In the appendix, we provide a more detailed description of the variable definitions and the sample restrictions.

In addition, the survey provides information on other two sets of variables which will be useful for our main empirical estimation: (i) demographics, in particular household size and the year of birth of the household head, (ii) mortgage payments for households with outstanding debt. On the one hand, the information on birth years will be used to verify that the heterogeneity we uncover across housing tenure groups does not reflect (omitted) differences in life-cycle positions (as opposed to genuine differences in debt positions that are independent of demographics). On the other hand, the mortgage payments data will be used to quantify the extent to which differences in mortgage market structures across the two countries, specifically that

[1] As documented in the household consumption literature (Aguiar and Bils (2015) and Attanasio et al. (2006) using the U.S. Consumer Expenditure Survey (CEX) and Crossley et al. (2012) and Brewer and O'Dea (2012) using the U.K. LCFS), the non-durable consumption and the durable expenditure reported by households fall short, when aggregated, of the figures in the U.K. and U.S. National Accounts. Following this literature, we adjust the household data in the following way: in each quarter and *for each* household, we scale-up the reported expenditure categories (either non-durable or durable) using the inverse of the ratio of aggregated expenditure (implied by the LCFS/CEX) to the values in the National Accounts.

the share of adjustable rate products in the U.K. is significantly larger than in the U.S., may change the effectiveness of monetary policy. The information on household size will allow us to conduct the analysis at the per capita level.

We convert weekly data into a quarterly time series using the date of interview. The resulting series is then deflated by the Retail Prices Index (excluding mortgage interest payments) for the U.K. and the Consumer Price Index for the U.S. to convert the data into real series. Our sample covers 1975 to 2007 for the U.K. and 1981 to 2007 for the U.S.. The key variables of interest are available in the FES from the mid-1970s whereas the CEX begins in 1981. Our focus is on interest rate changes, so we deliberately stop just prior to the financial crisis, excluding the period of "unconventional" monetary policy.

2.2 Grouping households into pseudo-cohorts

The first empirical challenge we face is that, to our knowledge, there are few, if any, datasets that contain disaggregated information on *both* (i) wealth/household balance sheets and (ii) a rich array of expenditure categories at the household level over a sufficiently long period of time. Unfortunately, the LCFS and the CEX are no exceptions but they do record detailed expenditure and income data as well as information on housing tenure positions, namely whether a household lives in rented accommodation, is an owner-occupier with a mortgage or owns the property outright without a mortgage. As shown in Cloyne and Surico (2015) for the U.K. — and further explored here for both the U.K. and the U.S. — housing tenure status is an effective proxy for the household debt position. This allows us to bypass the drawback that most surveys with rich expenditure data contain little other information about household balance sheets. Accordingly, and in keeping with the tradition of Browning et al. (1985), we employ a grouping estimator to aggregate individual observations into pseudo-cohorts by housing tenure.

At this point, it is worth discussing two potential concerns about grouping households by their housing tenure status. The first concern is about compositional change,

namely that a household may change housing tenure status in response to a monetary policy shock. The second concern is about selection, namely that the assignments into the mortgagor and outright owner tenure groups are not random and some other (unobserved) characteristics may be potentially responsible for the heterogeneity in our estimated responses.

In terms of compositional changes, the time series of the tenure shares in Figure 1 are clearly slow-moving. The variation in monetary policy we exploit, however, occurs at a much higher frequency (as can be seen from Figure 2). In Section 4, we formally provide evidence that compositional change seems unlikely to be driving our results by showing that the monetary policy shocks do not significantly affect the shares of households in each housing tenure group.

Turning to the issue of selection, a number of factors seem to make it less severe in our context. First, the choice to group by housing tenure can be motivated from various theoretical frameworks. For example, the distinction between households with and without mortgage debt fits well with the predictions of a range of theoretical heterogeneous agent models that would imply heterogeneous expenditure responses to monetary policy shocks. Prominent examples include the financial accelerator mechanism in Iacoviello (2005), following Kiyotaki and Moore (1997), where a collateral constraint governs the household's ability to extract equity from housing and the 'wealthy' hand-to-mouth framework in Kaplan and Violante (2014) where households have to pay a transaction cost to access their net illiquid wealth. Since our mortgagor group appears to have a close mapping with the constrained households in these models, our estimates can shed light on the empirical relevance of these theoretical mechanisms.

Second, we document in Section 3 that between 40% and 50% of mortgagors live with net liquid wealth below half of their monthly income and therefore appear far more likely to be liquidity constrained than outright owners. Hence, housing tenure seems a good predictor of the household's balance sheet position.[2]

[2] Kaplan and Violante (2014) for the U.S., Cloyne and Surico (2015) for the U.K. and Kaplan et al. (2014) for a number of other advanced economies show that households with mortgage debt

Third, one of our main findings — namely that the direct effect of monetary policy on interest payments seems less important in the aggregate than the indirect effect — is not based on a comparison across housing tenures but on the relative magnitude of the responses of two different variables (mortgage payments and income) for the *same* household group (mortgagors). Furthermore, we show that income responds by a similar order of magnitude for all housing tenure groups.

Finally, in Section 4, we discuss other possible explanations and show that our results for mortgagors and outright owners are robust to controlling for these other mechanisms. In particular, we show that the expenditure response of young mortgagors appears to be similar to the response of middle-aged mortgagors. The responses of middle-aged outright owners and middle-aged mortgagors are, however, still significantly different. We interpret this further evidence as suggesting that the heterogeneity that we uncover based on housing tenure exists over and above any possible heterogeneity purely due to demographics.

Selected descriptive statistics for all housing tenure groups are reported in Appendix A. There appears to be some (small) differences across the distributions of per-capita income and across the shares of post-compulsory educational attainment between mortgagors and outright owners. While the age difference between these two groups seems larger, (i) the age distributions for mortgagors and outright owners still overlap significantly and (ii) as already noted, the heterogeneous responses across housing tenure groups are not over turned in the sensitivity analysis of Section 4 where we further control for demographics.

Before ending this section, it is also worth noting that we have information on the remaining group of households in the sample, namely renters. These are a relatively heterogeneous group comprised of social renters (those renting from local authorities and housing associations or benefiting from certain government transfers) and private renters (who — on average — tend to represent around 10 % of the population). The balance sheet information presented in Cloyne and Surico (2015) suggests that

also tend to have higher levels of unsecured debt relative to outright owners.

renters are likely to be an interesting proxy for the type of liquidity constrained households typically found in one asset models. While our main focus in Section 3 is on the comparison between home-owners with mortgage debt and home-owners without mortgage debt, the results for renters are of independent interest as one may expect their responses to be more similar to those of mortgagors than outright owners. The findings for renters' expenditure and income responses are explored in Section 4.

2.3 Identification

Our goal is to examine the effect of monetary policy on the spending and income of different *groups* of households. As such, we face the usual macroeconomic reverse causation problem: the economy responds to movements in monetary policy, but monetary policy also responds to developments in the macroeconomy. To identify unanticipated changes in the short-term interest rate we need a monetary policy shock series that can be used for estimation.

There is a vast literature on the identification of monetary policy changes. Older approaches, mainly developed for the United States, relied on timing restrictions and a Choleski decomposition of the variance-covariance matrix of the residuals from a Vector Autoregression, such as Christiano et al. (1996, 1999). But when applied to the United Kingdom, this method produces a large rise in inflation following a monetary contraction, the so-called price puzzle, even after controlling for variables shown to ameliorate this issue for the U.S. (Cloyne and Huertgen (2015)). Another 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 and forecasts to reflect the forward-looking nature of monetary policy. Cloyne and Huertgen (2015) construct a measure for the U.K. employing this methodology and show that it improves on conventional

VAR methods. Hence, we use an updated version of the Romer and Romer (2004) shock series for the U.S. (whose original analysis ended in 1996) and the Cloyne and Huertgen (2015) shock series for the UK.[3] One particular advantage of using shocks based on the Romer and Romer (2004) method is that we have two comparable series across the two countries we study.

The shock series match the micro-data sample periods, which are from 1975 to 2007 for the U.K. and 1981 to 2007 for the U.S. The shock series deliberately stop before the recent financial crisis, when the policy rate hit the zero bound in both countries. To boost the number of household observations used to generate the pseudo-cohorts at each point in time, we aggregate household survey variables to a quarterly frequency. The original shock series are monthly but, following Romer and Romer (2004) and Coibion (2012), we sum up the monthly innovations to obtain a quarterly series. The construction of the U.K. series also allows for a break in 1993 around the adoption of the inflation targeting framework. The monetary policy shock series for the two countries are shown in Figure 2.

Cohort-specific Granger causality. The shock series we use should already be regarded as monetary innovations from a macroeconomic perspective. But there is still a concern that the monetary policymakers might have been reacting to the conditions in particular groups. While some of this should be captured in the policymakers' forecasts, for example if they were concerned about developments in the housing market, it is useful for our purposes to test whether the U.S. and U.K. shock series can be predicted by movements in cohort level consumption and income. Finding that these shocks are unpredictable on the basis of cohort level concerns would therefore be reassuring. Specifically, we conduct Granger causality tests based on a VAR which contains consumption, expenditure and income per capita for each household group. We cannot reject the hypothesis that the cohort-specific time-series from household survey data (as well as the aggregate time-series from national statistics) do not

[3]Unfortunately, the length of the sample that we consider prevents us from using a high frequency identification strategy as in Gertler and Karadi (2015).

Granger cause the monetary policy shocks in each country.

2.4 Empirical specification

Using the two monetary policy shock series, our empirical specification closely resembles Romer and Romer (2004). Accordingly, we 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 short samples. Specifically, we estimate the following equation:

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

where $X_{i,t}$ is real non-durable consumption, durable expenditure or income recorded by households interviewed at time t.[4] The monetary policy shocks are denoted by S and Z is a vector with additional controls, including quarterly dummies. The α terms represent intercepts and coefficients on a time trend polynomial, with a break in 1993 for the U.K. and no break for the U.S.. Finally, $i \in Mortgagors, OutrightOwners, Renters$ represents the housing tenure group each household belongs to. The orders of the lag polynomials are chosen using an optimal lag length criteria, namely the corrected AIC.[5] Standard errors are bootstrapped using a recursive wild bootstrap.

3 Main findings

In this section, we present the results from estimating our benchmark specification (1) with both aggregate and cohort level data. In order to make the results comparable with the previous literature, all the impulse response functions (IRFs) are computed by simulating a 25 basis points (bp) *temporary* cut in the policy rate. All figures

[4] Households interviewed at time t are typically asked to report expenditure over the previous three months (with the exception of non-durable consumption in the LCFS which refers to the previous two weeks). 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.

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

display point estimates together with bootstrapped 90% confidence bands generated from 5000 resamples. We begin with evidence using official national statistics before presenting results for non-durable consumption, durable expenditure, income and mortgage repayments using household survey data. In the last part of this section, we transform the percent changes estimated from our IRFs into the implied dollar changes and find that the mortgagor group's expenditure responds the most relative to income. Finally, we use data from the American Survey of Consumer Finance and the British Household Panel Survey to provide independent evidence on the extent to which mortgagors may be liquidity constrained despite owing sizable illiquid assets.

3.1 Evidence from official national statistics

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 U.K. and U.S. official aggregate statistics. These results are presented in Figure 3. We find that a cut in the policy rate raises durable expenditure, non-durable expenditure and disposable income. More specifically, a 25 basis point monetary policy expansion leads to (i) a persistent (but small) rise in non-durable consumption, which peaks at around 0.2% after about 10 quarters for the U.K. and 0.1% after 11 quarters for the U.S., (ii) a larger *percentage* increase in durable expenditure (peaking at 1.2% for the U.K. and 1% for the U.S.), consistent with the evidence in Barsky et al. (2007) and Sterk and Tenreyro (2015) and (iii) a rise in household income (that reaches its maximum at 0.4% in the U.K. and just below 0.3% in the U.S.). While the U.K. aggregate variables tend to exhibit a slightly larger adjustment, the differences between the two countries are not large or significant. But to establish the possible role of indebted households, including the direct effect of interest rate changes on mortgage payments, we need to look at the more disaggregated behavior of different housing tenure groups.

3.2 Evidence from household expenditure survey data

We now explore the heterogeneous response by housing tenure status. The results comparing mortgagors and outright owners can be seen in Figure 4 for the consumption of non-durable goods and services, in Figure 5 for the durable good expenditure, in Figure 6 for mortgage payments (mortgagors only) and in Figure 7 for income. The corresponding variables for renters are discussed in Section 4 and presented in Appendix Figure 20. In each chart, the top row refers to the U.K. and the bottom row to the U.S.. The left column corresponds to the behavior of mortgagors, the right column refers to outright owners.

Beginning with the response of non-durable consumption in Figure 4, the response of mortgagors tends to be larger than the adjustment made by outright owners. Specifically, the response of households with mortgage debt in the U.K. peaks at 0.3% after about 10 quarters but the response of households without debt is never statistically different from zero, suggesting that the behavior of mortgagors drives the aggregate result for non-durables in Figure 3. For the U.S. the pattern is similar, with the peak response in the left column reaching about 0.25%.

Strong evidence of a heterogeneous effect between groups can also be seen in the response of durable expenditures in Figure 5. The heterogeneity between housing tenure groups is now starker. The response of U.K. mortgagors' expenditure peaks at around 1.2%, whereas the reaction of outright owners' durables is statistically indistinguishable from zero. The bottom row paints a similar picture for the U.S., with the significant and persistent response of households with debt peaking around 1.2%, and driving the aggregate durable response reported in Figure 3.

In summary, in response to a monetary policy shock, the percentage changes in expenditure tend to be large and significant for mortgagors but small and insignificant for outright owners. Furthermore, this heterogeneity is far more pronounced for durable goods. Importantly, there does not seem to be any significant difference across the two countries. While the lack of heterogeneity in the response of mortgagors between the U.K and U.S. may already suggest a limited role for the different

mortgage market structures, in the next subsection we tackle this directly.

3.3 The response of mortgage payments and income

A possible explanation for the sensitivity of mortgagors' expenditure to monetary policy is that a change in the interest rate triggers a *direct* effect on mortgage payments. More specifically, a monetary expansion should lead to a fall in interest payments for borrowers and a fall in interest income for savers. But for this redistribution to have an impact on the wider economy, it would still need to be the case that borrowers (the mortgagor group in our context) are credit constrained, so that these cash flow effects do not net-out in the aggregate. This is where the comparison between the U.S. and the U.K. is an ideal assessment of this hypothesis. The U.S. tends to have longer duration mortgage contracts and a dominance of fixed rate products whereas the U.K. has shorter duration contracts and more variable rate products. As such, it should be that the effective lending rates facing indebted American households are relatively insensitive, leading to a smaller change in their repayments following a monetary expansion.

As discussed in Section 2, we use household mortgage payments from the LCFS and the CEX. Figure 6 reports the impulse response function for the *percentage change* in this variable following a cut in the policy rate, revealing that mortgage payments fall significantly following a monetary expansion. The response for the U.K. appears considerably faster than in the U.S., peaking at around 0.7% versus the U.S. peak of around 0.4%. As we show in the next section, these estimates imply that the direct effect of interest rate changes on repayments is nearly three times larger in the United Kingdom than in the United States. This is intuitive given the differences in the mortgage market structures. Our results therefore suggest that the distinction between adjustable and fixed rates may play some quantitative role in the transmission of monetary policy.

A different (but not mutually exclusive) explanation for the mortgagors' expenditure response, however, is that the bulk of the effects of the interest rate change is in

fact *indirect*. This can be best understood by looking at joint responses of consumption *and* income. Figure 7 shows that income responds significantly for both housing tenure groups and in a similar proportion across the two countries, with the average point estimates for mortgagors and outright owners typically around $0.3 - 0.4\%$.[6] In the next section, we show that the percentage changes in Figure 7 map into dollar changes in income that are significantly larger than the dollar changes in mortgage payments induced by the monetary policy shock.

3.4 Inspecting the mechanism

The evidence above is consistent with the presence of both direct and indirect effects of interest rate changes. But this does not yet establish whether one of the channels is quantitatively more important in accounting for the absolute magnitude of the response of mortgagors' expenditure. This requires converting the estimated percent changes in the IRFs into dollar changes and then assessing how the dollar change implied by the cash flow effect (the direct move in mortgage payments) and the general equilibrium effects (captured by the response of income) compares with the dollar change in total expenditure.

To this end, we convert the percentage changes in the impulse response functions of Figures 4 to 7 into an equivalent dollar change using the average value of each variable for each cohort in each country (as reported in the Appendix Table 2). We use the U.S. price level in 2007 and the average exchange rate between pounds sterling and U.S. dollars in that year to compute the cumulative change over the period of the simulated impulse response functions.[7]

In Table 1, we report the results (with 90% bootstrapped confidence bands in square brackets). The first three columns correspond to non-durable consumption,

[6] Trimming the top 5% of the financial income distribution does not overturn our main findings but reduces the uncertainty around the point estimates of the income responses by about 25%.

[7] The response of the policy rate to the monetary policy shock tends to be slightly more persistent in the U.S. than in the U.K., as can be seen in Coibion (2012) and Cloyne and Huertgen (2015). To make the magnitudes comparable, we rescale the U.K. numbers by the ratio of the cumulated response of the U.S. Federal Funds Rate and the cumulated response of the U.K. Bank Rate. This is like rescaling by the relative movement in the long-rate.

durable expenditure and mortgage payments. The last column reports the cumulative dollar change in household income. Panel A refers to the United Kingdom and Panel B to the United States. Within each panel the first row corresponds to mortgagors, the second row refers to outright owners without mortgage and, for completeness, the third row is for renters. In interpreting these magnitudes, it is worth noting that, while the absolute numbers in this table may appear small, we are considering a small and temporary change in interest rates (25 basis points on impact and then returning to zero relatively quickly over the forecast period).[8] These numbers are also an average of the effect on loan rates for newly originated mortgages and the effect on existing (adjustable and fixed rate) loans.

A number of important findings emerge from Table 1. First, the dollar change in mortgage payments in the U.K. is nearly three times larger than in the U.S., consistent with the notion that the share of adjustable rate products has been historically significantly higher in the U.K. (Besley et al. (2013)). Second, the change in average mortgage payments is significantly smaller than the overall change in mortgagors' spending on non-durable and durable goods. This suggests that the direct effect of the interest rate change on cash-flows alone does not generate sufficient resources to fund the expenditure change that we observe in the data.[9] Third, in contrast, the dollar change in mortgagors' income is of a similar order of magnitude as the dollar change in mortgagors' expenditure. But it is also not statistically different from the dollar change in income for the other tenure groups. The response of income for all groups seems most likely to reflect the general equilibrium effects of monetary policy on the macroeconomy. Fourth, the dollar changes in expenditure for outright home-owners are never statistically different from zero, despite significant movements

[8]Note that the size of our monetary policy shock is about twelve times smaller and at least five to six times less persistent than the shock in Keys et al. (2015) and Di Maggio et al. (2015).

[9]The size of the change in the average mortgage payments in Table 1 refers to a temporary 25 basis points cut in the policy rate and accords well with a back-of-the-envelope calculation using an *effective* mortgage duration of ten years, an *effective* loan to value ratio on outstanding debt of 0.5 and, for the U.K., the average house value from the Land Registry since 1995 (and from Halifax before then) as well as a share of mortgages on adjustable rates of 45%. This yields an average change in U.K. mortgage payments of 168 US dollars. Replacing the UK share of mortgage contracts on adjustable rates with a share of 15% for the U.S., we obtain a value of 56 dollars.

of their income in both countries. It is therefore the mortgagor group who adjusts expenditure significantly relative to income, which is consistent with the notion that households with debt are characterized by higher marginal propensities to consume.

Wealthy hand-to-mouth mortgagors. To corroborate the conclusion of Table 1, we draw on independent evidence on the extent to which households with mortgage debt may face a liquidity constraint, using the British Household Panel Survey (BHPS) and the American Survey of Consumer Finance (SCF) for the (multi-year) waves that correspond to our baseline samples.[10] As these households own sizable illiquid assets (in the form of housing) and respond significantly to changes in interest rates, they appear to fit well the definition of 'wealthy' hand-to-mouth (WHTM) put forward by Kaplan and Violante (2014). More specifically, we define a household as 'wealthy' hand-to-mouth if at any given point in time both (i) their net illiquid wealth is positive and (ii) their net liquid wealth is less than half of their total monthly household labor income.[11]

In Figure 8, we report the share of mortgagors who are 'wealthy' hand-to-mouth for pairs of temporally close waves in the BHPS and SCF. While there are more waves than displayed for the SCF, there are only three waves of the BHPS over our sample period (but we have confirmed that similar results emerge from the SCF waves that we

[10]These surveys do not contain wealth information at a sufficiently high frequency to be used for our main analysis and they lack rich consumption data over a long period of time.

[11]When constructing the relevant household income and wealth measures, we select variables to make the concepts of net liquid and illiquid wealth as consistent as possible across the two datasets. The BHPS only reports quantities for overall investment and debts whereas for specific assets it only records whether these are held or not. The SCF, in contrast, does provide quantities for particular assets and overall investment. Furthermore, the assets on which information is provided differ slightly between surveys. Accordingly, net liquid wealth in the U.K. is constructed as total amount of liquid savings and investments (National Savings Bank Accounts and Cash ISAs or TESSAs, Premium Bonds, Stocks and shares ISAs or PEPs) minus non-mortgage debt (Hire purchase agreements, Personal Loans, Credit and store cards, DWP Social Fund loans). Following Kaplan and Violante (2014), net liquid wealth in the U.S. is the value of checking, saving and MM accounts, directly held mutual funds, stocks, bonds and t-bills, net of outstanding unsecured debt. Net illiquid wealth in the U.K. is measured using a binary variable which takes value 1 if housing equity>0 or the household has positive investments in (relatively) illiquid instruments such as National Saving Certificates, NS/BS insurance bonds, private pensions, non-regular savings. Net illiquid wealth in the U.S. is the value of housing equity (housing value - mortgage debt) plus pension/retirement funds, life insurance, saving bonds and certificate of deposits.

have not reported). The clear message from this chart is that between 40% and 50% of households with mortgage debt have very low levels of liquid wealth, suggesting that they may find themselves liquidity constrained. In Figure 16 of Appendix C, we also show that most WHTM agents in the sample do have a mortgage. This section has therefore presented further evidence to support the idea that many mortgagors may behave in a liquidity-constrained manner, with important implications for the aggregate effects of monetary policy.

4 Further results

In the previous section, we showed that mortgagors tend to alter their overall expenditure far more than outright owners following a change in monetary policy. We also provided evidence on the relative response of expenditure and income, suggesting that mortgagors behave in a manner consistent with them facing liquidity constraints. Finally, we showed that, in the data, about half of the mortgage group have low liquid wealth and that the majority of 'wealthy' hand-to-mouth households hold a mortgage. But one may still be concerned that our housing tenure distinction is simply picking up another (deeper) characteristic or changes in group composition over time. In this section we explore this issue further. We also consider the results for renters.

4.1 Demographics

An important issue is whether our housing tenure distinction is simply picking up life-cycle effects. To explore this issue, we follow the micro-econometric literature and focus on birth cohorts. We regard households as 'older' if the head was born before 1935, as 'middle-aged' if the head was born in the interval [1935, 1949] and as 'younger' if the head was born after 1949.

In Figure 11 of the Appendix, we show the breakdown of our tenure groups by birth cohort. As expected, there is a prevalence of mortgagors among younger households and a prevalence of outright owners without mortgage debt among older households but, importantly, not all younger households are mortgagors and not all older house-

holds are outright owners. Furthermore, the middle-aged group is populated by even shares of all housing tenure cohorts.

Within each housing tenure group, we further sub-divide households into birth cohorts. We then consider three experiments to explore whether age/life-cycle considerations could be driving our results rather than mortgage debt per se. First, we investigate whether younger mortgagors respond more than older mortgagors. Second, we focus on whether the response of middle-aged mortgagors is similar to the response of middle-aged outright owners.[12] Third, we verify whether excluding households with a retired head makes a difference to our results. If the answers to these questions are all negative, we can be more confident that the heterogeneity across housing tenure groups documented in the previous section is *not* picking up omitted demographic factors.

The comparison between the first and the second columns in Appendix Figures 12 and 13 shows that younger and middle-aged mortgagors respond similarly. This is true both in terms of the magnitude and in terms of the significance of the point estimates (both for non-durable consumption and durable expenditure). This suggests that conditional on the housing tenure group, age — as proxied by birth cohort — does not seem to play a significant role in the transmission of monetary policy in any of the two countries. On the other hand, the comparison between the second and third columns in Appendix Figures 12 and 13 reveal that the changes in middle-aged mortgagors' expenditures are typically large and significant whereas the changes in middle-aged home-owners' expenditures are typically small and statistically indistinguishable from zero. We interpret these findings as further suggestive evidence that, conditional on the age/life-cycle position, household debt plays an important role in the monetary transmission mechanism.

Finally, we consider restricted samples from the LCFS and the CEX where we exclude households with a retired head. The results from this exercise are reported in Appendix Figures 14 and 15. The figures show that our baseline estimates in Section

[12] Unfortunately, there are neither enough mortgagors in the older birth cohort nor enough outright owners in the younger birth cohort for us to look at these two other sub-groups.

3 are confirmed when imposing this restriction.

In summary, the findings from the previous section are not overturned when considering the impact of demographics. In particular, the heterogeneous responses associated with housing tenures status appear to hold over and above any possible heterogeneity associated with age or birth cohort.

4.2 Compositional changes

To interpret our estimates as the causal effect of monetary policy on the expenditure and income of mortgagors, we need that the policy change does not cause households to move from one housing tenure status to another. Note that this is likely to be more problematic, if anything, for the U.K. survey data which consist of repeated cross-sections, than for the U.S. survey data where, given the short panel dimension, we already consider only those households who have not changed housing tenure status between interviews.

Housing tenure shares. In this exercise, we examine whether the monetary policy shock triggers any net inflows or outflows into each of the house tenure groups. Specifically, we look at the response of the group shares. As can be seen in Figure 1, the very gradual rate at which home ownership has changed in both countries relative to the high frequency movements in the monetary policy series, already suggests a limited response of the tenure shares. In Figure 17, we examine this formally. Each panel reports the response of the group shares for mortgagors, outright owners and renters. It is clear that none of the shares responds significantly, indicating that changes in monetary policy do not seem to trigger significant endogenous changes in the housing tenure status.[13] This is possibly unsurprising given that the shock is only 25 basis points and the dollar changes in income from Table 1 are not especially large in an absolute sense.

[13]While it may be theoretically possible that the inflows into one group might be offset 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 a monetary policy shock.

A propensity score approach. One way of addressing concerns about endogenous changes in group composition more explicitly is to apply the Attanasio et al. (2002) propensity score approach. Rather than grouping based on actual housing tenure, this approach groups households based on the probability of being a mortgagor, using exogenous household characteristics as predictors. Specifically, we run a probit regression over the full sample to generate individual predicted probabilities of having a mortgage based on a high order polynomial in age, education, a time trend and their interactions.[14] For households observed in quarter t, we compute the probability that they had a mortgage in the previous quarter. For these two periods, we classify households as 'likely' or 'unlikely mortgagors' if the probability in the first of the two periods is larger or smaller than the share of mortgagors in the sample.[15] We then take the growth in consumption across these two quarters for each group, from which we can construct the implied consumption series for each of the groups that we then use for estimation.

The results of this exercise are shown in Appendix Figures 18 and 19. As can be seen, the main findings of our earlier analysis are not overturned. The likely mortgagor group still exhibits stronger expenditure responses than the unlikely mortgagors, despite income increasing for both groups. The possibility of changes in group composition therefore does not seem to be driving our estimates.

4.3 Renters

Turning to renters, Figure 20 in the Appendix shows that, for both countries, the percentage changes in non-durable consumption are similar in magnitude and significance to those of mortgagors. The responses of durable goods are, however, typically smaller (especially in the U.K.) and less precisely estimated than for the other cohorts,

[14] To maximize the number of households in each quarter and cohort, we place no restrictions on the birth year of the household head in this exercise but include age among the demographic variables in the probit regressions. To sharpen the comparison between mortgagors and outright owners, we do not include renters in the analysis in this section. While these restrictions do not affect the point estimates from the propensity score method significantly, they improve their accuracy.

[15] As time variation in the probability of being a mortgagor may induce changes in the group composition, we use a constant threshold for determining the group of 'likely' mortgagors.

possibly reflecting the heterogeneous composition of the renter group. On the other hand, income moves in a similar manner to the other cohorts and by a significant amount. In both countries, the impulse response functions for renters translate into positive dollar changes in expenditure (Table 1). In particular, Table 1 shows that, in both countries, the response of non-durable expenditure for renters is greater than the response of durables. The difference between the two expenditure responses is also larger for renters than for mortgagors. The overall dollar change in expenditure relative to income appears far larger for renters than outright owners and is line with, or smaller than, the magnitude for mortgagors.

5 Theoretical insights

Our empirical results suggest four main findings (i) the expenditure response of mortgagors is far larger than the expenditure response of outright owners, (ii) the heterogeneity is more pronounced for durable goods, (iii) income responds significantly for all groups and (iv) the direct effect of interest rate changes in both countries is modest relative to the effect on expenditure and income.

To explore the possible mechanisms behind these results further, we need a framework that allows us to quantify the relative contribution of possibly competing channels. Crucially, given the structural differences between the U.K. and U.S. mortgage markets, the model should allow for a meaningfully distinction between fixed rate contracts with different durations (or a different mix of fixed and adjustable rate products). At the same time, we want the model to be tractable enough so that we can analyze the transmission of interest rate changes in general equilibrium. With the above goals in mind, we consider a simple environment with households that are heterogeneous in their degree of impatience. Households also derive utility from leisure, non-durable consumption and the flow of services associated with the stock of durable goods and the stock of housing that they choose to hold. In the full version of the model, we also allow for a choice between renting and owning. In addition, households can smooth consumption using a *long term* (multi-period) debt instrument.

The liquidity constraint. We assume that households are subject to a constraint in the amount they can borrow. We first present a simple version where the credit limit is fixed exogenously. This will already allow us to understand the differential response of constrained versus unconstrained households under fixed rate contracts with different maturities. Building on this, we then consider a richer version where borrowing needs to be backed by a collateralizable asset, in this case housing stock. In addition, households make a housing tenure decision between owning (possibly with a mortgage) and renting. While the exogenous credit limit version produces results qualitatively in line with the estimates in Section 3, we show that the presence of a collateral constraint provides one (but by no means the only) mechanism that can amplify the effects associated with an otherwise exogenous credit limit.

Multi-period debt. We assume that borrowing and lending can only go through a nominal, long-term, risk free bond (or mortgage). One unit of debt issued at t pays, starting in $t+1$, the sequence of nominal installments $1, \rho, \rho^2, \ldots$, which decay at a rate ρ, following Woodford (2001). Different values of ρ conveniently map into different effective average durations of fixed-rate periods. For example, $\rho = 0$ would correspond to a case in which the entire stock of debt in the economy is renegotiated in every quarter. On the other hand, a value of $\rho = 0.8$ (0.974) translates into a fixed-rate duration of about one (seven) year(s), which we take as a rough approximation of the average effective duration in the U.K. (U.S.) mortgage market.[16]

[16]On average over our sample period, nearly half of products in the U.K. mortgage market were originated at a fixed rate, with the most popular deal being over two years (Besley et al. (2013)). Accordingly, we regard an economy with $\rho = 0.8$ (or one year fixed rate period) as being sufficiently close to the average effective duration in the U.K. mortgage market. As for the U.S., Doepke and Schneider (2006) report that since the 2000s, the average duration of financial assets has been around four years. Given that mortgages are typically characterized by higher duration than any other asset, this would seem to represent a lower bound for our calibration. On the other hand, the pace of entries and exits in the mortgage market suggests that an average *effective* duration above ten years would probably be implausible. For the sake of concreteness, we set $\rho = 0.974$ (a seven year fixed rate duration) for the U.S. but we have verified that the set of impulse responses below are not sensitive to choosing any value between four and twenty years.

Rest of the economy. The other elements of the model are relatively standard features of a New Keynesian environment, such as sticky prices, habit formation and a Taylor rule for setting the short-term nominal interest rate. Houses are in fixed supply and wages are flexible. The model includes durable expenditures following Mertens and Ravn (2011) and Monacelli (2009). Finally, it is worth emphasizing that our model, while sufficiently rich to look at all the variables in our empirical analysis, has been kept deliberately stylized to highlight the relative importance of the key theoretical mechanisms that are most likely to be at play in the data. Accordingly, our theoretical analysis abstracts from a number of features which — in the empirical literature on DGSE models — have been shown to be quantitatively important to generate the persistence in the response of the endogenous variables observed in the data. Details and derivations of the two models below, including the description of the production side, pricing and monetary policy, are confined to the Appendix.

5.1 An exogenous credit limit

We first consider the case where households face an exogenous and constant constraint. Specifically, suppose there is a fixed credit limit, $\Omega_t = \bar{\Omega} \ \forall t$ such that

$$S_t b_{t+1} \leq \bar{\Omega} \tag{2}$$

where b_{t+1} is the real value of the debt repayment at the end of period t and $S_t b_{t+1}$ is the current market value of outstanding debt. Note that for $\rho = 0$, b_{t+1} becomes the real value of the entire outstanding debt and S_t becomes the inverse of the one-period bond return. This set up is similar to the one analyzed in Eggertsson and Krugman (2012), with the distinction that here we consider debt with maturities longer than one quarter.

Our objectives are twofold: (i) to see whether this simple framework can rationalize our empirical findings; (ii) to disentangle the importance of the direct and indirect channels. Specifically, the former is a *cash-flow* effect, through which the budget constraint of debtors is directly affected by the interest rate change. The latter is a wider,

indirect, *general equilibrium* effect where other variables such as household income can move, possibly significantly, following a monetary policy shock.

To quantify the relative importance of the cash-flow channel, we solve and simulate the model under different values of the duration parameter ρ, with zero representing the extreme case of an economy which refinances its entire stock debt in every period. The values of ρ are calibrated to match the average effective duration in the U.K. and U.S. mortgage markets discussed above.[17]

In Figure 9, we report the effects of a 25 basis point cut in the policy rate on non-durable consumption (top row), durable expenditure (middle row) and income (bottom row). Two important results are worth noting. First, this simple set-up can replicate the two main dimensions of heterogeneity we uncover in the micro data: (i) for a given expenditure category, constrained agents respond more than unconstrained agents, (ii) for a given household group, the change in durable goods is larger than the change in non-durables. This reflects that fact that it is the stock of durables that enters the utility function of the households. As income also moves in the data for both groups, the expenditure responses in the model reinforce our interpretation of debtors as hand-to-mouth agents.

Second, the impulse responses under different mortgage market structures show that the effects of monetary policy *are* larger when ρ is smaller, consistent with both our empirical findings for mortgage repayments and the theoretical results in Auclert (2015). The reason why this happens in the model is simple: when an indebted (constrained) household is financing a given consumption stream through debt with short maturities, the proportion of the total amount that needs to be re-financed each period is higher. An unexpected decrease in the refinancing costs generates an improvement in household resources. But, importantly, this does not appear to be main driver of the large response of debtors' consumption, even in the empirically unrealistic case in which everyone refinances the entire stock of debt in every period

[17] Importantly, and as shown in the appendix, the real interest rate and consumption/income in steady state are *independent* of the value of ρ. This ensures a meaningful comparison of impulse responses under economies with different values of ρ.

(i.e. $\rho = 0$). The simple model therefore already seems to capture the main aspects of our empirical findings, though the absolute magnitudes of the responses tend to be smaller than the peak effects that we have estimated in the micro data.

5.2 An endogenous collateral limit

In this section, we relax the assumption of a fixed borrowing limit and assess the quantitative performance of an extended model which adds two features: (i) an endogenous collateral constraint, (ii) a housing tenure decision, choosing between how much housing to own and how much housing to rent, with the relative price determined endogenously.

We embed the collateral constraint as in Iacoviello (2005) into our multi-period debt framework, with mortgagors who can borrow up to a given fraction ϕ of their expected housing wealth next period:

$$S_t b_{t+1} \leq \phi E_t \left(\frac{q^h_{t+1} h_t \pi_{t+1}}{R_t} \right) \tag{3}$$

where q^h_{t+1} is the real house price, h_t is the housing stock, π_{t+1} is the inflation rate between t and $t+1$, and R_t is the one-period nominal interest rate. Full details and derivations are reported in the Appendix.

In Figure 10, we show the results for mortgagors in the left column and those for outright owners in the right column (renters' responses are reported in the Appendix). Note that in this extended version of the model, mortgagors' income still comes from labor only while for outright owners this is the sum of labor and financial income, with the latter stemming from asset returns. The main message from the collateral constraint model in Figure 10 chimes with the previous results in Figure 9 from the exogenous credit limit model. In particular, it is still the case that (i) the spending responses are heterogeneous across both household groups and goods categories, (ii) the gap in the expenditure changes between the one year (solid red line) and the seven year (broken green line) maturity calibrations is small and (iii) the income responses of households with mortgage debt and outright owners are similar.

The difference between the calibration with a one quarter fixed-rate duration (blue line with circles) and the calibration with a seven year fixed-rate duration can be as large as 25%. On the one hand, this suggests that two economies with a very different mix of adjustable and fixed rate mortgage products may, in principle, exhibit quite different expenditure responses. On the other hand, Figure 10 also reveals that, using two empirically more plausible calibrations for the average effective fixed rate duration of one year for the U.K. and seven years for the U.S., the differences in the expenditure responses to a temporary monetary policy shock tend to be relatively small, consistent with the results in Garriga et al. (2013).[18]

The results in Figure 10 suggest that a more detailed specification of the constraint(s) facing indebted households can provide an important amplification mechanism for the effects of monetary policy. While in the Appendix we provide some evidence that a financial accelerator mechanism may be at play in both countries, modeling other frictions — such as the transactions costs of accessing illiquid wealth proposed by Kaplan and Violante (2014) and investigated further by Kaplan et al. (2015) in a business cycle model with incomplete markets and nominal rigidities — may have the potential to produce an even larger amplification, which could complement the collateral constraint channel.[19] Nevertheless, our key conclusion is that the general equilibrium effect on income, triggered by the behavior of debt-constrained mortgagors, appears quantitatively more important than the direct effect of an interest rate change on debt repayments. This would seem a key feature for any quantitative model of the monetary transmission mechanism to match.

[18]More extreme calibrations of the other structural parameters such as, for instance, the degree of price rigidity and the maximum loan to value in the constraint, can generate significantly larger gaps between the one quarter and the seven year duration impulse response functions. This would come, however, at the cost of two counterfactual predictions. First, the magnitude of both non-durable and durable spending would tend to become implausibly large relative to what we report in the empirical analysis. Second, the income responses would display a marked heterogeneity between mortgagors and outright owners. On the other hand, the small difference between fixed rate contracts of one year and seven years is robust to these more extreme parameterizations.

[19]In particular, Appendix F shows that, in both U.K. and U.S. data, (real) house prices and mortgage equity withdrawal change significantly following a monetary policy shock.

6 Conclusions

Does household indebtedness matter for the transmission of monetary policy? And if so, why? Our analysis suggests that it does matter: the reason is that mortgagors tend to hold little liquid wealth relative to their income and exhibit hand-to-mouth behavior despite owning sizable illiquid assets. Consequently, the general equilibrium effects of an interest rate change on income appear quantitatively more important than the direct 'cash-flow' effect on mortgage payments in accounting for the magnitudes of the estimated expenditure responses across heterogeneous debt positions. We reach these conclusions by performing a detailed evaluation of the effects of monetary policy using survey micro data for the United States and the United Kingdom, grouping households by their housing tenure status.

The focus on the U.S. versus the U.K. is motivated by the marked differences in mortgage market structures, with the majority of American contracts featuring longer durations and fixed rates and the majority of British deals featuring shorter durations and adjustable rates. The focus on households with debt versus outright owners is motivated by the close resemblance of these groups to the constrained and unconstrained agents typically found in heterogeneous agent business-cycle models with housing wealth. Indeed, we also report independent evidence that between 40% and 50% of mortgagors in each country are potentially hand-to-mouth, and that the majority of 'wealthy' hand-to-mouth households are mortgagors.

To corroborate the interpretation of our evidence, we lay out a simple heterogeneous agents framework with a credit constraint and multi-period debt. In the model, the credit constraint and the general equilibrium effect on income play a quantitatively more important role than the direct cash flow effect on mortgage payments in rationalizing our empirical findings. This paper therefore highlights a novel mechanism that works through liquidity shortages facing indebted households and extends our understanding of the transmission of monetary policy beyond the conventional intertemporal substitution channel in representative agent models.

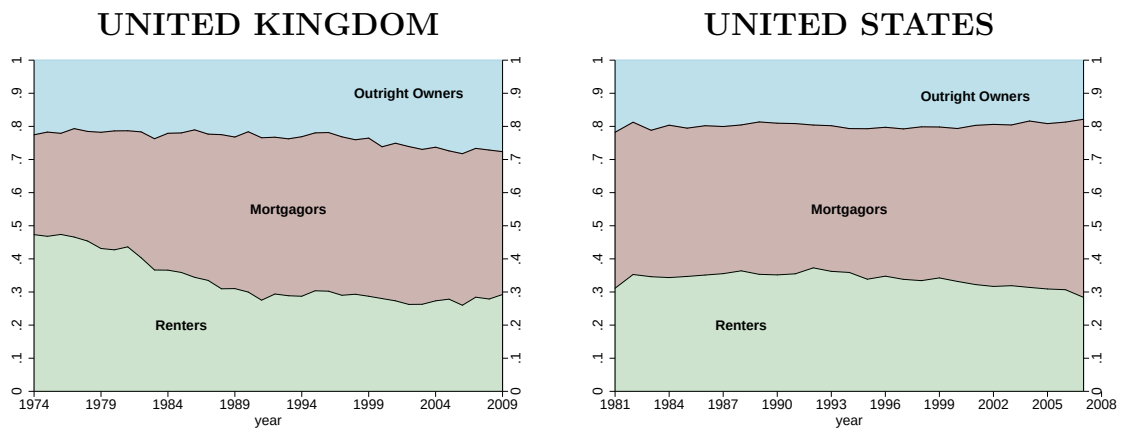

Figure 1: Share of mortgagors, outright home owners and renters in the U.K. (source: FES/LCFS, 1975-2009) and the U.S. (source: CEX, 1981-2009).

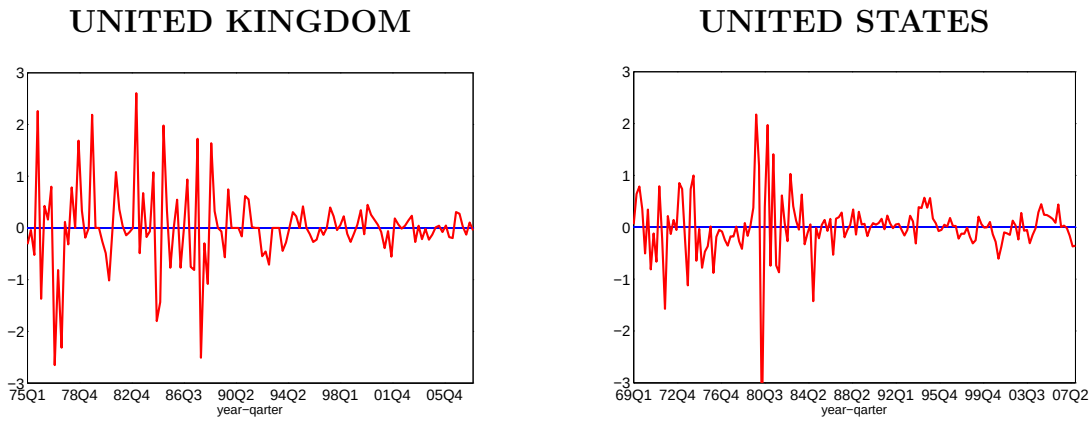

Figure 2: Monetary policy shocks series. United Kingdom: Cloyne and Huertgen (2015); United States: updated version of Romer and Romer (2004).

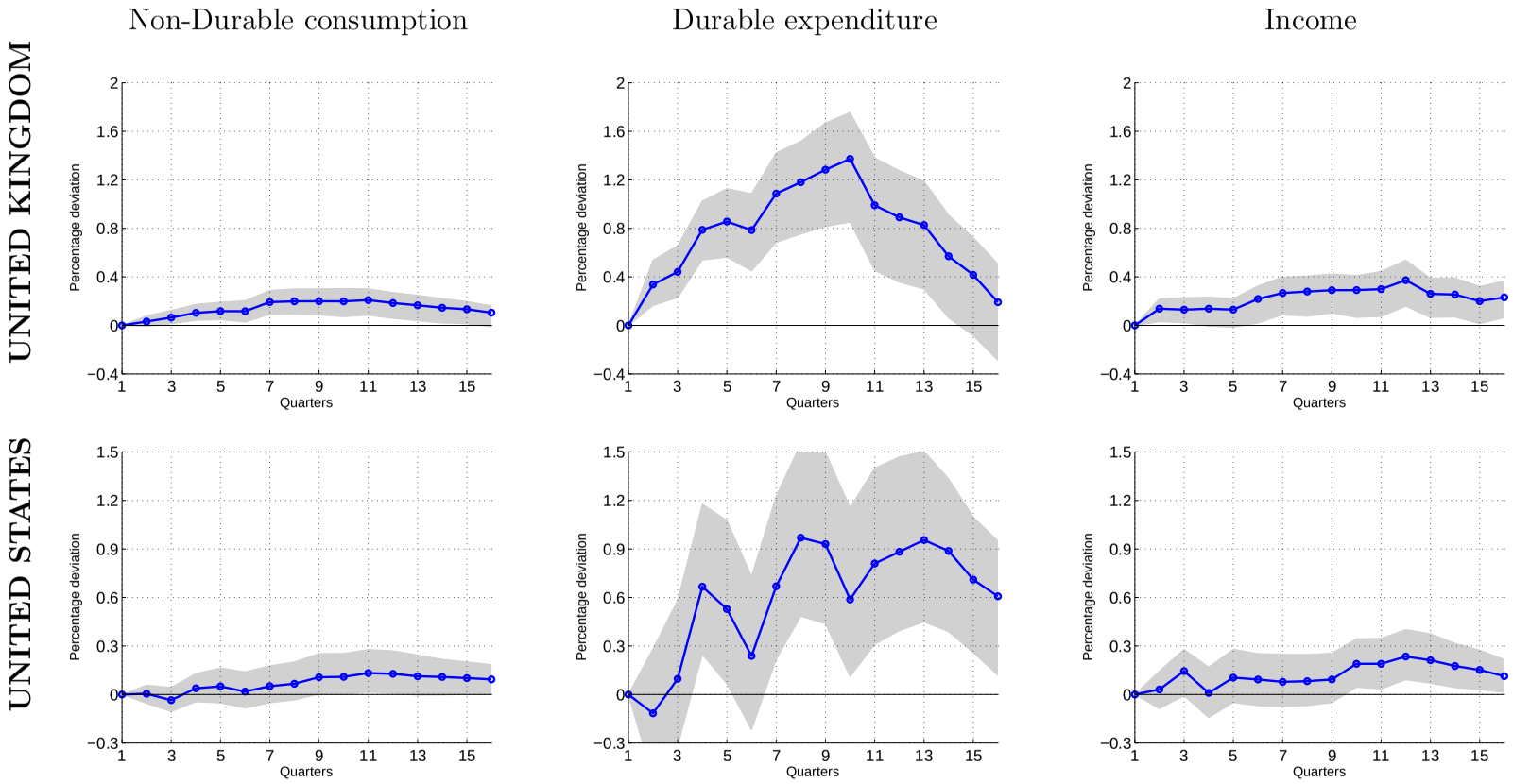

Figure 3: Dynamic effects of a 25 basis point unanticipated interest rate cut on the consumption of non-durable goods and services, the expenditure on durable goods and household income from official aggregate national statistics. Grey areas are bootstrapped 90% confidence bands. Top row: UK, data range 1975q1-2007q4. Bottom row: US, data range: 1981q1-2007q4.

Figure 4: Dynamic effects of a 25 basis point unanticipated interest rate cut on the consumption of non-durable goods and services by housing tenure group. Grey areas are bootstrapped 90% confidence bands. Top row: UK (FES/LCFS data). Bottom row: US (CEX data).

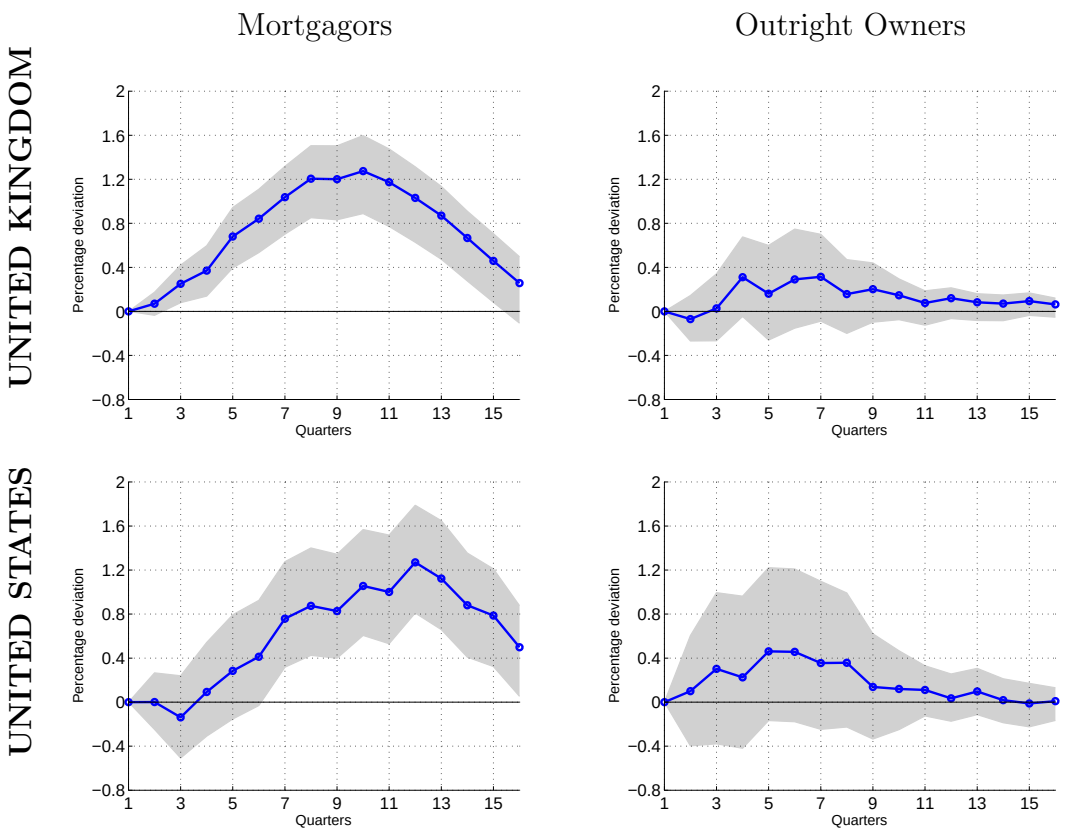

Figure 5: Dynamic effects of a 25 basis point unanticipated interest rate cut on the expenditure of durable goods by housing tenure group. Grey areas are bootstrapped 90% confidence bands. Top row: UK (FES/LCFS data). Bottom row: US (CEX data).

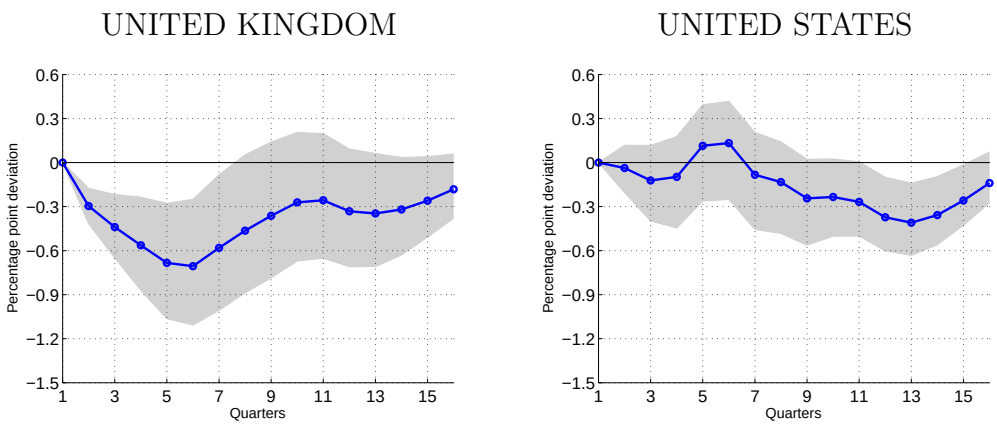

Figure 6: Dynamic effects of a 25 basis point unanticipated interest rate cut on mortgage payments. Grey areas are bootstrapped 90% confidence bands. Left: UK (FES/LCFS data). Right: US (CEX data).

Figure 7: Dynamic effects of a 25 basis point unanticipated interest rate cut on income by housing tenure group. Grey areas are bootstrapped 90% confidence bands. Top row: UK (FES/LCFS data). Bottom row: US (CEX data).

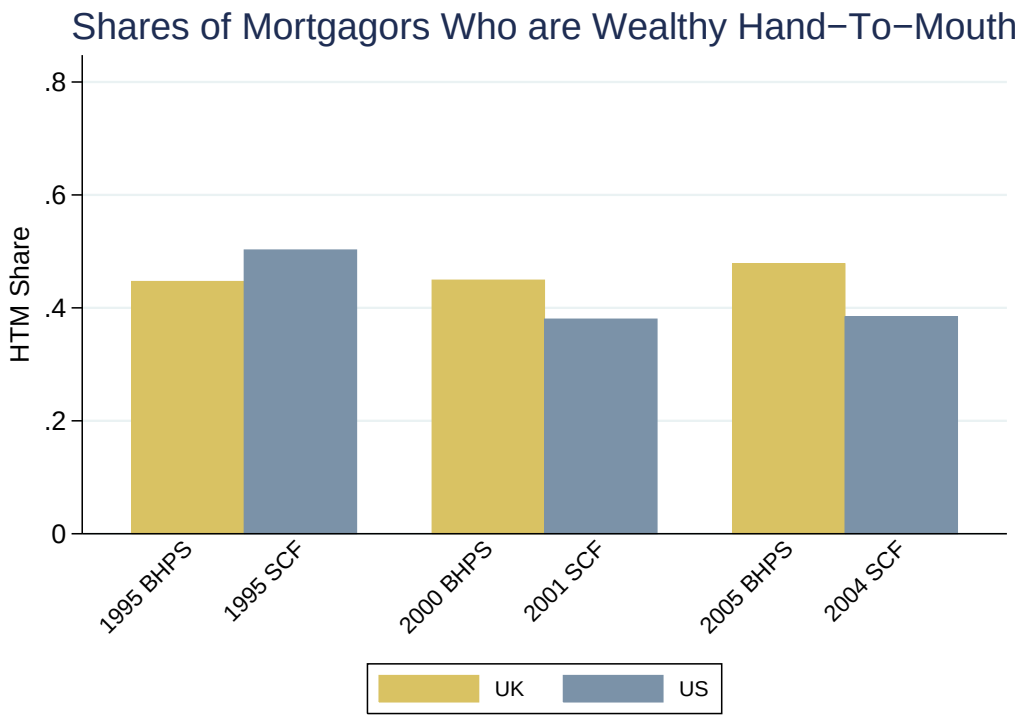

Figure 8: Shares of Wealthy Hand-To-Mouth (WHTM) mortgagors. U.K. (U.S.) data: 1995, 2000, 2005 waves of the British Household Panel Survey (Survey of Consumer Finances). A household is defined as WHTM if at any given point in time both (i) their net illiquid wealth is positive and (ii) their net liquid wealth is less than half of their total monthly household labor income.

Table 1: Cumulative changes over four years in US$

Panel A: United Kingdom

	non-durable consumption	*durable expenditure*	*mortgage payments*	*after-tax income*
Mortgagors	308.3 [112.8, 516.1]	292.3 [189.2 , 369.0]	**-166.4** [**-272.2 , -41.7**]	695.9 [186.5 , 1105.1]
Outright Owners	-62.6 [-148.2 , 77.4]	46.5 [-24.6 , 107.6]		451.7 [122.5 , 797.2]
Renters	155.3 [17.9 , 261.8]	19.0 [-36.5 , 62.9]		397.3 [94.2 , 596.1]

Panel B: United States

	non-durable consumption	*durables expenditure*	*mortgage payments*	*after-tax income*
Mortgagors	305.8 [58.3 , 554.3]	229.3 [122.0 , 350.8]	**-56.3** [**-112.8 , -4.3**]	757.3 [196.8 , 1302.0]
Outright Owners	-72.3 [-324.8 , 186.0]	54.8 [-10.5 , 127.8]		585.3 [83.3 , 1012.8]
Renters	223.3 [32.3 , 412.3]	123.5 [30.3 , 213.8]		439.3 [112.8 , 699.8]

Note: The Table reports point estimates and bootstrapped 90% confidence bands for the cumulative response (over the 16 quarters of the IRF) of the quarterly values of the variable of interest in 2007 US dollars, following an unanticipated 25 basis point cut in the policy rate. The magnitudes are per household averages.

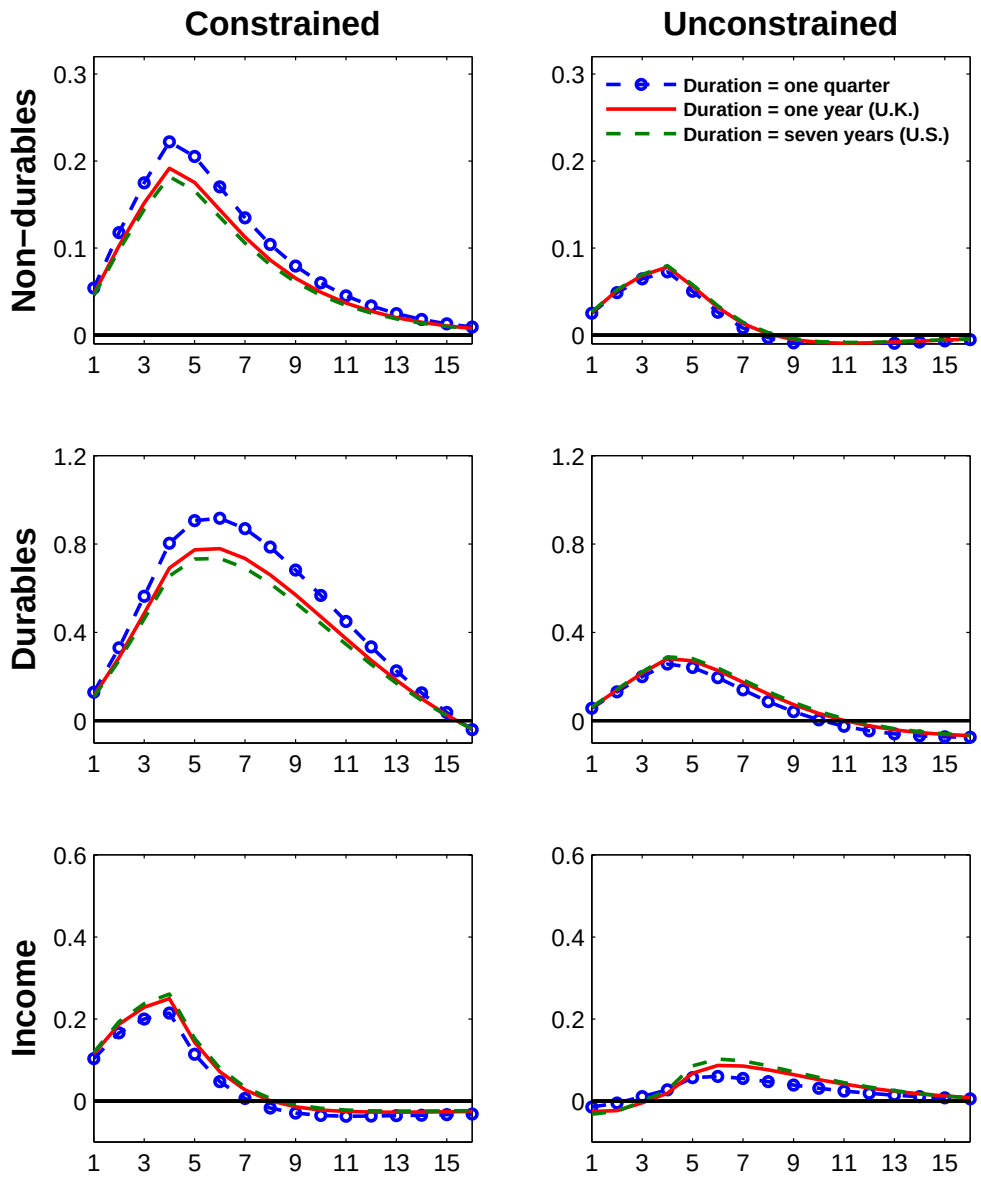

Figure 9: Response of non-durable consumption, durable expenditure and income in the exogenous debt limit model: constrained vs. unconstrained agents. Duration refers to the effective duration of fixed-rate mortgage contracts in the aggregate economy, which on average is about one year for the U.K. and 7 years for the U.S.

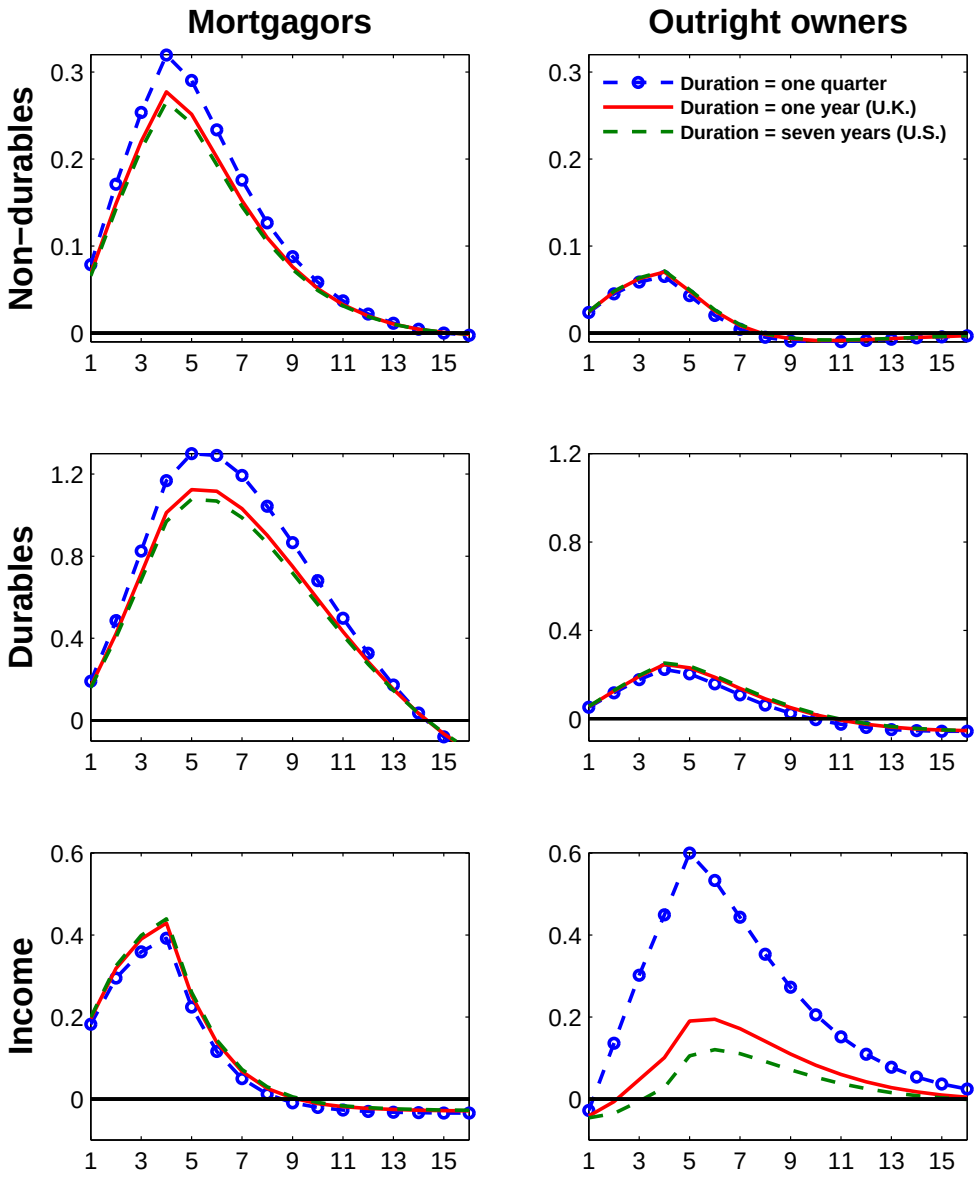

Figure 10: Response of non-durable consumption, durable expenditure and income in the housing collateral constraint model: mortgagors versus outright owners. Duration refers to the effective duration of fixed-rate mortgage contracts in the aggregate economy, which on average is about one year for the U.K. and 7 years for the U.S.

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ON-LINE APPENDIX

(not intended for publication)

Appendix A: Data sources and definitions

A.1: National statistics

The aggregate time-series for the U.K. and the U.S. come from the Office for National Statistics (ONS) and the National Income and Product Accounts (NIPA), respectively. Personal consumption expenditure on non-durable goods and services expenditure, personal consumption expenditure on durable goods and disposable income are all seasonally adjusted at the source. The series are divided by total population to obtain per-capita values. The deflator used for the U.K. (U.S.) is the Retail Price Index excluding mortgage interest payments (Consumer Price Index).

A.2: Household survey data

For the U.K., we use the Living Costs and Food Survey (formerly known as Family Expenditure Survey) from 1975 to 2007 (1978 to 2007 when we use educational attainment for the probit regressions). For the U.S., we use the Consumer Expenditure Survey (interview section) from 1981 to 2007.

Household expenditure. *Non-durable goods and services*: includes food, alcohol, tobacco, fuel, light and power, clothing and footwear, personal goods and services, fares, leisure services, household services, non-durable household goods, motoring expenditures and leisure goods. Between 1982 and 1987, food at home in the CEX is adjusted following Aguiar and Bils (2015). *Durable goods*: durable household goods, motor vehicles and durable leisure goods. This includes expenditure such as furniture and furnishings, electrical appliances and audio-visual equipment.

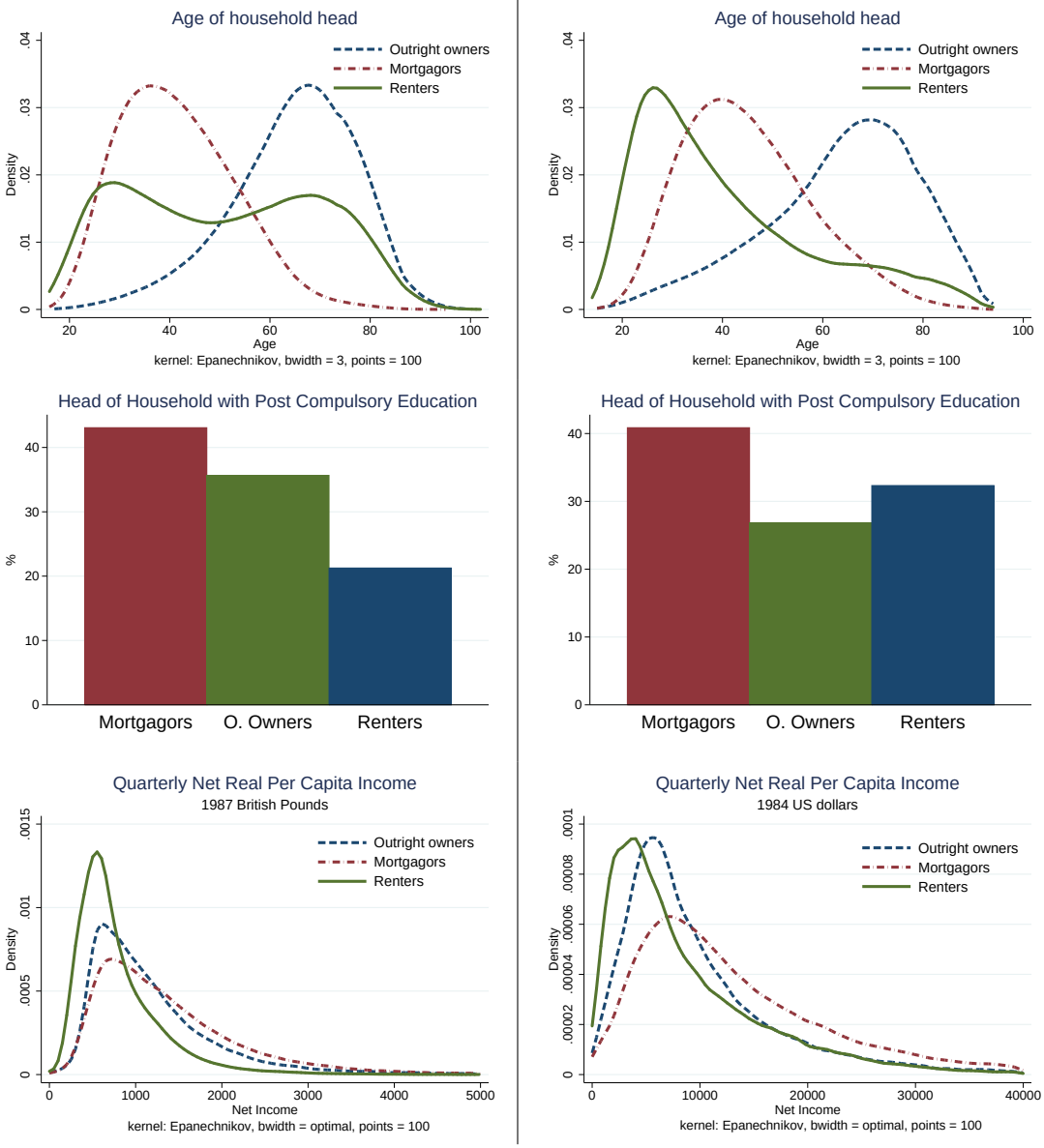
Mortgage payments and income. *Mortgage payments*: includes both interest payments and capital repayments (not available individually over the whole sample). *Net income*: sum of labor- and non-labor household income net of taxes paid.

Restrictions. We exclude households: (i) that do not report income, (ii) that report negative net income, (iii) that are in either the top or the bottom 1% of either the non-durable or the durable expenditure distributions of each housing tenure group at any quarter and (iv) whose head is either below 25 years old or above 74 years old. Finally, for the CEX, which features a short panel dimension, we only keep households that have not changed housing tenure status between interviews. The LCFS comprises repeated cross-sections and thus each household is observed only once. For comparability across countries and over time, all household variables in the LCFS for the U.K. (in the CEX for the U.S.) are deflated by the Retail Price Index excluding mortgage interest payments (Consumer Price Index) and divided by the household size to obtain real values in per-capita terms.

Appendix B: Housing tenure and demographics

Distribution of Demographic Characteristics Across Housing Tenure Groups

UK: 1975 - 2007 | **US: 1981 - 2007**



Note: Top row: age of the household head at the time of interview; middle row: share of household heads who completed *more than* compulsory education; bottom row: real per capita income net of taxes. Left: U.K. (LCFS), 1975q1-2007q4. Right: U.S. (CEX), 1981q1-2007q4.

Table 2: Mean Quarterly Household Expenditures and Income over the full sample, in 2007 US$

	Panel A: United Kingdom			
	non-durable expenditure	*durable expenditure*	*mortgage repayments*	*after-tax income*
Mortgagors	10,202	1,842	1,950	15,555
Outright Owners	10,030	1,625		13,617
Renters	6,807	750		9,310
	Panel B: United States			
	non-durable expenditure	*durables expenditure*	*mortgage repayments*	*after-tax income*
Mortgagors	14,767	2,470	2,352	20,500
Outright Owners	14,482	2,032		16,495
Renters	11,945	1,542		14,340

Note: Data for the UK comes from the Living Costs and Food Survey (LCFS) between 1975q1-2007q4; data for the US comes from the CEX between 1981q1-2007q4. The values in the table are average household level expenditures and income by cohort. In a given quarter these are constructed as a weighted average of all households within each cohort. Entries refer to sample averages converted into 2007 US dollars.

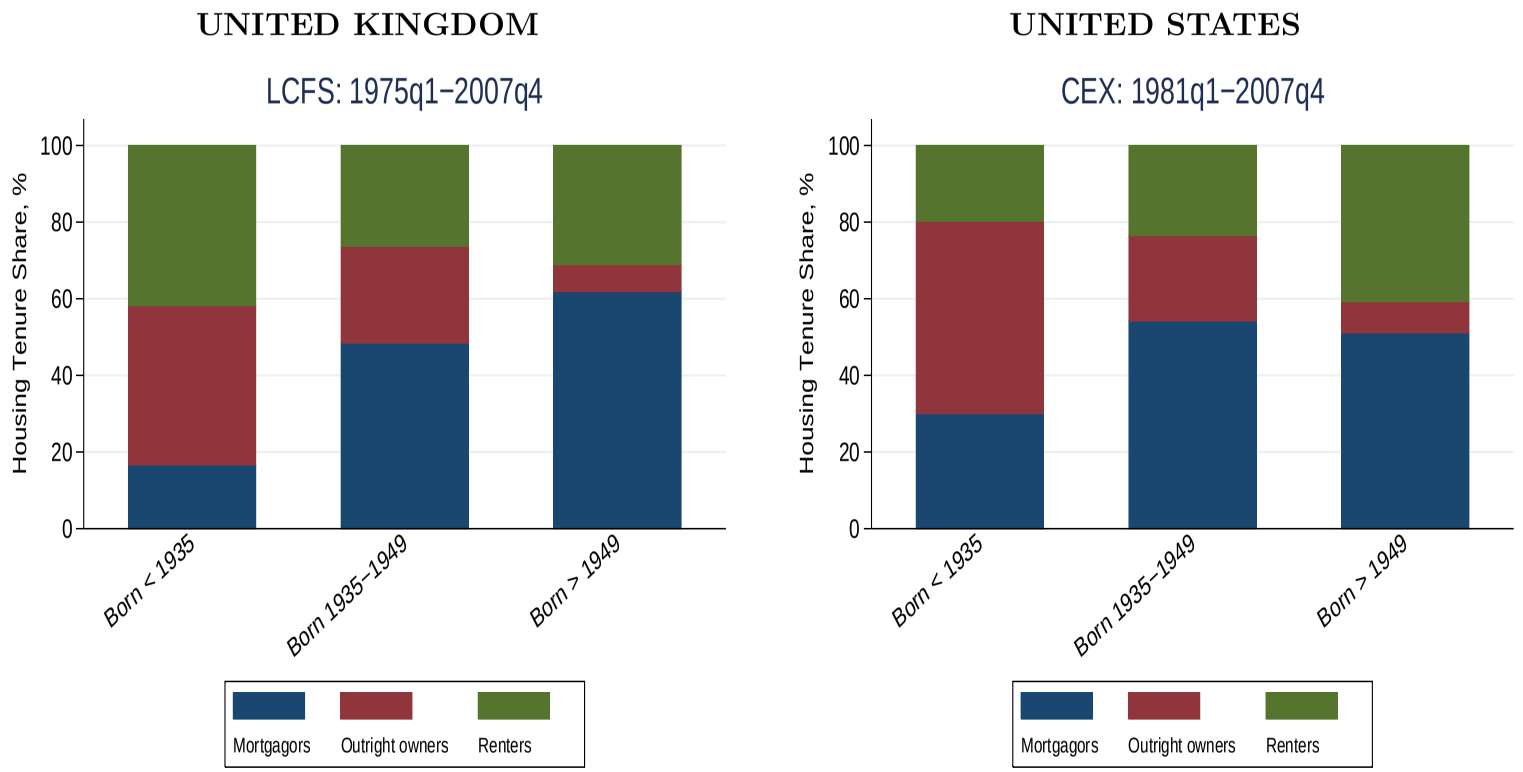


Figure 11: The share of mortgagors, outright home owners and renters for different birth cohorts in the US and the UK. Birth cohorts are defined by the birth year of the household head. Three birth cohorts are considered: younger households, middle aged households and older households. The year cut-offs are chosen to ensure there are enough observations in each cohort group. The cut-offs also ensure that each birth cohort has approximately the same average age across the two countries.

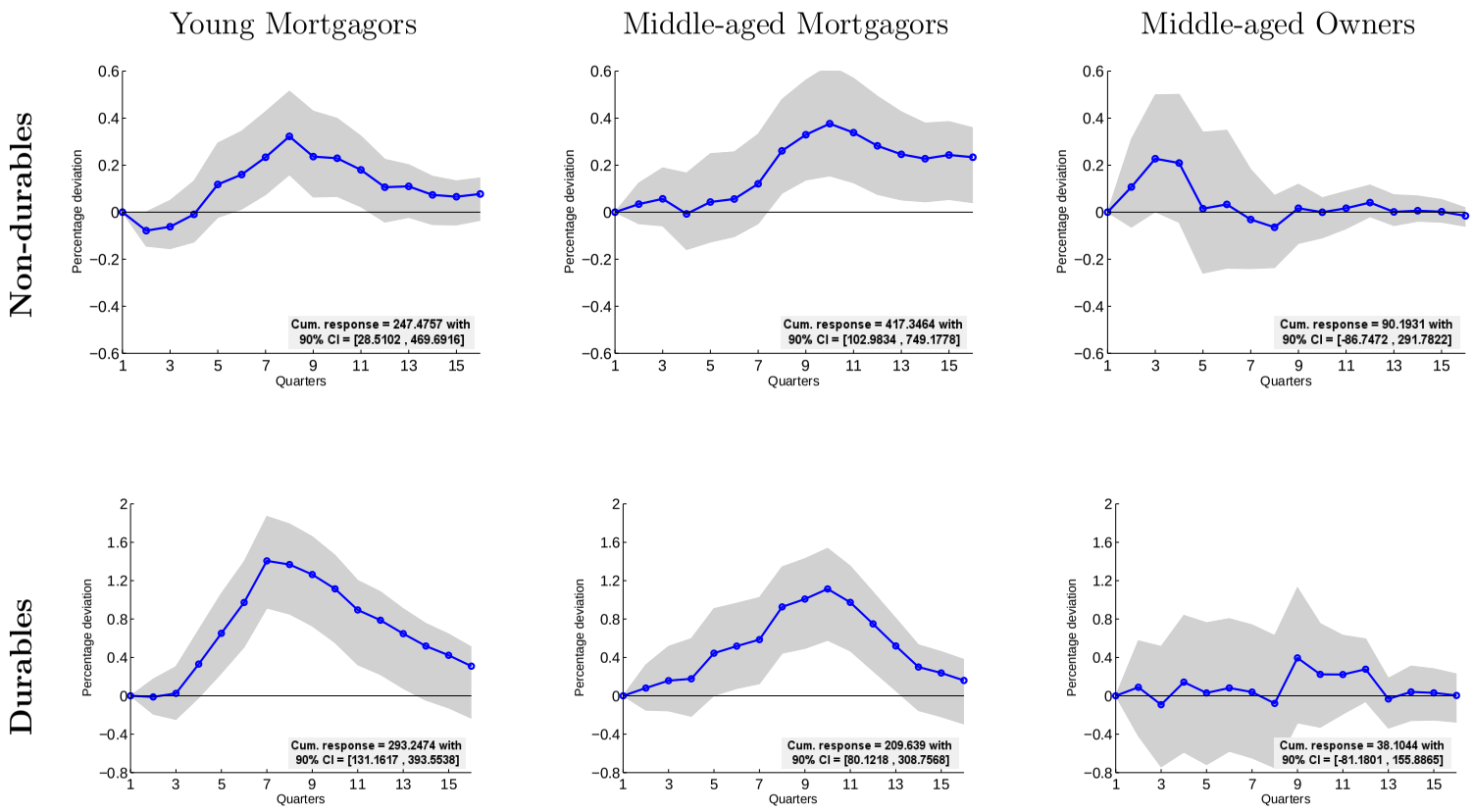


Figure 12: Dynamic effects of a 25 basis point unanticipated interest rate cut on non-durable consumption (top) and durable expenditure (bottom) for mortgagors born after 1949 (left column), mortgagors born between 1935 and 1949 (middle column) and outright owners born before 1935 (right column). Grey areas are bootstrapped 90% confidence bands. U.K. data: FES/LCFS (1975-2007).

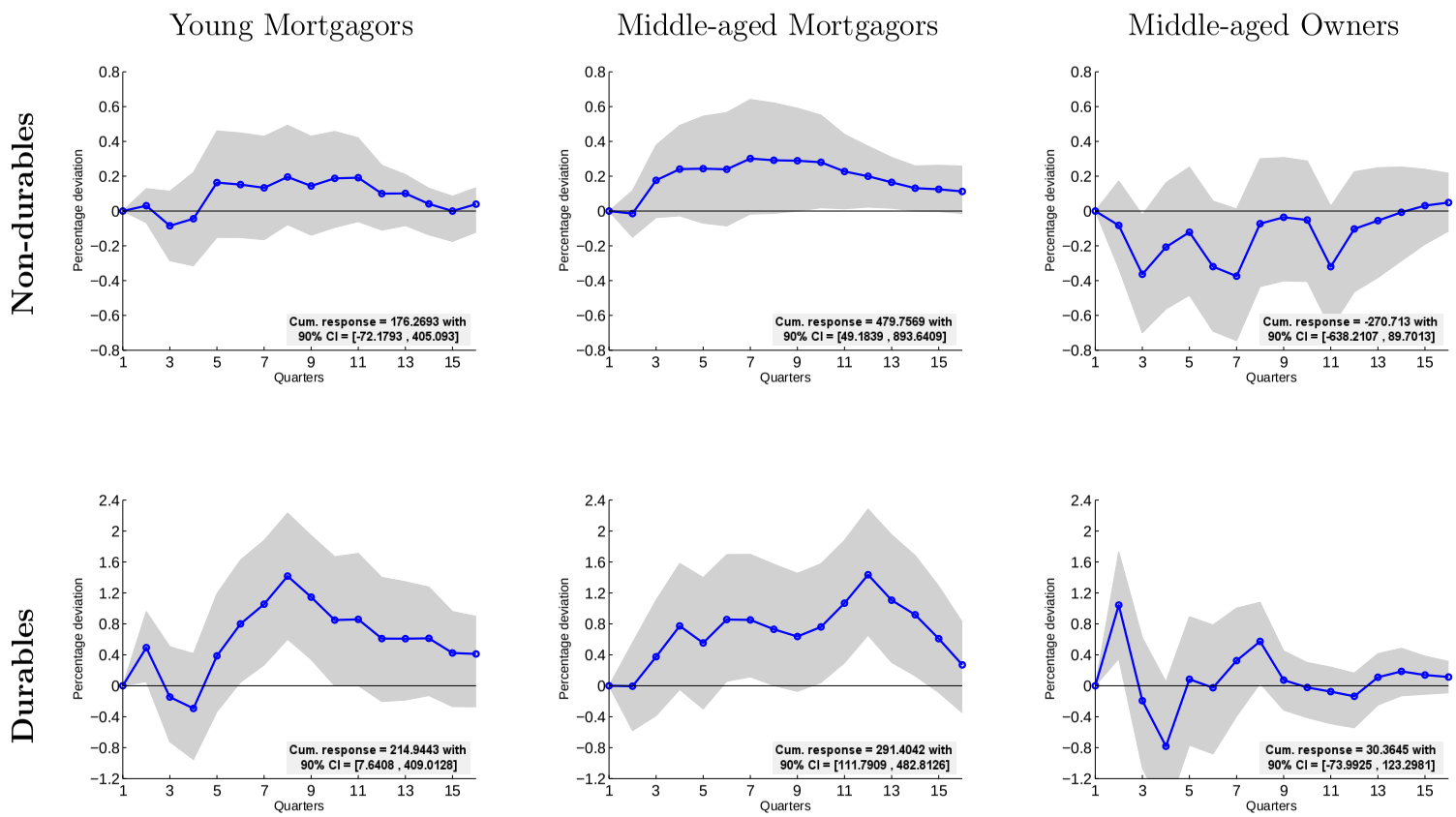


Figure 13: Dynamic effects of a 25 basis point unanticipated interest rate cut on non-durable consumption (top) and durable expenditure (bottom) for mortgagors born after 1949 (left column), mortgagors born between 1935 and 1949 (middle column) and outright owners born before 1935 (right column). Grey areas are bootstrapped 90% confidence bands. U.S. data: CEX (1981-2007).

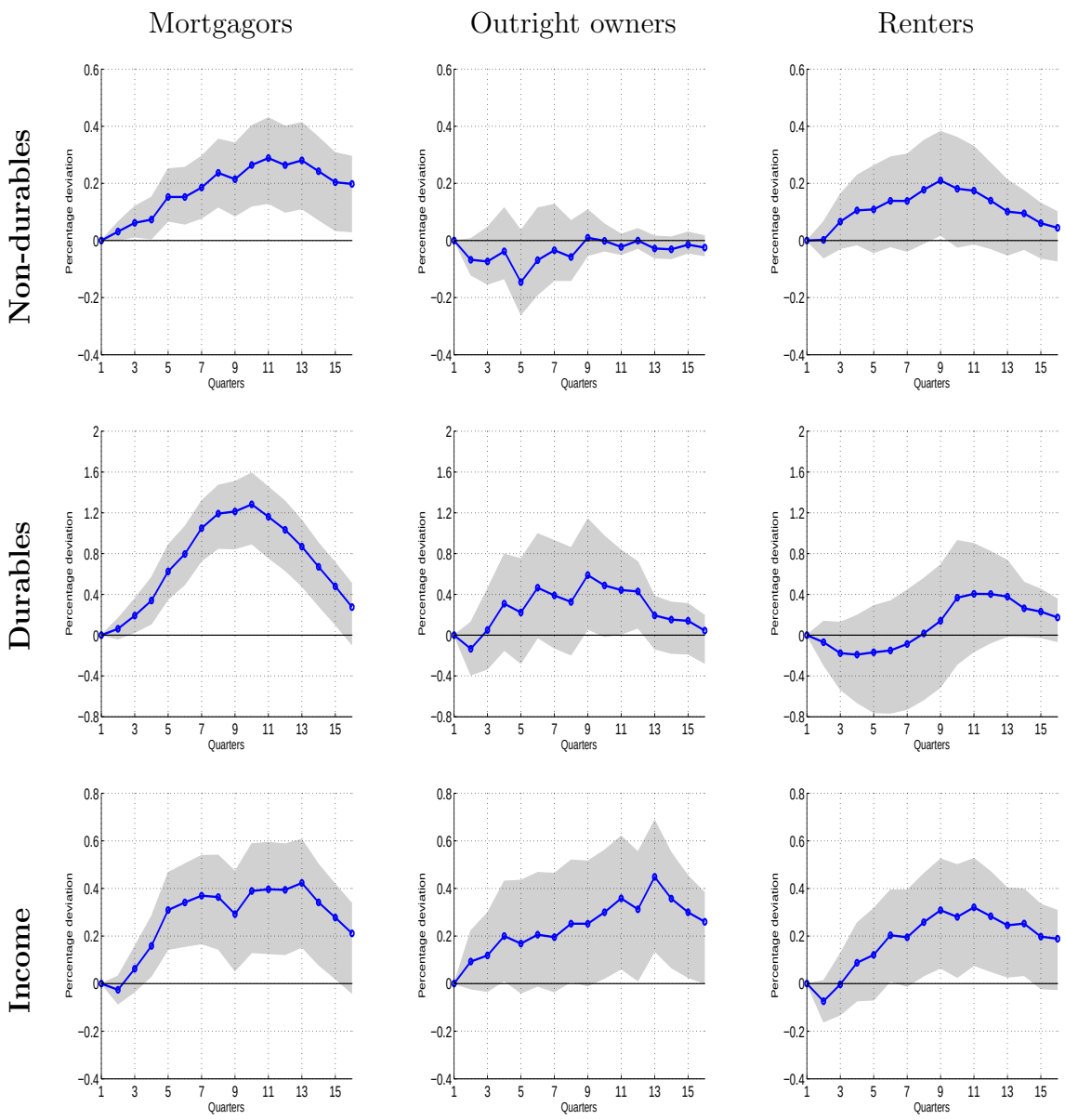


Figure 14: Dynamic effects of a 25 basis point unanticipated interest rate cut on non-durable consumption (ND), durable expenditure (D) and income net of tax for households below age 65. U.K. data: FES/LCFS (1975-2007). Grey areas are bootstrapped 90% confidence bands.

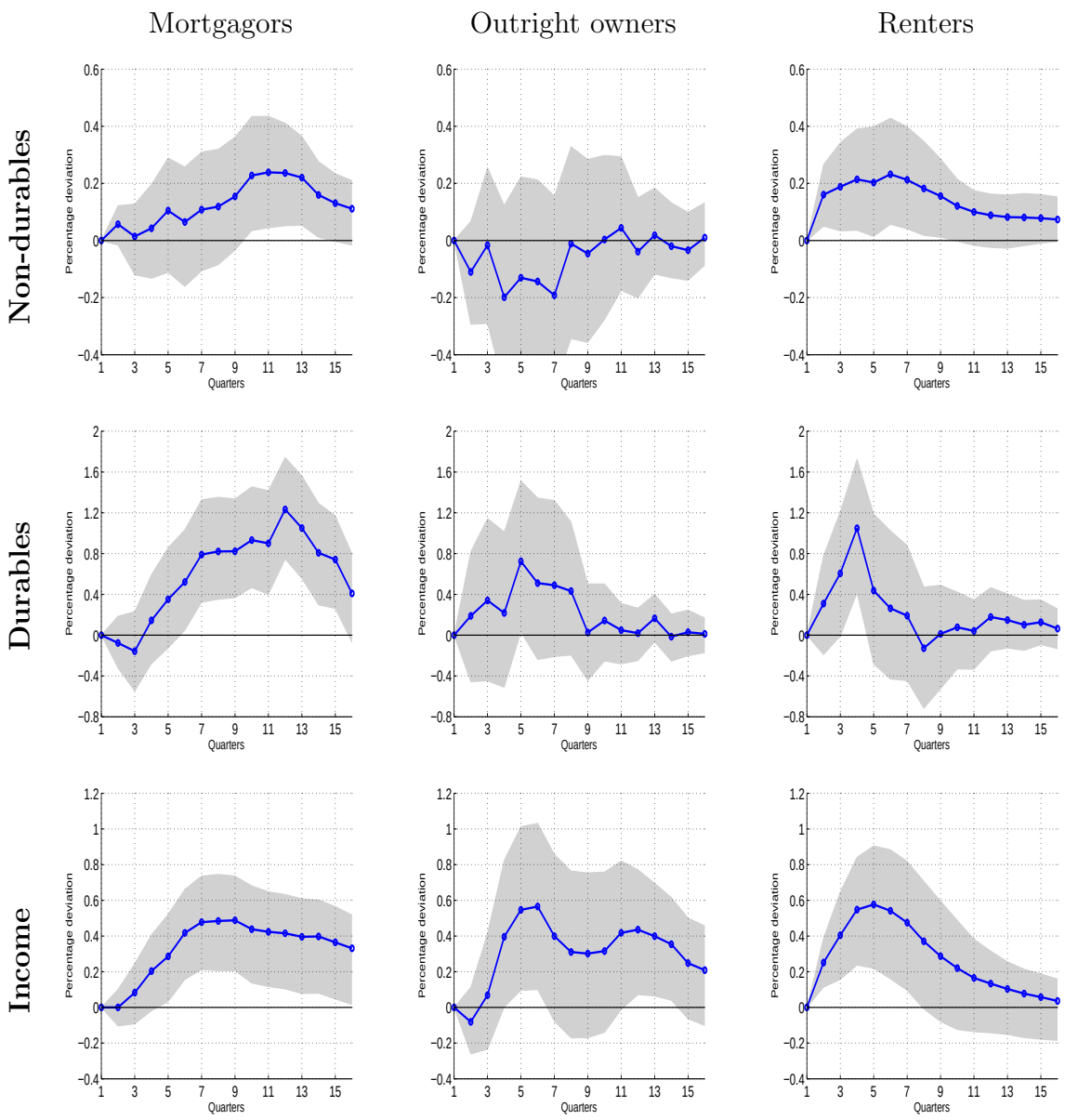


Figure 15: Dynamic effects of a 25 basis point unanticipated interest rate cut on non-durable consumption (ND), durable expenditure (D) and income net of tax for households below age 65. U.S. data: CEX (1981-2007). Grey areas are bootstrapped 90% confidence bands.

Appendix C: WHTM by housing tenure

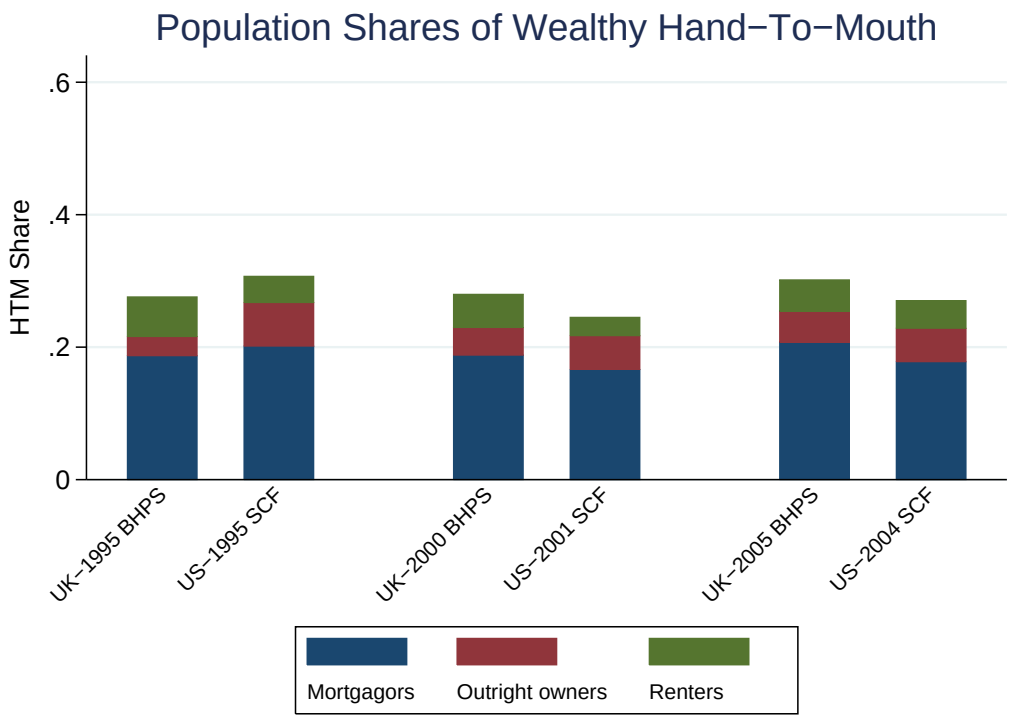


Figure 16: Shares of Wealthy Hand-To-Mouth (WHTM) households in the population, by housing tenure group. U.K. (U.S.) data: 1995, 2000, 2005 waves of the British Household Panel Survey (Survey of Consumer Finances). A household is defined as WHTM if at any given point in time both (i) their net liquid wealth is less than half of their total monthly household labor income and (ii) their net illiquid wealth is positive. U.K. (U.S.) data: 1995, 2000, 2005 waves of the BHPS (SCF).

Appendix D: Compositional changes and renters

In this Appendix, we report the impulse responses for the shares of mortgagors, outright owners and renters as well as on non-durable consumption, durable expenditure and disposable income for renters in the U.K. and U.S..

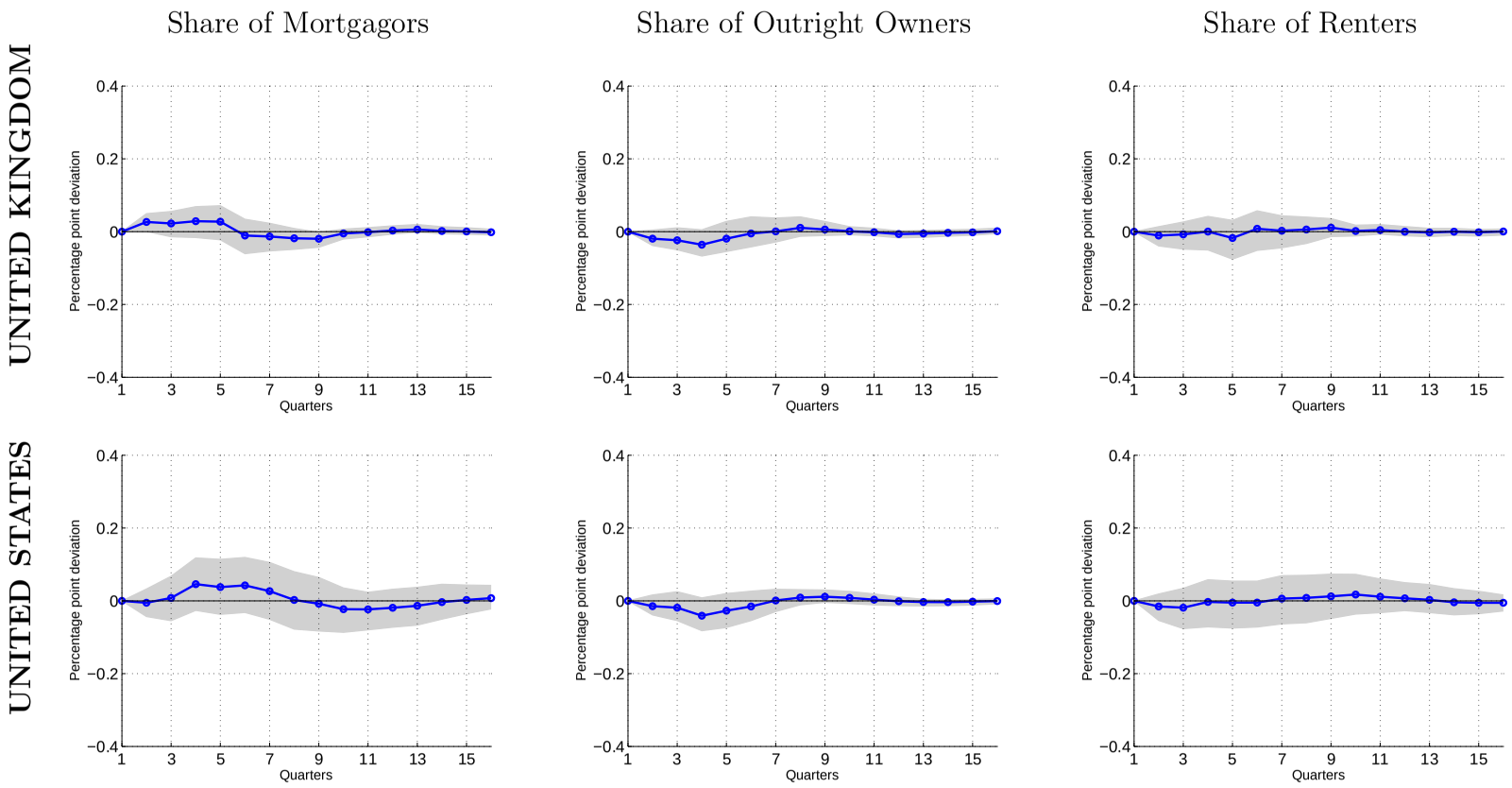


Figure 17: Dynamic effects of a 25 basis point unanticipated interest rate cut on the share of mortgagors, outright owners and renters. Grey areas are bootstrapped 90% confidence bands. U.K. data: LCFS (1975-2007) in top row; U.S. data: CEX (1981-2007).

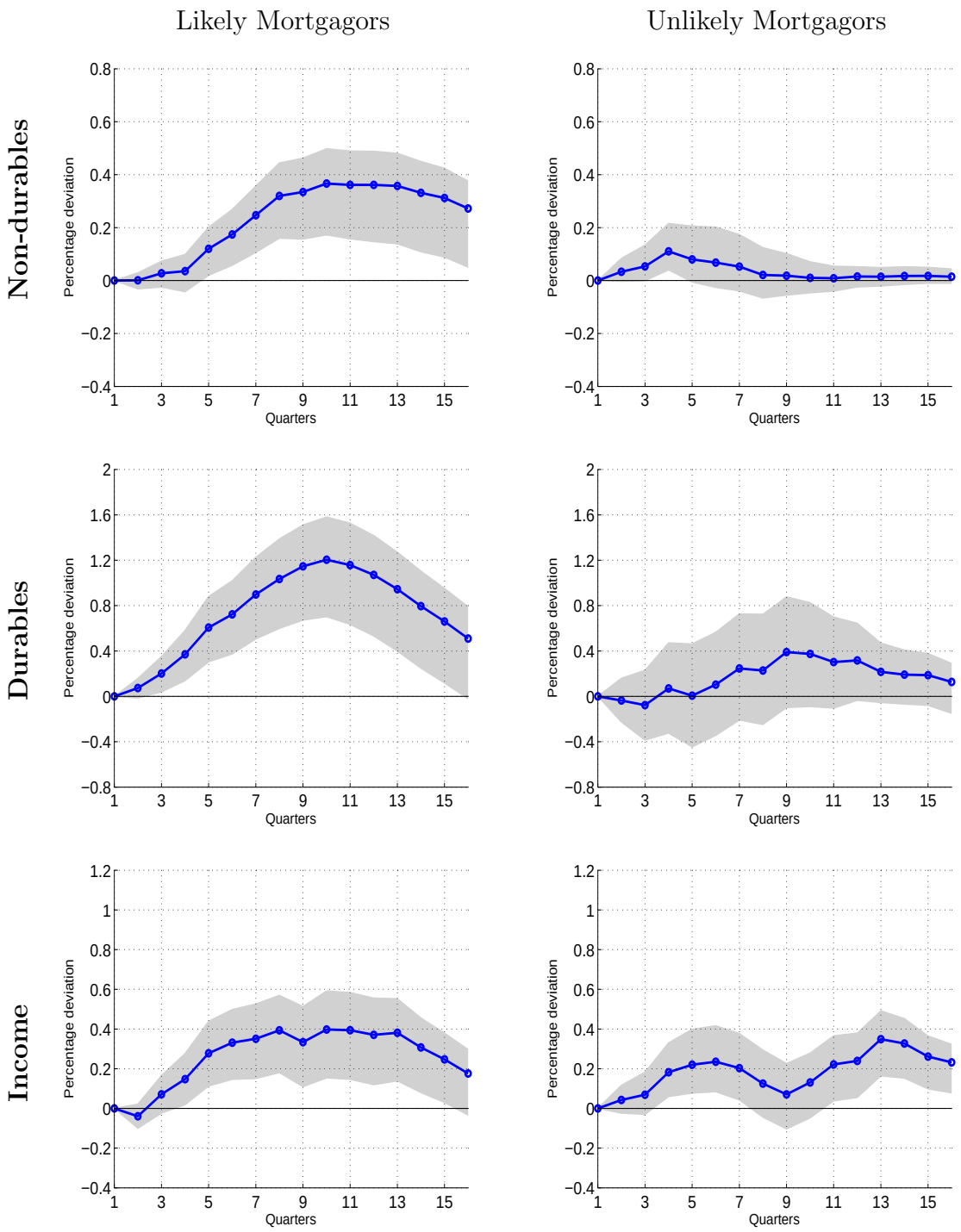


Figure 18: UK results for non-durable, durable and income net of taxes for "likely" and "unlikely" mortgagors, excluding renters. Groups computed following Attanasio et al (2002) propensity score approach using a fixed probability threshold. Grey areas are bootstrapped 90% confidence bands.

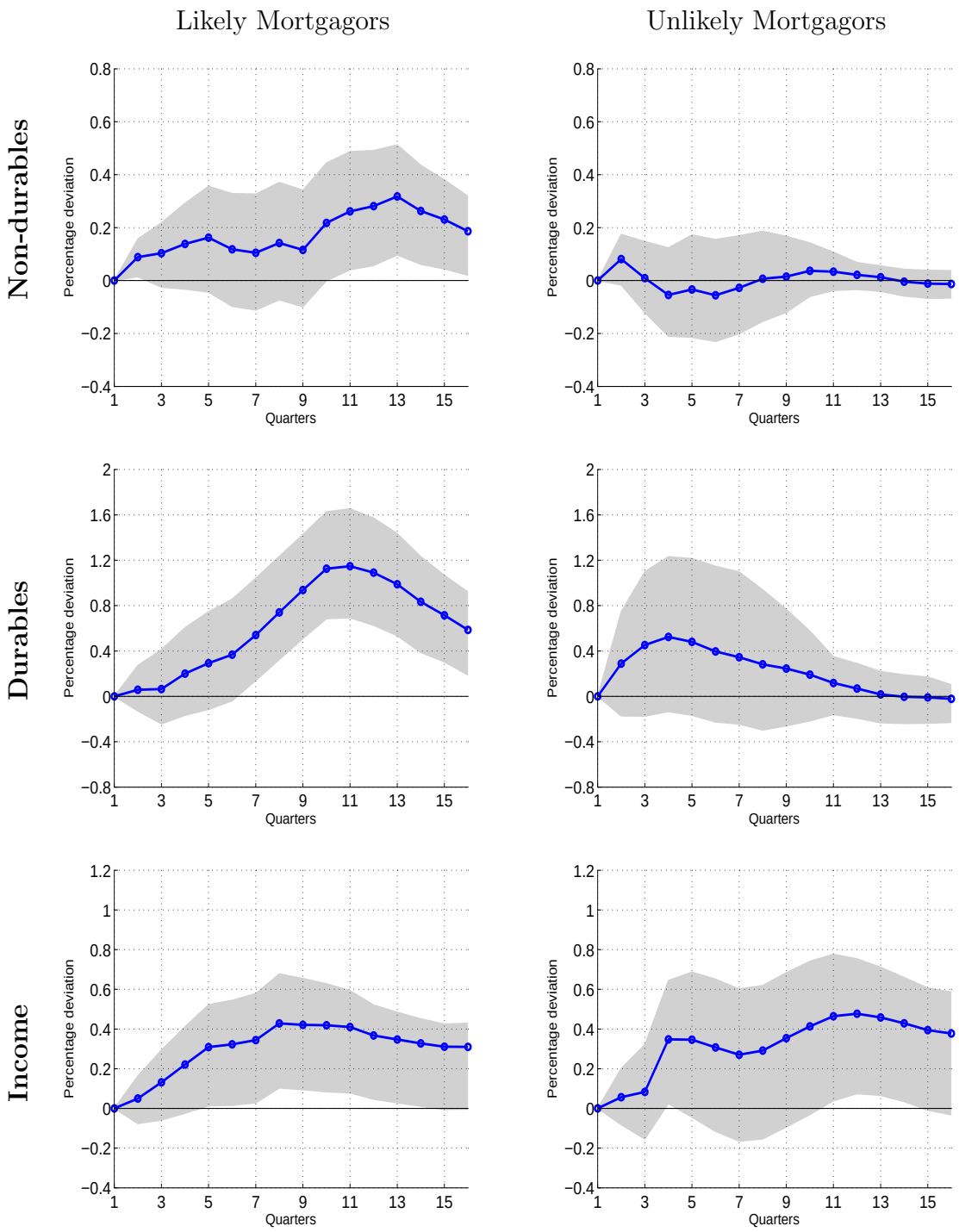


Figure 19: US results for non-durable, durable and income net of taxes for "likely" and "unlikely" mortgagors, excluding renters. Groups computed following Attanasio et al (2002) propensity score approach using a fixed probability threshold. Grey areas are bootstrapped 90% confidence bands.

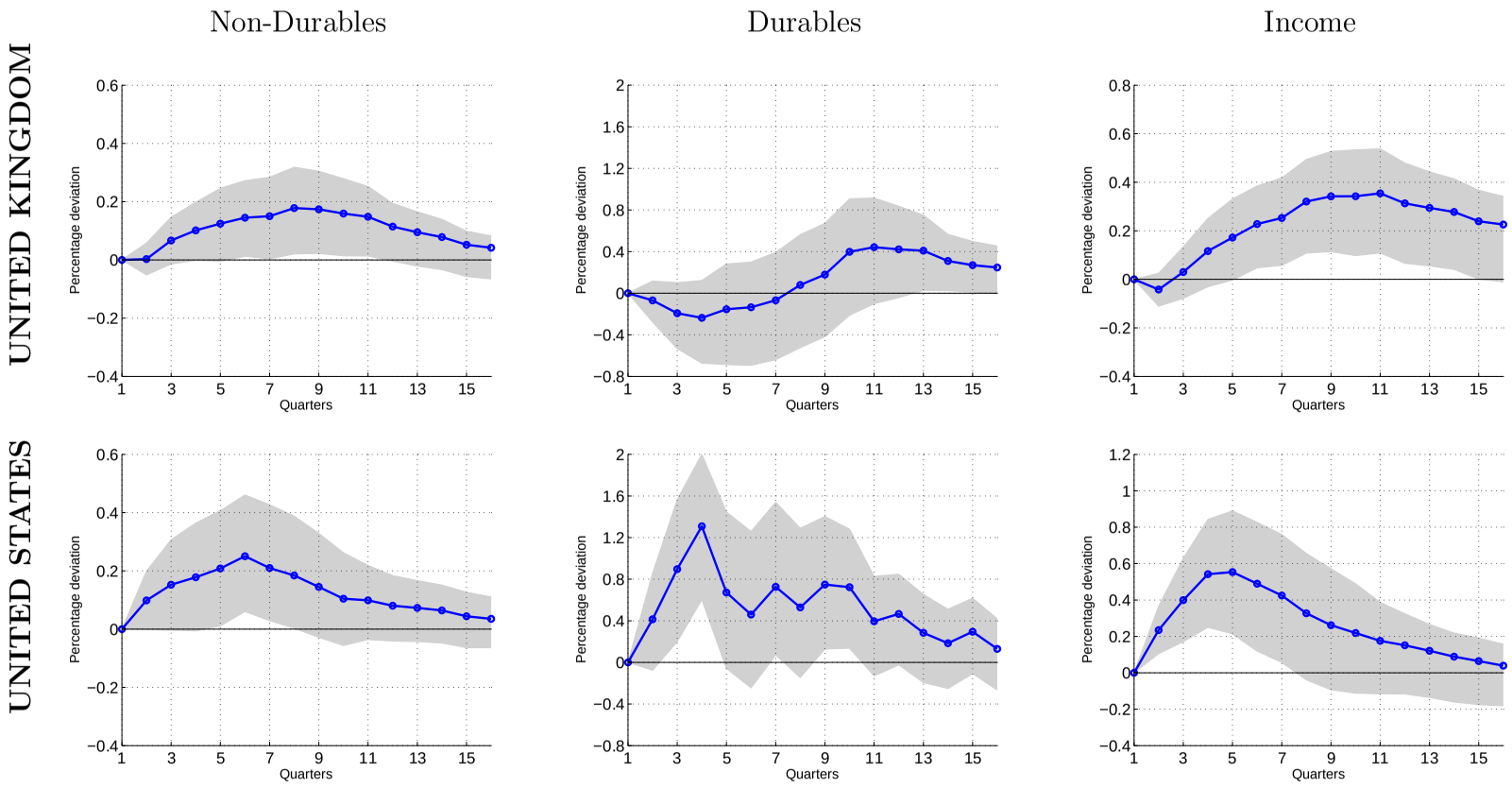


Figure 20: Dynamic effects of a 25 basis point unanticipated interest rate cut on non-durable consumption (ND), durable expenditure (D) and income net of taxes for renters. Grey areas are bootstrapped 90% confidence bands. U.K. data: FES/LCFS (1975-2007) in top row. U.S. data: CEX (1981-2007).

Appendix E: The full model

Households

There are, ex-ante, two types of households: *patient households* (PH) and *impatient households* (IH). These are differentiated by their discount factors β^H and β^L respectively, with $0 < \beta^L < \beta^H < 1$.[20] They all derive utility from the consumption bundle x_t, housing stock and/or services $\tilde{h}_t$ and dis-utility from labor L_t:

$$E_0\left[\sum_{t=0}^{\infty}\left(\beta^i\right)^t\left(\frac{x_t^{1-\sigma}}{1-\sigma}+j\log\tilde{h}_t-\frac{L_t^{\eta}}{\eta}\right)\right]$$

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

$$x_t \equiv C_t^{\theta}V_t^{1-\theta} - \mu C_{t-1}^{\theta}V_{t-1}^{1-\theta} \tag{4}$$

with C_t and V_t being non-durable consumption and the stock of durables, receptively; $\theta \in [0,1]$ is a share parameter and $\mu \in [0,1)$ captures habit persistence. The stock of durables for a household evolves according to the following law of motion:

$$V_{t+1} = \left(1-\Phi\left(\frac{D_t}{D_{t-1}}\right)\right)D_t + (1-\delta)V_t \tag{5}$$

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. There is a fixed stock of houses H, which are sold and bought at a price q_t^h.

Assets

Mortgages

Households can borrow/save through a multi-period (long term) instrument, which we refer to as bond or mortgage. One unit of debt issued at t pays, starting in $t+1$, the sequence of nominal installments $1, \rho, \rho^2, \ldots$, which decay at a rate $\rho \in [0,1]$. Therefore, if M_t units of debt are issued at t, the mortgage installment at $t+j$ is given by

$$pay_{t,t+j} = \rho^{j-1}M_t \quad j \geq 1 \tag{6}$$

[20] We assume that impatient (patient) households can trade a complete set of arrow securities with other impatient (patient) households, but not with the patient (impatient) households. This implies that idiosyncratic risk can be perfectly shared within households of the same type, but other risks cannot be insured with households of a different type.

The *total amount of installment payments* due at t is then given by

$$\begin{aligned} B_t &= \sum_{j=1}^{t} pay_{t-j,t} \\ &= M_{t-1} + \rho B_{t-1} \end{aligned} \tag{7}$$

Given this notation, the *value of the stock* of debt at the beginning of each period is given by

$$B_{t+1}^{stock} = \left(M_t + \rho M_{t-1} + \rho^2 M_{t-2} + ... + \rho^t M_0\right) \cdot S_t = B_{t+1} \cdot S_t$$

where S_t is the time-t price of one unit of debt. The value of the *real* stock is given by

$$b_{t+1}^{stock} \equiv \frac{B_{t+1}^{stock}}{P_{c,t}} = b_{t+1} S_t = \left(m_t + \rho \frac{b_t}{\pi_{c,t}}\right) S_t \tag{8}$$

where $m_t \equiv \frac{M_t}{P_{c,t}}$, $b_t \equiv \frac{B_t}{P_{c,t}}$ and $\pi_{c,t} \equiv \frac{P_{c,t}}{P_{c,t-1}}$.

One-period bonds

PH can also save through a nominal one-period bond, traded in zero net supply. One unit of such bond can be bought at a price of one, and earns a nominal return of R_t.

Production of durables and non-durables

Following Monacelli (2009), we model two sectors, producing durable investment goods D and non durable goods C using labor as the only input. In each sector, there are competitive final good producers and monopolistically competitive producers of intermediate varieties, facing the same cost of adjusting prices following Rotemberg (1982).

In the *symmetric equilibrium* where intermediate producers use the same amount of labor, it is possible to obtain an expression for the evolution of prices in each sector (Phillips curves)

$$\hat{\pi}_{D,t} = \beta^H E_t\left(\hat{\pi}_{D,t+1}\right) + \left(\frac{\epsilon_D - 1}{\vartheta_D}\right) \hat{mc}_{D,t} \tag{9}$$

$$\hat{\pi}_{c,t} = \beta^H E_t\left(\hat{\pi}_{c,t+1}\right) + \left(\frac{\epsilon_C - 1}{\vartheta_C}\right) \hat{mc}_{C,t} \tag{10}$$

where "$\hat{}$" variables denote deviation form a zero-inflation steady state, and $\pi_{j,t} \equiv \frac{P_{j,t}}{P_{j,t-1}}$ is the gross inflation rate in sector j.

Monetary policy

We assume that monetary policy is conducted through the short term (one-period) rate R_t, following a Taylor rule:

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

where $\pi_t \equiv \pi_{c,t}^{\alpha_\pi} \pi_{D,t}^{1-\alpha_\pi}$ is a composite inflation index, $Y_t = Y_{C,t}^{\alpha_y} Y_{D,t}^{1-\alpha_y}$ is a composite output index and $\bar{rr}, Y$ are steady state real rate and output.

E.1: The model with an exogenous credit limit

We first consider, along the lines of Eggertsson and Krugman (2012), the case where households face an exogenous[21] credit limit of the form

$$S_t b_{t+1} \leq E_t \left(\bar{\Omega} \frac{\pi_{t+1}}{R_t} \right) \tag{11}$$

If we define positive values of b_t as debt (negative values are savings), then the real budget constraint (in terms of the non-durable consumption good) for the impatient household reads

$$C_t + q_t^h \Delta h_t + q_t^d D_t + \frac{b_t}{\pi_{c,t}} = w_t L_t + S_t m_t \tag{12}$$

and for the patient household:

$$C_t^{'} + q_t^h \Delta h_t^{'} + q_t^d D_t^{'} - \frac{b_t^{'}}{\pi_{c,t}} = w_t L_t^{'} - S_t m_t^{'} + \Pi_{C,t} + \Pi_{D,c} \tag{13}$$

where patient household variables are denoted by "$'$".

The problem for the impatient household is to maximize the following expression:

$$W_{IH} = \max_{\{C_t, D_t, V_{t+1}, h_t, L_t, b_{t+1}, m_t\}} E_0 \sum_{t=0}^{\infty} \left(\beta^L\right)^t u\left(x_t, h_t, L_t\right)$$

subject to the budget constraint (12), the credit constraint (11), and the law of motion for the durable stock and the outstanding debt, (5), (7). We also assume a transversality (No-Ponzi games) condition.

Denote by λ_t the multiplier on the budget constraint; $\lambda_t q_t^v$ the multiplier on the law of motion for the durable stock, $\lambda_{M,t}$ the multiplier on the law of motion for mortgage repayments, and $\lambda_{CC,t}$ the multiplier on the credit constraint. The optimality

[21] One could also think of this as a borrowing limit tied to the steady state value of collateral.

conditions for $C_t, D_t, V_{t+1}, L_t, h_t$ as well as the Euler equation, can then be written respectively as

$$\lambda_t = \theta\left(\frac{C_t}{V_t}\right)^{\theta-1}\left(x_t^{-\sigma} - \mu\beta^L E_t\left(x_{t+1}^{-\sigma}\right)\right) \tag{14}$$

$$q_t^d = q_t^v\left(1 - \Phi\left(\frac{D_t}{D_{t-1}}\right) - \frac{\partial\Phi\left(\frac{D_t}{D_{t-1}}\right)}{\partial D_t}D_t\right) + \\ +\beta^L E_t\left(\frac{\lambda_{t+1}q_{t+1}^v}{\lambda_t}\frac{\partial\Phi\left(\frac{D_{t+1}}{D_t}\right)}{\partial D_t}D_{t+1}\right) \tag{15}$$

$$\lambda_t q_t^v = \beta^L E_t\left(\lambda_{t+1}\left(\frac{1-\theta}{\theta}\frac{C_{t+1}}{V_{t+1}} + (1-\delta)q_{t+1}^v\right)\right) \tag{16}$$

$$L_t^{\eta-1} = \lambda_t w_t \tag{17}$$

$$\lambda_t q_t^h\left(1 + \phi_h\frac{\Delta h_t}{h_{t-1}}\right) = \frac{j}{\tilde{h}_t} + E_t\left(\beta^L\lambda_{t+1}q_{t+1}^h\left(1 + \phi_h\frac{\Delta h_{t+1}}{h_t}\right)\right) \tag{18}$$

$$\lambda_t = \beta^L E_t\left(\lambda_{t+1}\frac{1+\rho S_{t+1}}{S_t\pi_{t+1}}\right) + \lambda_{CC,t}R_t \tag{19}$$

Condition (14) equates the shadow value of relaxing the budget constraint to the marginal utility of non-durable consumption, which is a function of habits μ. Conditions (15) and (16) are standard, and describe the expenditure and stock decisions for durables.[22] Equation (17) is the usual intratemporal condition equating the marginal rate of substitution between non-durable consumption and labor to the real wage. This condition is important to understand how a constrained household adjusts hours worked in order to compensate for being borrowing constrained. Equation (18) relates the shadow price of consumption to the marginal service value of housing in the current period, and its expected resale value in the next period. Note that in this version of the model, the only difference between D and housing is how they enter the utility of households. Finally, (19) is the modified Euler equation, which involves the (expected) one-period *holding return* on the long term mortgage $\frac{1+\rho S_{t+1}}{S_t\pi_{t+1}}$.

The problem for the PH is similar, but only facing constraints (13) and (5), (7). The main difference arises in the Euler equation which, for the patient household,

[22] To see things clearly, assume for the moment no adjustment costs, i.e. $\Phi = \Phi' = 0$. Then these two conditions can be combined into a standard optimality condition

$$q_t^d = \beta^L E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\left(U_{V,t} + (1-\delta)q_{t+1}^d\right)\right)$$

reads

$$\lambda_t^{'} = \beta^H E_t \left(\lambda_{t+1}^{'} \frac{1 + \rho S_{t+1}}{S_t \pi_{t+1}} \right) \tag{20}$$

No-arbitrage pricing

The price S_t of the mortgage can then be written as

$$S_t = E\left(\sum_{j=1}^{\infty} Q_{t,t+j} \rho^{j-1} \right) = \frac{1}{R_t} + \rho E\left(Q_{t,t+1} S_{t+1} \right) \tag{21}$$

where $Q_{t,t+j} = \left(\beta^H\right)^j \frac{\lambda_{t+j}}{\lambda_t}$ for $j \geq 1$ is the stochastic discount factor (SDF) of the patient household, between t and $t+j$. This second equality assumes, crucially, that there is *no arbitrage* when pricing. This means that a condition needs to be satisfied between the return of the long term debt and an implicit one-period bond.[23]

We can define the (Macaulay) duration of this contract as

$$D_t(\rho) = \sum_{j=1}^{\infty} \left(Q_{t,t+j} \cdot j \frac{\rho^{j-1}}{S_t} \right) \tag{22}$$

In a zero inflation steady state, equation (20) implies $Q_{t,t+j} = \frac{1}{R^j} = \left(\beta^H\right)^j$ and therefore the mortgage price in steady state is

$$S = \frac{\beta^H}{1 - \beta^H \rho}$$

while the steady state duration is equal to

$$D(\rho) = \frac{1}{1 - \beta^H \rho} \tag{23}$$

We log-linearize the economy around a zero-inflation steady state. All the derivations, together with the relevant steady state ratios are available on request.

[23] Up to a first order approximation, the key no-arbitrage pricing condition can be stated as

$$E_t\left(\frac{R_t}{\pi_{t+1}}\right) = E_t\left(\frac{1 + \rho S_{t+1}}{S_t \pi_{t+1}}\right)$$

Alternatively, we could also have assumed markets for two types of assets: a one-period bond, and a long-term mortgage, with households being able to use the short term bond only as a *saving* instrument which pays a gross *nominal* interest rate R_t^1. On the other hand, the mortgage market can be used *both* for saving and borrowing.

Parameterization

The exogenous credit limit model is parameterized using the values in Table 3 below. Most of these are relatively standard and well within the range of estimates available in the literature. Two parameters, however, deserve further explanation. In the collateral constraint model of the next section, the value of the housing demand shifter, j, pins down the maximum loan-to-value ratio in the impatient household's budget constraint. To set the latter to the empirically plausible value of 75%, we need $j = 0.468$. For the sake of comparability across the two models, we then impose the same value for j here.

Our framework abstracts from investment, government spending and net exports. Accordingly, at the aggregate level, income is equal to expenditure and therefore we need to calibrate the debt to expenditure ratio $\bar{\Omega}/Y$. The household debt to disposable income ratio (or the private credit to GDP) in the two countries has averaged around 110% while household expenditure tends to represent about 60% of output, implying a debt to expenditure ratio of about 1.8. Finally, we assume there are equal shares of constrained and unconstrained households.

Parameter	Description	Value
$\theta/(1-\theta)$	elasticity of substitution between ND and D stock	4
σ	elasticity of intertemporal substitution	0.5
β^L, β^H	discount factor: mortgagors, outright owners	0.95, 0.99
$1/(\eta-1)$	Frisch elasticity of labor supply	2
μ	habits parameter	0.5
j	housing demand shifter	0.468
δ	depreciation rate durables	0.025
$\varepsilon_{C,D}$	elasticity of varieties	4
$\vartheta_{C,D}$	cost of adjusting prices	150
r_π, r_Y, r_R	Taylor rule: CPI, output, smoothing	1.5,.05,.6
ω_{IH}	share constrained households	50%
ω_{PH}	share unconstrained households	50%
$\bar{\Omega}/Y$	debt to expenditure ratio	1.8
$1/(1-\beta^H\rho)$	Benchmark long term debt duration	1 year

Table 3: Calibration of the model.

E.2: The model with an endogenous collateral limit

We now assume that the housing stock h_t can be used as collateral, following Kiyotaki and Moore (1997) and Iacoviello (2005).[24] The credit constraint (11) now reads

$$S_t b_{t+1} \leq \phi E \left(q^h_{,t+1} h_t \frac{\pi_{t+1}}{R_t} \right) \tag{24}$$

where ϕ is the steady state loan-to-value (LTV) ratio, and $q^h_{,t+1} h_t$ is the real value of the housing stock at t+1.

There is a *rental market* through which households can rent (from/to others) housing services for one period at a rate p_t. Households are now also heterogeneous with respect to the utility they derive from renting.[25] Within the impatient households, there are now two groups of agents. We denote IHm those households who derive relatively higher utility from owned housing, and IHr those households who derive similar utility from renting or owning. The population shares of IHm, PH and IHr are *exogenous* and given by $(\omega_{IHm}, \omega_{PH}, 1 - \omega_{IH} - \omega_{PH})$, consistent with the evidence in Section 4.2 that the shares of each housing tenure group do not vary with changes in monetary policy. But, importantly, the housing tenure choice (how much house to own vs. rent) will be endogenous.

Housing utility (services) can be derived from housing owned or rented. Let $h_t \in \mathbb{R}^+$ be the housing stock *owned*, $s^-_t \in \mathbb{R}^+$ the housing rented *to* others, and $s^+_t \in \mathbb{R}^+$ the housing stock rented *from* others. Housing services are then given by

$$\tilde{h}_{t,i} = h_{t,i} - s^-_{t,i} + \gamma_i s^+_{t,i} \quad i \in \{PH, IHm, IHr\} \tag{25}$$

with $\gamma \in [0, 1)$ capturing different reasons why households might preference to own rather than to rent.

Crucially, γ is household specific: $0 < \gamma_{IHm} = \gamma_{PH} < \gamma_{IHr} = 1$. This means that PH and IHm derive a higher marginal utility from their housing stock that is not rented out, $h_{t,i} - s^-_{t,i}$, than from the housing stock that they may rent from others, s^+_t. For IHr, on the other hand, the marginal utility is equal whether its owned or rented. All households face an individual housing *feasibility* constraint

$$h_{t,i} - s^-_{t,i} \geq 0 \tag{26}$$

[24] Note that we are not allowing the stock of durable goods V_t to be collateralizable. The reason for this is twofold. First, although there might be some durable goods in the data that are collateralizable, this is not typically the case, even for large durables such as vehicles. Second, we want to distinguish the role of durable goods from that of the housing stock.

[25] This way of modeling renting and owning is a simplification. One could think of this as a reduced form way of capturing life-cycle considerations which are not present in this class of model.

meaning that they cannot rent out more than they currently own, $h_{t,i}$, and they cannot sub-let.[26]

Households also face a quadratic adjustment cost when adjusting the housing stock, given by

$$\xi_{h,t} = \phi_h \left(\frac{\Delta h_t}{h_{t-1}} \right)^2 \frac{q_t^h h_{t-1}}{2} \tag{27}$$

The impatient household (whether borrower or mortgagor/renter in equilibrium) solves the following optimization problem

$$W_{IH} = \max_{\left\{C_t, D_t, V_{t+1}, h_t, s_t^+, s_t^-, L_t, b_{t+1}, m_t\right\}} E_0 \sum_{t=0}^{\infty} \left(\beta^i\right)^t u\left(x_t, \tilde{h}_t, L_t\right)$$

subject to (Lagrange multipliers in parenthesis)

$$\begin{aligned}
C_t + q_t^d D_t + q_t^h \Delta h_t + \frac{b_t}{\pi_{c,t}} + \xi_{h,t} &= w_t L_t + S_t m_t + p_t \left(s_t^- - s_t^+\right) + T_t \quad (\lambda_t) \\
V_{t+1} &= \left(1 - \Phi\left(\frac{D_t}{D_{t-1}}\right)\right) D_t + (1-\delta) V_t \quad (\lambda_t q_t^v) \\
\tilde{h}_t &= \begin{cases} h_{t,i} + \gamma s_{t,i}^+ - s_{t,i}^- & \text{if } i = IHm \\ h_{t,i} + s_{t,i}^+ - s_{t,i}^- & \text{if } i = IHr \end{cases} \quad \left(\lambda_t^3\right) \\
h_t - s_t^- &\geq 0 \quad \left(\lambda_t^5\right) \\
s_t^- &\geq 0 \quad \left(\lambda_t^6\right) \\
s_t^+ &\geq 0 \quad \left(\lambda_t^7\right) \\
b_{t+1} &= m_t + \rho \frac{b_t}{\pi_t} \quad \left(\lambda_t^8\right) \\
S_t b_{t+1} &\leq \phi E \left(\frac{q_{,t+1}^h h_t \pi_{t+1}}{R_t} \right) \quad (\lambda_{BC,t})
\end{aligned}$$

The patient household solves

$$W_{PH} = \max_{\left\{C_t, D_t, V_{t+1}, h_t, s_t^+, s_t^-, L_t, b_{t+1}, m_t\right\}} E_0 \sum_{t=0}^{\infty} \left(\beta^H\right)^t u\left(x_t, \tilde{h}_t, L_t\right)$$

[26] Note that restriction (26) together with the non-negativity of $s_{t,i}^-$ already imply that $h_{t,i} \geq 0$.

subject to (Lagrange multipliers in parenthesis)

$$
\begin{aligned}
C_t + q_t^d D_t + q_t^h \Delta h_t - \frac{b_t}{\pi_{c,t}} + \xi_{h,t} &= w_t L_t - S_t m_t + p_t \left(s_t^- - s_t^+\right) + \Pi_{C,t} + \Pi_{D,c} + T_t \quad (\lambda_t) \\
V_{t+1} &= \left(1 - \Phi\left(\frac{D_t}{D_{t-1}}\right)\right) D_t + (1-\delta) V_t \quad (\lambda_t q_t^v) \\
\tilde{h}_t &= h_{t,i} + \gamma s_{t,i}^+ - s_{t,i}^- \quad \left(\lambda_t^3\right) \\
h_t - s_t^- &\geq 0 \quad \left(\lambda_t^5\right) \\
s_t^- &\geq 0 \quad \left(\lambda_t^6\right) \\
s_t^+ &\geq 0 \quad \left(\lambda_t^7\right) \\
b_{t+1} &= m_t + \rho \frac{b_t}{\pi_t} \quad \left(\lambda_t^8\right)
\end{aligned}
$$

Housing tenure in steady state

It can be shown that, for an owning-preference threshold $\bar{\gamma}$ such that $\gamma < \bar{\gamma}$, there exists zero-inflation steady state ($SS^{\pi=0}$) in which:[27]

1. The PHs 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 ($b^{''} = 0$), or (ii) rent to others ($s^{-''} = 0$). They instead rent housing services ($s^{+''} > 0$).
3. The IHms own housing ($h > 0$) but do not participate in the rental market ($s^- = s^+ = 0$).

Parameterization

In Table 4, we report the values used for the collateral constraint model which are, in most cases, the same as in Table 3. The steady state loan-to-value ratio, ϕ, (which did not appear in the previous parameterization) is set to 75%, consistent with the sample averages reported by Besley et al. (2013). On the other hand, the shares of mortgagors and outright owners mimic the average values we observe in the FES/LCSF and CEX.

[27] We assume that the conditions above also hold for states "near the SS". This is equivalent to requiring 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 the steady state $SS^{\pi=0}$. The assumption of no change in housing tenure following a monetary policy shock is, however, consistent with the results presented in Section 4.2.

Parameter	Description	Value
$\theta/(1-\theta)$	elasticity of substitution between ND and D stock	4
σ	elasticity of intertemporal substitution	0.5
β^L, β^H	discount factor: mortgagors, outright owners	0.95, 0.99
$1/(\eta-1)$	Frisch elasticity of labor supply	2
μ	habits parameter	0.5
j	housing demand shifter	0.468
δ	depreciation rate durables	0.025
$\varepsilon_{C,D}$	elasticity of varieties	4
$\vartheta_{C,D}$	cost of adjusting prices	150
r_π, r_Y, r_R	Taylor rule: CPI, output, smoothing	1.5,.05,.6
ω_{IH}	share of mortgagors	45%
ω_{PH}	share outright owners	35%
m	max LTV	0.75
$\bar{\Omega}/Y$	debt to expenditure ratio	1.8
$1/(1-\beta^H\rho)$	Benchmark long term debt duration	1 year

Table 4: Calibration of the model.

Renters

Figure 21 presents the impulse response functions for a 25bp cut in interest rates for non-durable consumption, durable expenditure and income of renters in the collateral constraint model. These responses are the analogue of the ones presented in Figure 10. Two interesting features are worth discussing. First, the renters' responses are relatively large, being only slightly smaller than those of mortgagors but larger than those of outright owners. The fact that renters' consumption responds significantly is intuitive given that these households are constrained and wealth-poor in our model.

Second, the renters' responses for non-durable consumption and for durable expenditure vary with the duration of mortgage contracts. While this may seem less intuitive, it can be understood by looking at the response of labor income. To the extent that different values for ρ produce different aggregate demand effects, these will also affect the renters' income.

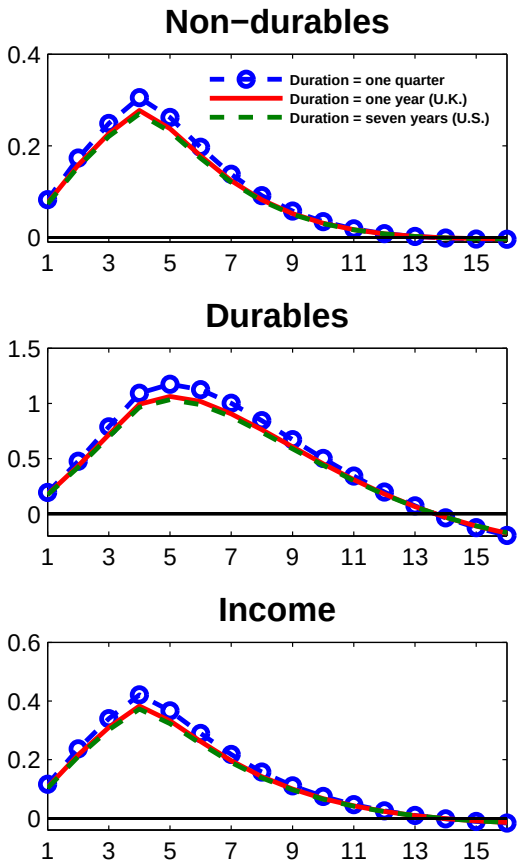


Figure 21: Response of non-durable consumption, durable expenditure and income in a model with a collateral constraint: results for renters. Duration refers to the effective duration of fixed-rate mortgage contracts in the aggregate economy which, on average, is about one year for the U.K. and around 7 years for the U.S.

Appendix F: House prices and mortgage equity withdrawal

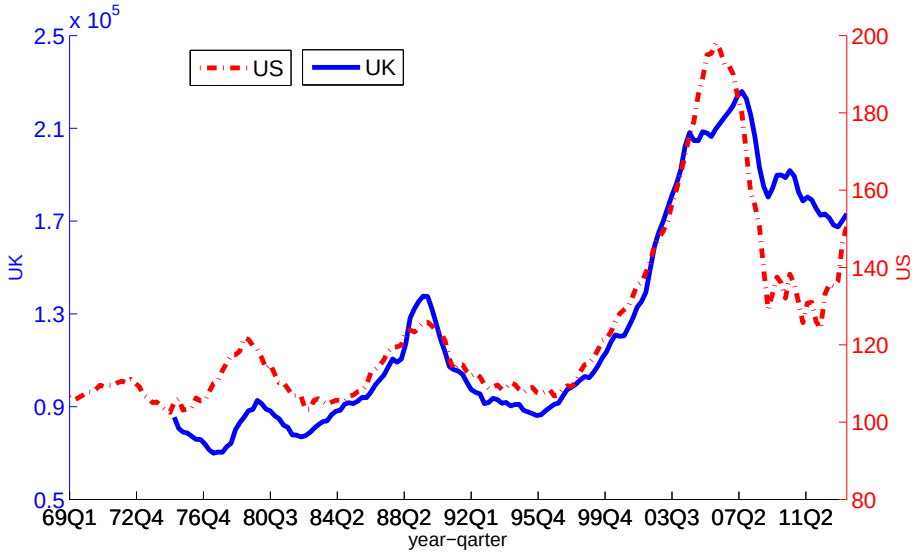


Figure 22: Real House Price indexes. UK source: NationWide. US source: Case Shiller

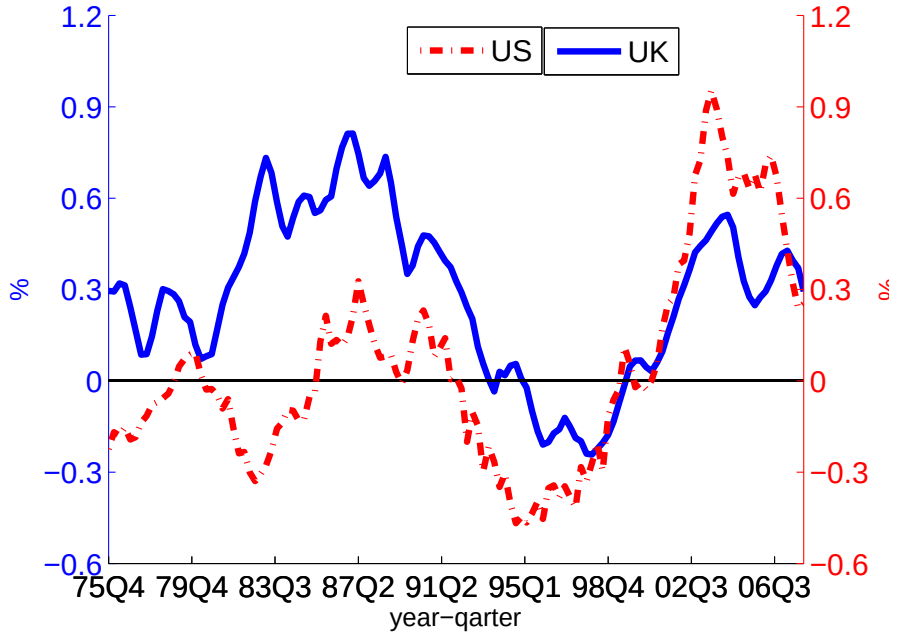


Figure 23: Mortgage Equity Withdrawal as a % of Net Housing Wealth.

Figure 24: IRF for aggregate real house prices (first column) and home equity withdrawal as a share of net housing wealth (second column). Grey areas are bootstrapped 90% confidence bands. Top row: U.K. (1975-2007). Bottom row: U.S. (1981-2007).