Household Debt and the Effects of Fiscal Policy

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Abstract

This paper examines how the effects of government spending shocks depend on the balance-sheet position of households. Employing U.S. household survey data, we find that in response to a positive government spending shock, households with mortgage debt have a large, positive consumption response, while renters have a smaller rise in consumption. Homeowners without mortgage debt, in contrast, have an insignificant expenditure response. We consider a dynamic stochastic general equilibrium (DSGE) model with three types of households: savers who own their housing, borrowers with mortgage debt, and rule-of-thumb consumers who rent housing, and show that it can successfully account for these findings. The model suggests that liquidity constraints and wealth effects, tied to the persistence of public spending, play a crucial role in the propagation of government spending shocks. Our findings provide both empirical and theoretical support for the notion that household mortgage debt position plays an important role in the transmission mechanism of fiscal policy.

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Keywords: Fiscal shocks, Government spending, Household balance sheets, Household debt

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1 Introduction

In the aftermath of the Great Recession, there has been growing interest in the role of household debt in the transmission of macroeconomic shocks, as policymakers have increasingly relied on fiscal policy to stabilize and stimulate the economy. This paper examines how the transmission of government spending shocks depends on the balance-sheet position or debt level of households in the economy.

Since mortgage debt constitutes the vast majority of household debt, we employ data on mortgagors, outright owners, and renters to proxy for the financial position of households. This is in the spirit of Cloyne and Surico (2017) and Cloyne, Ferreira and Surico (2020), who have shown that housing tenure status can be a useful proxy for debt and asset position, and exploiting information in the U.S. Consumer Expenditure Survey by tenure status allows us to circumvent the issue that few datasets have detailed information about household income, expenditures and liabilities over a long period of time.

Our first contribution is to provide new evidence on the heterogeneous effects of government spending effects, based on housing tenure status. Notably, we find that in response to a positive government spending shock, mortgagor households experience a large rise in their consumption. Renters also experience a rise in their consumption, but the magnitude of the increase is lower than mortgagors. Outright homeowners without mortgage debt, in contrast, have an insignificant consumption expenditure response to a public spending shock. There might be concerns about selection bias and endogenous choice into tenure status, and we show in our particular case, that the share of households in each group does not respond significantly to aggregate public spending shocks.

We further show how consumption patterns differ across durable and non-durable consumption. Our findings indicate that mortgagor and renter households consistently exhibit significant consumption responses for both durable and nondurable goods, while the response of outright homeowners primarily stems from non-durable goods. This heterogeneity cannot be explained by differences in income responses, which are similar across the three types of households. In addition, our results show that it is not the housing tenure status, per se, that matters but the level of household indebtedness or liquid wealth that differentiates the household response to a government spending shock. These results also provide further support for the importance of wealthy hand-to-mouth households in the propagation of aggregate shocks, which has been documented in earlier literature, such as Kaplan, Violante and Weidner (2014) and described further in the literature review. We show that these households also play a critical role in the transmission of government spending shocks.

Our second contribution is to provide a theoretical framework to rationalize these empirical findings and dig deeper into the transmission mechanism. We construct a dynamic stochastic general equilibrium (DSGE) model with housing and durable goods, borrowing and lending across heterogeneous households, and financial frictions in the form of collateral constraints similar to Iacoviello (2005). In departure from most literature, the model features three types of households: savers who own their housing, borrowers with mortgage debt, and rule-of-thumb consumers who rent housing. Thus, we introduce a rental housing market alongside owner-occupied housing. Since our focus is on mortgage debt, we model fixed-rate mortgage loans which are amortized over the long term, similar to Kydland, Rupert and Šustek (2016) and Alpanda and Zubairy (2017). We calibrate the parameters of the model in order to match micro-evidence and various data moments like housing shares of various types of households in the U.S. economy. While this model shares common features and mechanisms found in earlier work, here we focus on the question of the propagation of government spending shocks, and the role of different households with distinct housing tenure statuses.

We show that this model can successfully match aggregate responses of key macroeconomic variables and also account for the different responses across households to a public spending shock both qualitatively and quantitatively. Government spending shocks propagate through the economy primarily through wealth and liquidity effects. The persistence of the spending shock generates different degrees of wealth effects and plays an important role in the transmission of the shock. The patient households behave like Ricardian households by reducing their consumption while renter households exhibit hand-to-mouth behavior, expecting future tax increases. This behavior is less pronounced when the shock is less persistent, indicating a lower negative wealth effect resulting from a positive government spending shock. For the impatient households, government spending shocks help relax their borrowing constraint and thus their ability to borrow and consume. Therefore, particularly for those households with a mortgage, liquidity constraints play a crucial role in the propagation of government spending shocks.

We also consider the robustness of the heterogeneous consumption responses to variations in the parameters of the model, additional lines of credit such as home-equity lines of credit or refinancing, and the stance of monetary policy. Our findings provide both empirical and theoretical support for the notion that household mortgage debt position plays an important role in the transmission mechanism of fiscal policy.

1.1 Literature Review

Our paper contributes to the growing literature that has shown that we need a departure from a representative agent model to understand the aggregate consumption dynamics in response to a government spending shock. Galí, López-Salido and Vallés (2007) show in a New-Keynesian model with two types of agents that the presence of liquidity-constrained households matters for the aggregate consumption response. These non-Ricardian agents who can not borrow and save raise their consumption in response to a positive shock to public spending and if their share is large enough, lead to a rise in aggregate consumption. Similarly, others have considered the heterogeneous effects of government spending based on various features including income (Ma (2019) and references within) and age/demographics (Basso and Rachedi (2021)).

The pre-existing literature also establishes that household balance sheet position matters and wealthy hand-to-mouth households play an important role in the propagation of aggregate shocks including fiscal innovations. Notably, Kaplan and Violante (2014) show that wealthy hand-to-mouth or liquidity-constrained households are important to explain the response to transfers in the form of tax rebate checks. Cloyne and

Surico (2017) consider the role of tax shocks, and show empirically that mortgagor households have the largest response to tax shocks, focusing on survey data from the UK. Brinca et al. (2016) develop a life-cycle model with heterogeneous agents and incomplete markets, and find that the fiscal multiplier is highly sensitive to the fraction of the population facing binding credit constraints and to the average wealth level in the economy. In a similar spirit, we consider the role of household debt in the propagation of a different aspect of fiscal policy in the form of government spending shocks.

While our focus is on the different types of households, our paper is also related to studies that focus on the time and space variation in household indebtedness. For instance, Demyanyk, Loutskina and Murphy (2016) exploit U.S. regional data to document that relative fiscal multipliers are higher in areas with higher consumer indebtedness. Bernardini and Peersman (2018) employ historical data for the U.S. and show that the aggregate government spending multiplier is higher during periods of private debt overhang.

In a related study, Andres et al. (2021) use the information on balance sheets of households in PSID to document the share of different types of households in the data based on their balance sheet position, but unlike us, they do not consider the consumption patterns of these households. They explore a related but different question from us, which is the role played by the observed changes in the distribution of households in the transmission mechanism of government spending shocks by calibrating a DSGE model with the empirical weights estimated in the PSID across subsequent waves. They find that the effects of fiscal shocks are sensitive to the fraction of households in the left tail of the wealth distribution.

The remainder of this paper proceeds as follows. Section 2 and 3 describe our empirical estimation and discuss the dynamic effects of government spending shock. In Section 4, we present our model and its calibration. Section 5 discusses the results of the model with transmission mechanisms. Section 6 provides some extensions and robustness checks. Section 7 concludes.

2 Empirical approach

2.1 Identification and estimation methodology

In order to examine the effects of government spending shocks, we first need to specify our identification scheme. Notably, it is a challenge to identify innovations to government spending that are exogenous and unanticipated. We follow the approach introduced in Ramey (2011), and employ the Survey of Professional Forecasters (SPF) forecast errors for federal spending to identify government spending shocks. In particular, we consider the difference between actual government spending growth and the one-quarter ahead forecast of its growth rate by professionals. The key identifying assumption of this approach is that the shocks are orthogonal to professional forecasts of future government purchases and the forecasters are incorporating all available information about the state of the economy and other aspects in their forecasts. Thus, the forecast errors capture any surprise or news about government spending.

Unlike existing identification strategies including SVARs (Structural Vector Autoregressions) with short-run timing restrictions on the government spending variable a la Blanchard and Perotti (2002), these shocks are not subject to anticipation effects, since professional forecasts plausibly incorporate all existing data regarding the condition of the economy. The other alternative based on military news from narrative accounts, Ramey (2011) have low predictive power in the post-Korean war sample, which is the time period under consideration in this paper. In contrast, SPF forecast errors have been shown quantitatively to not to suffer from these anticipation effects and have large first-stage F-statistics for predicting total government and military spending in samples excluding large military events, like the World Wars and the Korean War (see Ramey (2011)).

In order to study the empirical effects of government spending shocks on both aggregate and disaggregate variables across various types of households, we employ the following VAR,

$$\mathbf{y}_t = \alpha_0 + \alpha_{1t} + A(L)\mathbf{y}_{t-1} + \mathbf{u}_t \tag{1}$$

where $\mathbf{y}_t$ is a $n \times 1$ vector with variables of interest, $\mathbf{A}(L)$ is a polynomial in the lag operator, and $\mathbf{u}_t$ is an error term. In the baseline estimation with aggregate macroeconomic variables, we consider the following ordering: with SPF forecast errors first followed by log of real government spending, log real per capita GDP and consumption, household debt (both flow and stock), house price index, and the Federal Funds rate.[1] We identify shocks to the first equation with SPF forecast errors (identified with a Cholesky decomposition) as the government spending shock of interest.[2]

In addition to considering the responses of macroeconomic aggregate variables, we investigate the existence of heterogeneity across households with different financial positions in response to a positive government spending shock. Since mortgage debt constitutes the vast majority of household debt, we employ household survey data on consumption and income across housing tenure status to proxy for the households' balance sheet position following Cloyne, Ferreira and Surico (2020).[3] Equation (2) indicates the order of a VAR analysis for three housing tenure groups: mortgagors, outright homeowners, and renters.[4]

Specifically, we consider SPF forecast errors first followed by the log of real government spending, log real per capita GDP, and housing tenure group-specific consumption (i.e. aggregate consumption, $rCON_t^i$, non-durable and durable consumption, $rNDC_t^i$ and rDC_t^i, respectively) or income (i.e. gross and net income,

[1]Data sources are available in Appendix A. Here government spending constitutes total government spending on government consumption and investment at the federal and state level, which is the commonly used measure in the literature.

[2]Note, that this is different from a Blanchard and Perotti (2002) type identification, as we consider the innovation to the forecast error as the spending shock, and not the innovation to the government spending variable. We choose a lag length of four based on the Akaike information criterion (AIC). We apply a linear time trend and the impulse responses are calculated based on the three-period moving average. The moving average is based on three periods: $(t-1, t, t+1)$ to smooth the responses over time. In our robustness analysis, we remove the moving average approach to smooth the IRFs and show that the results are overall unaffected.

[3]We employ the consumption and income series constructed by Cloyne, Ferreira and Surico (2020) in our empirical analysis. The next section provides further details on these data.

[4]The lag operator is equal to two with housing tenure group-specific variables. Standard errors are 68 and 90 percent confidence bands generated by Monte Carlo simulations.

Table 1: Consumption, income, and share by housing tenure group

Housing tenure group	Non-durable cons.	Durable cons.	Gross inc.	Net inc.	Share (%)
Mortgagors	2,860	480	3,412	3,052	46%
Outright owners	2,799	394	2,617	2,454	20%
Renters	2,324	301	2,394	2,149	34%

Notes: Table 1 reports the mean value of real per capita values of non-durable and durable expenditure and gross and net income for one quarter (deflated by consumer price index) for the CEX, 1981:Q1-2007:Q1.

rGI_t^i and rNI_t^i, respectively) as the last variable.

$$\mathbf{y}_t \equiv \begin{pmatrix} SPF\ FE_t \\ \log\ rGOV_t \\ \log\ rGDP_t \\ \log\ X_t^i \end{pmatrix} \tag{2}$$

where $i \in \{\text{mortgagors, outright homeowners, renters}\}$ and $X_t^i \in \{rCON_t^i, rNDC_t^i, rDC_t^i, rGI_t^i, rNI_t^i\}$.

2.2 Data

In this subsection, we describe the data used in the empirical estimation. The key aggregate variables used in the baseline empirical analysis such as real per capita GDP, government spending, and consumption are from National Income and Product Accounts (NIPA). Households' mortgage debt comes from the Board of Governors of the Federal Reserve System. The house price index in the baseline specification comes from the Census Bureau for the sale of new single-family houses. This is the series commonly used in the literature, e.g. by Iacoviello and Neri (2010), Favara and Imbs (2015) and Alpanda and Zubairy (2017).[5] The SPF forecast errors are constructed using the SPF forecasts for federal spending which are available from the Federal Reserve Bank of Philadelphia. Since the SPF forecasts for federal spending are available starting in 1981, it limits the start of our sample. We end our sample in 2007 in order to ensure we exclude the zero lower bound (ZLB) period. We also consider data from the U.S. Consumer Expenditure Survey (CEX) to investigate the heterogeneous responses across households. Survey of Consumer Finances (SCF) data is used to provide additional information about asset and wealth position across households in the baseline sample period.[6]

The CEX data contains the demographic characteristics (household size, birth year of household head,

[5] We also consider alternative series on the house price index including all transactions house price index from the U.S. Federal Housing Finance Agency and the median sales price of houses sold from the U.S. Department of Housing and Urban Development. These results are shown in the Appendix.

[6] In our baseline empirical analysis with a VAR approach, the sample period covers from 1981:Q4 to 2007:Q1. We use SCF data from 1995 to 2007 at a 3-year frequency. The SCF data includes net liquid and illiquid asset positions across housing tenure groups following Kaplan, Violante and Weidner (2014) definition.

Table 2: Share of each housing tenure group and wealthy HtM

PANEL A: Share of each housing tenure group

	1995	1998	2001	2004	2007
Number of observation					
Mortgagors	9,359	9,112	9,535	10,026	10,278
Outright homeowners	5,600	5,146	5,583	5,589	5,197
Renters	5,355	5,795	5,797	5,770	5,130
Total	20,314	20,053	20,915	21,385	20,605
Share of each group					
Mortgagors	0.46	0.45	0.46	0.47	0.50
Outright homeowners	0.28	0.26	0.27	0.26	0.25
Renters	0.26	0.29	0.28	0.27	0.25

PANEL B: Wealthy Hand-to-Mouth households

	1995	1998	2001	2004	2007
Wealthy HtM (Total)					
Mortgagors	0.16	0.12	0.11	0.13	0.15
Outright homeowners	0.04	0.03	0.03	0.03	0.03
Renters	0.06	0.06	0.06	0.05	0.05
Total	0.26	0.21	0.20	0.21	0.23

Notes: Table 2 reports the share of each housing tenure group and the share of wealthy Hand-to-Mouth for the SCF 1995-2007.

and educational attainment), housing-related variables (tenure status, outstanding mortgage debt, rental payments), consumption expenditure (weekly expenditure on non-durable and durable goods excluding housing), and income coverage (labor and non-labor income) for many decades.[7] Labor income includes wages and salaries and non-labor income includes income from investments and social payments, net of taxes.

Since mortgage debt accounts for the vast majority of household debt, we classify households by three housing tenure groups - mortgagors, outright owners, and renters - to proxy for the financial positions of households following Cloyne, Ferreira and Surico (2020).[8] Table 1 describes the mean value of real per capita consumption (in non-durable and durable goods), income (gross and net income), and the share of each housing tenure group out of total population (%) across three housing tenure groups in the sample period spanning 1981:Q4 to 2007:Q1. Mortgagors constitute the majority of households, with a share of about 47% of all households on average, followed by renters and then outright owners.

SCF data includes basic demographic features similar to the CEX, liquid wealth such as checking and

[7]Household size is used to determine the real per capita term and the birth year of the household head gives information about life-cycle positions across households, considered in a robustness check.

[8]For each housing tenure group, the data includes group-specific consumption (i.e. non-durable and durable expenditures) and income (i.e. gross and net income) based on the CEX. The final series of data is aggregated and converted into a quarterly frequency, deflated by the Consumer Price Index (CPI).

savings account, and illiquid wealth including home equity. Following Kaplan, Violante and Weidner (2014), we use the SCF data to define the wealthy hand-to-mouth (HtM) households who hold little or no liquid wealth despite owning sizable illiquid assets. Table 2 shows the share of each housing tenure group and wealthy hand-to-mouth based on SCF data.[9] Both the CEX and SCF data help us establish that mortgagors own sizable wealth based on housing (which is an illiquid asset) with a sizable debt mostly in the form of mortgages. Outright homeowners own both liquid and illiquid assets while renters tend to have low wealth. Housing tenure status can thus provide a useful proxy to represent the balance sheet positions of households. The share of each group varies over time but by a relatively insignificant amount.

3 Aggregate and disaggregate effects of government spending shocks

3.1 Aggregate estimation results

Figure 1 shows the impulse responses of key macroeconomic variables to a positive government spending shock. Government spending increases significantly in response to a shock to SPF forecast errors. Output and consumption rise for a few quarters and then fall. Consumption response peaks between four and five quarters.[10] The rise in GDP, hours, consumption, and real wages is consistent with previous literature (Blanchard and Perotti, 2002; Galí, López-Salido and Vallés, 2007; Ramey, 2011). We also find that both the stock and the flow of mortgage debt increase on impact while the persistence of the flow of debt is relatively small. Lastly, real house prices increase in response to a positive government spending shock. This has been documented by Khan and Reza (2017) and Larsen, Ravn and Santoro (2022). The persistence of house price response is dependent on the data series used.[11]

3.2 Disaggregate estimation results by housing tenure group

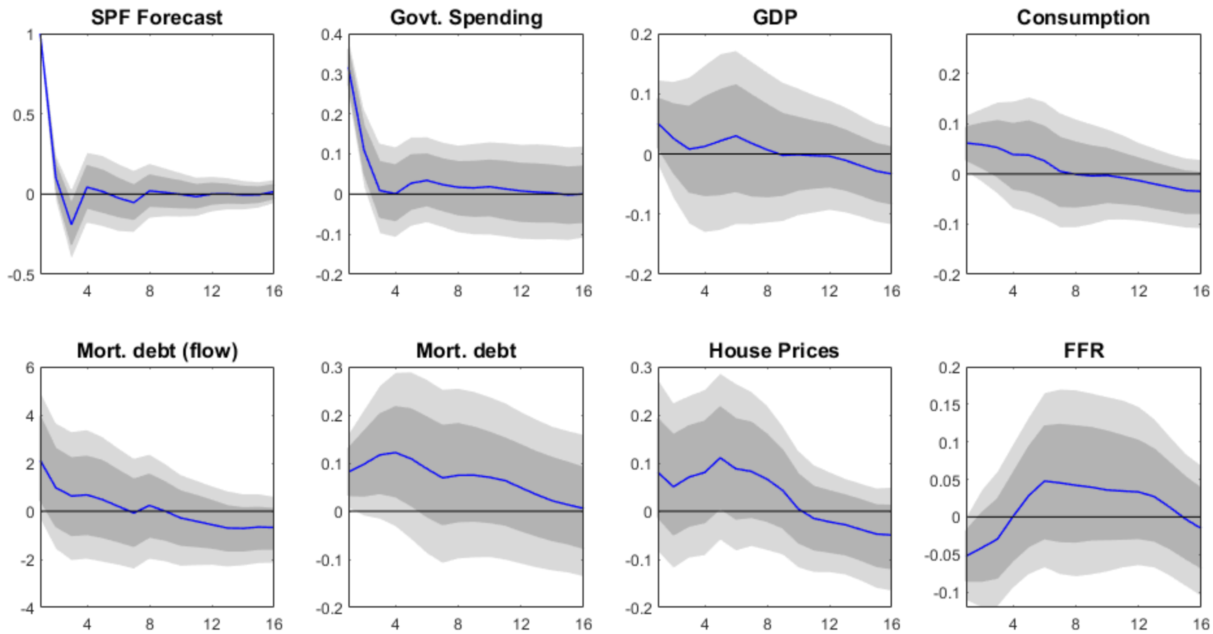
We now consider the response of housing tenure group-specific consumption and income to a positive government spending shock. Consumption data accounts for non-durable and services consumption and durable expenditure, and income data includes net and gross income across households. In Figure 2, we show the dynamic effects of aggregate government spending shocks on consumption including aggregate, durable, non-durable consumption, and the share of durable goods across the three housing tenure groups. The first column of Figure 2 illustrates the responses for mortgagors and the second and third columns show the responses of outright homeowners and renters, respectively.

[9] Both the CEX and SCF show that mortgagors account for the majority share on average, followed by renters and outright owners. In Appendix B, Table B.1 shows the share of asset and debt to income ratio of each housing tenure group.

[10] The aggregate consumption response is lower than disaggregate consumption responses by households due to a weighted averaging of responses from patient, impatient, and renting households. It's worth noting that mortgagor households represent 46% of the total population, while renters account for 34% and outright homeowners for 20%. Furthermore, the consumption response for outright homeowners moves in the opposite direction, which reduces the aggregate response when compared to the responses of individual housing tenure groups.

[11] In Appendix, Figure C.5 shows the impulse responses of key macroeconomic variables and house prices across alternative specifications.

Figure 1: Baseline impulse response functions of aggregate variables in response to a positive SPF shock

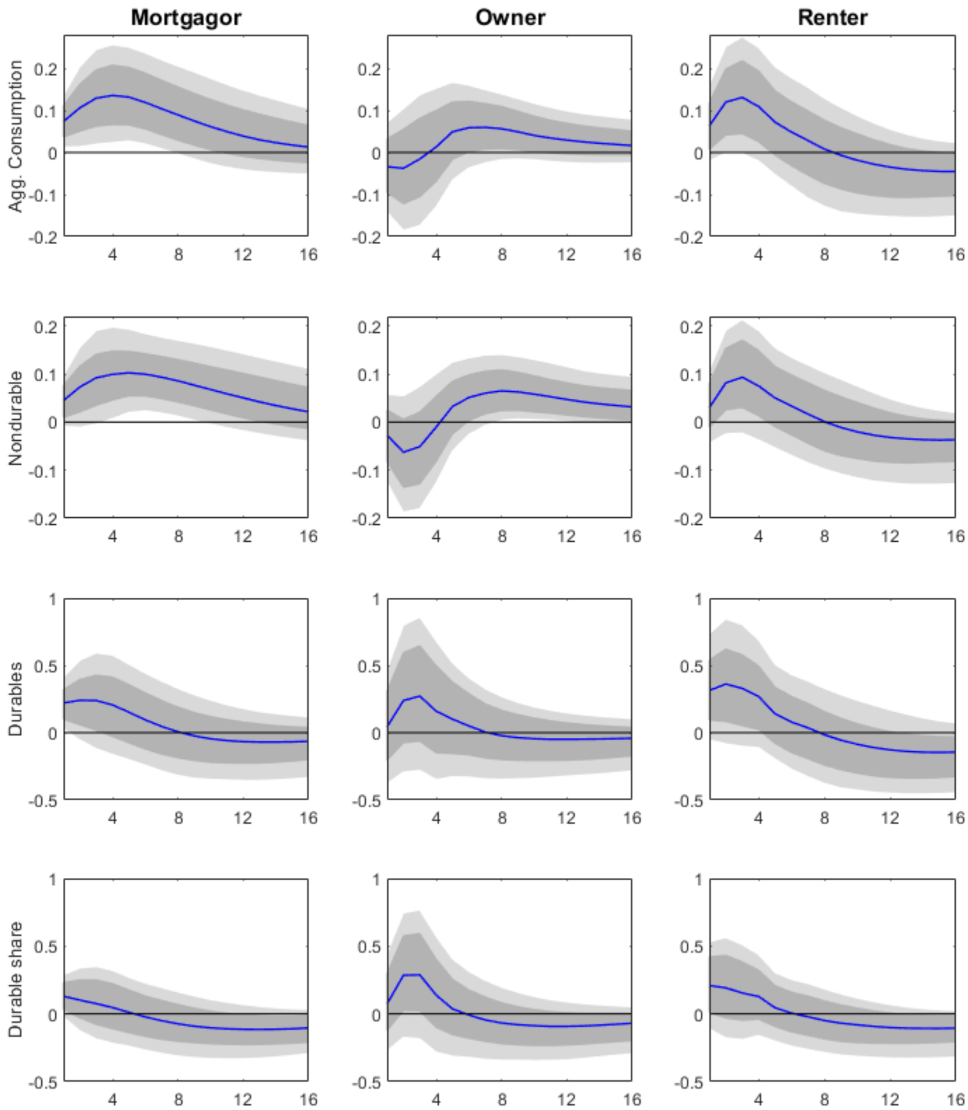


Notes: Figure 1 shows the impulse responses of government spending, GDP, consumption, mortgage debt (stock and flow), house price index, and FFR in response to a positive SPF shock with 68% and 90% confidence interval bands based on bootstrapped standard errors (shaded area).

For aggregate consumption responses, we find sizeable differences across households: i) aggregate consumption of mortgagors rises significantly, ii) renters households also raise their consumption expenditures but to a smaller extent than mortgagors, and iii) outright homeowners have an insignificant consumption response. When we decompose consumption into non-durable and durable expenditure, we find that mortgagors and renters increase both categories while outright homeowners have statistically insignificant responses for both. The response of the share of durable captures the relative changes in the share of durable expenditure in total consumption. The outright owners have a larger tendency to increase their durable share than the other two types of households. For mortgagors and renters, the peak aggregate and non-durable consumption responses occur after four to six quarters while durable consumption rises on impact and then falls gradually over time.

We also formally test whether these consumption responses across the various households are statistically significantly different (shown in the Appendix Figure C.4). For aggregate consumption and non-durable consumption, the differences are statistically significantly different across mortgagers and owners, and renters and owners at short horizons, and at longer horizons for differences between mortgagers and renters. The IRF differential suggests that the response of durable consumption is not statistically significantly different across the different households.

Figure 2: Consumption responses by housing tenure groups

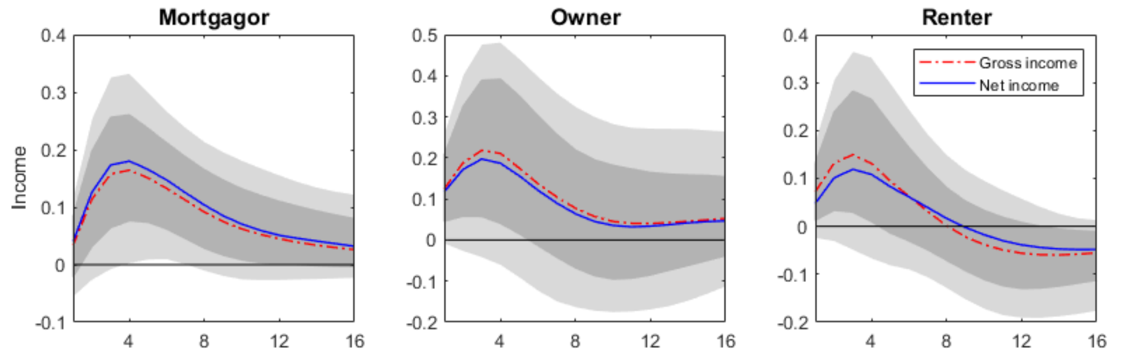


Notes: Figure 2 shows the impulse responses of aggregate consumption, durable, nondurable & services consumption, and durable share by housing tenure groups in response to a positive SPF shock with 68% and 90% confidence interval bands based on bootstrapped standard errors (shaded area).

Overall, we conclude there is heterogeneity in the consumption response across households based on whether they are mortgagors, outright owners or renters.

Next, we consider the income response across the various types of households. When the income of a certain group is more sensitive to changes in economic conditions, it could potentially drive the heterogeneity in the consumption response (Gornemann, Kuester and Nakajima, 2012). Figure 3 shows the dynamic effects

Figure 3: Income responses by housing tenure groups



Notes: Figure 3 shows the impulse responses of gross income (red dash-dotted) and net income (blue solid) by housing tenure groups in response to a positive SPF shock with 68% and 90% confidence interval bands based on bootstrapped standard errors (shaded area).

on gross and net income across the different housing tenure groups.[12] Both gross and net income of all types of households significantly rise in response to a positive government spending shock, which is consistent with the general equilibrium effects of aggregate demand shocks. However, the variations in gross and net income reactions across different household types are not substantial, suggesting that changes in net income are primarily influenced by shifts in gross income, rather than variations in taxes. In addition, this suggests no large heterogeneity in income responses across households, and suggests that the heterogeneity in consumption responses following a positive government spending shock cannot be explained by different income responses across households.

3.2.1 Role of wealthy hand-to-mouth households

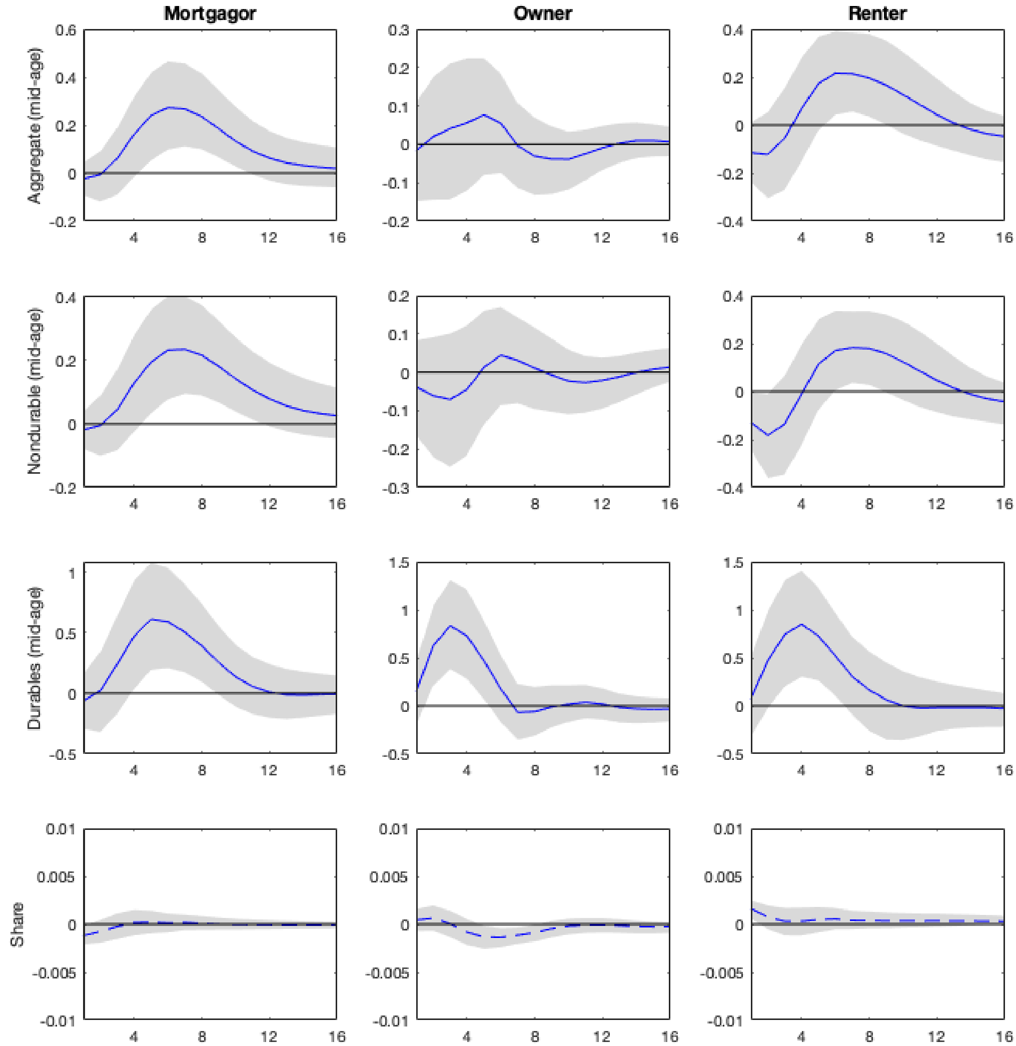
Our VAR analysis with group-specific data provides clear evidence of heterogeneity in consumption responses across the housing tenure groups. In order to test what drives this consumption heterogeneity, we consider the role of wealthy hand-to-mouth households following Kaplan, Violante and Weidner (2014). First of all, the key distinction across the three housing tenure groups is related to the households' balance sheet status. By definition, mortgagors own a sizable illiquid asset such as housing with sizable debt. Outright homeowners own sizable wealth in both liquid and illiquid assets. Renters do not own sizable wealth nor have mortgage debt. In Table B.1, we show that these characteristics are also consistent in micro-data based on the SCF for 1995-2007.[13]

Our results showing mortgagor households exhibiting the largest consumption response to government

[12] Net income is the sum of labor and non-labor household income after tax payment. Within income, we include wages and salaries, income from farm and non-farm businesses, and self-employment. Taxes include state and federal income taxes.

[13] Following Kaplan, Violante and Weidner (2014), we define net liquid assets as liquid assets minus liquid debt. This includes checking, saving, money market, and call accounts minus total credit card balances. The net illiquid asset contains the residential and non-residential real estate net of mortgages and related loans, retirement accounts, retirement accounts including future pensions, and saving bonds.

Figure 4: Robustness checks



Notes: Figure 4 plots the dynamic effects of a positive SPF shock on consumption responses for middle-aged subgroups and tenure share responses for each housing tenure group: mortgagors, homeowners, and renters. The shaded area indicates 68% confidence interval bands.

spending shocks are also similar to the evidence provided in earlier work, that we build off of. Cloyne and Surico (2017) and Cloyne, Ferreira and Surico (2020) show that households with mortgages adjust their expenditures the most in response to tax and monetary shocks, respectively. They also highlight the important role of liquidity of wealth.

Second, we show the distribution of wealthy hand-to-mouth in the total population and within group variation. As in Kaplan, Violante and Weidner (2014), we define the wealthy hand-to-mouth if households hold a positive net illiquid wealth and the net liquid wealth is less than half of their labor income.[14] In

[14]Net illiquid wealth includes not only home equity but also savings in bonds, future pensions, and life insurance; therefore,

Table 2, we show the share of each housing tenure group and the share of wealthy hand-to-mouth households. On average, mortgagor households account for almost half of the total population, which is similar to that in CEX data. The total share of wealthy hand-to-mouth households is around 25% where mortgagors have the largest share among the three groups. Mortgagors tend to have liquidity concerns and consume most of their disposable income despite owning sizable illiquid assets. Renter households have little to no wealth, and therefore, are consistent with the notion of poor hand-to-mouth. Kaplan, Violante and Weidner (2014) provide similar statistics for wealthy hand-to-mouth households and highlight implications of these types of households for the propagation of fiscal policy, namely transfer. Our paper illustrates their importance in the transmission of government spending shocks.

In summary, we find a significant increase in aggregate consumption responses following a positive government spending shock. This finding is mostly driven by mortgagors and there is clear evidence of heterogeneity of responses across households with different financial positions. Notably, this heterogeneity is not explained by changes in income. Based on household survey data, mortgagors exhibit behavior consistent with wealthy hand-to-mouth households while renters are more likely poor hand-to-mouth households. Our empirical findings suggest that the household balance sheet position plays an important role in the transmission mechanism of fiscal policy.

3.3 Robustness checks

There could be two potential concerns with our empirical analysis. First, there could be a selection issue in the grouping. Each housing tenure group has its own demographic characteristics and each household is not randomly assigned to a specific group. Over the life-cycle positions, mortgagors are mostly in their mid-age (around 35 to 45), outright owners are in their late 60s, and renters tend to be young (mostly in their 20s). To address whether there are any life-cycle effects on household heterogeneity, we use sub-groups by controlling the effects of age to avoid any possibility of selection issues following Cloyne, Ferreira and Surico (2020). We consider the middle-aged sub-group in each housing tenure group, using the demographic characteristics of the household head. We show in Figure 4, top three panels, that household heterogeneity does not come from demographic characteristics, and the life-cycle position does not change our main results. Notably, mid-aged mortgagor consumption is much more responsive than renters and outright owners in the same age group.

Second, there is a possibility of compositional changes in response to a positive government spending shock. First, note that the share of each housing tenure group is fairly stable over the sample period using the SCF data (see Table 2). Second, we also estimate the responses of housing tenure shares following a fiscal shock to test the existence of compositional changes. The share of each housing tenure group has an insignificant response to a positive government spending shock, shown in Figure 4, bottom panel, which suggests that there is only limited endogenous compositional change.

we also have some renters households who are wealthy hand-to-mouth.

4 Theoretical model featuring three types of households

In this section, we consider a closed-economy dynamic stochastic general equilibrium (DSGE) model to account for the empirical findings described in the previous section and determine the effects of government spending shocks on key macroeconomic variables. We construct a DSGE model with durable goods, housing, household debt, and features such as adjustment costs in capital and housing investment, costs of capital utilization, and price and wage rigidities. There are three types of households in the economy: patient households (savers), impatient households (borrowers), and renters, as in Alpanda and Zubairy (2016). Patient households own capital and housing, lend long-term debt to borrowers, and rent some housing to renters. Impatient households own housing, rent some housing to renters, and are subject to LTV constraints on their borrowing, similar to Kiyotaki and Moore (1997) and Iacoviello (2005). Renter households are hand-to-mouth consumers who consume their disposable income. Our model also features a production side with non-housing goods producers, rental service producers, and residential and non-residential investment producers. We differentiate between the flow and stock of household debt with consideration of long-term fixed-rate mortgages as in Kydland, Rupert and Šustek (2016), and Alpanda and Zubairy (2017). The model also includes housing related taxes as in Alpanda and Zubairy (2016). In our sensitivity analysis, we examine the role of the moderate degree of habit formation and housing adjustment costs and introduce housing market related features such as refinancing and home equity.

4.1 Households

4.1.1 Patient households (savers)

The economy is populated by a continuum of measure one of infinitely-lived patient households indexed by i, whose intertemporal preferences over consumption, $x_{P,t}$, housing, $h_{P,t}$, and labor supply, $n_{P,t}$ are described by the following expected utility function:[15]

$$E_0 \sum_{t=0}^{\infty} \beta_P^t \upsilon_t \left[\log x_{P,t}(i) + \xi_h \log h_{P,t}(i) - \xi_n \frac{n_{P,t}(i)^{1+\vartheta}}{1+\vartheta} \right], \tag{3}$$

where E_t is the expectations operator conditional on information available at time t for patient households, $0 < \beta_P < 1$ is the time-discount parameter, ξ_h and ξ_n determine the relative importance of housing and labor in the utility function, and ϑ denotes the inverse of the Frisch-elasticity of labor supply. Patient households consume both non-durable and durable goods, and it is modeled as a weighted average. Specifically, the habit-adjusted consumption basket for patient households, $x_{P,t}$, is given by

$$x_{P,t}(i) = c_{P,t}(i)^{\theta} s_{P,t}(i)^{1-\theta} - \mu_c c_{P,t-1}(i)^{\theta} s_{P,t-1}(i)^{1-\theta}, \tag{4}$$

[15] As in Iacoviello (2005), the size of household is normalized to a unit measure for households.

where θ is a share parameter, μ_c is a parameter for habit persistence, $c_{P,t}$ denotes the non-durable consumption, and $s_{P,t}$ is the stock of durable consumption. When $\theta = 1$ and $\mu_c = 0$, the above expression reduces to the case with no durable goods and no habit formation in the consumption basket. The preference shock, υ_t, follows an AR(1) process:

$$\log \upsilon_t = \rho_\upsilon \log \upsilon_{t-1} + \varepsilon_{\upsilon,t}. \tag{5}$$

Patient households provide heterogeneous labor services which are aggregated into a homogeneous labor service by perfectly-competitive labor intermediaries that use a standard Dixit-Stiglitz aggregator. These labor intermediaries rent labor services to goods producers, with the labor demand curve facing each patient household given by,

$$n_{P,t}(i) = \left(\frac{W_{P,t}(i)}{W_{P,t}} \right)^{-\eta_w} n_{P,t}, \tag{6}$$

where $W_{P,t}$ is the aggregate nominal wage rate and $n_{P,t}$ is labor services of patient households. η_w is the elasticity of substitution between the differentiated labor services.

The patient households' period budget constraint is given by

$$\begin{aligned} x_{P,t}(i) + q_{h,t}\left[\, \tilde{i}_{hP,t}(i) + \tilde{i}_{hRP,t}(i)\right] + q_{k,t}\tilde{i}_{k,t}(i) + \frac{B_t(i)}{P_t} + \frac{L_t(i)}{P_t} \leq \frac{W_{P,t}(i)}{P_t} n_{P,t}(i) + r_{hP,t} h_{RP,t}(i) \\ + r_{k,t}k_{t-1}(i) + (1 + R_{t-1}) \frac{B_{t-1}(i)}{P_t} + \left[R^M_{t-1}(i) + \kappa\right] \frac{D_{t-1}(i)}{P_t} + \frac{\Pi_t}{P_t} + tr_{P,t} - tax_{P,t} - adj.\ costs, \end{aligned} \tag{7}$$

where $\tilde{i}_{hP,t}$, $\tilde{i}_{hRP,t}$, and $\tilde{i}_{k,t}$ denote the patient households' new investment in owner-occupied housing, rental housing owned by patient households, and capital, respectively, while $q_{h,t}$ and $q_{k,t}$ are the relative prices of stock of housing and capital. $r_{hP,t}$ and $r_{k,t}$ are the rental income that patient households earn from owning and renting out rental housing and capital.

The laws of motion for the stock of durable goods, $s_{P,t}$, owner-occupied and rental housing owned by patient households, $h_{P,t}$ and $h_{RP,t}$, and capital stock holdings, k_t, for patient households are given by,

$$s_{P,t}(i) = (1 - \delta_s) s_{P,t-1}(i) + \tilde{c}_{P,t}(i) \tag{8}$$

$$h_{P,t}(i) = (1 - \delta_h)\, h_{P,t-1}(i) + \tilde{i}_{hP,t}(i), \tag{9}$$

$$h_{RP,t}(i) = (1 - \delta_h)\, h_{RP,t-1}(i) + \tilde{i}_{hRP,t}(i), \tag{10}$$

$$k_t(i) = (1 - \delta_k)\, k_{t-1}(i) + \tilde{i}_{k,t}(i), \tag{11}$$

where δ_s, δ_h, and δ_k are the depreciation rates for durable goods, housing, and capital. $\tilde{c}_t$ denotes the purchases of new consumer durable goods.

Patient households receive government transfers, $tr_{P,t}$, and lump-sum profits from goods producers, Π_t. Households also pay taxes on their consumption, income, capital and interest income, and their owned property. Note that the property tax on housing, τ_p, is deductible when paying income taxes. The total tax burden of patient households is given by,

$$\begin{aligned} tax_{P,t} = \tau_c x_{P,t}(i) + \tau_{yP}\left[\frac{W_{P,t}(i)}{P_t} n_{P,t}(i) + r_{hP,t} h_{RP,t}(i) - \delta_h h_{RP,t-1}(i) - \tau_p q_{h,t}\left[h_{P,t}(i) + h_{RP,t}(i)\right]\right] \\ + \tau_k\left(r_{k,t} - \delta_k\right) k_{t-1}(i) + \tau_b\left(R_{t-1}\frac{B_{t-1}(i)}{P_t} + R^M_{t-1}(i)\frac{D_{t-1}(i)}{P_t}\right) + \tau_p q_{h,t}\left[h_{P,t}(i) + h_{RP,t}(i)\right], \end{aligned}$$

where τ_c is the consumption tax rate, τ_{yP} denotes the income tax rate on patient households, and τ_k and τ_b are the tax rates on capital and interest income, respectively.

Patient households purchase one-period nominal government bonds, B_t, and lend to impatient households, L_t, and receive a predetermined nominal interest rate of R_t on the bonds and collect mortgage payments as the sum of interest and principal payments. The law of motion for the stock of household debt, D_t, is as follows,

$$\frac{D_t(i)}{P_t} = (1-\kappa)\frac{D_{t-1}(i)}{P_t} + \frac{L_t(i)}{P_t}, \tag{12}$$

where κ is the constant amortization rate which determines the principal payment amount paid out of the stock of mortgage debt.

Each period, new lending, L_t, is subject to a fixed mortgage interest rate; hence, the effective interest rate on the mortgage stock, R^M_t, is determined as follows,

$$R^M_t(i)\frac{D_t(i)}{P_t} = (1-\kappa)\frac{D_{t-1}(i)}{P_t}R^M_{t-1}(i) + \frac{L_t(i)}{P_t}R^F_t, \tag{13}$$

which can be rewritten as,

$$R^M_t(i) = \left(1 - \frac{L_t(i)}{D_t(i)}\right)R^M_{t-1}(i) + \frac{L_t(i)}{D_t(i)}R^F_t, \tag{14}$$

where R^F_t denotes a fixed mortgage interest rate on new mortgage loans.

Note that when $\kappa = 1$, our model features the full amortization rate (i.e. one-period debt) and Eq.(12) implies that the stock and the flow of mortgage debt are equal to each other (i.e. $D_t = L_t$). Then, the effective interest rate of mortgages (coupled with $R^M_t(i) = R^F_t$ and the Euler condition for government debt) is equal to the interest rate on government debt (i.e. $R^M_t = R^F_t = R_t$ for all t).

Wage rigidities are introduced via Rotemberg (1982) type of quadratic cost of wage adjustments, given by,

$$\frac{\kappa_w}{2}\left(\pi^{-1}\frac{W_{P,t}(i)}{W_{P,t-1}(i)} - 1\right)^2 \frac{W_{P,t}}{P_t} n_{P,t}, \tag{15}$$

where κ_w denotes a scale parameter and π is the steady state inflation rate. Our model also features quadratic adjustment costs in housing and capital stocks with κ_h and κ_k as their corresponding level parameter values.[16] Housing adjustment costs ensure that housing stocks are not sold rapidly across patient and impatient

[16] Capital adjustment costs are defined as $(\kappa_k/2)[(k_t(i)/k_{t-1}(i)) - 1]^2 q_{k,t} k_t$, Owner-occupied and rental housing adjustment costs are specified as $(\kappa_h/2)[(h_{P,t}(i)/h_{P,t-1}(i)) - 1]^2 q_{h,t} h_{P,t}$ and $(\kappa_h/2)[(h_{R,t}(i)/h_{R,t-1}(i)) - 1]^2 q_{h,t} h_{R,t}$, respectively.

households, and the amount of substitution between housing and non-housing sectors is limited.

The patient households' objective is to maximize utility subject to their budget constraints with the No-Ponzi conditions. The first-order condition of owner-occupied housing sets the marginal cost of obtaining one more unit of housing equal to the marginal utility gains from housing services and expected present discounted value of capital gains net of taxes, which is as follows (ignoring housing stock adjustment costs):

$$q_{h,t} = \frac{\upsilon_t \xi_h}{\lambda_{P,t} h_{P,t}} + E_t \left[\left(\beta_P \frac{\lambda_{P,t+1}}{\lambda_{P,t}} \right) \left[1 - \delta_h - \tau_{p,t+1}(1 - \tau_{yP}) \right] q_{h,t+1} \right], \tag{16}$$

where $\lambda_{P,t}$ is the Lagrange multiplier on the budget constraint. Similarly, the first-order conditions for rental housing and capital imply that their marginal costs are equal to the expected marginal gain in net tax rental income and capital gains. The rest of the optimality conditions are shown in the Appendix.[17]

4.1.2 Impatient households

The economy is also populated by a continuum of unit measure of infinitely-lived impatient households. The utility function of impatient households is identical to patient households, except for their time-discount factor. Similar to Iacoviello (2005), the discount factor of impatient households is smaller than patient households which facilitates borrowing and lending across agents (i.e. $\beta_I < \beta_P$). Labor services are also heterogeneous across impatient households, and are aggregated into a homogeneous labor service using a standard Dixit-Stiglitz aggregator by perfectly-competitive labor intermediaries. The labor demand function of each impatient household is then given by,

$$n_{I,t}(i) = \left(\frac{W_{I,t}(i)}{W_{I,t}} \right)^{-\eta_w} n_{I,t}, \tag{17}$$

where $W_{I,t}$ is the aggregate nominal wage rate and $n_{I,t}$ denotes the labor services of impatient households.[18]

The impatient households' budget constraint is as follows:

$$\begin{aligned}
(1+\tau_c) x_{I,t}(i) + q_{h,t} \left[\tilde{i}_{hI,t}(i) + \tilde{i}_{hRI,t}(i) \right] + \left[R^M_{t-1}(i) + \kappa \right] \frac{D_{t-1}(i)}{P_t} &\leq \frac{W_{I,t}(i)}{P_t} n_{I,t}(i) \\
+ (1+\tau_{yI}) r_{hI,t} h_{RI,t}(i) + \frac{L_t(i)}{P_t} + tr_{I,t} - \tau_p q_{h,t} [h_{I,t}(i) + h_{RI,t}(i)] \\
- \tau_{yI} \left[\frac{W_{I,t}(i)}{P_t} n_{I,t}(i) - \tau_p q_{h,t} [h_{I,t}(i) + h_{RI,t}(i)] - R^M_{t-1}(i) \frac{D_{t-1}(i)}{P_t} \right] - \textit{adj. costs},
\end{aligned} \tag{18}$$

where $x_{I,t}$ denotes a habit-adjusted consumption basket including non-durable and durable goods. $\tilde{i}_{hI,t}$ and $\tilde{i}_{hRI,t}$ denote residential housing investment and rental housing owned by impatient households, respectively.

Impatient households also receive lump-sum transfers from the government, $tr_{I,t}$, and pay taxes on their consumption and income. Similar to patient households, the property tax on housing, τ_p, is deductible when

[17] See Appendix E for more details.

[18] η_w is the elasticity of substitution between the differentiated labor services as shown in the patient households' problem. Also, $\theta_w = \eta_w/(\eta_w - 1)$, where θ_w is the real wage markup over the marginal rate of substitution at the steady state.

paying income taxes, τ_{yI}. There also exists quadratic adjustment costs on their wages (to capture wage stickiness) and housing stocks. In our model, only patient households are assumed to own capital. This assumption in addition to the borrowing constraint (shown below) helps capture the fact that the impatient households have liquidity constraints and thus are the wealthy hand-to-mouth households. Similar to the patient households, the impatient households are allowed to own rental housing but their share is much smaller than patient households, as discussed in the calibration section.

The law of motion for the stock of debt held by the impatient households, D_t, and the evolution of the effective mortgage rate, R_t^M, follow Eq.(12) and (13), as shown previously. The law of motion of housing and rental housing for the impatient households are similar to patient households: $h_{I,t}(i) = (1-\delta_h) h_{I,t-1}(i) + i_{hI,t}(i)$ and $h_{RI,t}(i) = (1-\delta_h) h_{RI,t-1}(i) + i_{hRI,t}(i)$.

Impatient households face a borrowing constraint which is given by,

$$\frac{L_t(i)}{P_t} = \phi q_{h,t} \left[\tilde{i}_{hI,t}(i) + \tilde{i}_{hRI,t}(i)\right], \tag{19}$$

where ϕ is the loan-to-value (LTV) ratio on new housing investment. As our model features a borrowing constraint with the flow instead of the stock of housing, the purchase of housing in the current period increases the level of housing in the next period, and therefore, households face a lower need for investing. This dampens the marginal gain in the next period of the borrowing constraint in that corresponding period.[19]

The impatient households' first-order condition with respect to housing (ignoring adjustment costs) is given as,

$$(1-\phi\mu_t) q_{h,t} = \frac{\upsilon_t \xi_h}{\lambda_{I,t} h_{I,t}} + E_t \left[\left(\beta_I \frac{\lambda_{I,t+1}}{\lambda_{I,t}} \right) \{(1-\delta_h)(1-\phi\mu_{t+1}) - \tau_p(1-\tau_{yI})\} q_{h,t+1} \right], \tag{20}$$

where μ_t is the Lagrange multiplier for impatient households' borrowing constraint. Eqn.(20) implies that the marginal cost of obtaining a unit of housing is equal to the marginal utility gain from housing and the expected present discounted value of net-of-tax capital gains.

The optimality condition with respect to new borrowing is given by,

$$1 - \mu_t = \Omega_{dI,t} + \Omega_{rI,t} R_t^F, \tag{21}$$

where $\Omega_{dI,t}$ and $\Omega_{rI,t}$ denote the Lagrange multiplier on the laws of motion for mortgage debt and the effective mortgage interest rate, respectively. The rest of the optimality conditions are discussed in Appendix E.

[19] In our sensitivity analysis, we also examine the role of refinancing and home equity withdrawal by adding features related to these. Typically, mortgage equity withdrawals constitute less than two percent of existing equity per quarter in data.

4.1.3 Renter households

There is a continuum of unit measure of infinitely-lived renter households indexed by i with the utility function identical to impatient households. Note that renter households have an identical discount factor to impatient households (i.e. $\beta_R = \beta_I < \beta_P$), and solve a problem that is not intertemporal, as they live hand-to-mouth, consuming their disposable income in each period. The budget constraint of the renter households is given by,

$$(1+\tau_c)x_{R,t}(i) + \frac{P_{hP,t}}{P_t}h_{RP,t}(i) + \frac{P_{hI,t}}{P_t}h_{RI,t}(i) \leq (1-\tau_{yR})\frac{W_{R,t}(i)}{P_t}n_{R,t}(i) + tr_{R,t} - adj.costs, \tag{22}$$

where $x_{R,t}$ denotes a habit-adjusted consumption basket including non-durable and durable goods. τ_c and τ_{yR} denote proportional taxes on consumption and income for renter households, respectively. Renter households earn wage income and get transfers from the government, $tr_{R,t}$, and rent housing, $h_{R,t}$, from patient and impatient households where $h_{R,t} = h_{RP,t}(i)^{\mu_h} h_{RI,t}(i)^{1-\mu_h}$ with μ_h representing the share for rental housing owned by patient households.[20] Note that there are adjustment costs for wage stickiness similar to patient and impatient households.

The first-order condition with respect to rental housing owned by patient households is given by,

$$p_{hP,t} = \frac{\upsilon_t \xi_h \mu_h}{\lambda_{R,t} h_{RP,t}}. \tag{23}$$

where $\lambda_{R,t}$ is the Lagrange multiplier on the renters' budget constraint. Similarly, the first-order condition with respect to rental housing owned by impatient households is given by,

$$p_{hI,t} = \frac{\upsilon_t \xi_h (1-\mu_h)}{\lambda_{R,t} h_{RI,t}}. \tag{24}$$

Eqn.(23) and Eqn.(24) imply that the marginal cost of acquiring a unit of rental housing is equal to the marginal utility gain. The rest of the first-order conditions for renter households are discussed in the Appendix.

4.2 Production

4.2.1 Non-housing goods producers

There is a continuum of monopolistically competitive non-housing goods producers indexed by j, whose production technology is given by,

$$y_{n,t}(j) = [u_t(j)\,k_{t-1}(j)]^{\alpha}\left[n_{P,t}(j)^{\psi_P}\, n_{I,t}(j)^{\psi_I}\, n_{R,t}(j)^{\psi_R}\right]^{1-\alpha} - f_n, \tag{25}$$

[20] We also normalize for the amount of government transfers across three types of households with an allowance of the size related to their labor share in the production.

where y_n is non-housing output, α is the capital share in the production function, and ψ_i (for $i = P, I, R$ where $\psi_P + \psi_I + \psi_R = 1$) denotes the labor share of each household: patient, impatient, and renters households. u_t denotes the capital utilization rate and f_n is a fixed cost of production.

The final goods producers follow a standard Dixit-Stiglitz model to aggregate heterogeneous goods into a homogeneous good and the demand curve for the final goods producer is given by:

$$y_{n,t}(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\eta_n} y_{n,t}, \tag{26}$$

where $y_{n,t}$ and η_n are aggregate non-housing output and the elasticity of substitution between goods, respectively. Firm j's objective is to maximize its profit, subject to a utilization cost and a price adjustment cost. For more details on the non-housing goods' producers problem, see Appendix E.

4.2.2 Investment goods and rental services producers

There is a unit measure of perfectly-competitive investment goods producers following Bernanke, Gertler and Gilchrist (1999). Non-residential investment goods producers purchase new capital investment goods from final goods producers at a relative price of 1 and turn their $i_{k,t}$ units of goods into $\tilde{i}_{k,t}$ units of effective investment goods. These goods are sold to end-users later at the relative price of $q_{k,t}$. Our model's production function also captures adjustment costs in the change in investment that are similar to those in Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2007).

Non-residential investment goods producers maximize their expected discounted value of future profits, given by,

$$\max E_0 \sum_{t=0}^{\infty} \beta_P^t \frac{\lambda_{P,t}}{\lambda_{P,0}} \left[q_{k,t}\tilde{i}_{k,t} - q_{k,t}\frac{\kappa_{ik}}{2}\left(\frac{i_{k,t}}{i_{k,t-1}} - 1\right)^2 \tilde{i}_{k,t} - i_{k,t} \right], \tag{27}$$

where κ_{ik} is the adjustment cost parameter in capital investment.

Residential investment goods producers solve an analogous problem to the capital investment goods producers and maximize their profit subject to the law of motion of housing. The total housing investment (i.e., $i_{h,t} = i_{hP,t} + i_{hI,t} + i_{hR,t}$) is purchased from final-goods producers at a relative price of 1 and turned into $\tilde{i}_{h,t}$ units of effective housing investment goods that can be purchased by end users at the relative price $q_{h,t}$.[21]

Rental services producers maximize their expected discounted value of future profits, given by,

$$\begin{aligned} \max E_0 \sum_{t=0}^{\infty} \beta_P^t \frac{\lambda_{P,t}}{\lambda_{P,0}} \Bigg[& \frac{P_{hP,t}(i)}{P_t} h_{RP,t}(i) + \frac{P_{hI,t}(i)}{P_t} h_{RI,t}(i) - r_{hP,t} h_{RP,t}(i) - r_{hI,t} h_{RI,t}(i) \\ & - \frac{\kappa_{ph}}{2}\left(\frac{P_{hP,t}(i)}{P_{hP,t-1}(i)\pi} - 1\right)^2 \frac{P_{hP,t}}{P_t} h_{RP,t} - \frac{\kappa_{ph}}{2}\left(\frac{P_{hI,t}(i)}{P_{hI,t-1}(i)\pi} - 1\right)^2 \frac{P_{hI,t}}{P_t} h_{RI,t} \Bigg], \end{aligned} \tag{28}$$

where κ_{ph} is the price adjustment cost parameter in rental services.

[21] Rental housing investment is decomposed into units owned by patient households and impatient households (i.e., $i_{hR,t} = i_{hRP,t} + i_{hRI,t}$).

The demand curve faced by rental services owned by households j where $j = \{P, I\}$ is given by,

$$h_{Rj,t}(i) = \left(\frac{P_{hj,t}(i)}{P_{hj,t}}\right)^{-\eta_h} h_{Rj,t}, \tag{29}$$

where η_h is the elasticity of substitution between rental services.

The optimality condition with respect to housing rental rate is given by,

$$\left(\frac{\pi_{hj,t}}{\pi} - 1\right)\frac{\pi_{hj,t}}{\pi} = E_t\left[\beta_P \frac{\lambda_{P,t+1}}{\lambda_{P,t}}\left(\frac{\pi_{hj,t+1}}{\pi} - 1\right)\frac{\pi_{hj,t+1}}{\pi}\frac{\pi_{hj,t+1}}{\pi_{t+1}}\frac{h_{Rj,t+1}}{h_{Rj,t}}\right] - \frac{\eta_h - 1}{\kappa_{ph}}\left(1 - \theta_h \frac{r_{hj,t}}{p_{hj,t}}\right), \tag{30}$$

where θ_h is the real housing services markup over the marginal rate of substitution at the steady state.

The relative price of rental housing services for $j = \{P, I\}$ and rental inflation is given by

$$\frac{\pi_{hj,t}}{\pi_t} = \frac{p_{hj,t}}{p_{hj,t-1}}. \tag{31}$$

4.3 Government and monetary policy

The government issues bonds, collects taxes, and pays transfers to households (patient, impatient, and renters households). Note that the aggregate tax revenue is generated from consumption, income, property, capital and interest rate income taxes from various types of households, as detailed earlier in their respective budget constraints.

The aggregate level of transfer payments to households is given by,

$$tr_t = \Xi y_n - \varrho_b b_{t-1}, \tag{32}$$

where Ξ denotes a level parameter and ϱ_b determine the response of transfers to government debt.[22] Government debt cannot follow a Ponzi scheme. We ensure this condition by assuming aggregate transfers, tr_t, are distributed to each type of household based on their respective labor shares (i.e. $tr_{i,t} = \psi_i tr_t$ for $i = \{P, I, R\}$).

The government faces a budget constraint as follows,

$$tax_t + b_t = \left(\frac{1 + R_{t-1}}{\pi_t}\right) b_{t-1} + g_t + tr_t, \tag{33}$$

where g_t is government expenditure which follows an exogenous AR(1) process:

$$\log g_t = (1 - \rho_g)\log g + \rho_g \log g_{t-1} + \varepsilon_{g,t}, \tag{34}$$

where $\varepsilon_{g,t}$ represents an i.i.d government spending shock with variance σ_g^2. Following the empirical evidence,

[22] Following Leeper, Walker and Yang (2010), government debt cannot follow a Ponzi scheme. We ensure this condition by the adjusted level of either taxes, government spending, or transfers.

this government spending shock is the shock of interest for us, and we will focus on its propagation through the economy in Section 5.

The central bank sets monetary policy following a Taylor rule, given by,

$$R_t = R + a_\pi \log\left(\frac{\pi_{c,t}}{\pi}\right) + a_y \log\left(\frac{y_t}{y}\right), \tag{35}$$

where R denotes the steady-state level of nominal interest rate in gross terms. a_π and a_y are the coefficients of inflation and output gap, respectively.

4.4 Market clearing conditions

The goods market clears

$$x_t + i_t + g_t = y_{n,t} - \text{adj.costs}, \tag{36}$$

where $x_t = x_{P,t} + x_{I,t} + x_{R,t}$ denote total consumption. Total investment is $i_t = i_{k,t} + i_{h,t}$ where $i_{k,t}$ is non-residential investment and $i_{h,t} = i_{hP,t} + i_{hI,t} + i_{hR,t}$ is residential investment.

A competitive equilibrium is defined as the set of prices, allocations, and policies where households maximize the discounted present value of utility, firms maximize their profits, and all markets clear.

4.5 Calibration

We calibrate the model parameters so that the model's steady state matches some of the key statistics in the U.S. macroeconomic and financial data and our model is set in a quarterly frequency.[23] Table 3 summarizes our calibration values and Table 4 represents the steady-state ratios of the model and its counterparts in the data.

The time-discount factor of patient households, β_P, is set to 0.9916, implying a steady-state annualized real interest of nearly 4 percent. The time-discount factors of impatient and renter households, β_I and β_R, are fixed at 0.9852 to match a Lagrange multiplier on household debt equivalent to a 200 basis point spread on the risk-free rate.[24] The inverse of the Frisch labor supply elasticity is set to 1. This value is picked as a compromise between the estimated values in the Real Business Cycle and New Keynesian literature (Smets and Wouters, 2007).

The labor disutility parameter, ξ_n, and the housing preference parameter, ξ_h, are set to 0.13 and 0.6 to match the aggregate housing to GDP share and are close to the estimates in Justiniano, Primiceri and Tambalotti (2015). We set the habit formation parameter, μ_c, to 0.85, which is in the range of 0.8 and 0.9

[23] Data target ratios come from the National Income and Product Accounts (NIPA), Flow of Funds Accounts (FOF), the 2001 Residential Financial Survey (RFS), and the 2011 American Housing Survey (AHS). The calibration methodology of using steady-state relationships in the model is similar to Cooley, Hansen and Prescott (1995). Parameters related to durable stock are based closely on the findings in Mertens and Ravn (2011), and other parameters are mostly drawn from Alpanda and Zubairy (2016, 2017).

[24] As in Alpanda and Zubairy (2016), this value reflects the spread between 30-year mortgages and 10-year Treasury bonds of around 170 bps on average over 1971-2014.

Table 3: Model Parameters

Description	Symbol	value
Discount factor	β_P, β_I, β_R	0.9916, 0.9852, 0.9852
Inverse labor supply elasticity	ϑ	1.00
Level for housing and labor in utility	ξ_h, ξ_n	0.13, 0.60
Habit formation in consumption behaviors	μ_c	0.85
Share for non-durable consumption	θ	0.70
Share for rental housing owned by patient households	μ_h	0.90
LTV ratio on new regular mortgages	ϕ	0.85
Amortization rate on household loans	κ	0.018
Capital share in production	α	0.30
Depreciation rates	δ_h, δ_k, δ_s	0.01, 0.013, 0.025
Investment adj. cost	κ_{ih}, κ_{ik}, κ_{dc}	1.00, 2.00, 100
Stock adj. cost	κ_h, κ_k, κ_s	2.00, 2.00, 100
Labor shares in production	Ψ_P,Ψ_I, Ψ_R	0.26, 0.47, 0.27
Tax rates		
Consumption tax rate	τ_c	0.05
Capital income tax rate	τ_κ	0.40
Interest income tax rate	τ_b	0.15
Property tax rate	τ_p	0.0035
Income tax rate	τ_{yP}, τ_{yI}, τ_{yR}	0.30, 0.30, 0.20
Transfers	Ξ	0.024
Response of transfers to gov. debt	ϱ_b	5.00
AR(1) Government spending shock	ρ_g	0.85
Taylor rule for inflation response	a_π	1.50
Taylor rule for output gap	a_y	0.01

suggested in Fuhrer (2000) to fit the data. The share parameter, θ, is calibrated to align with the estimates in Mertens and Ravn (2011) and is set to 0.7.[25]

The steady-state non-residential investment to GDP ratio is about 14% while the capital-to-GDP ratio is 1.85 on annualized basis in the data. Based on these values, we calibrate the quarterly depreciation rate for capital stocks, δ_k, to 1%. Capital investment adjustment cost parameters, κ_{ik}, is calibrated to be 2, which is rounded to be close to estimates in Eberly, Rebelo and Vincent (2012) and Justiniano, Primiceri and Tambalotti (2015).[26] The capital share in production, α, is set to 0.3 using the capital-output ratio and the model-implied after-tax rental rate of capital.

The steady-state LTV ratio, ϕ, is calibrated to be 0.85 in order to match the first mortgage loan ratio (median value) to the purchase of one unit of mortgaged properties estimated by Duca, Muellbauer and Murphy (2011). The share for rental housing owned by patient households, μ_h, is calibrated to 0.90 to match our data moment related to housing price.[27] In data, the residential investment-to-GDP ratio is about 5% while the housing-to-GDP ratio is about 1.24. In order to match these, we calibrate the depreciation of

[25] Mertens and Ravn (2011) set the share parameter to 0.8. This value is calibrated to target durable share in total consumption during the post-WWII period in the U.S.

[26] Housing investment adjustment cost, κ_{ih}, is treated similar to capital adjustment cost and is set to 1.00.

[27] The Rental Housing Finance Survey (RHFS) reveals that individual investors own almost 80% of all rental housing units, while a smaller proportion of the total units are accounted for by rental units involving new mortgages.

Table 4: Model steady-state ratios

Description	Symbol	Model	Data target
Total consumption/GDP	c/y	0.61	0.61
Share of patient household	c_P/c	0.55	
Share of impatient household	c_I/c	0.27	
Share of renter household	c_R/c	0.17	
Total investment/GDP	i/y	0.19	0.19
Non-residential investment/GDP	i_k/y	0.14	0.14
Residential investment/GDP	i_h/y	0.05	0.05
Government expenditure/GDP	g/y	0.20	0.20
Tax revenue/GDP	tax/y	0.33	
Transfers/GDP	tr/y	0.02	
Wage share in non-housing income	$1-\alpha$	0.70	
Share of patient households	ψ_P	0.26	0.26
Share of impatient households	ψ_I	0.47	0.47
Share of renter households	ψ_R	0.27	0.27
Capital stock/GDP (qtr)	k/y	11.06	
Durable stock/GDP (qtr)	s/y	7.28	
Share of patient households	s_P/s	0.60	
Share of impatient households	s_I/s	0.25	
Share of renter households	s_R/s	0.15	
Housing stock/GDP (qtr)	h/y	4.97	
Share of patient households	h_P/h	0.61	
Share of impatient households	h_I/h	0.28	
Share of renter households	h_R/h	0.09	

housing, δ_h, to 0.01.[28] The amortization rate on household loans, κ, is set to 0.018 to imply the duration of mortgage loans around 18 years in the model.[29] The depreciation rate of durable stock, δ_s, is assumed to be shorter than housing and set to 0.025 following Mertens and Ravn (2011). We set the durable stock and durable investment adjustment costs parameter, κ_s and κ_{dc}, to 100 to match the magnitude of response of durable goods output to a fiscal innovation.[30]

We calibrate the wage share of impatient households, Ψ_I, to 0.47 and their share of housing, h_I/h, to 0.28. The wage share of rental households Ψ_R is set to 0.27 with the rental housing share, h_R/h, of 0.09 which is similar to those values from the RFS and AHS surveys. The wage share of patient households, Ψ_P, is thus set to 0.26 and the share of patient households' housing, h_P/h, to 0.61.[31]

The steady-state government expenditure to GDP ratio, g/y, is set to 20% based on the NIPA data average over the sample period under consideration. The steady-state transfers to GDP ratio is calibrated at 0.01 and the level parameter for transfers, Ξ, is set to 0.02. The responsiveness of transfers to government debt is assumed to be 5, in order to ensure that the government intertemporal budget holds and to preserve

[28] This value is also consistent with estimates in Hull (2017) and Wilhelmsson (2008).
[29] This mortgage loan duration is close to AHS average duration of outstanding loan data.
[30] Erceg and Levin (2006) sets the adjustment cost of the durable stock to 600 to match the response of durable goods.
[31] We aim to target the average share of each housing tenure group based on the SCF data (1995 to 2007). Altering this value to match the CEX share (1981 to 2007) also gives consistent simulation results.

determinacy within the model. Income tax rates for the patient and impatient households, τ_{yP} and τ_{yI}, are set to 0.3 while the renters households income tax rate, τ_{yR}, is set to 0.2 to imply tax progressivity. The consumption tax rate and property tax rate, τ_c and τ_p, are set to 0.05 and 0.0035, respectively. We also calibrate the capital and interest rate income tax, τ_k and τ_b, as 0.40 and 0.15 following Alpanda and Zubairy (2016). The government shock persistence, ρ_g, is set to 0.85. In our sensitivity analysis, we alter this persistence parameter to explore the role of the negative wealth effect of the shock. The Taylor rule coefficients of inflation response and output gap, a_π and a_y, are set to 1.50 and 0.01, respectively.

5 Model Results

In this section, we analyze the effects of government spending shocks based on the benchmark parameters. First, we present the dynamic effects on aggregate variables. We then compare consumption and income responses among different types of households and illustrate some of the possible transmission mechanisms of heterogeneity.

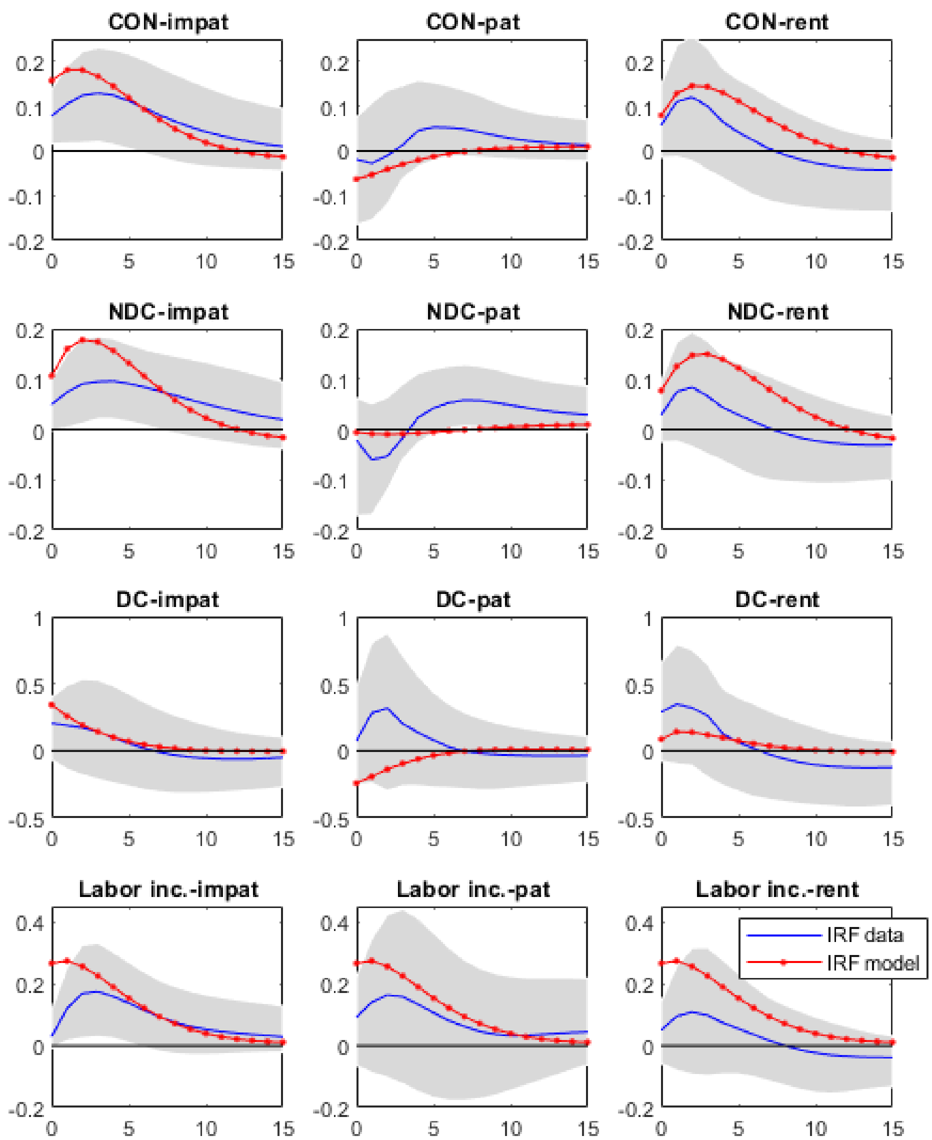
5.1 Benchmark results

Figure 5: Impulse responses in the benchmark model

Notes: Figure 5 shows the impulse response of consumption, household debt, and house price in response to a positive government spending shock. The blue line indicates the empirical responses and the red line indicates the model responses. The shaded area indicates 90% confidence interval bands.

Figure 5 illustrates the effects of a positive government spending shock based on the baseline calibration parameter values described in Section 4.5 for some of the key aggregate variables, along with their empirical counterparts. In response to a positive government spending shock, aggregate consumption increases significantly, and has a hump-shaped response. Also, there is a corresponding hump-shaped increase in the stock of household debt that is within the confidence bands of the empirical response. Note that we are also able to generate a rise in house prices to a positive government spending shock on impact quantitatively,

Figure 6: Impulse responses in the benchmark model across households



Notes: Figure 6 shows the impulse response of aggregate consumption (CON), non-durable and service (NDC) and durable (DC) consumption, and labor income across different households (patient, impatient, and renters) in response to a positive government spending shock. The blue line indicates the empirical responses and the red line indicates the model response. The shaded area indicates 90% confidence interval bands.

though not the persistence of the corresponding empirical response, although the response is within the estimated confidence bands. Khan and Reza (2017) have shown that most standard models face a challenge in generating a positive response of house prices to a government spending shock, and even their proposed fix does not generate a hump-shaped response.[32] Additional model responses are shown in Figure F.1 in the appendix. Notably, in the model private investment is crowded out, which is consistent with findings from Galí, López-Salido and Vallés (2007) and Mountford and Uhlig (2009).[33] Labor and real wages both rise. Inflation and interest rate also rise on impact.

Figure 6 displays the dynamic responses among three types of households - patient, impatient, and renters - to a positive shock to government spending. Our model generates heterogeneous consumption responses across agents: impatient households (borrowers) have a large and persistent increase, patient households' (savers) consumption declines on impact at a relatively small magnitude, renters households have a similar response to impatient households but the increase is slightly smaller. Labor, wage, and labor income increase for all households. Overall, we do not find any heterogeneity in the labor market responses. Notably, the rise in labor income is of the same magnitude across all types of households.

Higher government spending generally induces negative wealth effects for all agents and the supply of labor increases, which results in the rise of output. The labor income response is not heterogeneous across households, but the consumption response is. Consumption of impatient households responds the most and this may be explained by the effects of spending shock on their borrowing ability and relaxing their liquidity constraints. Patient households tend to cut their consumption while supplying more labor, which is more like a representative household's behavior. Renters are more like hand-to-mouth consumers as they do not hold any assets, and therefore, spend their disposable labor income on consumption expenditures. The overall responses we see are consistent with the general equilibrium effects of a positive government spending shock, as a rise in aggregate demand, though there exists heterogeneity in the responses across the different types of households.

5.2 Transmission mechanisms

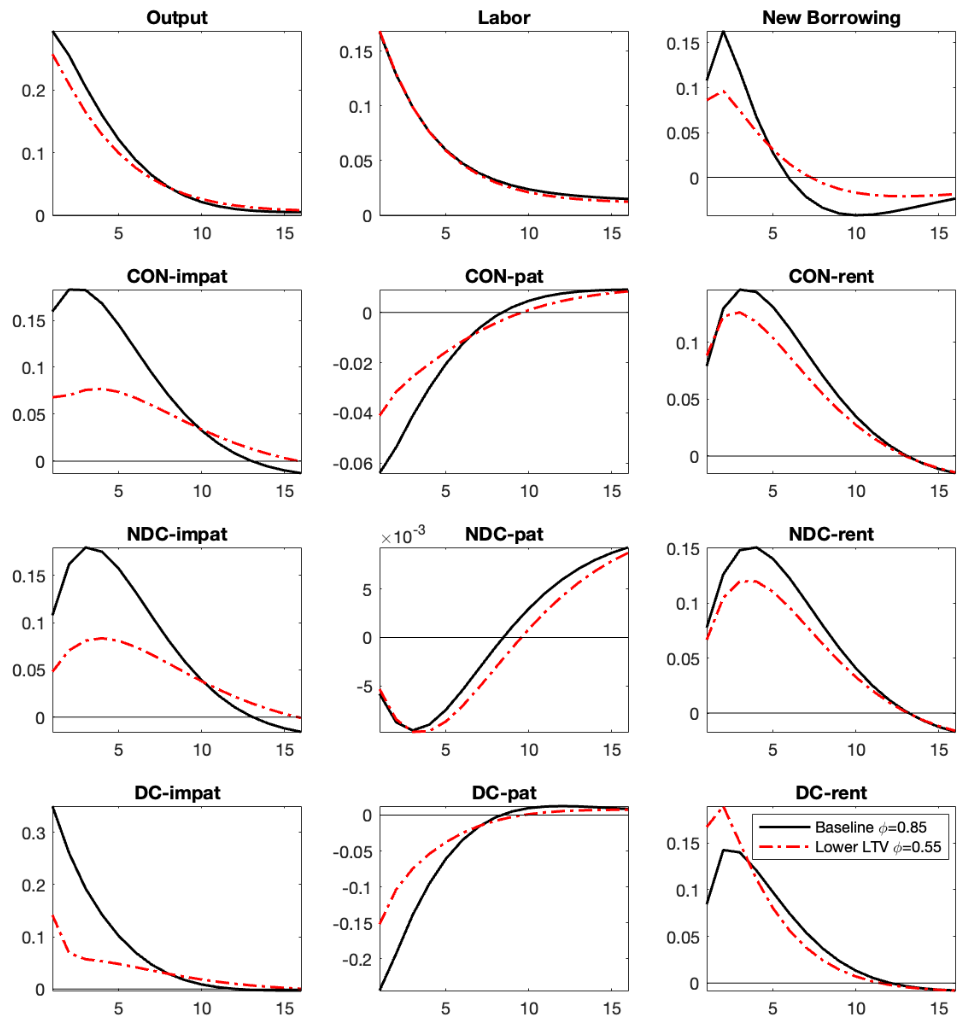
Given the model results, we now explore the potential transmission mechanisms of a government spending shock in generating heterogeneous consumption responses. In the standard RBC model, households face higher taxes following a positive government spending shock, and therefore experience negative wealth effects (Aiyagari, Christiano and Eichenbaum, 1992; Baxter and King, 1993). This negative wealth effect induces the representative household to decrease consumption and increase labor supply, implying output rises as a result.[34] The investment response depends on the persistence of government spending shocks. The presence of nominal rigidities implies a shift in the labor demand in response to increased demand due to public spending.

[32] In a recent contribution, Larsen, Ravn and Santoro (2022) are able to match the persistent response of house prices to government spending shocks by considering a model featuring endogenous entry in the intermediate goods sector and a taste for variety, which generates increasing returns in aggregate production. In our model, both patient and impatient households demand housing and also hold rental housing, though with different shares. The increase in housing investment from the impatient households for housing for themselves and for rental housing, raises housing demand sufficiently to help generate an overall rise in house prices on impact.

[33] A positive government spending shock crowds out non-residential investment on impact and residential investment with a delay in our model results.

[34] In a standard RBC model, a higher labor supply lowers the real wage and consumption is crowded-out

Figure 7: Impulse responses to a positive government spending shock for varying values of ϕ



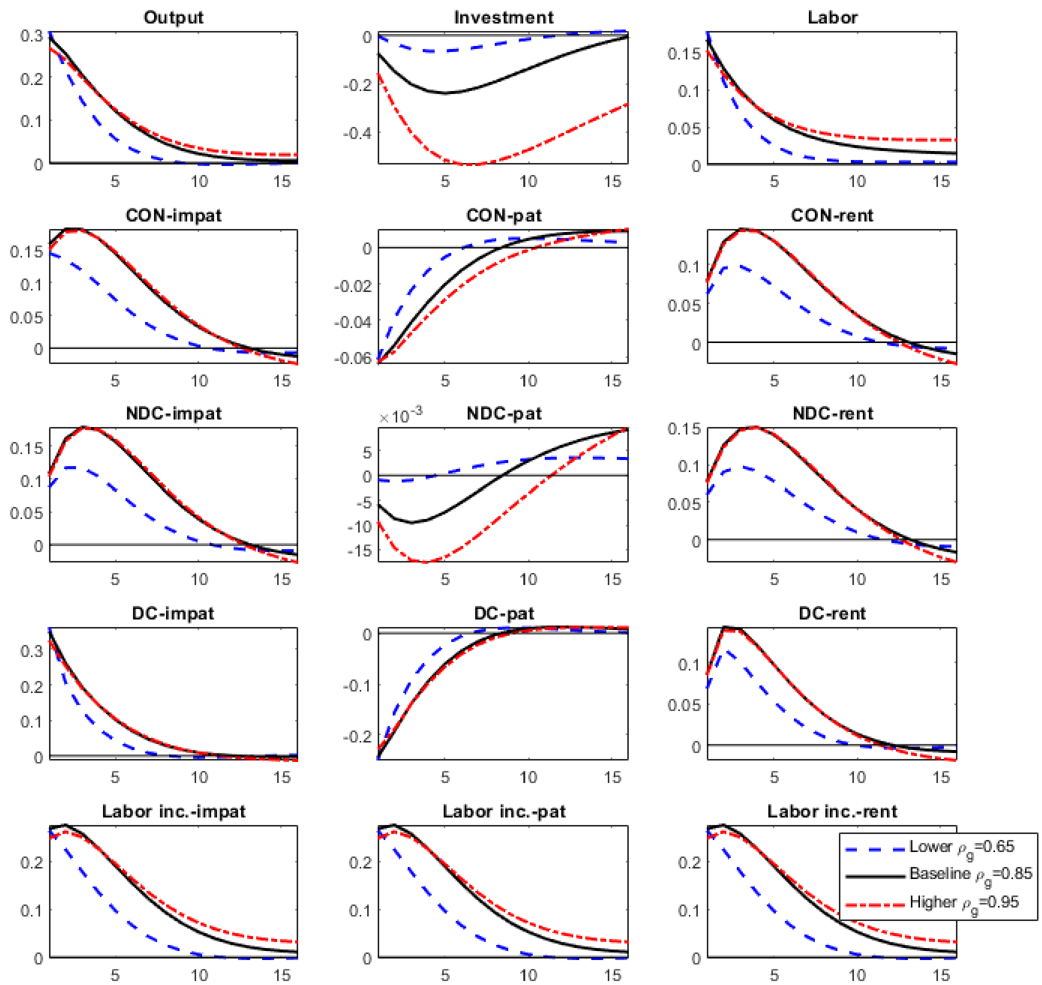
Notes: Figure 7 shows the impulse response of key macroeconomic variables at an aggregate level and total consumption (CON), non-durable and service (NDC) and durable (DC) consumption across different households (patient, impatient, and renters) in response to a positive government spending shock. The solid line indicates the baseline model results. The red dotted line represents the lower LTV ratio which lowers the borrowing ability of impatient households.

As a result, we see an overall rise in wages. In the presence of liquidity constrained households, this positive response of wages can translate into an overall increase in consumption.[35]

Our paper contributes to the new-Keynesian literature studying the effects of fiscal shocks by extending the model with households in different financial positions. In this case, the households' consumption responses following a government spending shock are determined by the income effect, credit effect, and wealth effect.

[35]See for instance the model featuring a share of rule-of-thumb consumers that helps generates a positive response of consumption in (Galí, López-Salido and Vallés, 2007).

Figure 8: Impulse responses to a positive government spending shock for varying values of ρ_g



Notes: Figure 8 shows the impulse response of key macroeconomic variables at an aggregate level and total consumption (CON), non-durable and service (NDC) and durable (DC) consumption across different households (patient, impatient, and renters) in response to a positive government spending shock. The solid line indicates the baseline model results. The blue dash-dotted line represents the lower ρ_g and the red dotted line represents the higher ρ_g indicating the high persistence of the shock.

As shown above, the labor income goes up for all of them since wages and labor for all three households rise, and that too to a similar degree and puts upward pressure on their consumption. Thus the differences across the various households are likely driven by the other two channels. In particular, the two potential transmission channels we consider are as follows: (i) liquidity constraints, and (ii) the persistence of shock propagating the negative wealth effect.

In the model, the impatient household faces a borrowing constraint given by $l_t = \phi q_{h,t} \left[\tilde{i}_{hI,t}(i) + \tilde{i}_{hRI,t}(i)\right]$ with the baseline LTV ratio, $\phi = 0.85$. Since house prices rise in response to a government spending shock, this implies that the credit constraint for the impatient household is loosened by the spending shock. The steady-state LTV ratio, ϕ, plays an important role in dictating the degree of borrowing ability of these households in response to house price changes. As shown in Figure 7, the lower level of LTV ratio (i.e. a larger down-payment requirement) clearly affects the consumption responses of impatient households negatively, while the consumption responses of patient and renters households are almost identical. At $\phi = 0.55$, output, labor, and labor income are almost identical while the new borrowing slightly falls and the lower borrowing power induces impatient households to reduce their consumption relatively. This tightening of borrowing constraint causes impatient households to reduce consumption by 57%, which is the largest relative change in consumption across three households. Overall, when borrowing constraints are tighter, patient households' consumption falls less and renters' consumption rises less and so the heterogeneity across the three agents is reduced. Despite the negative wealth effect following a positive government spending shock, the liquidity and credit effects still boost impatient households' consumption expenditures overall.

One of the main mechanisms through which a post-government spending shock affects consumption is through the negative wealth effect channel following a positive government spending shock. High spending generates the expectation of higher taxes today or in the future. For the renter households, since they consume their disposable income each period, only current taxes matter and if taxes do not rise immediately, they do not face these negative wealth effects on their consumption. These types of consumers are highlighted in Galí, López-Salido and Vallés (2007). On the other hand, the patient households are the Ricardian households in the model and bear the largest brunt of this negative wealth effect.[36] In Figure 8, we show the impulse responses with different degrees of shock persistence, which determines the size of the negative wealth effect. The baseline shock persistence, ρ_g, is set to 0.85. When we consider a less persistent shock, and ρ_g equal to 0.65, the increase in output, labor, and consumption on impact are less significant and persistent compared to the baseline result. Consumption response heterogeneity across households is reduced as patient households have a lower and less persistent level of negative wealth effects, cutting their consumption by less. Impatient and renters households exhibit larger consumption responses; however, this only lasts up to four quarters after the shock. Similarly, when we consider a more persistent shock, and ρ_g to be 0.95, then the decline in the consumption response of the patient household is even larger on impact.

In summary, we find that the liquidity constraints and the persistence of the shock play an important role in the propagation of government spending shocks, with the former of particular importance to the mortgagors and the latter of particular importance to the patient households (savers). Notably, our findings provide theoretical support for the notion that household mortgage debt positions play an important role in the transmission mechanism of fiscal policy. In the next section, we further test the robustness of our results to alternative parameterizations.

[36]The model indicates that consumption and labor income taxes are equally distributed among the three household types. Despite the similar tax burdens for consumption and labor income among the three household types, patient households face greater expenses due to property taxes, which were not considered in the empirical analysis. Given that patient households own most of the rental housing, they are likely to be disproportionately affected by an increase in house prices followed by a positive public spending shock.

6 Extensions and robustness analysis

In this section, we further distinguish between the effects on durable and non-durable consumption across the different types of households. We then discuss some robustness analysis for our model results.

6.1 Robustness to alternative parameterization

In Figure 9, we conduct several robustness analyses by altering the baseline parameterization. In our sensitivity analyses, we consider the case with (i) moderate habit formation in consumption, (ii) refinancing and equity withdrawal on existing loans, and (iii) low adjustment costs in the housing stock.

The role of habit formation. In the baseline model calibration, we focus on the case with habit formation (i.e., $\mu_c = 0.85$) in consumption. In this subsection, we reduce the degree of habit formation to model specification to explore the effects on expenditure heterogeneity. As shown in the first row of Figure 9, imposing a moderate value of habit formation does not alter heterogeneous consumption responses across different types of households qualitatively.[37] Reducing the level of habit formation results in a consumption response that still forms a hump-shaped pattern, while the impact response is slightly higher than the baseline case.

Role of refinancing and equity withdrawal. In the benchmark model, the new lending is determined by the steady-state LTV ratio associated with new investment in housing. In our sensitivity analysis, we consider the role of refinancing and home equity withdrawal to consider additional effects on mortgage debt. From our model, note that the effective interest rate on mortgage stock is given by,

$$R_t^M(i)d_t(i) = (1-\Phi)(1-\kappa)\frac{d_{t-1}(i)}{\pi_t}R_{t-1}^M(i) + \left[l_t(i) + \Phi(1-\kappa)\frac{d_{t-1}(i)}{\pi_t}\right]R_t^F, \tag{37}$$

where Φ is the refinancing rate.

With the home equity withdrawal rate, Υ, the new lending is then given by

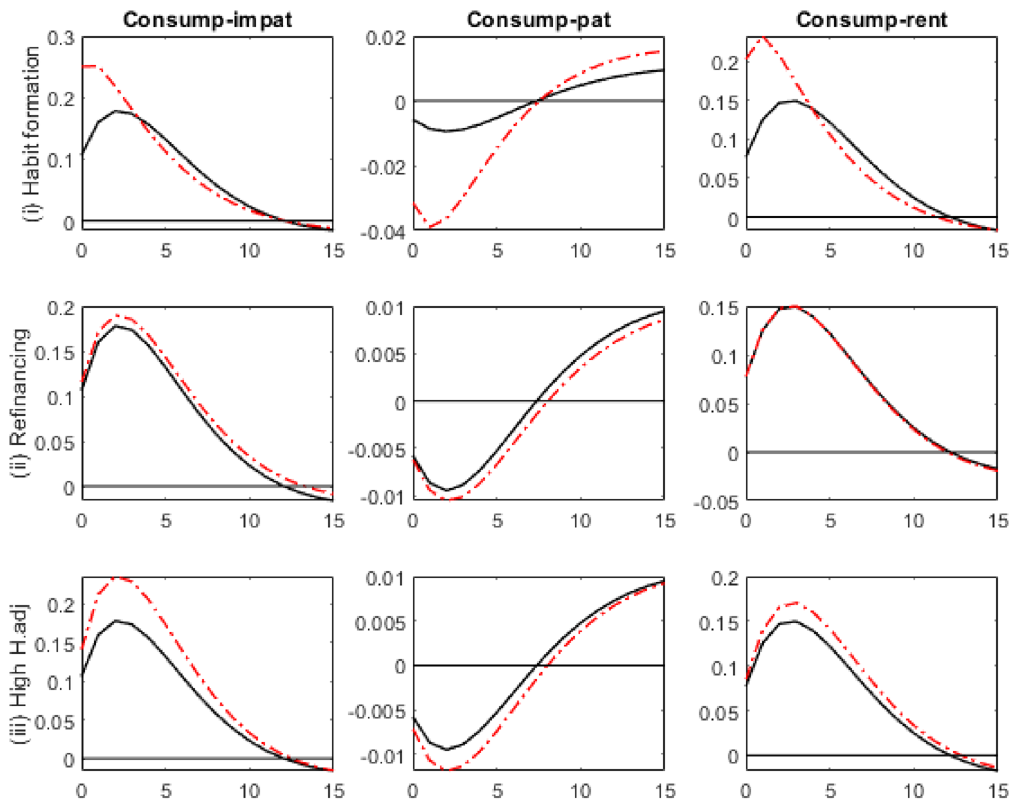
$$l_t = \phi q_{h,t}\tilde{i}_{hI,t}(i) + \Upsilon\left[q_{h,t}(1-\delta_h)h_{I,t-1}(i) - (1-\kappa)\frac{d_{t-1}(i)}{\pi_t}\right]. \tag{38}$$

Following Greenspan and Kennedy (2005) and Alpanda and Zubairy (2017), we set the refinancing rate to 0.0475 and the home equity withdrawal rate to 0.0172.[38] Figure 9 second row displays the sensitivity of consumption variations with alternative parameterization. Allowing refinancing and home equity withdrawal enhances the borrowing ability of impatient households, which slightly increases their consumption response

[37]In the figure, we show the baseline level of habit formation with $\mu_c = 0.85$ (black solid line). Imposing a moderate value of habit formation, $\mu_c = 0.5$ (red dash-dotted line) still provides similar results.

[38]The ratio of repayments from refinancing is averaged around 4.4% (implying 7.8 years of an interest rate duration) quarterly during 1991-2005 based on the data provided by Greenspan and Kennedy (2005). Following Alpanda and Zubairy (2016), we consider the average interest rate duration of 7.1 years with the refinancing rate, Φ, to 0.0475. We also set the home equity withdrawal rate to 0.0172 to match the 1.72% of existing equity of borrowers during 1991-2005.

Figure 9: The effects of fiscal policy under alternative parameterizations



Notes: Figure 9 shows the dynamics of aggregate consumption responses with alternative parameterizations in response to a positive government spending shock. The first row shows the baseline case (solid line, $\mu_c = 0.85$) with habit formation and a moderate level of habit formation (red dash-dotted line, $\mu_c = 0.5$). The second row shows the baseline case without refinancing (solid line) and an alternative case with refinancing and equity withdrawal (red dash-dotted line). The third row shows the comparison between the baseline (solid line, $\kappa_h = 2$) and an alternative response with a higher adjustment in the housing stock (red dash-dotted line, $\kappa_h = 10$).

but the changes are rather small in magnitude. This suggests that for the propagation of fiscal shocks, the additional channel coming from refinancing does not alter the results considerably.

Adjustment costs in housing stock. The third row of Figure 9 shows the consumption responses when the degree of housing stock adjustment costs, κ_h, change. When we increase adjustment costs in housing stock, κ_h to be 10.00, the house price rises by more and housing stock accumulates more slowly. Impatient households face a rise in their collateral values which further strengthens their borrowing ability. As a result, the consumption of impatient households rises by more.

6.2 Alternative Monetary Stance: Considering ZLB

In this subsection, we discuss how the effects of government spending shocks are different when monetary policy is constrained by zero lower bound (ZLB). In particular, we consider the following monetary policy rule:

$$R_t = \max\left[R + a_\pi \log\left(\frac{\pi_{c,t}}{\pi}\right) + a_y \log\left(\frac{y_t}{y}\right), 0\right]$$

A vast literature has shown that the aggregate effects of government spending are amplified when short-term rates are constrained by the ZLB (Eggertsson (2011); Christiano, Eichenbaum and Rebelo (2011)).

We generate a ZLB scenario in our model, where ZLB binds for four quarters, with negative preference shock, and consider the responses to a government spending shock in this case.[39] We find that in response to a positive government spending shock, output and consumption increase significantly and these effects are amplified under ZLB. The impulse responses of key variables for our baseline case along with an alternative scenario when the ZLB binds, are shown in the appendix, Figure G.1.

In Table 5, we compute the cumulative output and consumption multipliers.[40] We find that the one-year cumulative output multiplier is 1.72 in the ZLB period which is higher than that of 1.36 in normal times.[41] At longer horizons, the output multiplier increases even more under ZLB.

ZLB periods can lead to divergent consumption responses, especially among impatient and renter households, who experience larger quantitative differences in their responses during normal times and ZLB periods. In contrast, patient households exhibit a consumption response that is similar to a representative agent model during both normal times and ZLB periods and their consumption is crowded out due to the longer-lasting intertemporal substitution effect.

Under ZLB, the rise in government spending is inflationary due to a rise in demand, which decreases the real interest rate as nominal rates are bound at zero. A lower real interest rate generates the intertemporal substitution effects, which stimulates current consumption. This effect becomes evident under ZLB for impatient and renter households while the level of consumption response increases the most for impatient households. In contrast, the presence of habit formation breaks the tight link between consumption growth and the real interest rate for patient households, causing their aggregate consumption response to be negative even when the ZLB is in effect. When we consider $\mu_c = 0$ (i.e., no habit formation), we can generate a rise in the consumption response of patient households also.

Table 5 also shows the cumulative consumption multipliers at the aggregate and disaggregate levels. We find that the one-year integral consumption multiplier is around 0.17 during normal times while it is

[39] We generate this scenario by employing the Occbin code of Guerrieri and Iacoviello (2015), by introducing a preference shock driven recession that takes the interest rate to the ZLB.

[40] All horizons are shown in Figure G.2 in the Appendix G.

[41] Miyamoto, Nguyen and Sergeyev (2018) find the on-impact output multiplier as 1.5 in the zero lower bound and Christiano, Eichenbaum and Rebelo (2011) also find that the multiplier is substantially larger than one. The amplification effect of ZLB on our baseline government spending multiplier is relatively smaller than some of these documented studies, as Abo-Zaid and Kamara (2020) point out that a model with credit constraints potentially dampens the consumption response relative to one in the absence of these constraints.

Table 5: Output and consumption multipliers

	Normal times	ZLB (4 quarters)	%Δ (Base, ZLB 4Q)
PANEL A: Output multipliers			
One-year Integral	1.36	1.72	0.26
Two-year Integral	1.30	1.77	0.36
PANEL B: Consumption multipliers			
One-year Integral	0.17	0.25	0.47
Two-year Integral	0.22	0.36	0.64
PANEL C: Consumption multipliers for **Impatient** Households			
One-year Integral	0.12	0.16	0.33
Two-year Integral	0.13	0.20	0.54
PANEL D: Consumption multiplier for **Patient** Households			
One-year Integral	-0.05	-0.05	0.00
Two-year Integral	-0.03	-0.04	0.33
PANEL E: Consumption multipliers for **Renter** Households			
One-year Integral	0.05	0.08	0.60
Two-year Integral	0.07	0.11	0.57

higher during ZLB periods. Impatient and renter households have positive consumption multipliers in both normal times and in the ZLB scenario, while the magnitude is much higher for the latter case. However, patient households have small and negative consumption multipliers during and outside of the ZLB, where the degree of consumption crowding out is reduced during ZLB. From this exercise, we conclude that the effects of government spending shock on the economy are amplified and aggregate output and consumption are crowded-in during ZLB periods.

7 Conclusion

Employing U.S. household survey data, this paper examines how the effects of government spending shocks depend on the balance-sheet position of households. Since mortgage debt constitutes the vast majority of household debt, we use housing tenure status to proxy for the financial positions of the households. In response to a positive government spending shock, we find that mortgagor households experience a large, positive consumption response, while renters have a smaller rise in consumption. Outright homeowners without mortgage debt, in contrast, have an insignificant consumption expenditure response to a public spending shock. We consider a dynamic stochastic general equilibrium (DSGE) model with housing and financial frictions and provide a theoretical framework to rationalize these empirical findings and transmission mechanisms. Our model features three types of households: savers who own their housing, borrowers with mortgage debt, and rule-of-thumb consumers who rent housing. We show that this model can successfully match heterogeneous consumption responses. The model suggests that liquidity constraints and wealth effects tied to the persistence of public spending, play a crucial role in the propagation of government spending shocks. Our findings provide both empirical and theoretical support for the notion that household mortgage debt position plays an important role in the transmission mechanism of fiscal policy.

This paper shows the importance of housing tenure and mortgage status in the propagation of government spending shocks. Given the substantial variation in homeownership across countries, these findings might have implications for the relative magnitudes of the effects of government spending shocks on aggregate variables across countries. This is left for future research.

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Appendix

A Data sources

A.1 Aggregate data

Table A.1: Data description

Data	Description	Source
NGDP	Nominal GDP	BEA
PGDP	GDP deflator	BEA
GOV	Nominal government purchases	BEA
NCONS	Nominal personal consumptoin expenditure	BEA
NCDUR	Personal consumption expenditures: Durable goods	BEA
NCDC	Personal consumption expenditures: Nondurable goods	BEA
NCSV	Personal consumption expenditures: Service goods	BEA
Population	Population, thousands (POPTHM)	FRED
Hours	Total hours worked	BLS
PBUS	Nonfarm business Sector: Implicit price deflator	BLS
Wages	Nonfarm business sector: Compensation per hour	BLS
Tbill3	3-month Treasury bill (TB3MS)	FRED
HHDEBT	Households and nonprofit organizations;	FRED
	debt securities and loans; liability (CMDEBT)	
HPI	House price index;	
	Price Indexes of New Single-Family Houses Sold Including Lot Value	Census Bereau
	All-Transactions House Price Index for the United States, Index	FRED
	Median sales price for new houses sold (MSPNHSUS)	FRED
Recession	NBER recession periods	FRED
SPF shock	Survey of Professional Forecasters forecast error shock	Ramey (2011)

Note: Table A.1 reports the data source for key aggregate variables. Real values are all deflated by GDP deflator for the sample period, 1981:Q1-2007:Q1.

A.2 Data by housing tenure groups

We use the U.S. Consumer Expenditure Survey (CEX) data which is available from the U.S. Bureau of Labor Statistics for the sample period, 1981-2007. We use the household expenditure and income data constructed by different types of housing tenure groups following Cloyne, Ferreira and Surico (2020). Consumption data covers non-durable goods and services (food, alcohol, tobacco, clothing and footwear, leisure goods, household services) and durable expenditures (motor vehicles, durable leisure goods, durable household goods). In terms of income data, labor income includes wages and salaries and non-labor income includes income from investments and social payments, net of taxes. Households are excluded from the sample if (i) the income data is missing or the net income is negative, (ii) the expenditure is in either top or the bottom 1% of distribution, (iii) the household head is aged either below 25 or above 74 years old.

The U.S. Survey of Consumer Finance (SCF) data which is available from the Federal Reserve is also used for the sample period, 1995-2007. This household survey data includes a triennial cross-sectional survey of U.S. households. We use the information on households' balance sheets, wealth and asset positions, pensions, demographic characteristics, and income to classify households who are wealthy hand-to-mouth following Kaplan, Violante and Weidner (2014).

B Asset, Wealth, and Debt to Income Ratio

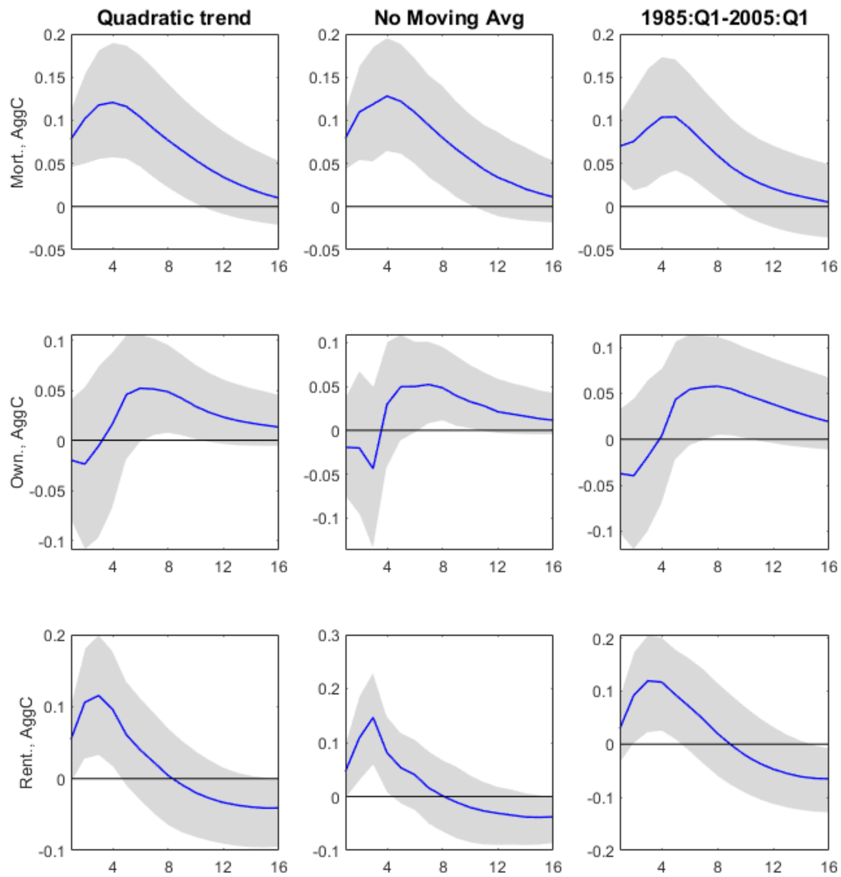
Table B.1: Asset, wealth, and debt to income ratio by housing tenure

	PANEL A: 1995 SCF		PANEL B: 1998 SCF		PANEL C: 2001 SCF		PANEL D: 2004 SCF		PANEL E: 2007 SCF	
Asset	Mean	95% Conf. interval	Mean	95% Conf. interval	Mean	95% Conf. interval	Mean	95% Conf. interval	Mean	95% Conf. interval
Mortgagors	540,976	[525,118, 556,834]	664,010	[644,196, 683,824]	799,320	[775,740, 822,899]	850,222	[826,873, 873,570]	957,274	[931,649, 982,900]
Outright homeowners	599,946	[575,176, 624,715]	820,483	[782,035, 858,931]	1,028,879	[983,941, 1,073,817]	1,186,705	[1,134,975, 1,238,434]	1,367,399	[1,304,774, 1,430,025]
Renters	77,098	[70,687, 83,508]	75,459	[69,744, 81,174]	88,321	[79,961, 96,681]	85,913	[77,562, 94,265]	97,034	[87,667, 106,402]
Net liquid asset										
Mortgagors	46,492	[42,967, 50,018]	90,778	[84,409, 97,147]	115,131	[107,793, 122,468]	90,039	[84,657, 95,421]	92,356	[86,910, 97,803]
Outright homeowners	105,282	[97,034, 113,530]	173,283	[160,420, 186,146]	203,731	[187,892, 219,571]	236,670	[217,578, 255,762]	250,772	[232,421, 269,123]
Renters	12,747	[9,303, 16,192]	11,994	[10,610, 13,379]	19,304	[15,210, 23,399]	14,421	[10,749, 18,092]	16,826	[13,571, 20,082]
Net illiquid asset										
Mortgagors	178,597	[173,314, 183,881]	213,069	[206,743, 219,396]	258,878	[251,567, 266,188]	283,353	[275,083, 291,623]	324,389	[315,765, 333,013]
Outright homeowners	208,039	[201,820, 214,258]	261,544	[252,092, 270,995]	348,328	[334,778, 361,879]	408,219	[392,586, 423,852]	467,158	[447,044, 487,272]
Renters	18,921	[17,124, 20,719]	19,671	[17,592, 21,750]	20,040	[18,003, 22,078]	14,286	[12,769, 15,804]	18,605	[16,509, 20,700]
Home equity										
Mortgagors	96,065	[93,634, 98,495]	107,436	[104,563, 110,309]	136,836	[132,925, 140,746]	168,845	[163,892, 173,798]	192,533	[187,676, 197,391]
Outright homeowners	148,703	[144,692, 152,714]	170,233	[164,526, 175,939]	212,581	[205,845, 219,318]	270,776	[261,220, 280,331]	303,421	[289,629, 317,214]
Renters	0	0	0	0	0	0	0	0	0	0
Debt to income										
Mortgagors	1.80	[1.74, 1.87]	2.76	[1.97, 3.54]	1.80	[1.74, 1.86]	2.39	[2.29, 2.50]	2.47	[2.41, 2.53]
Outright homeowners	0.51	[0.30, 0.71]	0.25	[0.22, 0.28]	0.28	[0.24, 0.33]	0.32	[0.28, 0.35]	0.51	[0.42, 0.60]
Renters	0.43	[0.39, 0.47]	0.56	[0.47, 0.64]	0.95	[0.40, 1.51]	0.43	[0.40, 0.46]	0.49	[0.45, 0.53]

Note: Table B.1 reports mean and 95% confidence interval value of an asset, net liquid asset, net illiquid asset (including home equity), and debt to income ratio by housing tenure group. Data are from SCF for 1995-2007 and each series is in the corresponding year's dollar.

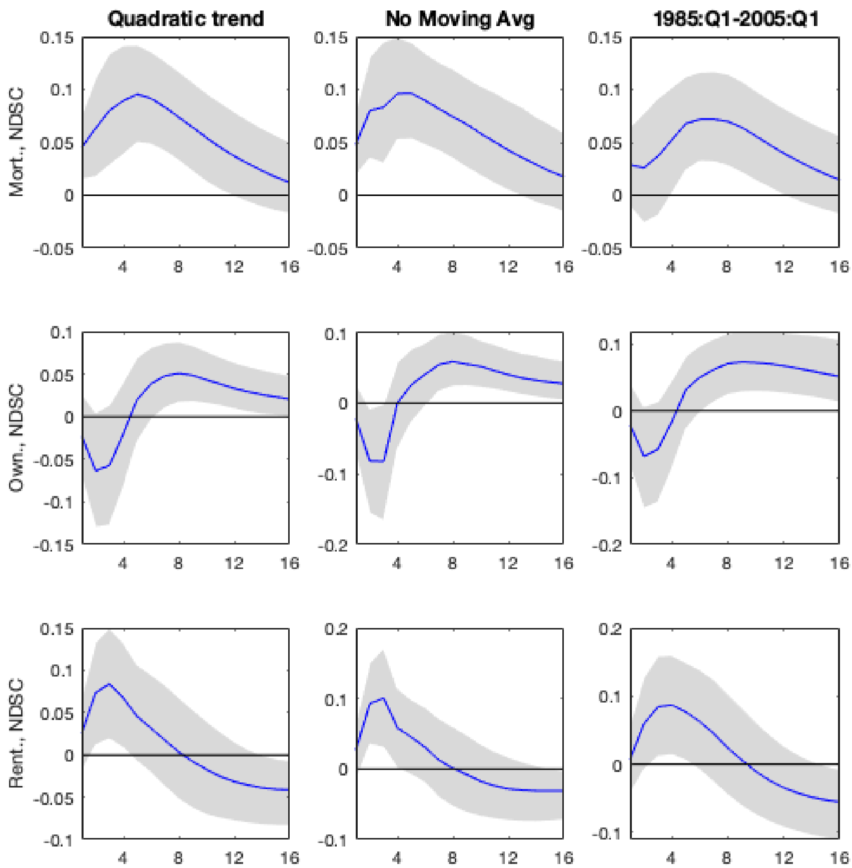
C Robustness checks for empirical analysis

Figure C.1: Impulse responses of **aggregate** consumption in response to a positive govt spending shock



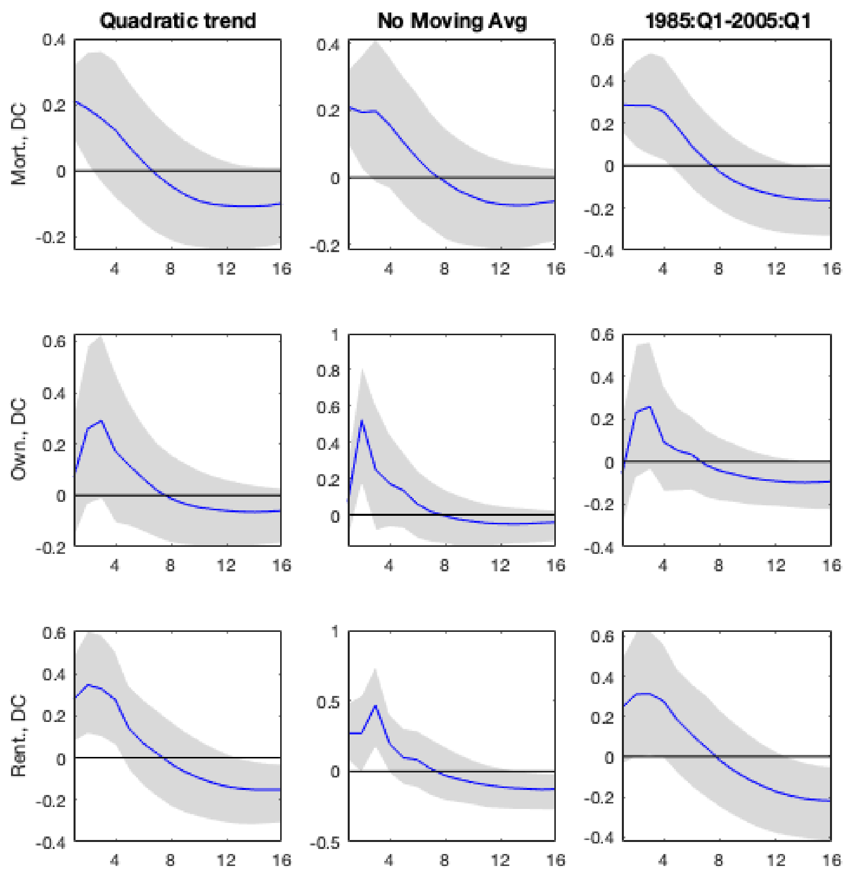
Notes: Figure C.1 plots the impulse responses of aggregate consumption in response to a positive government spending shock with 68 % confidence interval bands based on bootstrapped standard errors (shaded area).

Figure C.2: Impulse responses of **non-durable** consumption in response to a positive govt spending shock



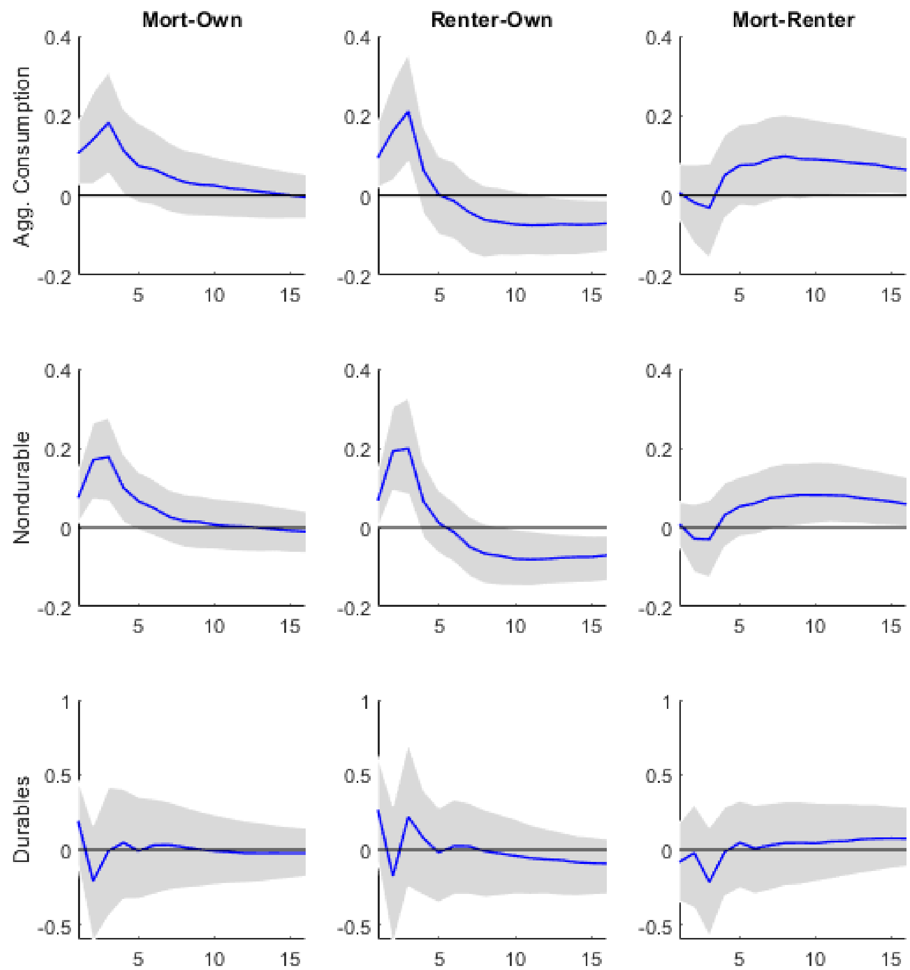
Notes: Figure C.2 shows the impulse responses of non-durable consumption responses to a positive SPF shock by each housing tenure group. The shaded area indicates 68 % confidence interval bands.

Figure C.3: Impulse responses of **durable** consumption in response to a positive govt spending shock



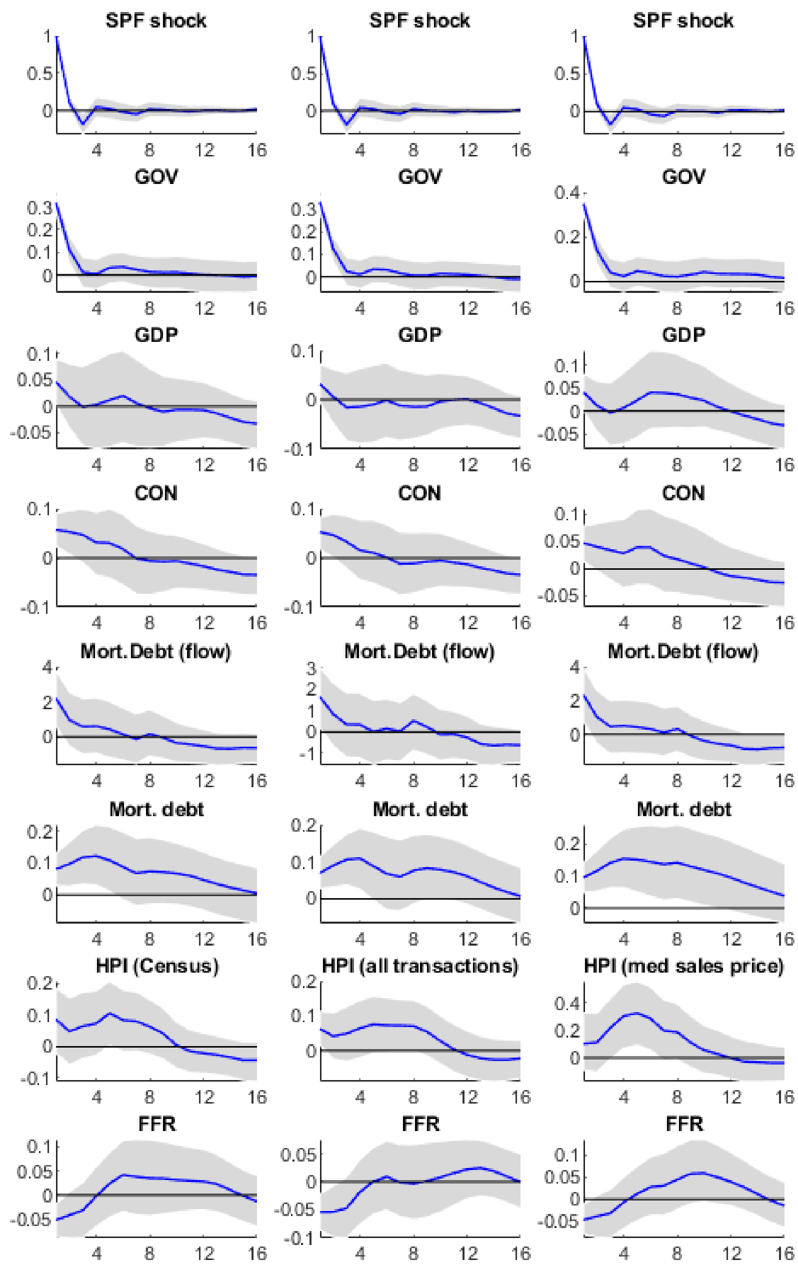
Notes: Figure C.3 shows the impulse responses of durable consumption responses to a positive SPF shock by each housing tenure group. The shaded area indicates 68% confidence interval bands.

Figure C.4: Impulse responses of difference in consumption across three types households in response to a positive govt spending shock



Notes: Figure C.4 shows the difference in impulse response across three types of agents to a positive SPF shock by each housing tenure group. The first column indicates the difference in consumption response (aggregate, non-durable, and durable) across mortgagors and outright homeowners. The second and third columns represent the difference in consumption across renters and outright homeowners and mortgagors and renters households, respectively. The shaded area indicates 68% confidence interval bands.

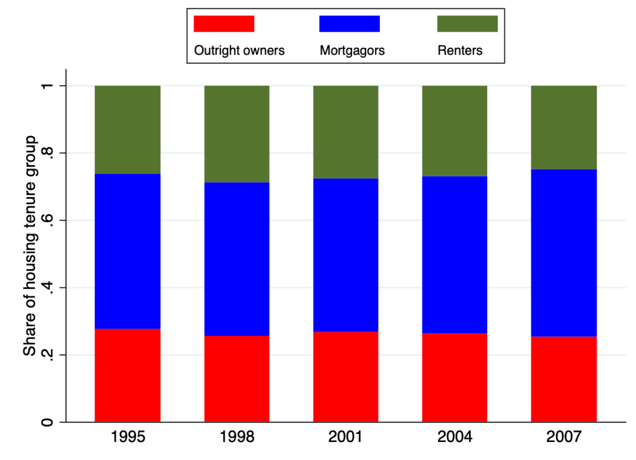
Figure C.5: Impulse responses across alternative house price index



Notes: Figure C.5 shows the impulse responses of key aggregate variables across three different measures of the house price index (house price index of new single-family houses sold from Census Beraeau, all transactions house price index, and median sales price for new houses sold) in response to a positive SPF shock. The shaded area indicates 68% confidence interval bands.

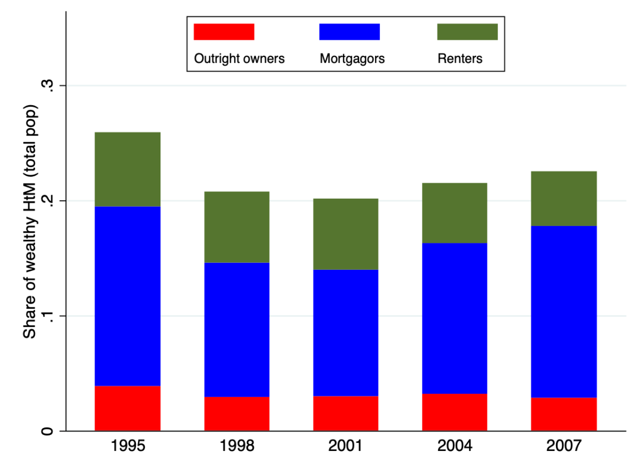
D Share of housing tenure groups

Figure D.1: Share of housing tenure group (total population, SCF)



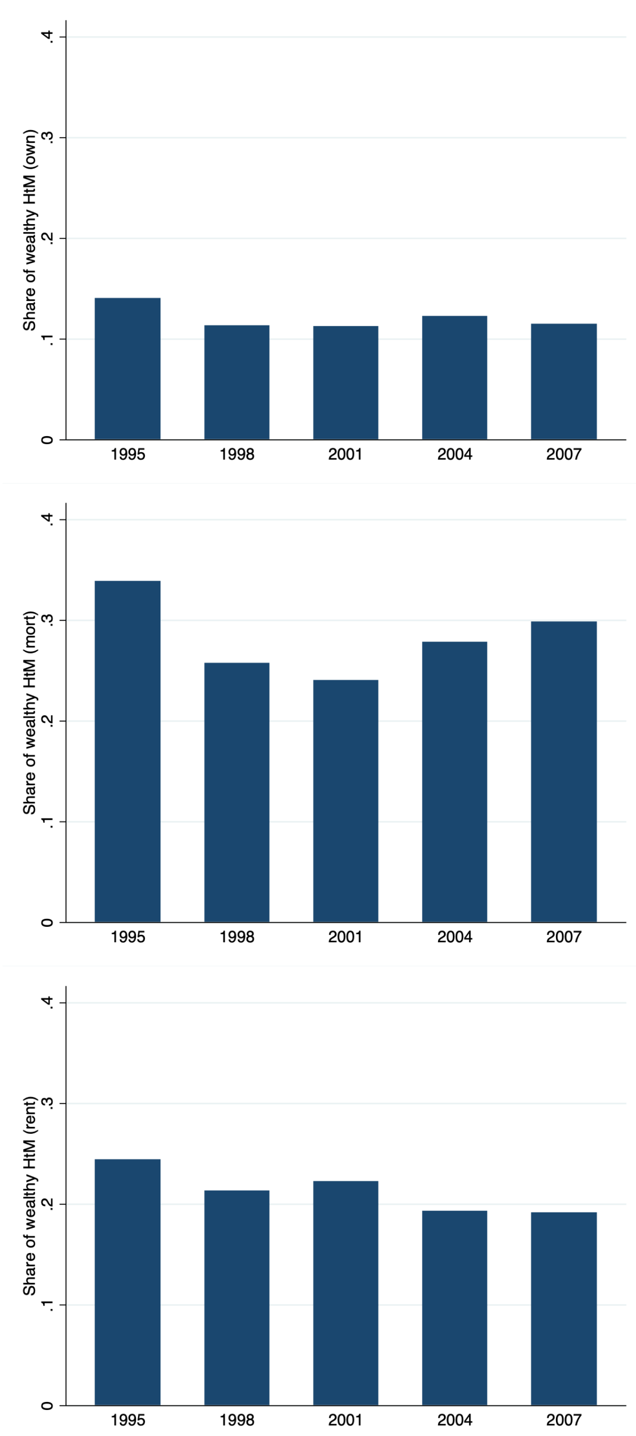
Notes: Figure D.1 shows the share of each housing tenure group in the total population.

Figure D.2: Share of wealthy hand to mouth by housing tenure group (total population, SCF)



Notes: Figure D.2 shows the share of wealthy Hand-to-Mouth (HtM) by housing tenure groups in the total population.

Figure D.3: Share of wealthy hand to mouth by housing tenure group (within group, SCF)



Notes: Figure D.3 shows the share of wealthy Hand-to-Mouth (HtM) within each housing tenure group.

E Model: First order conditions

E.1 Patient Households (savers)

$$\theta\left(\frac{s_{P,t}}{c_{P,t}}\right)^{1-\theta}\left[\frac{\upsilon_t}{x_{P,t}}-\beta_P\mu_c E_t\left\{\frac{\upsilon_{t+1}}{x_{P,t+1}}\right\}\right]=(1+\tau_c)\,\lambda_{P,t} \tag{E.1}$$

$$\begin{aligned}&\left[1+\tau_p\,(1-\tau_{yP})+\kappa_h\left(\frac{h_{P,t}}{h_{P,t-1}}-1\right)\frac{h_{P,t}}{h_{P,t-1}}\right]q_{h,t}=\frac{\upsilon_t\xi_h}{\lambda_{P,t}h_{P,t}}\\&+E_t\left[\left(\beta_P\frac{\lambda_{P,t+1}}{\lambda_{P,t}}\right)\left[1-\delta_h+\kappa_h\left(\frac{h_{P,t+1}}{h_{P,t}}-1\right)\left(\frac{h_{P,t+1}}{h_{P,t}}\right)^2\right]q_{h,t+1}\right]\end{aligned} \tag{E.2}$$

$$\begin{aligned}&\left[1+\tau_p\,(1-\tau_{yP})+\kappa_h\left(\frac{h_{RP,t}}{h_{RP,t-1}}-1\right)\frac{h_{RP,t}}{h_{RP,t-1}}\right]q_{h,t}=(1-\tau_{yP})\,r_{hP,t}\\&+E_t\left[\left(\beta_P\frac{\lambda_{P,t+1}}{\lambda_{P,t}}\right)\left\{\left[1-\delta_h+\kappa_h\left(\frac{h_{RP,t+1}}{h_{RP,t}}-1\right)\left(\frac{h_{RP,t+1}}{h_{RP,t}}\right)^2\right]q_{h,t+1}+\tau_{yP}\delta_h\right\}\right]\end{aligned} \tag{E.3}$$

$$\begin{aligned}&\left[1+\kappa_k\left(\frac{k_t}{k_{t-1}}-1\right)\frac{k_t}{k_{t-1}}\right]q_{k,t}\\&=E_t\left[\left(\beta_P\frac{\lambda_{P,t+1}}{\lambda_{P,t}}\right)\left\{\left[1-\delta_k+\kappa_k\left(\frac{k_{t+1}}{k_t}-1\right)\left(\frac{k_{t+1}}{k_t}\right)^2\right]q_{k,t+1}+(1-\tau_k)\,r_{k,t+1}+\tau_k\delta_k\right\}\right]\end{aligned} \tag{E.4}$$

$$\begin{aligned}&\left[(1+\tau_c)+\kappa_s\left(\frac{s_{P,t}}{s_{P,t-1}}-1\right)\frac{s_{P,t}}{s_{P,t-1}}+\frac{\kappa_s}{2}\left(\frac{s_{P,t}}{s_{P,t-1}}-1\right)^2\right]q_{s,t}=\frac{(1+\tau_c)(1-\theta)}{\theta}\frac{c_{P,t}}{s_{P,t}}\\&+E_t\left[\left(\beta_P\frac{\lambda_{P,t+1}}{\lambda_{P,t}}\right)\left\{\left[(1+\tau_c)(1-\delta_s)+\kappa_s\left(\frac{s_{P,t+1}}{s_{P,t}}-1\right)\left(\frac{s_{P,t+1}}{s_{P,t}}\right)^2\right]q_{s,t+1}\right\}\right]\end{aligned} \tag{E.5}$$

$$\upsilon_t\xi_n n_{P,t}^{\vartheta}=\lambda_{P,t}\Omega_{nP,t}\,(1-\tau_{yP})\,w_{P,t} \tag{E.6}$$

$$\begin{aligned}&\left(\frac{\pi_{wP,t}}{\pi}-1\right)\frac{\pi_{wP,t}}{\pi}\\&=E_t\left[\beta_P\frac{\lambda_{P,t+1}}{\lambda_{P,t}}\left(\frac{\pi_{wP,t+1}}{\pi}-1\right)\frac{\pi_{wP,t+1}}{\pi}\frac{\pi_{wP,t+1}}{\pi_{t+1}}\frac{n_{P,t+1}}{n_{P,t}}\right]-\frac{(\eta_w-1)\,(1-\tau_{yP})}{\kappa_w}\,(1-\theta_w\Omega_{nP,t})\\&\text{where } \theta_w=\frac{\eta_w}{\eta_w-1},\ \pi_{wP,t}=\frac{W_{P,t}}{W_{P,t-1}}\end{aligned} \tag{E.7}$$

$$\frac{\pi_{wP,t}}{\pi_t}=\frac{w_{P,t}}{w_{P,t-1}} \tag{E.8}$$

$$1 = E_t \left[\left(\beta_P \frac{\lambda_{P,t+1}}{\lambda_{P,t}} \right) \left(\frac{1 + (1 - \tau_b) R_t}{\pi_{t+1}} \right) \right] \tag{E.9}$$

$$1 = \Omega_{dP,t} + \Omega_{rP,t} R_t^F \tag{E.10}$$

$$\Omega_{dP,t} + \Omega_{rP,t} R_t^M = E_t \left[\left(\beta_P \frac{\lambda_{P,t+1}}{\lambda_{P,t}} \right) \left(\frac{(1 - \tau_b) R_t^M + \kappa + (1 - \kappa) \left\{ \Omega_{dP,t+1} + \Omega_{rP,t+1} R_t^M \right\}}{\pi_{t+1}} \right) \right] \tag{E.11}$$

$$\Omega_{rP,t} = E_t \left[\left(\beta_P \frac{\lambda_{P,t+1}}{\lambda_{P,t}} \right) \left(\frac{1 - \tau_b + (1 - \kappa) \Omega_{rP,t+1}}{\pi_{t+1}} \right) \right] \tag{E.12}$$

E.2 Impatient Households (borrowers)

$$\theta \left(\frac{s_{I,t}}{c_{I,t}} \right)^{1-\theta} \left[\frac{\upsilon_t}{x_{I,t}} - \beta_I \mu_c E_t \left\{ \frac{\upsilon_{t+1}}{x_{I,t+1}} \right\} \right] = (1 + \tau_c) \lambda_{I,t} \tag{E.13}$$

$$\begin{aligned} \left[1 + \tau_p (1 - \tau_{yI}) + \kappa_h \left(\frac{h_{I,t}}{h_{I,t-1}} - 1 \right) \frac{h_{I,t}}{h_{I,t-1}} - \phi \mu_t \right] q_{h,t} &= \frac{\upsilon_t \xi_h}{\lambda_{I,t} h_{I,t}} \\ + E_t \left[\left(\beta_I \frac{\lambda_{I,t+1}}{\lambda_{I,t}} \right) \left\{ \left[(1 - \delta_h) [1 - \phi \mu_{t+1}] + \kappa_h \left(\frac{h_{I,t+1}}{h_{I,t}} - 1 \right) \left(\frac{h_{I,t+1}}{h_{I,t}} \right)^2 \right] q_{h,t+1} \right\} \right] & \end{aligned} \tag{E.14}$$

$$\begin{aligned} \left[1 + \tau_p (1 - \tau_{yI}) + \kappa_h \left(\frac{h_{RI,t}}{h_{RI,t-1}} - 1 \right) \frac{h_{RI,t}}{h_{RI,t-1}} - \phi \mu_t \right] q_{h,t} &= (1 - \tau_{yI}) r_{hI,t} \\ + E_t \left[\left(\beta_I \frac{\lambda_{I,t+1}}{\lambda_{I,t}} \right) \left\{ \left[(1 - \delta_h) [1 - (\phi - \Upsilon) \mu_{t+1}] + \kappa_h \left(\frac{h_{RI,t+1}}{h_{RI,t}} - 1 \right) \left(\frac{h_{RI,t+1}}{h_{RI,t}} \right)^2 \right] q_{h,t+1} + \tau_{yI} \delta_h \right\} \right] & \end{aligned} \tag{E.15}$$

$$\begin{aligned} \left[(1 + \tau_c) + \kappa_s \left(\frac{s_{I,t}}{s_{I,t-1}} - 1 \right) \frac{s_{I,t}}{s_{I,t-1}} + \frac{\kappa_s}{2} \left(\frac{s_{I,t}}{s_{I,t-1}} - 1 \right)^2 \right] q_{s,t} &= \frac{(1 + \tau_c)(1 - \theta)}{\theta} \frac{c_{I,t}}{s_{I,t}} \\ + E_t \left[\left(\beta_I \frac{\lambda_{I,t+1}}{\lambda_{I,t}} \right) \left\{ \left[(1 + \tau_c)(1 - \delta_s) + \kappa_s \left(\frac{s_{I,t+1}}{s_{I,t}} - 1 \right) \left(\frac{s_{I,t+1}}{s_{I,t}} \right)^2 \right] q_{s,t+1} \right\} \right] & \end{aligned} \tag{E.16}$$

$$\upsilon_t \xi_n n_{I,t}^{\vartheta} = \lambda_{I,t} \Omega_{nI,t} (1 - \tau_{yI}) w_{I,t} \tag{E.17}$$

$$\left(\frac{\pi_{wI,t}}{\pi}-1\right)\frac{\pi_{wI,t}}{\pi}$$

$$=E_t\left[\beta_I\frac{\lambda_{I,t+1}}{\lambda_{I,t}}\left(\frac{\pi_{wI,t+1}}{\pi}-1\right)\frac{\pi_{wI,t+1}}{\pi}\frac{\pi_{wI,t+1}}{\pi_{t+1}}\frac{n_{I,t+1}}{n_{I,t}}\right]-\frac{(\eta_w-1)(1-\tau_{yI})}{\kappa_w}(1-\theta_w\Omega_{nI,t}) \tag{E.18}$$

where $\pi_{wI,t}=\dfrac{W_{I,t}}{W_{I,t-1}}$

$$\frac{\pi_{wI,t}}{\pi_t}=\frac{w_{I,t}}{w_{I,t-1}} \tag{E.19}$$

$$1-\mu_t=\Omega_{dI,t}+\Omega_{rI,t}R_t^F \tag{E.20}$$

$$\Omega_{dI,t}+\Omega_{rI,t}R_t^M=E_t\left[\beta_I\frac{\lambda_{I,t+1}}{\lambda_{I,t}}\left(\frac{(1-\tau_{yI})R_t^M+\kappa+(1-\kappa)\left\{\Omega_{dI,t+1}+\Omega_{rI,t+1}R_t^M\right\}}{\pi_{t+1}}\right)\right] \tag{E.21}$$

$$\Omega_{rI,t}=E_t\left[\beta_I\frac{\lambda_{I,t+1}}{\lambda_{I,t}}\left(\frac{1-\tau_{yI}+(1-\kappa)\Omega_{rI,t+1}}{\pi_{t+1}}\right)\right] \tag{E.22}$$

E.3 Renter Households

$$\theta\left(\frac{s_{R,t}}{c_{R,t}}\right)^{1-\theta}\left[\frac{\upsilon_t}{x_{R,t}}-\beta_R\mu_cE_t\left\{\frac{\upsilon_{t+1}}{x_{R,t+1}}\right\}\right]=(1+\tau_c)\lambda_{R,t} \tag{E.23}$$

$$p_{hP,t}=\frac{\upsilon_t\xi_t\mu_h}{\lambda_{R,t}h_{RP,t}} \tag{E.24}$$

$$p_{hI,t}=\frac{\upsilon_t\xi_t(1-\mu_h)}{\lambda_{R,t}h_{RI,t}} \tag{E.25}$$

$$\left[(1+\tau_c)+\kappa_s\left(\frac{s_{R,t}}{s_{R,t-1}}-1\right)\frac{s_{P,t}}{s_{R,t-1}}+\frac{\kappa_s}{2}\left(\frac{s_{R,t}}{s_{R,t-1}}-1\right)^2\right]q_{s,t}=\frac{(1+\tau_c)(1-\theta)}{\theta}\frac{c_{R,t}}{s_{R,t}}$$
$$+E_t\left[\left(\beta_R\frac{\lambda_{R,t+1}}{\lambda_{R,t}}\right)\left\{\left[(1+\tau_c)(1-\delta_s)+\kappa_s\left(\frac{s_{R,t+1}}{s_{R,t}}-1\right)\left(\frac{s_{R,t+1}}{s_{R,t}}\right)^2\right]q_{s,t+1}\right\}\right] \tag{E.26}$$

$$\upsilon_t\xi_n n_{R,t}^{\vartheta}=\lambda_{R,t}\Omega_{nR,t}(1-\tau_{yR})w_{R,t} \tag{E.27}$$

$$
\begin{aligned}
&\left(\frac{\pi_{wR,t}}{\pi}-1\right)\frac{\pi_{wR,t}}{\pi} \\
&\quad = E_t\left[\beta_R\frac{\lambda_{R,t+1}}{\lambda_{R,t}}\left(\frac{\pi_{wR,t+1}}{\pi}-1\right)\frac{\pi_{wR,t+1}}{\pi}\frac{\pi_{wR,t+1}}{\pi_{t+1}}\frac{n_{R,t+1}}{n_{R,t}}\right]-\frac{(1-\tau_{yR})(\eta_w-1)}{\kappa_w}(1-\theta_w\Omega_{nR,t}) \qquad \text{(E.28)} \\
&\quad \text{where } \pi_{wR,t}=\frac{W_{R,t}}{W_{R,t-1}}
\end{aligned}
$$

$$
\frac{\pi_{wR,t}}{\pi_t}=\frac{w_{R,t}}{w_{R,t-1}} \tag{E.29}
$$

E.4 Non-residential, Residential investment, and Rental services Producers

$$
\begin{aligned}
&q_{k,t}-\kappa_{ik}q_{k,t}\left(\frac{i_{k,t}}{i_{k,t-1}}-1\right)\frac{i_{k,t}}{i_{k,t-1}}-q_{k,t}\frac{\kappa_{ik}}{2}\left(\frac{i_{k,t}}{i_{k,t-1}}-1\right)^2 \\
&\quad +E_t\left[\beta_P\frac{\lambda_{P,t+1}}{\lambda_{P,t}}\kappa_{ik}q_{k,t+1}\left(\frac{i_{k,t+1}}{i_{k,t}}-1\right)\left(\frac{i_{k,t+1}}{i_{k,t}}\right)^2\right]=1
\end{aligned} \tag{E.30}
$$

$$
\begin{aligned}
&q_{s,t}-\kappa_{\tilde{c}}q_{s,t}\left(\frac{\tilde{c}_t}{\tilde{c}_{t-1}}-1\right)\frac{\tilde{c}_t}{\tilde{c}_{t-1}}-q_{s,t}\frac{\kappa_{\tilde{c}}}{2}\left(\frac{\tilde{c}_t}{\tilde{c}_{t-1}}-1\right)^2 \\
&\quad +\beta_P E_t\left\{\frac{\lambda_{P,t+1}}{\lambda_{P,t}}\kappa_{\tilde{c}}q_{s,t+1}\left(\frac{\tilde{c}_{t+1}}{\tilde{c}_t}-1\right)\left(\frac{\tilde{c}_{t+1}}{\tilde{c}_t}\right)^2\right\}=1
\end{aligned} \tag{E.31}
$$

$$
\begin{aligned}
&q_{h,t}-\kappa_{ih}q_{h,t}\left(\frac{i_{h,t}}{i_{h,t-1}}-1\right)\frac{i_{h,t}}{i_{h,t-1}}-q_{h,t}\frac{\kappa_{ih}}{2}\left(\frac{i_{h,t}}{i_{h,t-1}}-1\right)^2 \\
&\quad +E_t\left[\beta_P\frac{\lambda_{P,t+1}}{\lambda_{P,t}}\kappa_{ih}q_{h,t+1}\left(\frac{i_{h,t+1}}{i_{h,t}}-1\right)\left(\frac{i_{h,t+1}}{i_{h,t}}\right)^2\right]=1
\end{aligned} \tag{E.32}
$$

$$
\begin{aligned}
&\left(\frac{\pi_{hj,t}}{\pi}-1\right)\frac{\pi_{hj,t}}{\pi} \\
&\quad = E_t\left[\beta_P\frac{\lambda_{P,t+1}}{\lambda_{P,t}}\left(\frac{\pi_{hj,t+1}}{\pi}-1\right)\frac{\pi_{h,t+1}}{\pi}\frac{\pi_{hj,t+1}}{\pi_{t+1}}\frac{h_{Rj,t+1}}{h_{Rj,t}}\right]-\frac{\eta_h-1}{\kappa_{ph}}\left(1-\theta_h\frac{r_{hj,t}}{p_{hj,t}}\right) \qquad \text{(E.33)} \\
&\quad \text{where } \theta_h=\frac{\eta_h}{\eta_h-1} \quad \text{for } j\in\{P,I\}
\end{aligned}
$$

$$
\frac{\pi_{hP,t}}{\pi_t}=\frac{p_{hP,t}}{p_{hP,t-1}} \tag{E.34}
$$

$$
\frac{\pi_{hI,t}}{\pi_t}=\frac{p_{hI,t}}{p_{hI,t-1}} \tag{E.35}
$$

E.5 Non-housing goods producers

$$\Omega_{n,t}\left(1-\alpha\right)\psi_P\left(\frac{y_{n,t}+f_{n,t}}{n_{P,t}}\right)=w_{P,t} \tag{E.36}$$

$$\Omega_{n,t}\left(1-\alpha\right)\psi_I\left(\frac{y_{n,t}+f_{n,t}}{n_{I,t}}\right)=w_{I,t} \tag{E.37}$$

$$\Omega_{n,t}\left(1-\alpha\right)\psi_R\left(\frac{y_{n,t}+f_{n,t}}{n_{R,t}}\right)=w_{R,t} \tag{E.38}$$

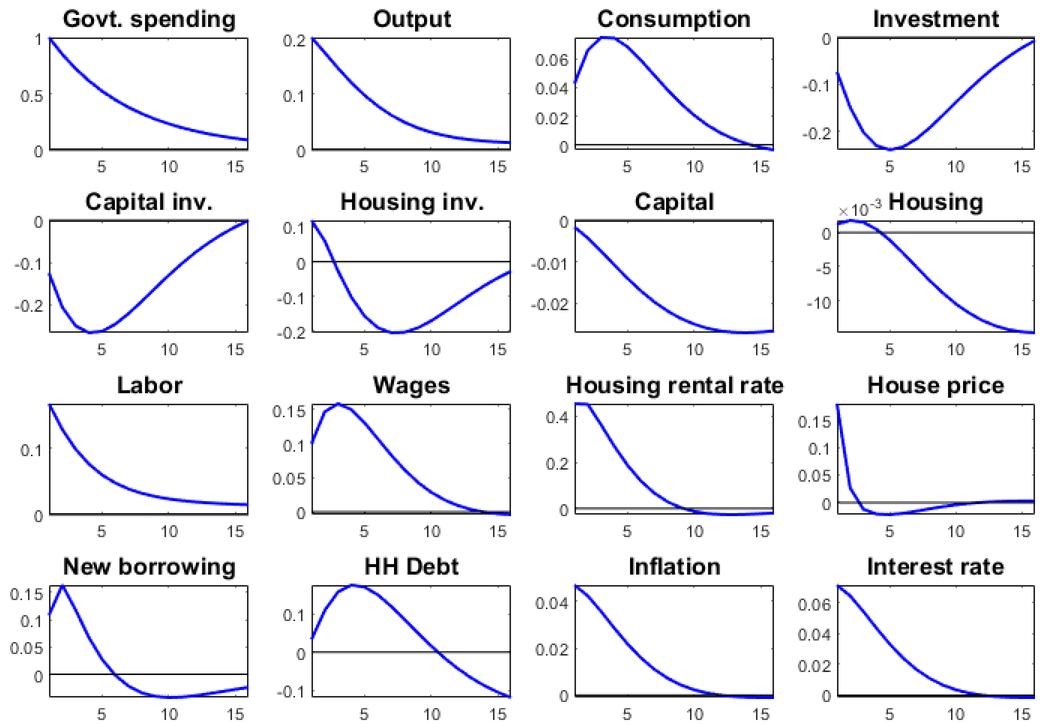
$$\Omega_{n,t}\alpha\frac{y_{n,t}+f_{n,t}}{k_{t-1}}=r_{k,t}+\frac{\kappa_u}{1+\varpi}\left(u_t^{1+\varpi}-1\right) \tag{E.39}$$

$$\begin{aligned}&\Omega_{n,t}\alpha\frac{y_{n,t}+f_{n,t}}{u_t}=\kappa_u u_t^{\varpi}k_{t-1}\\&\text{where } u=1,\ \kappa_u=\frac{\alpha}{k/y_n}\end{aligned} \tag{E.40}$$

$$\begin{aligned}&\left(\frac{\pi_t}{\pi}-1\right)\frac{\pi_t}{\pi}=E_t\left\{\beta_P\frac{\lambda_{P,t+1}}{\lambda_{P,t}}\left(\frac{\pi_{t+1}}{\pi}-1\right)\frac{\pi_{t+1}}{\pi}\frac{y_{n,t+1}}{y_{n,t}}\right\}-\frac{\eta_n-1}{\kappa_{pn}}\left(1-\theta_n\Omega_{n,t}\right)\\&\quad\text{where }\ \theta_n=\frac{\eta_n}{\eta_n-1}\end{aligned} \tag{E.41}$$

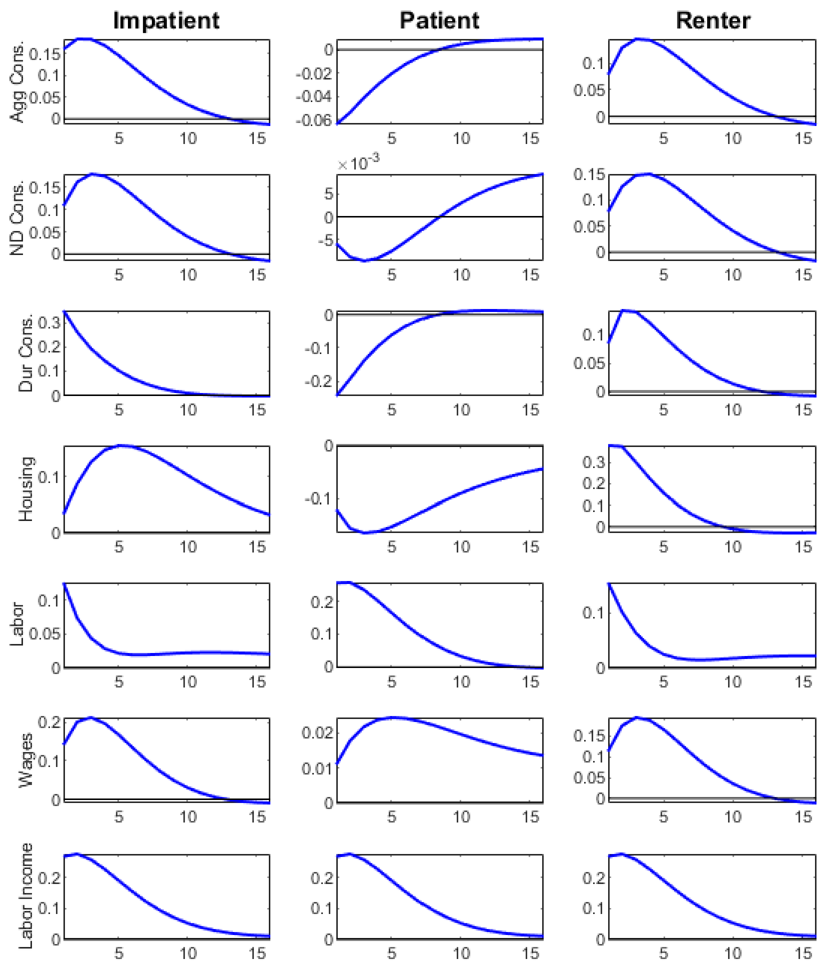
F Model results

Figure F.1: Impulse responses for **aggregate** variables in the model



Notes: Figure F.1 shows the impulse response of aggregate variables in response to a positive government spending shock in the baseline model with durable goods.

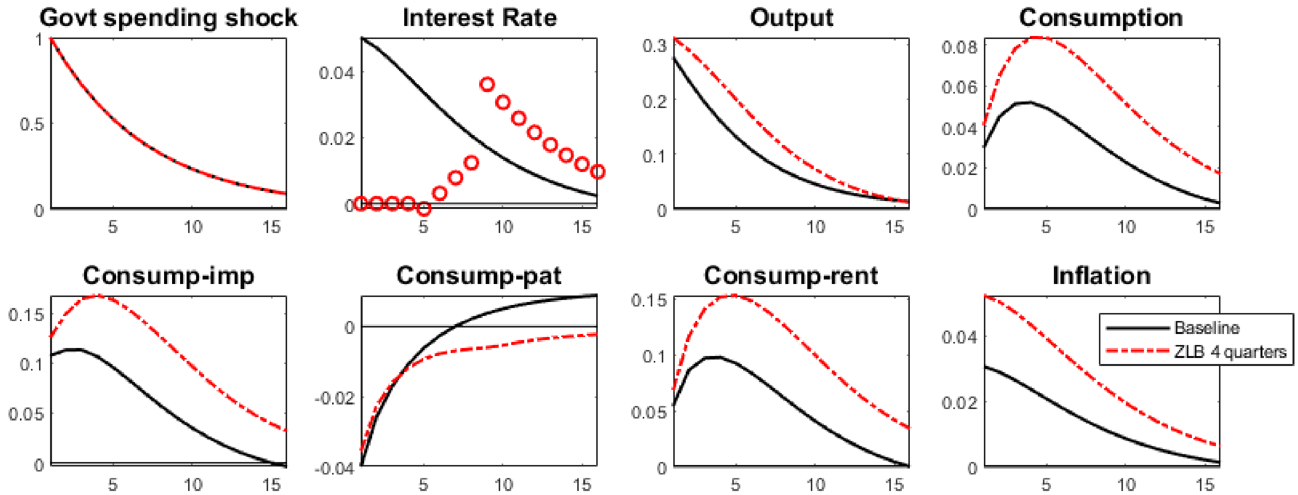
Figure F.2: Impulse responses for **disaggregate** variables in the model



Notes: Figure F.2 shows the impulse responses of disaggregate variables in response to a positive government spending shock in the baseline model with durable goods.

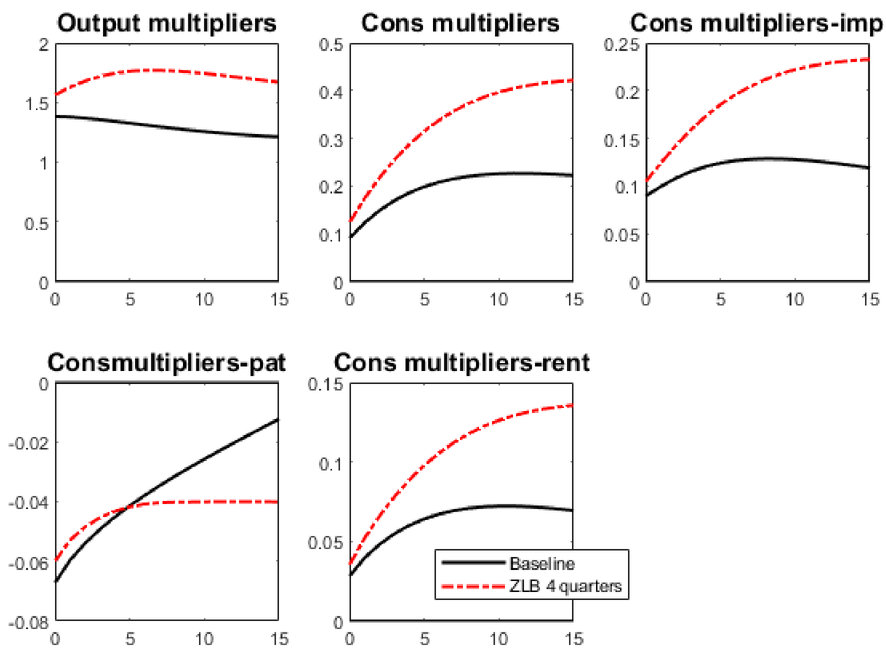
G Multipliers in normal times and during ZLB periods

Figure G.1: Impulse responses with ZLB periods



Notes: Figure G.1 shows the impulse responses of key aggregate variables and consumption across different households (impatient, patient, and renters) for the baseline model and ZLB period (four quarters).

Figure G.2: Cumulative output and consumption multipliers



Notes: Figure G.2 plots the cumulative output and consumption multipliers (both aggregate and disaggregate across different households) in and out of ZLB periods. The black solid line represents multipliers during normal times and the red dash-dotted line indicates multipliers under ZLB for four quarters.