Addressing Household Indebtedness: Monetary, Fiscal or Macroprudential Policy?*

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Abstract

In this paper, we build a DSGE model with housing and household debt, and compare the effectiveness of monetary policy, housing-related fiscal policy, and macroprudential regulations in reducing household indebtedness. The model features long-term fixed-rate borrowing and lending across two types of households, and differentiates between the flow and the stock of household debt. We use Bayesian methods to estimate model parameters related to dynamics, while level parameters are calibrated to match key ratios in the U.S. data. We find that monetary tightening is able to reduce the stock of real mortgage debt in the short-run, but causes a deterioration in the household debt-to-income ratio. We also find that LTV tightening is more effective and less costly in addressing household indebtedness, followed by reducing the tax deductibility of mortgage interest, increasing property taxes, and monetary tightening.

Keywords: Household debt, monetary policy, housing-related fiscal policy, regulatory LTV.

JEL Classification: E52, E62, R38.

1 Introduction

The elevated levels of household debt posed serious financial stability and macroeconomic risks to the U.S. economy in the late 2000s. Since the rise in household debt had been accompanied by a decrease in mortgage underwriting standards and exuberant expectations regarding future house price gains, the U.S. financial system was exposed to a sudden reversal in housing markets. Once the exuberance in the housing market waned, the decline in house prices and the resulting increase in mortgage defaults put the balance sheets of financial institutions in danger, since many were directly or indirectly exposed to housing. The economic fallout resulting from the financial crisis was also more painful and prolonged relative to a standard recession, as households and financial institutions engaged in a long deleveraging process following the crisis.

Preventing household indebtedness from rising to unsustainable levels, or appropriately dealing with high household debt after the situation arises, remain critical issues of discussion among economists. Policymakers already possess a suite of tools with the potential to address concerns related to high levels of household debt.

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First, *macroprudential regulations* can be tightened to ensure a decline in credit; for example, the regulatory loan-to-value (LTV) ratio on new mortgage lending can be reduced. Second, on the fiscal realm, *housing-related tax policies* could be tightened; for example, the statutory or effective tax rates on residential properties may be increased or the tax deductibility of mortgage interest can be curbed. Finally, and arguably as the last line of defense, *monetary policy* can be tightened to induce an increase in mortgage rates and discourage new lending.[1]

For policymakers, it is important to assess the effectiveness of these policies in reducing household debt, and evaluate their side effects on macroeconomic variables such as output and inflation. In this paper, we build a DSGE model with housing and household debt, and consider the effectiveness of the aforementioned policies in reducing household indebtedness. As is well known, macroprudential tools, such as regulatory LTV, are more "targeted" towards the housing sector, and would therefore potentially have a lower adverse impact on the rest of the economy. Housing-related tax policies also have a direct affect only on the housing sector as well, but may be "broader" in terms of their reach. In particular, a reduction in tax deductibility of mortgage interest would (likely) apply to all mortgage borrowers, including those that borrowed in periods prior to the implementation of the new policy. This is in contrast to regulatory LTV, which would only affect new mortgage borrowing with no direct impact on previous borrowers. On the other hand, an increase in property taxes would impact all homeowners, including those that have no outstanding mortgage debt; thus, property taxes are even broader in their scope relative to the mortgage interest deduction rules. Monetary policy is broadest in its scope among the policies discussed here, since it would directly impact the non-housing sectors of the economy and the borrowing taking place for purposes other than housing.

Note that all four policies mentioned above can potentially reduce the level of household debt, but their adverse side-effects on output would differ based on the scope of each policy. In particular, the direct effects of targeted policies are more confined to the housing sector and to borrowers; thus, these policies are able to reduce the quantity of new mortgage lending without leading to large spillovers to demand from other sectors and from non-borrower households. In fact, in certain instances, the adverse effects to output from the decline in borrowers' demand can be partially offset by the increase in demand coming from saver households and the non-housing sector. For monetary policy, the direct effects generated from a tightening are more evenly spread between the housing and non-housing sectors and between borrower and saver households; therefore, reducing household indebtedness by the same amount would potentially lead to a larger adverse effect on output. In Table 1, we summarize the scope of the four policies we consider in this paper.

A related issue is the effect of these four policies on inflation. This has a key influence on household debt dynamics because mortgage loans are extended in nominal terms, and are therefore subject to debt-deflation type of effects in real terms. In particular, consider the following law of motion of household debt (also featured in our model in section 2):

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

where κ is the amortization rate for existing debt, and D_t and L_t are the stock and flow of nominal household debt, respectively. Dividing through by the price level, P_t, the above law of motion can be written as

$$d_t = (1-\kappa) \frac{d_{t-1}}{\pi_t} + l_t, \tag{2}$$

where π_t is the inflation rate, and $d_t = D_t/P_t$ and $l_t = L_t/P_t$ denote the stock and flow of *real* household

[1] See the IMF working paper by Crowe et al. (2011) for a detailed list of policy tools that are used by different countries in dealing with real estate booms.

debt, respectively. Thus, for a policy to be successful in reducing the stock of real household debt, it should be able to substantially reduce new household loans, l_t, while not leading to a large decline in the inflation rate, π_t. This is especially true for mortgage loans, for which the amortization rate is very low, and thus, the share of new loans in the stock of mortgage debt is small. If a policy is too "blunt" and has large adverse spillovers to other sectors of the economy, it could cause a significant decline in the inflation rate relative to the decline in new loans, thereby leading to an *increase*, rather than a decrease, in the stock of real mortgage debt (and the debt-to–income ratio). Svensson (2013) has recently argued that monetary "leaning against the wind" in Sweden would have this perverse impact in the short run since the price level and output would decline faster than the stock of nominal mortgage debt stock, all specified relative to a baseline.

In this paper, we build a DSGE model with housing and household debt, and consider the effectiveness of the four policies listed in Table 1 in reducing household indebtedness, paying special attention to the effects of monetary policy in light of Svensson's criticism. Our model features borrowing and lending across two types of households as in Iacoviello (2005), but mortgage loans are amortized over the long-term similar to Kydland et al. (2012) and Garriga et al. (2013), thus allowing us to differentiate between the flow and the stock of household debt. This is key for differentiating the effects of policies that apply only to new lending (e.g. regulatory LTV) as opposed to all existing mortgage debt (e.g. mortgage interest deduction). The constraint on borrower households is imposed on the flow rather than the stock of household debt, and new mortgage loans are modeled as fixed-rate. Nevertheless, we allow the average duration of the fixed interest rate to be shorter than the full amortization duration of the loan. This feature captures the notion that a significant share of new mortgage loans in the real world are adjustable-rate, and some fixed-rate mortgages are refinanced before the end of their amortization period.[2] We endogenize the supply of housing by considering residential investment producers who face investment adjustment costs as in Justiniano et al. (2013). Following Christiano et al. (2005) and Smets and Wouters (2007), the model also features nominal frictions in the form of price and wage stickiness and indexation, as well as real frictions such as habit formation and capital utilization costs. We estimate parameters determining model dynamics using Bayesian likelihood methods and U.S. data, while matching the steady-state relationships in the model to their counterparts in the data through calibration of level parameters.

Using the model, we first analyze the effects of monetary policy on household debt. Given our benchmark parameters, we do not find evidence that monetary policy has perverse effects on the stock of household debt; in particular a 100 bp tightening in the policy rate results in a peak decline of about 0.25 percent in the real stock of debt within a year. Given that the response of output to monetary policy is stronger however, our model implies a deterioration in the household debt-to-income ratio with monetary tightening. Thus, our baseline results suggest that while monetary policy may be a good "last line of defense" against the build-up of certain financial imbalances, it is not that effective (or even perverse) when it comes to households' mortgage debt, which remains an area of major concern in many economies.

We conduct several sensitivity analyses on key parameters to investigate the importance of model features in generating our baseline results on monetary policy. In particular, reducing the adjustability of the mortgage interest rate (equivalent to increasing the share of fixed-rate mortgages from 80 percent in the baseline case) limits the ability of monetary policy to reduce the level of real mortgage debt. Conversely, the effects of monetary policy on real household debt strengthens when the mortgage rate adjusts faster, since the pass-

[2] According to the 2011 American Housing Survey of the Census Bureau, about 80 percent of all new mortgage loans are fixed-rate, and the rest are mostly standard adjustable-rate. Also, nearly a third of all outstanding mortgages are refinancing of a previous mortgage loan, where most of these refinancings were undertaken to reduce interest payments without altering the amortization of the loan.

through from the policy rate to the mortgage rate faced by borrowers is larger. Other key factors determining the response of household debt to monetary policy are the slope of the New Keynesian Philips curve and adjustment costs in housing. A steeper New Keynesian Phillips curve results in a larger decline in inflation, π_t, and hence, to a smaller decline (or even an increase) in real household debt, d_t, with monetary policy tightening (see equation 2). Similarly, larger adjustment costs in the housing stock results in smaller declines in new mortgage lending, l_t, reducing the impact of monetary tightening on household debt.

In order to shed further light on this issue, we also run vector autoregressions (VAR) on standard macroeconomic variables and mortgage debt, identifying shocks through recursive short-term restrictions. Our VAR analysis suggests that innovations in the monetary policy shock leads to a small decline, not to an increase, in the stock of real mortgage debt, consistent with our DSGE model. Note however that the VARs also imply that the output effects of monetary policy are more muted than is implied by the DSGE model; hence, household debt-to-income ratio also goes down in the VARs, in contrast to the DSGE model.

In the second portion of the results section, we compare the effectiveness of fiscal and macroprudential tools in reducing household debt along with monetary policy. Among the four policies we consider, we find that LTV tightening is the most effective and least costly in reducing household debt, followed by reducing tax deductibility of mortgage interest, increasing property taxes, and finally, monetary policy. This ranking is consistent with the scope of each policy in targeting new household loans versus other aspects of the economy, as explained in the previous paragraphs.

1.1 Related literature

Our work is related to a few different strands of the literature. First, there are several papers that consider the effects of monetary policy and changes in regulatory LTV in a DSGE setting similar to Iacoviello (2005). A non-exhaustive list includes Boivin et al. (2010), Christensen and Meh (2011), Crowe et al. (2011), Kannan et al. (2012), Justiniano et al. (2013), Gelain et al. (2013), Rubio and Carrasco-Gallego (2013), and Iacoviello (forthcoming). Our paper differs from the above in analyzing the effects of monetary and macroprudential policy in a setting with long-term debt where the effects of LTV apply only to new loans and not to the whole stock of mortgage debt. The effects of regulatory LTV may potentially be exaggerated, especially in the short-run, when regulatory changes apply to all outstanding stock of debt.

Second, there are several empirical papers that consider the effects of monetary policy on household credit and the appropriateness of "monetary leaning" against financial imbalances. More recent work include Laseen and Strid (2013), who conduct VAR analysis using Swedish data. Similar to our VAR finding using U.S. data, they find that monetary policy shocks are able to reduce real household debt and the debt-to-income ratio. Robstad (2014) uses Bayesian VARs with Norwegian data, and find that monetary policy tightening have a small negative effect on household credit, but leads to an increase in the household debt-to-income ratio, in line with our findings using the DSGE model.

Third, Kydland et al. (2012) and Garriga et al. (2013) analyze the effects of fixed-rate mortgages for business cycles and the transmission of monetary policy in a general equilibrium setting. Our set-up is most similar to these papers, although there are several important differences. In our paper, we also allow savers to accumulate housing similar to Iacoviello; which is more consistent with the data since a substantial proportion of homeowners have full equity in their houses. We also differentiate between the amortization rate of the loan and the duration of its interest rate to capture the effects of adjustable-rate mortgages and refinancing of existing loans. Our focus is also different in this paper than theirs; in particular, our focus is on the impact on household debt while their focus is on business cycle dynamics. In addition, we consider the effects of alternative policy tools such as fiscal and macroprudential policies in our paper, and estimate model parameters related to dynamics rather than calibrate them.[3] Gelain et al. (2014) also use the long-term debt structure introduced in Kydland et al. (2012) to analyze the effects of monetary policy on household debt.[4] Our paper differs from theirs in several respects as well. They use a borrowing constraint that is responsive to housing equity, more similar to the original Iacoviello (2005) set-up, whereas we impose the borrowing constraint on the flow, not the stock, of household debt. The role of home equity loans seems to be more limited in the U.S. than is implied by the standard set-up as these loans only constitute about 8 percent of the total stock of mortgages according to Flow-of-Funds data. Gelain et al. (2014) focus on Norway and their model features only adjustable-rate mortgages with a long amortization period, while we concentrate on the U.S. economy and take into account the effects of fixed-rate mortgages. Furthermore, we estimate our model parameters related to dynamics instead of calibrate them, as well as consider the effects of alternative policies to monetary policy, while their focus is on the role of irrational expectations in driving house price booms and household debt.

Finally, our paper is related to the empirical literature analyzing the effects of housing-related fiscal policy. Poterba and Sinai (2008) use household-level data from the Survey of Consumer Finances to analyze how reforms to the tax treatment of mortgage interest deduction would influence the effective cost of housing services as well as the distribution of tax burdens. Kuttner and Shim (2013) uses panel data from 57 countries to evaluate the effectiveness of non-interest rate policy tools (including housing-related taxes and regulatory LTV) in stabilizing household credit. They find that housing-related taxes have a discernible impact on house price appreciation, but not as much on household credit growth rates.

The next section introduces the model. Sections 3 discusses the parameterization of the model, section 4 present the results, and section 5 concludes.

2 Model

The model is a closed-economy DSGE model with housing and household debt. There are two types of households in the economy: patient households (savers), and impatient households (borrowers) similar to Iacoviello (2005). Unlike Iacoviello (2005), we consider long-term mortgages, differentiate between the flow and the stock of household debt, and impose the borrowing constraint on the flow of household debt instead of on the stock following Kydland et al. (2012) and Garriga et al. (2013). In particular, we extend their set-up by allowing borrowing in fixed-rate and adjustable-rate mortgages simultaneously, while retaining the same long duration for their amortization rate. Our model also features housing-related taxation (i.e. mortgage interest deduction and property taxation) as in Alpanda and Zubairy (2013), as well as monetary policy and LTV regulation.

On the production side, goods producers rent capital and labor services to produce an output good that can be used for consumption, non-residential and residential investment and government purchases. There is wage-stickiness in the labor market, and price-stickiness in the goods market. The model also features investment goods producers to generate fluctuations in the relative price of assets, as well as monetary, fiscal

[3] Also see Forlati and Lambertini (2012, 2014) who analyze the effects of long-term household debt with default in a setting similar to Bernanke et al. (1999).

[4] We became aware of this paper during a conference where we also presented preliminary results from our paper. The two papers were developed independently, feature key differences in terms of their modeling, and have different focus.

and macroprudential policies in the form of rules. In what follows, we analyze the agents in the model in blocks.

2.1 Households

2.1.1 Patient households (savers)

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

$$E_t \sum_{\tau=t}^{\infty} \beta_P^{\tau-t} \upsilon_\tau \left[\log \left[c_{P,\tau}(i) - \zeta c_{P,\tau-1} \right] + \xi_{h,\tau} \log h_{P,\tau}(i) - \xi_n \frac{n_{P,\tau}(i)^{1+\vartheta}}{1+\vartheta} \right], \tag{3}$$

where t indexes time, $\beta_P < 1$ is the time-discount parameter, ζ is the external habit parameter for consumption, and ϑ is the inverse of the Frisch-elasticity of labor supply. $\xi_{h,t}$ and ξ_n determine the relative importance of housing and labor in the utility function, and the former is specified as exogenous AR(1) process:

$$\log \xi_{h,t} = (1-\rho_h) \log \xi_h + \rho_h \log \xi_{h,t-1} + \varepsilon_{h,t}. \tag{4}$$

The preference shock, υ_t, also follows an AR(1) process as:

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

Labor services are heterogeneous across the patient households, and are aggregated into a homogenous labor service by perfectly-competitive labor intermediaries, who in turn rent these labor services to goods producers. The labor intermediaries use a standard Dixit-Stiglitz aggregator; therefore, the labor demand curve facing each patient household is given by

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

where $W_{P,t}$ and $n_{P,t}$ are the aggregate nominal wage rate and labor services for patient households, respectively, and $\eta_{n,t}$ is a time-varying elasticity of substitution between the differentiated labor services. To capture cost-push shocks on wages, we specify an exogenous AR(1) process on $\theta_{w,t} = \eta_{n,t}/(\eta_{n,t}-1)$ as:

$$\log \theta_{w,t} = (1-\rho_w) \log \theta_w + \rho_w \log \theta_{w,t-1} + \varepsilon_{w,t}, \tag{7}$$

where θ_w is the mark-up of real wage over the marginal rate of substitution at the steady-state.

The patient households' period budget constraint is given by

$$\begin{aligned} & c_{P,t}(i) + q_{h,t} \widetilde{i}_{hP,t}(i) + q_{k,t} \widetilde{i}_{k,t}(i) + \frac{B_t(i)}{P_t} + \frac{L_t(i)}{P_t} \\ & \quad \leq (1-\tau_n) \frac{W_{P,t}(i)}{P_t} n_{P,t}(i) + (1-\tau_k) r_{k,t} k_{t-1}(i) + \tau_k \delta_k k_{t-1}(i) + (1+R_{t-1}) \frac{B_{t-1}(i)}{P_t} + \frac{M_t(i)}{P_t} \\ & \qquad + tr_{P,t} + \frac{\Pi_t}{P_t} - \tau_{p,t} (1-\tau_n) q_{h,t} h_{P,t-1}(i) - \text{adj. costs}, \end{aligned} \tag{8}$$

where $q_{h,t}$ and $q_{k,t}$ are the relative prices of housing and capital, respectively, and $\widetilde{i}_{hP,t}$ and $\widetilde{i}_{k,t}$ denote the patient households' new investment in these real assets. The laws of motion for patient households' housing and capital stocks, $h_{P,t}$ and k_t, are given by

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

$$k_t(i) = (1-\delta_k) k_{t-1}(i) + \widetilde{i}_{k,t}(i), \tag{10}$$

where δ_h and δ_k are the corresponding depreciation rates.

B_t denotes the amount of 1-period nominal government bonds purchased by patient households, while L_t is the amount of new lending to impatient households to finance the latter's housing purchases. $r_{k,t}$ denotes the rental income patient households receive from their holdings of capital. Households are taxed at proportional rates of τ_n and τ_k, on their labor and capital incomes, respectively. $\tau_{p,t}$ is the (time-varying) property tax rate on housing. Note that property taxes and capital depreciation are deductible when paying income taxes.

Patient households receive transfers from the government, $tr_{P,t}$, and the profits of the goods producers, Π_t, in lump-sum fashion. They also earn a pre-determined nominal interest rate of R_t on their government bond holdings, and receive mortgage payments from impatient households in the amount of M_t. These mortgage payments are the sum of interest and principal payments as

$$\frac{M_t(i)}{P_t} = \left[R^M_{t-1}(i) + \kappa\right] \frac{D_{t-1}(i)}{P_t}, \tag{11}$$

where D_{t-1} denotes the stock of mortgage debt carried from the previous period, and R^M_{t-1} is the effective interest on all mortgages outstanding. κ denotes the amortization rate for determining the principal payments out of the stock of mortgage debt, hence, the law of motion for the stock of debt is given by:

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

New mortgage loans, L_t, carry a fixed mortgage interest rate, R^F_t, and a fraction Φ of existing loans are refinanced each period at this rate as well. Thus, the effective interest rate on the stock of mortgages, R^M_t, evolves according to

$$R^M_t(i) = (1-\Phi)\left(1 - \frac{L_t(i)}{D_t(i)}\right) R^M_{t-1}(i) + \left[\frac{L_t(i)}{D_t(i)} + \Phi\left(1 - \frac{L_t(i)}{D_t(i)}\right)\right] R^F_t. \tag{13}$$

Note that when $\Phi = 1$, all mortgages are refinanced every period, and the above expression, coupled with the law of motion of debt in (12), implies that the effective mortgage rate is identical to the current mortgage rate at all times (i.e. $R^M_t = R^F_t$). As we show later, $\Phi = 1$ also implies (using the Euler condition for short-term government debt) that the current mortgage rate, R^F_t, is equal to the policy rate, R_t, for all t as well. Thus, as Φ approaches 1, the model gets closer to an economy with only adjustable-rate mortgages, while when Φ is 0, the model features only fixed-rate mortgages whose rates are fixed for the whole amortization duration of the loan. Note also that if we have single period debt (i.e. $\kappa = 1$), equation (12) implies that the stock and the flow of mortgage debt would be equal to each other (i.e. $D_t = L_t$), and the effective interest rate on mortgages would again be equal to the interest on government bonds, R_t. Note however that this does not render our model equivalent to the standard Iacoviello (2005) set-up, as new borrowing in our set-up is constrained by borrowers' *investment* in housing, not their total holdings (see the next subsection on impatient households).

Wage-stickiness is introduced via a quadratic cost of wage adjustment similar to Rotemberg (1982),

$$\frac{\kappa_w}{2}\left(\frac{W_{P,t}(i)/W_{P,t-1}(i)}{\pi_{t-1}^{\varsigma_w}\pi^{1-\varsigma_w}}-1\right)^2\frac{W_{P,t}}{P_t}n_{P,t}, \tag{14}$$

where κ_w is a scale parameter, $\pi_t = P_t/P_{t-1}$ is the aggregate inflation factor, and ς_w determines indexation of wage adjustments to past inflation. There are also quadratic adjustment costs in the stocks of housing and capital, with level parameters κ_h and κ_k, respectively.[5] These adjustment cost ensure that housing cannot be sold quickly across the two types of agents, and limit the amount of substitution between the housing and non-housing sectors.

The patient households' objective is to maximize utility subject to their budget constraint and the appropriate No-Ponzi conditions. The first-order-condition with respect to consumption equates the marginal utility gain from consumption to the marginal cost of spending a dollar out of the budget, i.e. the Lagrange multiplier $\lambda_{P,t}$. Similarly, the optimality condition for labor equates the marginal rate of substitution between labor and consumption to the after-tax wage rate.

The optimality condition for housing equates the marginal cost of acquiring a unit of housing to the marginal utility gain from housing services and the discounted value of expected capital gains net of taxes, which can be written as (ignoring adjustment costs in the stock of housing):

$$q_{h,t}=\xi_{h,t}\frac{c_{P,t}-\zeta c_{P,t-1}}{h_{P,t}}+E_t\left[\left(\beta_P\frac{\lambda_{P,t+1}}{\lambda_{P,t}}\right)\left[1-\delta_h-\tau_{p,t+1}\left(1-\tau_n\right)\right]q_{h,t+1}\right]. \tag{15}$$

Similar to housing, the optimality condition for capital equates the marginal cost of purchasing a unit of capital to the expected marginal gain in rental income and capital gains net of taxes, which can be written as (ignoring adjustment costs in the stock of capital):

$$q_{k,t}=E_t\left[\left(\beta_P\frac{\lambda_{P,t+1}}{\lambda_{P,t}}\right)\left[\left(1-\delta_k\right)q_{k,t+1}+\left(1-\tau_k\right)r_{k,t+1}+\tau_k\delta_k\right]\right]. \tag{16}$$

The optimality conditions with respect to labor and wages can be combined to derive a New-Keynesian wage Phillips curve (after log-linearization):

$$\widehat{\pi}_{wP,t}-\varsigma_w\widehat{\pi}_{t-1}=\beta_P E_t\left[\widehat{\pi}_{wP,t+1}-\varsigma_w\widehat{\pi}_t\right]-\frac{\left(\eta_n-1\right)\left(1-\tau_n\right)}{\kappa_w}\left(\widehat{w}_{P,t}-\widehat{MRS}_{P,t}-\widehat{\theta}_{w,t}\right), \tag{17}$$

where the nominal wage inflation, $\widehat{\pi}_{wP,t}$, and the real wage rate, $\widehat{w}_{P,t}$, for patient households are related as

$$\widehat{\pi}_{wP,t}-\widehat{\pi}_t=\widehat{w}_{P,t}-\widehat{w}_{P,t-1}. \tag{18}$$

Since households are wage-setters in the labor market, wages are marked-up relative to the marginal rate of substitution between leisure and consumption, where $MRS_{P,t} = -U_{n,t}/U_{c,t}$. Wage stickiness, along with exogenous mark-up shocks, provide variation in the wedge between wages and MRS with a long-run correction to the steady-state mark-up.

The first-order-condition condition for government bonds equates the marginal utility cost of foregone consumption from saving to the expected discounted utility gain from the resulting interest income net of

[5] These costs are specified as $(\kappa_h/2)\left[h_{P,t}(i)/h_{P,t-1}(i)-1\right]^2 q_{h,t}h_{P,t}$ and $(\kappa_k/2)\left[k_t(i)/k_{t-1}(i)-1\right]^2 q_{k,t}k_t$, respectively.

taxes:

$$1 = E_t \left[\left(\beta_P \frac{\lambda_{P,t+1}}{\lambda_{P,t}} \right) \frac{1 + R_t}{\pi_{t+1}} \right]. \tag{19}$$

The first-order-conditions for new mortgage lending is given by

$$1 = \Omega_{dP,t} + \Omega_{rP,t} R_t^F, \tag{20}$$

where $\Omega_{dP,t}$ denotes the Lagrange multiplier with respect to the law of motion of mortgage debt, and $\Omega_{rP,t}$ denotes the Lagrange multiplier on the law of motion of effective mortgage interest rate. Both these Lagrange multipliers are specified as relative to the Lagrange multiplier on the budget constraint. The above condition equates the marginal loss from a unit of foregone consumption to the benefits of adding to the stock of mortgage debt at a fixed interest rate of R_t^F. In turn, the Euler conditions for the stock of mortgage debt and the effective mortgage interest rate are given by

$$\Omega_{dP,t} + \Omega_{rP,t} R_t^M = E_t \left[\left(\beta_P \frac{\lambda_{P,t+1}}{\lambda_{P,t}} \right) \frac{R_t^M + \kappa + (1-\kappa) \left\{ \Omega_{dP,t+1} + \Omega_{rP,t+1} \left[(1-\Phi) R_t^M + \Phi R_{t+1}^F \right] \right\}}{\pi_{t+1}} \right], \tag{21}$$

and

$$\Omega_{rP,t} = E_t \left[\left(\beta_P \frac{\lambda_{P,t+1}}{\lambda_{P,t}} \right) \frac{1 + (1-\Phi)(1-\kappa) \Omega_{rP,t+1}}{\pi_{t+1}} \right], \tag{22}$$

respectively.

Note that when $\Phi = 1$, the Euler condition for the stock of debt in (21) reduces to

$$1 = E_t \left[\left(\beta_P \frac{\lambda_{P,t+1}}{\lambda_{P,t}} \right) \frac{1 + R_t^M}{\pi_{t+1}} \right], \tag{23}$$

where we have used the first-order condition with respect to new loans given in equation (20), and the fact that $R_t^M = R_t^F$ when $\Phi = 1$. Thus, coupled with the Euler condition for government debt given in equation (19), we have $R_t^M = R_t^F = R_t$ for all t when $\Phi = 1$.[6] Thus, in this set-up, adjustable-rate long-term loans are equivalent to 1-period loans, and the amortization rate of loans is of consequence only due to the fixity of the interest rate on these loans.

2.1.2 Impatient households (borrowers)

The economy is also populated by a unit measure of infinitely-lived impatient households. Their utility function is identical to that of patient households, except that their time-discount factor is assumed to be less than patient households as in Iacoviello (2005); hence, $\beta_I < \beta_P$. Labor services of impatient households are also heterogeneous, and are aggregated into a homogenous labor service by perfectly-competitive labor intermediaries using a Dixit-Stiglitz aggregator. The labor demand curve facing each impatient household is thus given by

$$n_{I,t}(i) = \left(\frac{W_{I,t}(i)}{W_{I,t}} \right)^{-\eta_{n,t}} n_{I,t}, \tag{24}$$

where $W_{I,t}$ and $n_{I,t}$ are the aggregate nominal wage rate and labor services for impatient households, respectively.

[6] The same result can be obtained when mortgage debt is fully amortized each period (i.e. 1-period debt with $\kappa = 1$).

The impatient households' period budget constraint is given by

$$c_{I,t}(i) + q_{h,t}\widetilde{i}_{hI,t}(i) + \frac{M_t(i)}{P_t} \leq (1-\tau_n)\frac{W_{I,t}(i)}{P_t}n_{I,t}(i)$$
$$+\frac{L_t(i)}{P_t} + tr_{I,t} - \tau_{p,t}(1-\tau_n)q_{h,t}h_{I,t-1}(i) + I_{m,t}\tau_n R^M_{t-1}(i)\frac{D_{t-1}(i)}{P_t} - \text{adj. costs}, \quad (25)$$

where $c_{I,t}$, $\widetilde{i}_{hI,t}$, and $tr_{I,t}$ denote consumption, investment in housing and lump-sum transfers received from the government, respectively. $I_{m,t}$ is a time-varying indicator function that determines to what extent interest payments on borrowing is deductible when paying income taxes. Impatient households also face quadratic adjustment costs on their wages and housing stock similar to patient households.

The definition of mortgage payments and the laws of motion for the stock of debt and the effective interest on mortgage loans is the same as in patient households. The law of motion for impatient households' housing stock, $h_{I,t}$, is given by

$$h_{I,t}(i) = (1-\delta_h)h_{I,t-1}(i) + \widetilde{i}_{hI,t}(i). \quad (26)$$

Impatient households also face a constraint on their new borrowing in the form of

$$\frac{L_t(i)}{P_t} \leq \phi_t q_{h,t}\widetilde{i}_{hI,t}(i), \quad (27)$$

where ϕ_t is the LTV ratio on mortgage lending. Note that this borrowing constraint is materially different than the less realistic, but more commonly used in the literature, borrowing constraint in the stock of housing given by

$$\frac{D_t(i)}{P_t} \leq \phi_t q_{h,t}h_{I,t}(i). \quad (28)$$

Given the laws of motion for the stock of debt (12) and the stock of housing of impatient households (26), the two types of borrowing constraints would be equivalent only if $\kappa = \delta_h$, and house prices do not move over time, i.e. $q_{h,t} = q_{h,t-1}$. The former condition can be approximately true with long mortgage amortization rates (hence a small κ), while the latter condition would require a relatively elastic housing supply. Since housing supply is relatively inelastic, changes in house prices are frequent and significant. When the borrowing constraint is on the stock of debt, the effects of house prices on the stock of debt is exaggerated as households rush to take out new loans based on the increase in the equity value of their existing homes. In reality, home equity loans constitute a very small percentage (in the order of about 8 percent) of the stock of mortgage loans held by households, and do not move over time as quickly as would be implied by the model with borrowing constraint in the stock of debt. On the other hand, our specification omits this channel altogether, and therefore could be slightly underestimating the impact of policies on household debt through their effects on home equity loans.

The first-order conditions of impatient households with respect to their consumption and labor are similar to those of patient households. For housing, the optimality condition equates the marginal cost of acquiring a unit of housing with the marginal utility and expected net-of-tax capital gains (ignoring adjustment costs in stock of housing):

$$(1-\mu_t\phi_t)q_{h,t} = \xi_{h,t}\frac{c_{I,t}-\zeta c_{I,t-1}}{h_{I,t}} + E_t\left[\left(\beta_I\frac{\lambda_{I,t+1}}{\lambda_{I,t}}\right)\left[(1-\delta_h)(1-\mu_{t+1}\phi_{t+1}) - \tau_{p,t+1}(1-\tau_n)\right]q_{h,t+1}\right], \quad (29)$$

where μ_t is the Lagrange multiplier on the borrowing constraint. Note that the marginal cost of purchasing a unit of housing today is dampened by the shadow gain from the relaxation of the borrowing constraint with the increase in the level of housing. However, since the borrowing constraint is on the flow, and not on the stock, of housing, the marginal gain next period is also dampened by the borrowing constraint tomorrow because today's housing purchase increases the housing level tomorrow, thereby reducing the need to invest in housing further next period.

The optimality condition for new borrowing is given by

$$1-\mu_t=\Omega_{dI,t}+\Omega_{rI,t}R_t^F, \tag{30}$$

where $\Omega_{dI,t}$ denotes the Lagrange multiplier with respect to the law of motion of mortgage debt, and $\Omega_{rI,t}$ denotes the Lagrange multiplier on the law of motion of effective mortgage interest rate. The above condition equates the marginal gain from borrowing (excluding the shadow cost of tightening the borrowing constraint) to the marginal cost of adding to the stock of mortgage debt at a fixed interest rate of R_t^F. In turn, the Euler conditions for the stock of mortgage debt and the effective mortgage interest rate are given by

$$\Omega_{dI,t}+\Omega_{rI,t}R_t^M=E_t\left[\left(\beta_I\frac{\lambda_{I,t+1}}{\lambda_{I,t}}\right)\frac{\left(1-I_{m,t+1}\tau_n\right)R_t^M+\kappa+(1-\kappa)\left\{\Omega_{dI,t+1}+\Omega_{rI,t+1}\left[\left(1-\Phi\right)R_t^M+\Phi R_{t+1}^F\right]\right\}}{\pi_{t+1}}\right], \tag{31}$$

and

$$\Omega_{rI,t}=E_t\left[\left(\beta_I\frac{\lambda_{I,t+1}}{\lambda_{I,t}}\right)\frac{1-I_{m,t+1}\tau_n+\left(1-\Phi\right)\left(1-\kappa\right)\Omega_{rI,t+1}}{\pi_{t+1}}\right], \tag{32}$$

respectively.

Note that when $\Phi=1$ or $\kappa=1$, the Euler condition for the stock of debt reduces to

$$1-\mu_t=E_t\left[\left(\beta_I\frac{\lambda_{I,t+1}}{\lambda_{I,t}}\right)\frac{1+\left(1-I_{m,t+1}\tau_n\right)R_t}{\pi_{t+1}}\right], \tag{33}$$

similar to the standard model with 1-period debt.

2.2 Production

2.2.1 Goods production

There is a unit measure of monopolistically competitive goods producers indexed by j. Their technology is described by the following production function:

$$y_t\left(j\right)=z_t\left[u_t\left(j\right)k_{t-1}\left(j\right)\right]^{\alpha}\left[n_{P,t}\left(j\right)^{\psi}n_{I,t}\left(j\right)^{1-\psi}\right]^{1-\alpha}-f, \tag{34}$$

where α is the share of capital in overall production, and ψ denotes the share of patient households in the labor input. u_t denotes the utilization rate of capital, and f is a fixed cost of production. The aggregate productivity shock, z_t, follows an AR(1) process.

Goods are heterogeneous across firms, and are aggregated into a homogenous good by perfectly-competitive final goods producers using a standard Dixit-Stiglitz aggregator. The demand curve facing each firm is given by

$$y_t\left(j\right)=\left(\frac{P_t\left(j\right)}{P_t}\right)^{-\eta_{y,t}}y_t, \tag{35}$$

where y_t is aggregate output, and $\eta_{y,t}$ is a time-varying elasticity of substitution between the differentiated goods. We specify an exogenous AR(1) process on $\theta_{p,t} = \eta_{y,t}/(\eta_{y,t} - 1)$,

$$\log \theta_{p,t} = (1 - \rho_p) \log \theta_p + \rho_p \log \theta_{p,t-1} + \varepsilon_{p,t}, \tag{36}$$

where θ_p is the mark-up of price over marginal cost at the steady-state.

Firm j's profits at period t is given by

$$\frac{\Pi_t(j)}{P_t} = \frac{P_t(j)}{P_t} y_t(j) - \frac{W_{P,t}}{P_t} n_{P,t}(j) - \frac{W_{I,t}}{P_t} n_{I,t}(j) - r_{k,t} k_{t-1}(j) - \frac{\kappa_u}{1+\varpi} \left[u_t(j)^{1+\varpi} - 1 \right] k_{t-1}(j) - \text{adj. costs}, \tag{37}$$

where κ_u and ϖ are the level and elasticity parameters in the utilization cost specification. Similar to wage-stickiness, price-stickiness is introduced through quadratic adjustment costs, where κ_p is the level parameter, and ς_p captures the extent to which price adjustments are indexed to past inflation.

A firm's objective is to choose the quantity of inputs, output, and its own output price each period to maximize the present value of profits (using the patient households' stochastic discount factor) subject to the demand function they are facing with respect to their output from the aggregators. At the optimum, the marginal product of each input is equated to their respective marginal cost. The optimality condition for capital utilization similarly equates the marginal cost of increasing utilization at the margin with the revenue gain that arises from increased production; in log-linear form this condition is given by:

$$\widehat{u}_t = \frac{1}{\varpi} \widehat{r}_{k,t}. \tag{38}$$

The first-order condition for prices yield (after log-linearization) the following New Keynesian Phillips curve for domestic goods inflation:

$$\widehat{\pi}_t = \frac{\beta_P}{1+\beta_P \varsigma_p} E_t \widehat{\pi}_{t+1} + \frac{\varsigma_p}{1+\beta_P \varsigma_p} \widehat{\pi}_{t-1} + \frac{\eta_y - 1}{(1+\beta_P \varsigma_p)\kappa_p} \left(\widehat{w}_{P,t} + \widehat{n}_{P,t} - \frac{1}{\theta_p} \widehat{y}_t + \widehat{\theta}_{p,t} \right), \tag{39}$$

Due to market power, domestic producers set the price of their goods at a mark-up relative to marginal cost. The adjustment costs in price-setting, as well as exogenous mark-up shocks, introduce variation in these mark-ups with a long-run adjustment to the steady-state constant mark-up. The nominal rigidities in price-setting imply that shocks that alter the marginal cost of production feed into domestic goods inflation slowly.

2.2.2 Investment goods producers

There is a unit of perfectly-competitive capital goods producers who purchase $i_{k,t}$ units of the new capital investment goods from final goods firms at a relative price of 1, and turn it into $\widetilde{i}_{k,t}$ effective units of investment goods that can be purchased by end-users at the installed capital price of $q_{k,t}$. This production is akin to investment-specific technological change where $\widetilde{i}_{k,t} = z_{k,t} i_{k,t}$, but investment goods producers are also subject to adjustment costs in the change in investment similar to Christiano et al. (2005) and Smets and Wouters (2007). The investment producers' objective is thus to maximize

$$E_t \sum_{\tau=t}^{\infty} \beta_P^{\tau-t} \frac{\lambda_{P,\tau}}{\lambda_{P,t}} \left[q_{k,\tau} \widetilde{i}_{k,\tau} - i_{k,t} - \frac{\kappa_{ik}}{2} \left(\frac{i_{k,\tau}}{i_{k,\tau-1}} - 1 \right)^2 q_{k,\tau} z_{k,\tau} i_{k,\tau} \right], \tag{40}$$

where κ_{ik} is the investment adjustment cost parameter, and future profits are discounted using the patient households' stochastic discount factor. Note that the investment-specific technological change shock (investment shock for short), $z_{k,t}$, follows an AR(1) process.

The first-order-condition of capital investment producers yields an investment demand equation of non-residential investment demand, which in log-linearized form can be written as:

$$\widehat{i}_{k,t} = \frac{\beta_P}{1+\beta_P} E_t \widehat{i}_{k,t+1} + \frac{1}{1+\beta_P} \widehat{i}_{k,t-1} + \frac{1}{(1+\beta_P)\,\kappa_{ik}} \left(\widehat{q}_{k,t} + \widehat{z}_{k,t}\right). \tag{41}$$

Housing producers are modeled analogous to capital producers. These firms purchase the total housing investment goods, $i_{h,t} = i_{hP,t} + i_{hI,t}$, from final goods firms at a relative price of 1, and turn it into $\widetilde{i}_{h,t}$ effective units of housing investment goods that can be purchased by households at the installed capital price of $q_{h,t}$. The first-order-condition of housing investment producers yields a similar demand equation for residential investment, which in log-linearized form can be written as:

$$\widehat{i}_{h,t} = \frac{\beta_P}{1+\beta_P} E_t \widehat{i}_{h,t+1} + \frac{1}{1+\beta_P} \widehat{i}_{h,t-1} + \frac{1}{(1+\beta_P)\,\kappa_{ih}} \left(\widehat{q}_{h,t} + \widehat{z}_{h,t}\right). \tag{42}$$

where κ_{ih} is the housing investment adjustment cost parameter, and $z_{h,t}$ is a residential investment shock following an AR(1) process. Note that when investment adjustment costs are large, the housing supply becomes relatively more inelastic, and therefore, house prices become more responsive to shocks.

2.3 Monetary, Fiscal and Macroprudential Policy

2.3.1 Monetary policy

The Central Bank targets the nominal interest rate using a Taylor rule

$$\log R_t = \rho \log R_{t-1} + (1-\rho) \left(\log R + a_\pi \log \frac{\pi_t}{\pi} + a_y \log \frac{y_t}{y} \right) + \widetilde{\varepsilon}_{r,t}, \tag{43}$$

where ρ determines the extent of interest rate smoothing, R is the steady-state value of the (gross) nominal policy rate, a_π and a_y, are the long-run response coefficients for inflation and output gap, respectively. $\widetilde{\varepsilon}_{r,t}$ denotes the monetary policy shock, and follows an AR(1) process.

2.3.2 Fiscal policy

The total tax revenue of the government is given by

$$tax_t = \tau_n \left(\frac{W_{P,t}}{P_t} n_{P,t} + \frac{W_{I,t}}{P_t} n_{I,t} - I_{m,t} \frac{R^M_{t-1}}{\pi_t} d_{t-1} \right) + \tau_k \left(r_{k,t} - \delta_k\right) k_{t-1} + \tau_{p,t} \left(1-\tau_n\right) q_{h,t} h_{t-1}. \tag{44}$$

Aggregate transfer payments to households are determined by:

$$tr_t = \Xi y - \varrho_b \frac{B_{t-1}}{P_{t-1}}, \tag{45}$$

where Ξ is a level parameter, and ϱ_b determines the response of transfers to government debt.[7] Aggregate transfers are distributed to patient and impatient households in proportion to their labor shares. The law of motion for government debt accumulation is given by:

$$\frac{B_t}{P_t} = R_{t-1}\frac{B_{t-1}}{P_t} + g_t + tr_t - tax_t, \tag{46}$$

where government expenditure, g_t, follows an exogenous AR(1) process given by

$$\log g_t = (1-\rho_g)\log g + \rho_g \log g_{t-1} + \varepsilon_{g,t}. \tag{47}$$

For the baseline case used in the estimation, we set the property tax rate to a constant, (i.e. $\tau_{p,t} = \tau_p$), and assume full deductibility of mortgage interest (i.e. $I_{m,t} = 1$).

2.3.3 Macroprudential policy

We assume that the actual LTV on new loans faced by borrowers, ϕ_t, can deviate from regulatory LTV, ϕ_t^{reg}, by an exogenous factor; hence:

$$\phi_t = \phi_t^{reg} + \widetilde{\varepsilon}_\phi, \tag{48}$$

where $\widetilde{\varepsilon}_\phi$ follows an AR(1) process with mean 0. In the baseline case used for the estimation of the model, we set the regulatory LTV to a constant value (i.e. $\phi_t^{reg} = \phi^{reg}$).

2.4 Market clearing conditions

The goods market clearing condition is given by:

$$c_t + i_t + g_t = y_t - \text{adj.costs}, \tag{49}$$

where total consumption is $c_t = c_{P,t} + c_{I,t}$, and total investment is $i_t = i_{k,t} + i_{h,t}$.

The model's equilibrium is defined as prices and allocations such that households maximize discounted present value of utility, and all firms maximize discounted present value of profits subject to their constraints, and all markets clear.

3 Estimation

We estimate the parameters of the model using Bayesian likelihood methods (An and Schorfheide, 2007; Fernández-Villaverde, 2010) and U.S. macroeconomic and financial data. In what follows, we describe the data used and the estimation methodology.

3.1 Data

In our estimation, we use 10 quarterly data series from the U.S. for the period 1984Q1 to 2007Q4. We start our sample from the Great Moderation period to capture the more recent monetary policy stance against inflation, and exclude the post-crisis period where conventional monetary policy was restricted by the zero

[7] Note that either taxes, government expenditure or transfers need to adjust to the level of debt so that the government cannot run a Ponzi scheme. We choose to make the adjustment through transfers based on the results of Leeper et al. (2010).

lower bound. The observable variables are in the estimation are output (y), consumption (c), non-residential investment (i_k), residential investment (i_h), labor (n), real wage (w), GDP-deflator inflation (π), policy rate (R), house price index (q_h), and household debt (d).

All data were obtained from the FRED database of the Federal Reserve Bank of St. Louis, except for the early part of the house price series which is from the Census Bureau. GDP and its expenditure components were deflated using the GDP deflator. For labor hours, we use the index series "Nonfarm Business Sector: Hours of All Persons", and for real wage, we use the index series "Nonfarm Business Sector: Real Compensation per Hour", constructed by the Bureau of Labor Statistics. The policy rate refers to the Federal Funds Rate, and was converted from monthly to quarterly by averaging. For the house price series, we use the "S&P/Case-Shiller National Composite Home Price Index", but extend the early part of the series between 1984Q1-1986Q4 using the "Price Index of New Single-Family Houses Sold Including Lot Value" from the Census Bureau. The nominal house price index was also deflated using the GDP deflator. Household debt data refers to "Home Mortgages" on the liability side of Households and Nonprofit Organizations' balance sheet, which was deflated as well. The inflation and interest rates were demeaned prior to estimation, while the other series were HP-filtered (which was conducted including pre-1984 and post-2007 data to reduce concerns related to endpoints with HP-filtering).

3.2 Bayesian estimation

We estimate only the parameters that have an effect on the dynamics the model, but not on its steady-state, with the exception of the habit parameter, ζ (which affects both dynamics and steady-state in our set-up with heterogeneous households). The rest of the parameters are restricted within the estimation (i.e. recalibrated with each iteration) to ensure that the implied steady-state of the model matches with pre-specified data target ratios from the National Income and Product Accounts (NIPA), Flow of Funds Accounts (FOF), the 2001 Residential Finance Survey (RFS; Census Bureau), and the 2011 American Housing Survey (AHS; Census Bureau). Table 2 lists these calibrated parameter values and Table 3 presents the main ratios at the steady-state of the model versus the data targets. Tables 4 and 5 present the estimated structural and shock parameters, respectively.

3.2.1 Steady-state targets and other restrictions imposed on the estimation

The trend inflation factor, π, is set to 1.005 corresponding to 2% annual inflation. The time-discount factor of patient households, β_P is set to 0.9926 to match an annualized 3% real risk-free interest rate. The time-discount factor of the impatient households, β_I, is set to 0.988, which implies a 200 basis point spread on the risk-free rate if borrowers were allowed to engage in non-mortgage borrowing. The level parameter for housing in the utility function, ξ_h, is calibrated to ensure that housing value of households is around 1.07 times annual GDP consistent with FOF data. The level parameter for labor supply, ξ_n, is calibrated to ensure that labor supply of patient households is equal to 1 at the steady-state without loss of generality.

In the data, residential and non-residential investment are about 5% and 13% of output respectively, while housing-to-GDP and capital-to-GDP ratios are about 1.07 and 1.5 on an annualized basis. Based on these, we calibrate the quarterly depreciation rates for housing and capital stocks, δ_h and δ_k, to 1.2% and 2.2%, respectively. The share of capital in domestic production, α, is calibrated to 0.21 using the capital-output ratio and the model-implied after-tax rental rate of capital. The fixed cost of production, f, is set equal to $\theta_p - 1$ times the steady-state level of output to ensure that pure economic profits are zero at the steady-state, thus, eliminating the incentive for entry and exit in the long-run of the stochastic economy. Similarly, the level parameter for the utilization cost specification, κ_u, is calibrated to ensure that the utilization rate is equal to 1 at the steady-state without loss of generality.

According to AHS, about 80% of all new mortgage loans are fixed-rate; we thus set the share of adjustable-rate mortgages, Φ, to 0.2. The share of standard adjustable-rate mortgages is in fact slightly less than 20 percent in the data due to the presence of other types of mortgages (such as balloon or graduated payment mortgages). 20% share is still a reasonable calibration to use since refinancing activity increases the interest rate adjustability of fixed-rate mortgages. In particular, nearly a third of all outstanding mortgages were extended as a refinancing of a previous mortgage loan, which implies that every year, about a percent of existing stock of debt is refinanced on average.

RFS data implies that the median first mortgage loan as a share of its house purchase price is 91%; we thus set the steady-state LTV ratio on new mortgages, ϕ^{reg}, equal to 0.91. According to the AHS data, the average ratio of outstanding mortgage loan to house value is 0.66. Based on this, we calibrate the amortization rate, κ, to 0.0112, which implies that the value of outstanding debt is 66% of the value of housing owned by borrowers (i.e. average LTV on all outstanding loans is 0.66). This amortization rate also implies that the average duration of mortgage loans is close to 30 years.[8] Based on FOF data averaged over the post-war period, the ratio of mortgage debt owed by households relative to their real estate holdings is around 0.37. Given an LTV ratio of 0.66 for the average borrower, this implies that borrower households own about 56% of the total housing stock. We calibrate the wage share of patient households, ψ, to 0.4, to hit this target.

Steady-state government expenditure is calibrated to ensure that its share in output, g/y, is 20%. The labor income tax rate, τ_n is set to 0.23, and the capital income tax rate, τ_k, is set to 0.41, following Zubairy (2014). The (quarterly) property tax rate, τ_p, is set to 0.0035, which implies an annual property tax rate of 1.4%, based on the 50-State Property Tax Comparison Study conducted by the Minnesota Taxpayers Association (2011). The level parameter for transfers, Ξ, is calibrated to satisfy the government budget constraint with zero government debt at the steady-state.

3.2.2 Prior distributions

Tables 4 and 5 report the prior distributions used for each estimated parameter, and corresponding posterior mean estimates (along with the 10th and 90th percentiles of the posterior distributions). We estimate a rescaled version of the price and wage adjustment cost parameters, κ_p and κ_w, to constrain the estimates within the unit interval and make the estimates more comparable to the literature using Calvo (1983) type price and wage setting. In particular, we estimate κ_p^{est} and κ_w^{est}, where

$$\kappa_p = \frac{[10(\theta_p - 1) + 1]\,\kappa_p^{est}}{\left(1 - \kappa_p^{est}\right)\left(1 - \beta_P \kappa_p^{est}\right)}, \text{ and } \kappa_w = \frac{[10(\theta_w - 1) + 1]\,\kappa_w^{est}}{\left(1 - \kappa_w^{est}\right)\left(1 - \beta_P \kappa_w^{est}\right)}. \tag{50}$$

At the mean of their prior distributions (i.e. 0.5), these are analogous to assuming 2-quarter price and wage stickiness in the Calvo setting, along with more curvature in the *Kimball* aggregator functions used in Smets and Wouters (2007) instead of the standard Dixit-Stiglitz functional forms we use here. The utilization cost elasticity parameter was also rescaled as $\varpi = \varpi^{est}/(1-\varpi^{est})$ to constrain its estimate within the unit interval.

For the parameters with a unit support, we use beta priors with mean 0.5 and standard deviation 0.2. These

[8] Note that the average amortization for 30-year mortgages is 0.0118 (Garriga et al., 2013). This slight discrepancy in our calibration does not alter the results in any discernible manner.

parameters are the utilization cost elasticity parameter, ϖ^{est}, price and wage adjustment cost parameters, κ_p^{est} and κ_w^{est}, indexation parameters, ς_p and ς_w, the Taylor rule smoothing parameter, ρ, and the shock persistence parameters. For the habit parameter, ζ, we use a more informative beta prior with mean 0.95 and standard deviation 0.025 to ensure that the estimation yields impulse responses with a significant degree of consumption persistence in line with the related DSGE literature and VAR evidence.

For parameters with positive support, we mainly use gamma priors. In particular, for the labor supply elasticity parameter, ϑ, we use gamma priors with mean 5 and standard deviation 2, and for the steady-state (gross) mark-up in prices and wages, θ_p and θ_w, we use gamma priors with mean 1.5 and standard deviation of 0.2. For the Taylor rule response coefficient on inflation, a_π, we also use a gamma prior with mean 1.5 and standard deviation of 0.2, while the output gap response coefficient, a_y, has a gamma prior with mean 0.125 and standard deviation 0.05. For the parameter determining the responsiveness of transfers to government debt, ϱ_b, we use a gamma prior with mean 0.01 and standard deviation of 0.005, where the low mean value is intended to preserve the determinacy of the model while ensuring that government debt does not play a major role in determining dynamics.

Since we do not have strong prior beliefs on the capital and housing stock adjustment cost parameters, κ_k and κ_h, and the investment adjustment cost parameters, κ_{ik} and κ_{ih}, we use uniform priors bounded by 0 and 20 for these parameters. Finally, for the shock standard deviations, we use inverse-gamma priors with 0.5 percent mean and infinite variance.

3.2.3 Posterior estimates

The mean and the 10th and 90th percentiles of the posterior distributions of the parameters are reported in Tables 4 and 5.[9] The data are quite informative about most of the parameters, and the estimates are by-and-large standard. The habit parameter, ζ, has a posterior mean equal to 0.89. ϑ has a posterior mean of 2.37, implying a labor supply elasticity of around 0.42. The estimate for the utilization parameter, ϖ^{est}, implies that the elasticity of capacity utilization with respect to the rental rate of capital is around 5. The estimates for the investment adjustment cost parameters, κ_{ik} and κ_{ih}, are 6.0 and 4.2, respectively. Similarly, the stock adjustment cost parameters, κ_k and κ_h, are estimated as 9.2 and 1.6, respectively.

The mean estimates for price and wage mark-up parameters, θ_p and θ_w, are 1.9 and 1.6. The estimates for the price and wage adjustment cost parameters, κ_p^{est} and κ_w^{est}, are 0.69 and 0.76; consistent with significantly flat Philips curves during the Great Moderation period. The indexation parameters, ς_p and ς_w, have estimated means of 0.16 and 0.38, indicating that indexation to past inflation is not an important feature of the data, especially for prices. The Taylor rule is fairly persistent with mean ρ equal to 0.75, and the mean estimates for the long-run reaction coefficients a_π and a_y are 1.36 and 0.13, respectively. The mean estimate for ϱ_b, the parameter determining the responsiveness of transfers to government debt, is 0.013. Finally, among the shocks, the housing demand, productivity, residential investment, price mark-up and government expenditure shocks are estimated to be fairly persistent.

4 Results

In this section, we first analyze the effects of monetary policy on mortgage debt in our model based on the benchmark estimation. We also conduct sensitivity analysis on our baseline results by altering key parameters,

[9] For the Metropolis-Hastings algorithm in *Dynare*, we used a single chain of 250,000 draws with a 45% initial burn-in phase. The acceptance rate was about 23%.

and complement our analysis with VARs. In the second portion of the results section, we compare the effectiveness of fiscal and macroprudential tools in reducing mortgage debt relative to monetary policy.

4.1 Effects of monetary policy on mortgage debt

Figure 1 plots the impulse responses to a 100 bp (annualized) innovation in the monetary policy shock. The pass-through from the policy rate, R_t, to the long-term mortgage rate is incomplete since the policy rate is expected to slowly decline from its peak. The current mortgage interest rate, R_t^F, increases by about 60 bp (annualized), but the overall rate faced by borrowers on their existing mortgages, R_t^M, increases only by about 15 bp (annualized) at impact and about 25 bp (annualized) at the peak. Faced with higher rates, impatient households reduce the level of new borrowing, l_t, by 7.8 percent (which in figure 1 is plotted as level deviation from steady-state), and their purchases of housing and consumption. This decline in demand leads to a reduction in overall residential and non-residential investment, $i_{h,t}$ and $i_{k,t}$, and a decline in asset prices, $q_{h,t}$ and $q_{k,t}$. The increase in discounting of future returns by patient households also lead to a decline in their consumption demand as well, although the decline in house prices prompts them to purchase some new housing in the very short run, which also declines after several periods following the impact period of the shock. The overall decline in demand leads to a decline in production and wages, and aggregate output, y_t, and inflation, π_t, fall as a result as well. In particular, output falls by about 50 bp at the peak, while inflation is reduced by about 12 bp (annualized).

Given our benchmark estimates, we do not find evidence that monetary policy has perverse effects on the stock of household debt, d_t, due to the muted response of inflation to the monetary policy shock along with the sizable decline in new borrowing. In particular, the stock of real debt declines at impact and stays lower than the steady-state for about 3 years with a peak impact of about 0.25 percent, and is statistically equal to 0 after the 3-year horizon. Note however that the decline in output is stronger than the decline in the real stock of mortgage debt; thus our model predicts a deterioration in the household debt-to-income ratio with monetary tightening. In the next subsection, we conduct several sensitivity analyses on key parameters to investigate the importance of model features and parameterization in generating the above results related to the effects of monetary policy on household debt.[10]

4.1.1 Sensitivity analysis

First, we alter the parameter determining the interest adjustability of mortgages, Φ. Note that this parameter was fixed to 0.2 prior to estimation given that on average about 80 percent of all new mortgages are fixed-rate. In Figure 2, we compare how the benchmark results change when we reduce Φ to 0, thereby setting the duration of the interest rate fixity to be equal to the duration of the mortgage loan (i.e. nearly 30 years). We keep all the rest of the parameters of the model the same. The decline in Φ significantly limits the ability of monetary policy to reduce the level of real mortgage debt as the pass-through from the policy rate to the mortgage rate is far weaker, and borrowers do not face additional income effects from the resetting of interest rates on their existing loans. The responses of consumption, output and also inflation are also slightly lower relative to the benchmark case. The smaller decline in inflation also helps in cushioning the effects of monetary policy on the real stock of household debt through debt-deflation effects. Conversely, the

[10] In what follows (Figures 2-11), we use the posterior mode estimates as our baseline rather than the posterior means used here. Note that the difference between using posterior mean estimates of the parameters (Figure 1) and the posterior mode estimates (Figure 2 baseline) is negligible.

effects of monetary policy on real household debt strengthens when the mortgage rate adjusts faster, since the pass-through from the policy rate to the mortgage rate faced by borrowers is larger (see Figure 3). Note however that with fixed-rate mortgages, a smaller change in the mortgage rate has a larger impact on new lending as households are incentivised to lock-in the low rate for a long time. In our model, the interest rate pass-through effect dominates the lock-in effect, and more rate adjustability implies stronger impact of monetary policy on household debt.

Second, we consider the slope of the New Keynesian Philips curve, which is one of the main factors determining the response of inflation to the monetary policy shock. In Figure 4, we consider a steeper Philips curve by reducing κ_p^{est} from 0.69 in our baseline case to 0.5, reflecting an average price-stickiness of 6 months in the Calvo set-up. This results in a significantly larger decline in inflation from monetary tightening, and a smaller decline in output (and new lending) relative to the baseline case. The resulting real household debt declines at impact, albeit far smaller than the baseline case, and increases above its initial steady-state value within 2 years.

Third, we alter the adjustment costs in the stock of housing, κ_h. Reducing this parameter to 0 implies that borrowers are willing to reduce their level of new investment in housing as they do not face adjustment costs while changing their stock. This results in a larger decline in new mortgage lending, l_t, strengthening the impact of monetary tightening on household debt (see Figure 5). Increasing these costs to 50 has the opposite effect. Indeed in this case, new loans decline so little that the comparable decline in the inflation rate leads to an increase in the real stock of household debt at the impact period of the monetary tightening and beyond (see Figure 6).

4.1.2 Caveats

There are several caveats on our main results on the effects of monetary policy on household debt. First, the way we capture the interest rate adjustability of mortgages is equivalent to assuming a constant share of fixed-rate and adjustable-rate mortgages. Endogenizing this choice could weaken the effectiveness of monetary policy in reducing household debt since monetary policy tightening would likely reduce the share of adjustable rate mortgages, and weaken the pass-through effect discussed above.

Second, our model abstracts from home equity lines of credit (HELOCs) on existing homes, which are mainly adjustable-rate and of much shorter duration than standard mortgages. Home equity loans are also potentially more sensitive to house prices than regular mortgages. Note however that home equity loans constitute only about 8 percent of all outstanding housing loans, and would therefore play a limited role.

Third, according to the 2011 American Housing Survey, the majority of refinanced mortgages reduced interest rates on the previous loan without changing its remaining amortization period. Our specification for interest rate adjustability captures this notion. However, some refinancing activity was undertaken to shorten the amortization period of the previous loan or to take out cash payment out of home equity, which we do not capture. Also, the overall quantity and timing of refinancing activity likely depend on the monetary policy stance, but our framework does not capture this endogeneity. This potentially could strengthen the effect of monetary policy on household debt because monetary policy tightening would also lead to a slowdown in refinancing activity, increasing the effective duration of mortgage loans.

Fourth, our analysis ignores non-mortgage household debt such as credit cards or car loans. These constitute about a fourth of all borrowing by households, and are far more short-term and adjustable-rate relative to mortgages.

Finally, our analysis ignores the risk-taking channel of monetary policy, and in particular that monetary policy itself may lead to exuberance in housing markets. If this is indeed the case, then monetary tightening may help lower household debt also through its curbing impact on exuberance in housing markets.

4.1.3 VAR analysis

In this subsection, we use VARs in order to find corroborating evidence on the effects of monetary policy on mortgage debt. Our baseline VAR includes the log of real GDP, the log of the GDP-deflator price level, the federal funds rate in level, the log of real mortgage debt stock, and the log of real house prices. We use the same data series used for the DSGE model's estimation (although following common practice, we do not HP-filter the real variables for the VARs and leave them in their log-levels), and we use quarterly data for the same time period between 1984Q1 and 2007Q4. We identify the shocks, including the monetary policy shock, through recursive short-term restrictions, using the ordering of variables as listed above. This ordering reflects the notion that real GDP and prices react to monetary policy with at least a quarter lag, while the change in interest rates can alter the level of credit and house prices within the impact quarter as well. We have conducted sensitivity analysis on this choice of ordering, but this does not yield any discernible change in the basic results regarding the impact of monetary policy on household debt. The lag length in our baseline VAR is set to 2 based on both the Akaike and Schwarz information criteria, although using 1 or 4 lag lengths instead do not alter the main results.

Figure 7 presents the impulse responses of each variable in the benchmark VAR from the monetary policy shock. The monetary policy shock (which is about 50 bp at the peak) generates a peak response in the level of real output of 26 bp while the price level declines very gradually to about 30 bp, but only after 8 years. Monetary policy tightening also reduces the level of real household debt by 1.4 percent at the peak after 5 years, and leads to a nearly 2 percent decline in house prices. Although there are differences in magnitudes, this is inline with our main finding that monetary policy tightening reduces the level of real household debt. Note however that the VAR predicts a stronger decline in mortgage debt relative to output, implying a decline in the debt-to-income ratio as well, in contrast to our findings in the DSGE set-up.[11]

Our baseline VAR exhibits a small and insignificant price puzzle in the first two years after the policy shock; that is the price level responds slightly positively at first. This may reflect the absence of variables in the VAR that capture higher expectations of inflation when monetary policy is active. An alternative explanation for the price puzzle is that the increased interest costs of borrowing firms are reflected in their marginal cost and therefore price-setting. To overcome the price puzzle, we also tried including an oil price index, or expected 1-year or 5-year inflation series constructed by the Cleveland Fed. None of these changes resulted in a material difference in results from the baseline case. We also tried different ordering of variables (in particular with respect to the ordering of household debt in the VAR), excluding house prices from the VAR, starting the data sample from the 1960s, and changing the lag length of the VAR to 1 or 4. In almost all of these combinations, we found that innovations in the monetary policy shock leads to a small decline, and not to an increase, in the stock of real mortgage debt. The implied debt-to-income ratio typically declines in these cases as well.

[11] The baseline VAR generates reasonable (at least qualitatively) impulse responses to other shocks in the model as well. In particular, demand shocks (identified by innovations to the log output equation) generate an increase in output and prices, while supply shocks (identified by innovations to the price equation) generate an increase in prices and a fall in output.

4.2 Effects of fiscal and macroprudential policy on mortgage debt

In this section, we compare the effectiveness of fiscal and macroprudential tools in reducing household debt and compare them to those from monetary policy. So far, we had kept the housing-related fiscal and macroprudential tools constant; in this section we investigate how exogenous and near-permanent changes in these tools would affect household debt and other macroeconomic variables. In particular, we let the property tax rate, the tax deductibility of mortgage interest, and regulatory LTV follow AR(1) processes as:

$$\tau_{p,t} = (1 - \rho_\tau)\,\tau_p + \rho_\tau \tau_{p,t-1} + \varepsilon_{\tau,t}, \tag{51}$$

$$I_{m,t} = (1 - \rho_m)\,I_m + \rho_m I_{m,t-1} + \varepsilon_{m,t}, \tag{52}$$

and

$$\phi_t^{reg} = \rho_{reg}\phi_{t-1}^{reg} + (1 - \rho_{reg})\,\phi^{reg} + \varepsilon_{reg,t}, \tag{53}$$

where the persistence parameters ρ_τ, ρ_m, and ρ_{reg} are set very close to unity (i.e. 0.9999), and the shocks result in near-permanent changes in these policies in the short-run.[12] In terms of normalizing the magnitude of these policy shocks, we pick the size of the fiscal shocks so that the peak response of output is equal to that from lowering regulatory LTV by percentage points.

4.2.1 Increasing the property tax rate

In Figure 8, we plot the impulse responses of model variables to a surprise 0.22 pp (annualized) increase in the property tax rate (i.e. the property tax rate increases from 1.4 percent to 1.62 percent in annualized terms; hence, $\tau_{p,t}$ increases from 0.014/4 to 0.0162/4 at impact). The increase in the property tax rate reduces the future returns that patient and impatient households expect to receive from investing in housing in the next period (see their first-order conditions with respect to housing given in equations 15 and 29), thereby reducing the demand for residential investment goods, $i_{h,t}$, everything else constant. The relative price of housing, q_h, falls due to the decline in housing demand, but slowly reverts back to its steady-state level within 5 years of the shock as the effect of investment adjustment costs dissipates and the supply of housing adjusts. New household lending, l_t, declines as impatient households reduce their demand for housing and the fall in house prices tightens their collateral constraint. This in turn leads to a decline in the stock of real household debt, d_t, over time as well.

Given the adverse income effects from increased property taxes and the tightening of their collateral constraint from reduced house prices, impatient households are forced to reduce their consumption expenditures, $c_{I,t}$, as well. Patient households, on the other hand, switch their expenditures from housing to consumption and capital investment, $i_{k,t}$, but the decline in house prices in general equilibrium also cushion the decrease in their demand for housing in the short-run as well. Aggregate consumption, c_t, decreases in the short-run reflecting the stronger impact from the fall in borrowers' consumption, $c_{I,t}$, while it increases above its steady-state value after several periods given the increase in consumption demand from patient households, $c_{P,t}$. This increase in saver consumption is also partly due to the decline in the policy rate, R_t, which is

[12] Of course, this also ensures that the model remains stationary and makes its computation feasible through perturbation methods. In Alpanda and Zubairy (2013), we had considered permanent changes in fiscal policies and had computed exact solutions for the transition paths. Near-permanent policy changes computed with log-linearization yielded very similar transition path results in the short-run relative to those we got from the exact solution under permanent changes. We thus consider the stationary model here with near-permanent changes. This can also capture the notion that agents place a small probability on the reversal of these policies back to their original values in the long-run.

triggered by the decline in aggregate output, y_t, and inflation, π_t. The decline in the policy rate also reduces long-term mortgage rates, R_t^F, but this is not strong enough to reverse the fall in housing demand of impatient households in general equilibrium.

4.2.2 Reducing the tax deductibility of mortgage interest

Figure 9 presents the impulse responses of model variables to a 30 percent decline in the tax deductibility of mortgage interest (i.e. $I_{m,t}$ decreases from 1 to 0.7 at impact). Unlike property taxes, which directly affect borrowers *and* savers, the direct impact from the change in mortgage interest deduction is felt solely by borrowers. This direct impact on impatient households is similar to an increase in the effective mortgage rate they face (see their first-order condition with respect to the stock of mortgage debt in equation 31). Similar to property taxes, this leads to a decline in borrowers' demand for housing and mortgage borrowing, thereby leading to an overall fall in house prices. But now the decline in house prices incentivizes patient households to increase their level of housing, $h_{P,t}$. Qualitatively and quantitatively, this is the most important difference between the effects of property taxes and mortgage interest deductions. Both policies reduce the overall demand for residential investment and house prices, but the latter policy's effects on output are cushioned by the increase in housing by patient households. This ensures that for the same decline in household debt, mortgage interest deduction has a smaller output impact relative to property taxes.

Otherwise, the qualitative effects of the two policies on aggregate variables are similar (see Figures 8 and 9). Aggregate consumption, c_t, declines due to the decline in impatient households' consumption, $c_{I,t}$, which in turn is mainly due to the decline in borrowers' income from the increase in their tax burden and the fall in their wages. Patient households increase consumption, $c_{P,t}$, along with the increase in housing, $h_{P,t}$, due to the fall in the policy rate, R_t, which in turn is induced by the fall in overall inflation and output. The fall in the policy rate also induces an increase in business investment, $i_{k,t}$, and an increase in capital prices, $q_{k,t}$, as well.

4.2.3 Lowering the regulatory LTV ratio on new mortgages

Figure 10 plots the impulse responses of model variables to a 5 pp decrease in the regulatory LTV ratio (i.e. ϕ_t^{reg} decreases from 0.91 to 0.86 at impact). This time, the direct effect of the policy is on the borrowing constraint of impatient households, not on their budget constraint. In particular, at impact the level of housing investment desired by impatient households is higher than the available amount of loans they can take out, thus the Lagrange multiplier on the borrowing constraint increases significantly. This multiplier presents a shadow cost on new borrowing, working through a similar channel as an increase in the mortgage rates faced by borrowers on new loans (see first-order conditions of borrowers with respect to the flow and stock of debt given in equations 30 and 31). Note that there is an important difference between regulatory LTV and the mortgage interest deduction in this respect. The former presents a shadow cost that is equivalent to increasing the interest rate on new loans only (i.e. R_t^F), while the latter presents a real cost that is equivalent to increasing the effective interest rates on all existing loans, (i.e. R_t^M). Furthermore, as a real cost, mortgage interest deductions also have direct adverse income effects for borrowers, unlike regulatory LTV which has a direct impact only on the borrowing constraint and affects the budget constraint of borrowers only indirectly.

Again the qualitative effects of the LTV policy is similar to the two fiscal policies (see Figures 8-10). As the borrowing constraint binds tighter due to the fall in regulatory LTV, borrowers are forced to reduce their demand for housing, which, in general equilibrium, leads to a fall in house prices and overall residential investment. Given the substitutability between housing and consumption, and the decline in their wages, $w_{I,t}$, borrowers also decrease their consumption demand. The overall impact of the LTV policy on the economy is to reduce aggregate output, y_t, which is accompanied by a decline in inflation, π_t, as the derived demand for labor declines and wages fall. The fall in inflation prompts the central bank to reduce the policy rate, R_t. This prompts patient households to increase their consumption expenditures, $c_{P,t}$, but aggregate consumption, c_t, declines nevertheless, due to the decline in impatient households' consumption, $c_{I,t}$. The decline in the policy rate also lowers the long-term mortgage interest rates, which slightly moderates the fall in housing and consumption demand of borrowers. The decline in house prices induces patient households to increase their purchases of housing, $h_{P,t}$, similar to mortgage interest deduction.

4.2.4 Comparing the effects of the four policies

In Figure 11, we show the effects of the four policies on key model variables on the same plot and for an 80 period horizon. Among the four policies we consider, regulatory LTV (red solid line) is the most effective tool in reducing household debt per unit of lost output, followed by reducing tax deductibility of mortgage interest, increasing property taxes, and finally, monetary policy. In particular, after scaling the size of the fiscal and LTV shocks to have the same peak impact on output, regulatory LTV and mortgage interest deduction have comparable effects on household debt for the first 7 years after impact. Notice however that the stock of real debt declines further with regulatory LTV after 7 years, since its impact on new housing loans is more persistent and its impact on inflation is less persistent, relative to those from mortgage interest deduction. Thus, on a present value basis, regulatory LTV is able to reduce household debt over the medium horizon with less per unit output cost than mortgage interest deduction. After normalization, property taxes have similar impact on output in present value terms to mortgage interest deduction, but less ability to reduce the stock of household debt per unit of output lost. Finally, compared to the other policies, monetary policy can reduce real household debt only by a small amount while having a large adverse impact on output. Notice that in Figure 11, we are considering only a temporary shock to monetary policy (with its persistence parameter set to its estimated value in section 3), but increasing its persistence tends to make the trade-off regarding household debt per unit of output significantly worse. This is because more persistence in the interest rate leads to a relatively larger decline in inflation than the fall in new lending. Note that we also do not scale the impact monetary policy, as the 100 bp shock considered in Figure 11 already conveys the main message expressed above regarding the unattractive trade-off offered by monetary policy with regards to household debt and output.

The effectiveness ranking of the four policies described above is consistent with the scope of each policy in targeting new household loans versus other aspects of the economy, as discussed previously. In particular, monetary tightening is a broad tool that adversely affects capital accumulation as well as aggregate consumption and residential investment, thereby causing a large decline in output. In comparison, property taxes are targeted towards the housing sector, but have direct effects on both savers and borrowers. Their effects on output are thus more muted relative to monetary policy, as savers reduce their demand for housing, but switch their expenditures to consumption and capital. Note that this channel is somewhat moderated by the presence of adjustment costs in the stock of patient households' housing, but not fully. Mortgage interest deductions are even more targeted than property taxes as they impact only borrower households and not the savers. In this case, the decline in house prices induces savers to increase their residential housing holdings as well, cushioning the impact on overall output even further. Finally, LTV policy is even more targeted than mortgage interest deductions as their direct impact is only on new loans, and not on all existing debt. Thus, their costs are equivalent to increasing the interest rate on new lending only, unlike mortgage interest deduction which presents a cost akin to increasing the effective interest rates on all existing loans. Furthermore, regulatory LTV does not have the direct adverse income effects related to the increase in overall tax burden on households when fiscal tools are used.

An important caveat for our comparison is the fact that only monetary policy leads to a comovement between the housing and the non-housing sectors in the model. In particular, with housing-related fiscal policies or regulatory LTV policy, the tightening in the housing sector is partially offset by an increase in business investment. However, there may be other sources of comovement between the two sectors in the real world which our model currently ignores, and which may lead to a decline in the non-housing sectors with fiscal and macroprudential policies as well. For example, the decline in house prices may erode bank capital and have adverse effects on the credit supply to the non-housing factors (Alpanda et al., 2014). These and other additional sources of comovement between the housing and the non-housing sectors could render the fiscal and macroprudential policies less effective in reducing household debt relative to our baseline results, but would not, by themselves, alter the basic ranking of the four policies in terms of their effectiveness in reducing household debt.

5 Conclusion

In this paper, we build a DSGE model with housing and household debt, and consider the effectiveness of monetary policy, housing-related fiscal policy, and macroprudential regulations in reducing household indebtedness. Unlike the majority of the literature, our model features long-term mortgages and differentiates between the flow and the stock of household debt. Given our benchmark parameters, we do not find evidence that monetary policy has perverse effects on the stock of household debt. Nevertheless, given that the response of output to monetary policy is stronger, there is deterioration in the household debt-to-income ratio despite monetary tightening. We also find that LTV tightening would be more effective and less costly in reducing household debt, followed by increasing property taxes, reducing the tax deductibility of mortgage interest, and monetary policy.

In future work, we plan to extend our framework to include home equity loans as well as non-mortgage borrowing to arrive at a more complete picture of the effects of monetary policy on household debt. We also plan to analyze the effects of exuberance in housing markets, and the role that monetary policy and other policy tools can play in curbing this channel when reducing household debt.

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Table 1: Different policies for addressing household indebtedness	
Policies (from more to less "targeted")	Direct effect on
- Regulatory LTV	new mortgage borrowing / new borrowers
- Mortgage interest deduction	all outstanding mortgages / all existing borrowers
- Property taxes	all homeowners (including those with full equity)
- Monetary policy	housing and non-housing sectors

Table 2. Calibrated structural parameters		
	Symbol	Value
Inflation target (gross, qrt.)	π	1.005
Discount factor	β_P, β_I	0.9926, 0.9877
Level for housing and labor in utility	ξ_h, ξ_n	0.97, 4.62
Interest-rate adjustability of mortgages	Φ	0.2
LTV ratio on new mortgages	ϕ^{reg}	0.91
Amortization rate on HH loans	κ	0.0112
Share of capital in production	α	0.206
Share of patient HH in labor income	ψ	0.397
Depreciation rates	δ_h, δ_k	0.0117, 0.0217
Fixed costs in production	f	1.0392
Utilization cost level	κ_u	0.0343
Transfers	Ξ	0.0208
Tax rates - labor income	τ_n	0.23
- capital income	τ_k	0.41
- property	τ_p	0.014/4

Table 3. Model steady-state ratios versus data targets			
	Symbol	Model	Data target
Total consumption / GDP	c/y	0.62	0.62
share of patient households	c_P/c	0.45	
share of impatient households	c_I/c	0.55	
Total investment / GDP	i/y	0.18	0.18
residential investment / GDP	i_h/y	0.05	0.05
non-residential investment / GDP	i_k/y	0.13	0.13
Government expenditure / GDP	g/y	0.20	0.20
Tax revenue / GDP	tax/y	0.22	
Transfers / GDP	tr/y	0.02	
Wage share in non-housing income	$1-\alpha$	0.79	
share of patient households	ψ	0.40	
share of impatient households	$1-\psi$	0.60	
Capital stock / GDP (qtr)	k/y	6.00	6.00
Housing stock / GDP (qtr)	h/y	4.28	4.28
share of patient households	h_P/h	0.44	0.44
share of impatient households	h_I/h	0.56	0.56
Mortgage debt / total housing value	d/h	0.37	0.37
average LTV on outstanding loans	d/h_I	0.66	0.66
LTV on new loans	l/i_{hI}	0.91	0.91

Table 4. Estimated structural parameters						
			Posterior dist.			
	Symbol	Prior dist.	Mode	Mean	10%	90%
Habit in consumption	ζ	B(0.95,0.025)	0.8710	0.8858	0.8443	0.9323
Inverse labor supply elasticity	ϑ	G(5,2)	1.6654	2.3685	0.8420	3.7128
Utilization cost elasticity	ϖ^{est}	B(0.5,0.2)	0.1816	0.2120	0.0422	0.3709
Stock adj. cost - capital	κ_k	U(0,20)	5.2829	9.1900	0.8118	16.9315
- housing	κ_h	U(0,20)	1.4240	1.6372	1.2229	2.0826
Investment adj. cost - capital	κ_{ik}	U(0,20)	5.1273	6.0029	1.3875	10.4933
- housing	κ_{ih}	U(0,20)	2.0823	4.1832	1.7124	6.9832
Mark-up - price	θ_p	G(1.5,0.2)	1.8454	1.9296	1.5892	2.2838
- wage	θ_w	G(1.5,0.2)	1.4916	1.6310	1.2837	1.9621
Adj. cost - price	κ_p^{est}	B(0.5,0.2)	0.6899	0.6950	0.5918	0.7975
- wage	κ_w^{est}	B(0.5,0.2)	0.7601	0.7571	0.6333	0.8762
Indexation - price	ς_w	B(0.5,0.2)	0.0770	0.1641	0.0134	0.3317
- wage	ς_p	B(0.5,0.2)	0.3357	0.3767	0.0779	0.6432
Response of transfers to gov. debt	ϱ	G(0.01,0.005)	0.0087	0.0131	0.0074	0.0195
Taylor rule - persistence	ρ	B(0.5,0.2)	0.7350	0.7488	0.6959	0.8033
- inflation	a_π	G(1.5,0.2)	1.3145	1.3611	1.1468	1.5846
- output	a_y	G(0.125,0.05)	0.1264	0.1263	0.1178	0.1346

Prior distributions: B: beta, G: gamma, U: uniform, IG: inverse gamma.

Table 5. Estimated shock parameters						
				Posterior dist.		
	Symbol	Prior dist.	Mode	Mean	10%	90%
Persistence - preference	ρ_υ	B(0.5,0.2)	0.1348	0.1587	0.0364	0.2700
- housing demand	ρ_h	B(0.5,0.2)	0.8556	0.8563	0.8014	0.9126
- productivity	ρ_z	B(0.5,0.2)	0.8474	0.8494	0.8013	0.8980
- investment (k)	ρ_{zk}	B(0.5,0.2)	0.1519	0.2228	0.0471	0.3851
- investment (h)	ρ_{zh}	B(0.5,0.2)	0.9772	0.8737	0.7029	0.9918
- price mark-up	ρ_p	B(0.5,0.2)	0.6597	0.5745	0.3767	0.7876
- wage mark-up	ρ_w	B(0.5,0.2)	0.1393	0.1579	0.0459	0.2720
- monetary policy	ρ_r	B(0.5,0.2)	0.5113	0.5042	0.3891	0.6094
- government exp.	ρ_g	B(0.5,0.2)	0.9020	0.8920	0.8175	0.9613
- LTV	ρ_ϕ	B(0.5,0.2)	0.2947	0.3117	0.1664	0.4625
St. dev. - preference	σ_υ	IG(0.05,∞)	0.0700	0.0808	0.0567	0.1067
- housing demand	σ_h	IG(0.05,∞)	0.1209	0.1440	0.0911	0.1974
- productivity	σ_z	IG(0.05,∞)	0.0042	0.0042	0.0037	0.0047
- investment (k)	σ_{zk}	IG(0.05,∞)	0.1877	0.2362	0.0853	0.3846
- investment (h)	σ_{zh}	IG(0.05,∞)	0.0142	0.0289	0.0122	0.0577
- price mark-up	σ_p	IG(0.05,∞)	0.0398	0.0645	0.0228	0.1080
- wage mark-up	σ_w	IG(0.05,∞)	0.3526	0.5806	0.2144	0.9990
- monetary policy	σ_r	IG(0.05,∞)	0.0011	0.0011	0.0010	0.0013
- government exp.	σ_g	IG(0.05,∞)	0.0116	0.0118	0.0104	0.0131
- LTV	σ_ϕ	IG(0.05,∞)	0.0542	0.0598	0.0491	0.0707

Prior distributions: B: beta, G: gamma, U: uniform, IG: inverse gamma.

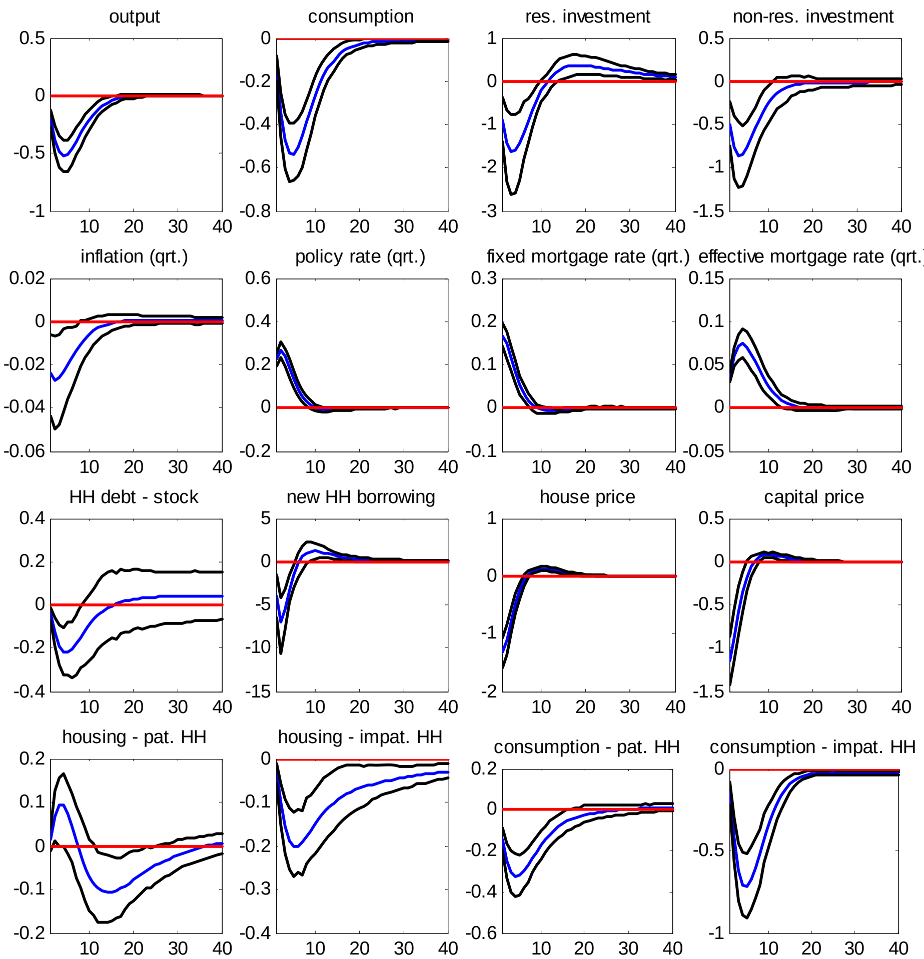

Figure 1: Impulse responses to a 100 bps. (annualized) innovation in the Taylor rule. The y-axes denote percent deviation of each variable from its steady-state. The impulse responses plotted as solid blue lines reflect the posterior mean estimates of the parameters, while the black lines denote the 90th percentile confidence intervals for the impulse responses.

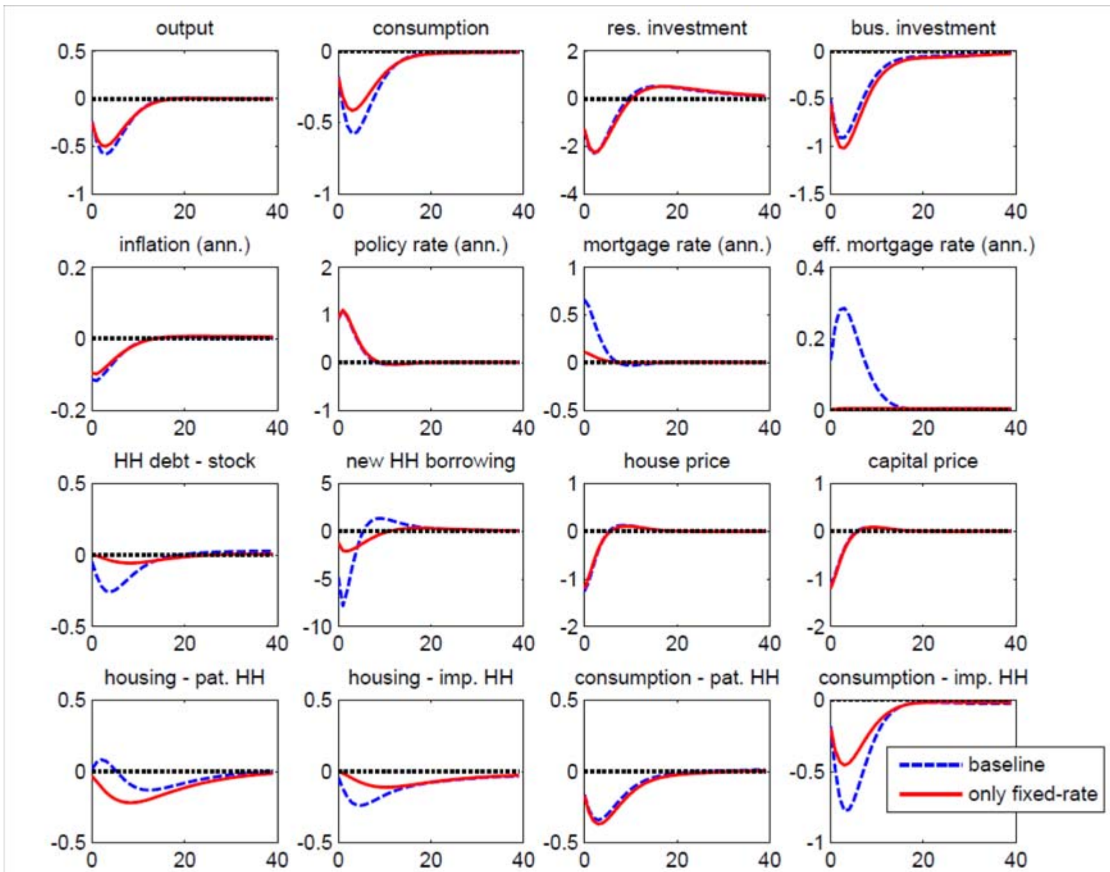

Figure 2: Comparing impulse responses to a 100 bps. (annualized) innovation in the monetary policy shock in the baseline case versus a case with only fixed-rate mortgages (i.e. $\Phi = 0$). The y-axes denote percent deviation of each variable from its steady-state.

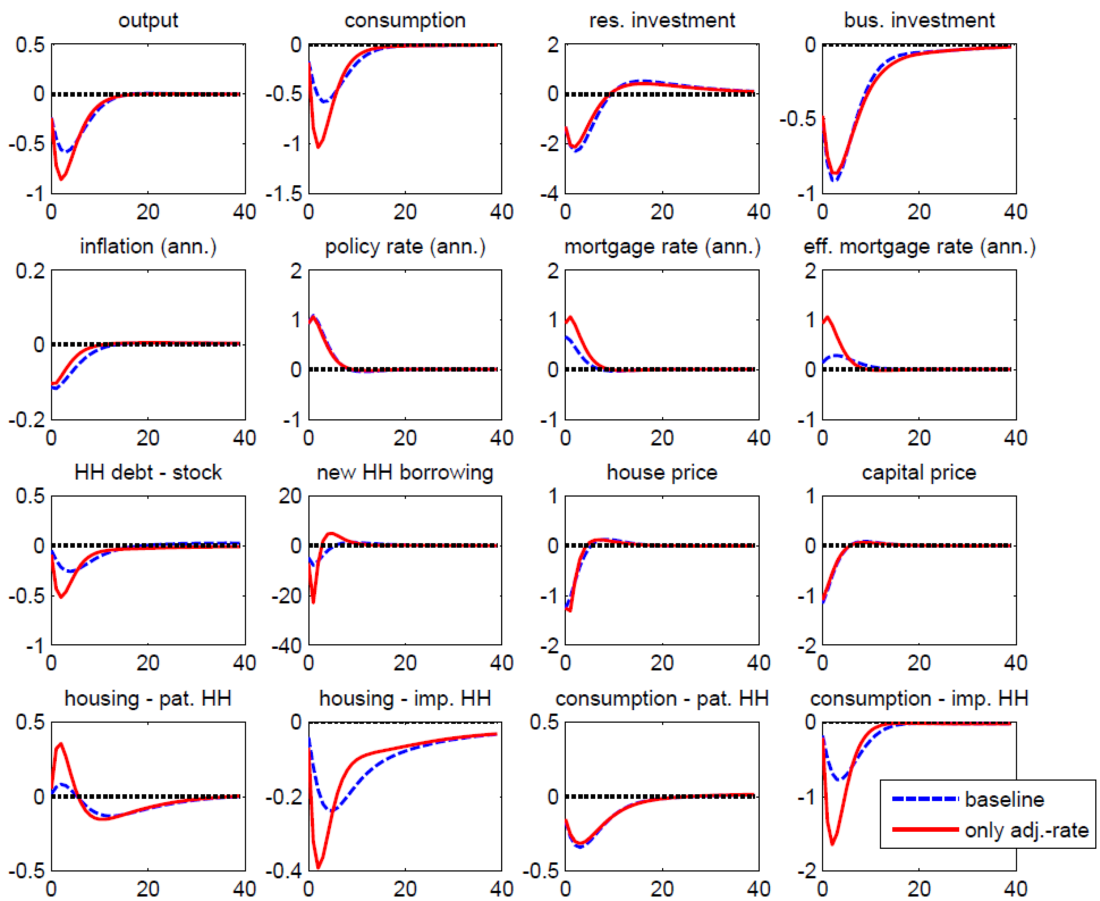

Figure 3: Comparing impulse responses to a 100 bps. (annualized) innovation in the monetary policy shock in the baseline case versus a case with only adjustable-rate mortgages (i.e. $\Phi = 1$). The y-axes denote percent deviation of each variable from its steady-state.

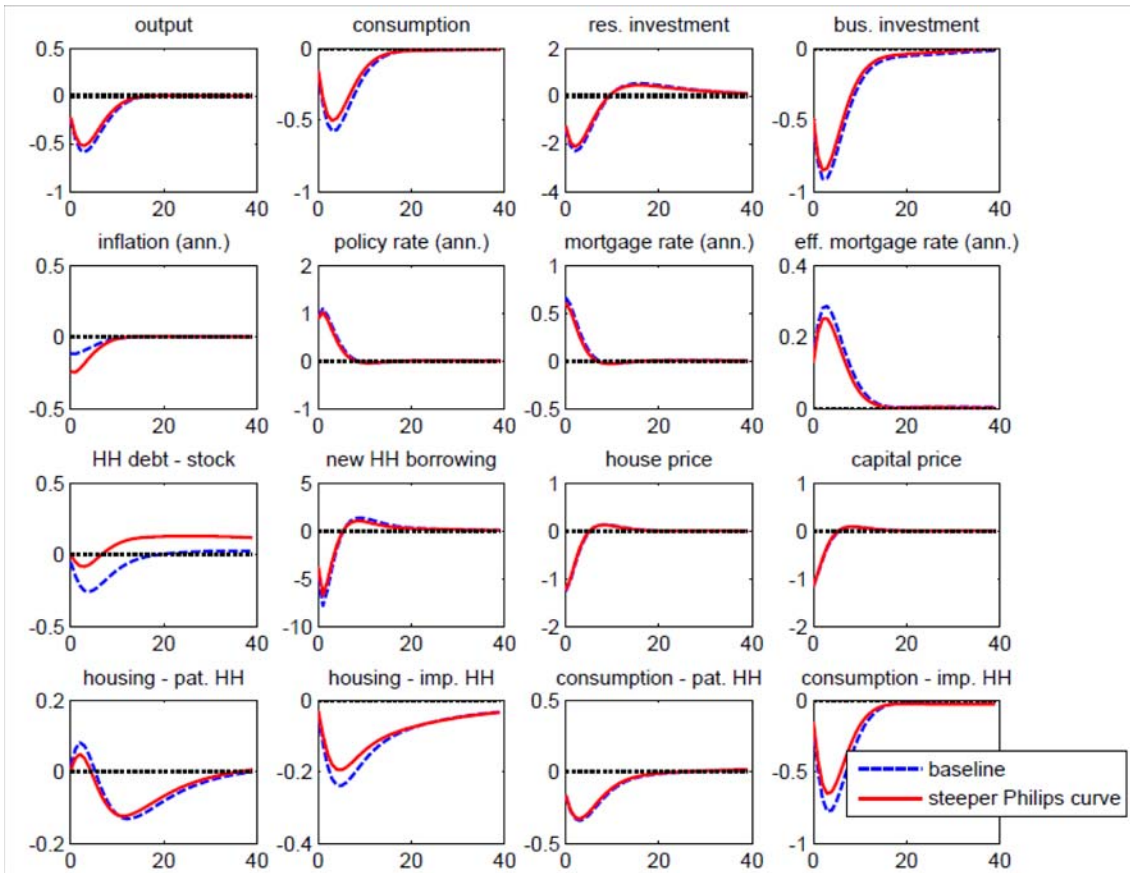

Figure 4: Comparing impulse responses to a 100 bps. (annualized) innovation in the monetary policy shock in the baseline case versus a case with a steeper New Keynesian Philips curve (i.e. $\kappa_p^{est} = 0.5$). The y-axes denote percent deviation of each variable from its steady-state.

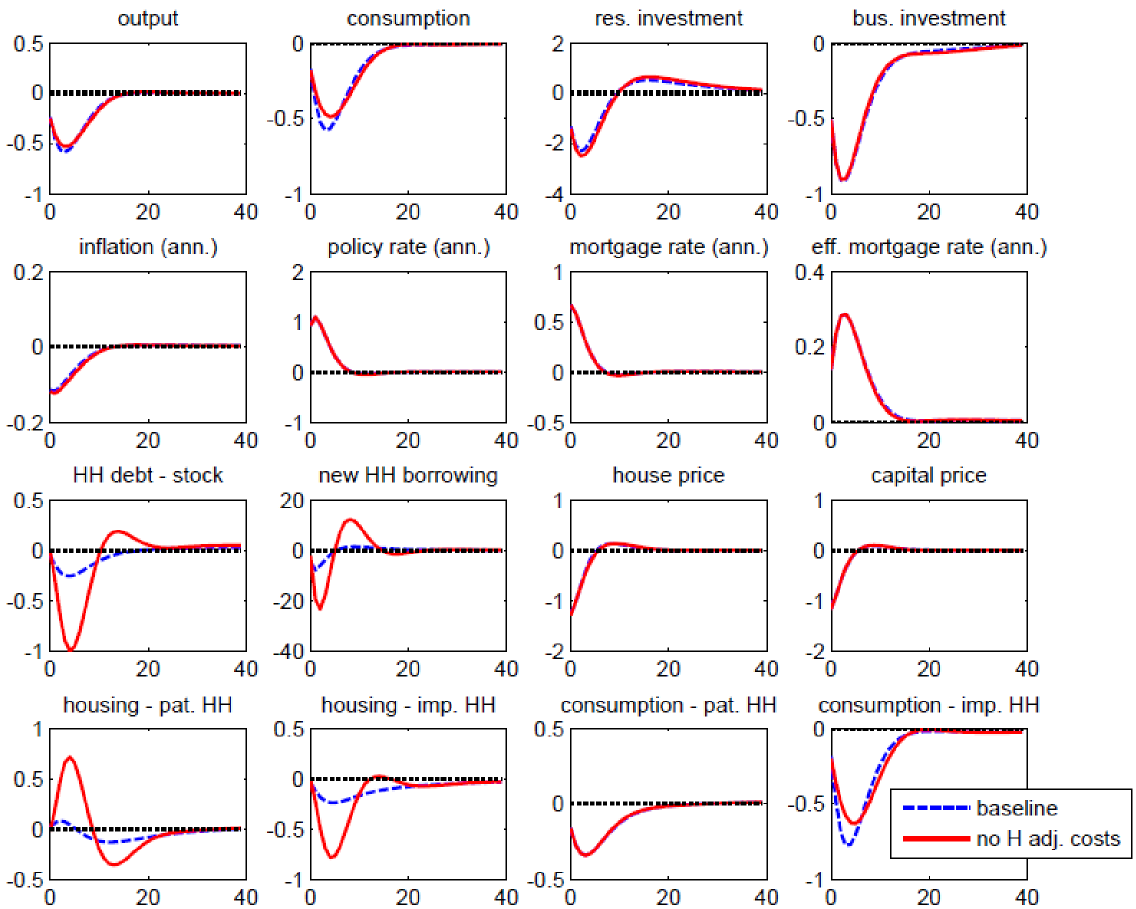

Figure 5: Comparing impulse responses to a 100 bps. (annualized) innovation in the monetary policy shock in the baseline case versus a case with no adjustment costs in the stock of housing (i.e. $\kappa_h = 0$). The y-axes denote percent deviation of each variable from its steady-state.

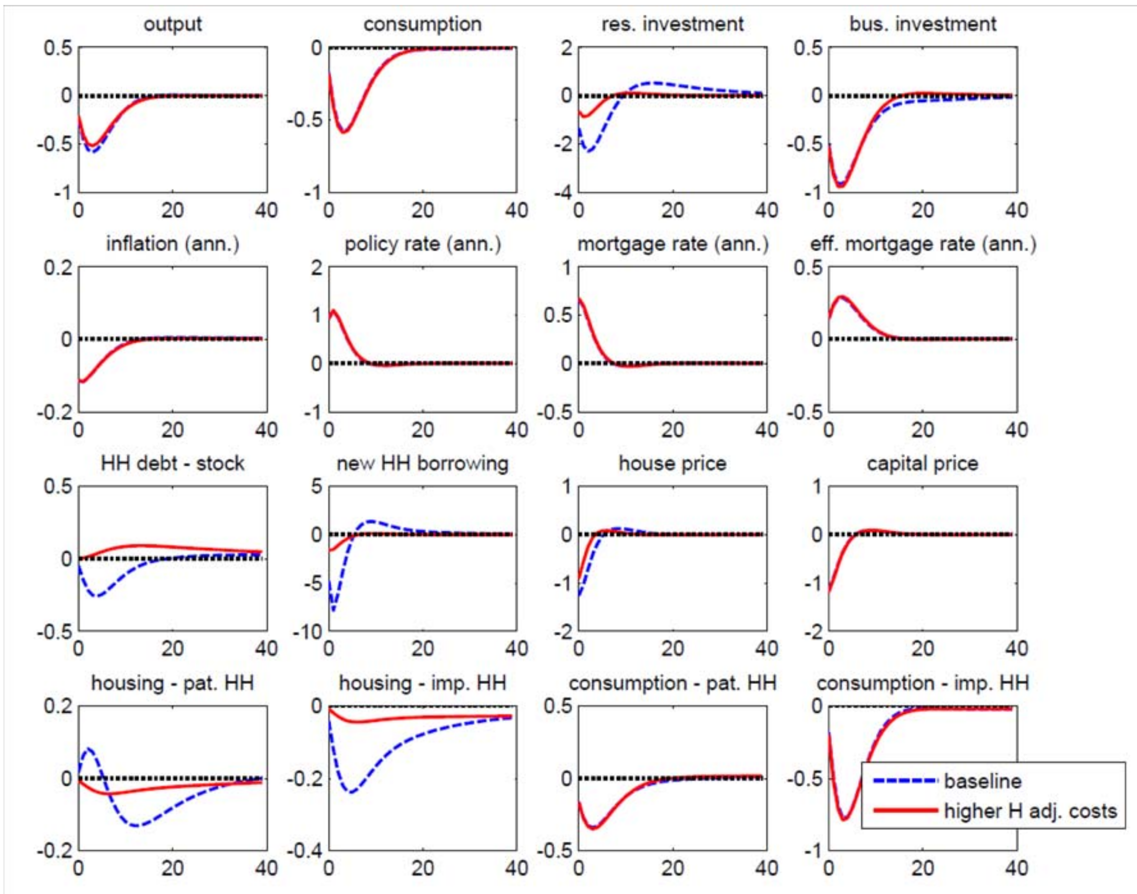

Figure 6: Comparing impulse responses to a 100 bps. (annualized) innovation in the monetary policy shock in the baseline case versus a case with high adjustment costs in the stock of housing (i.e. $\kappa_h = 50$). The y-axes denote percent deviation of each variable from its steady-state.

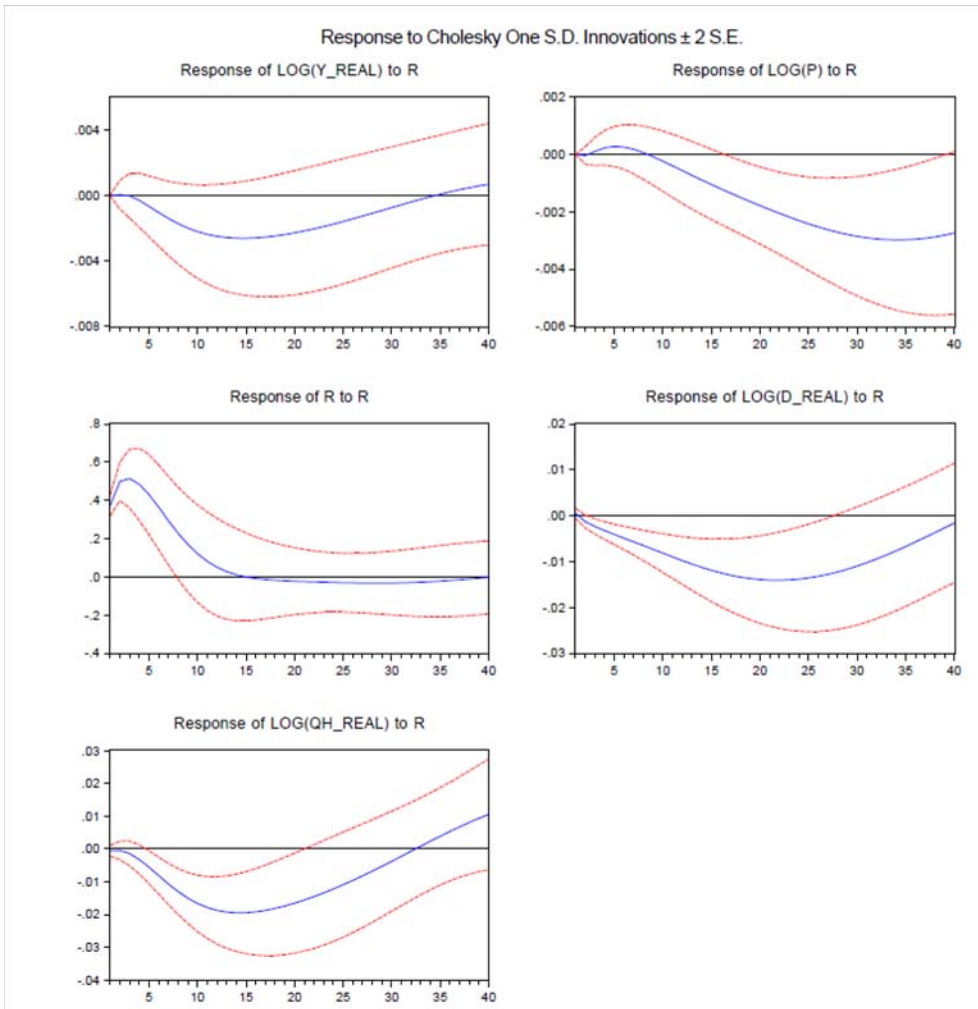

Figure 7: Impulse responses to a one standard deviation monetary policy shock in the baseline VAR on log real GDP, log price level, policy rate, real household debt, and real house price. The VAR includes 2 lags, and shocks are identified through ordering as listed above.

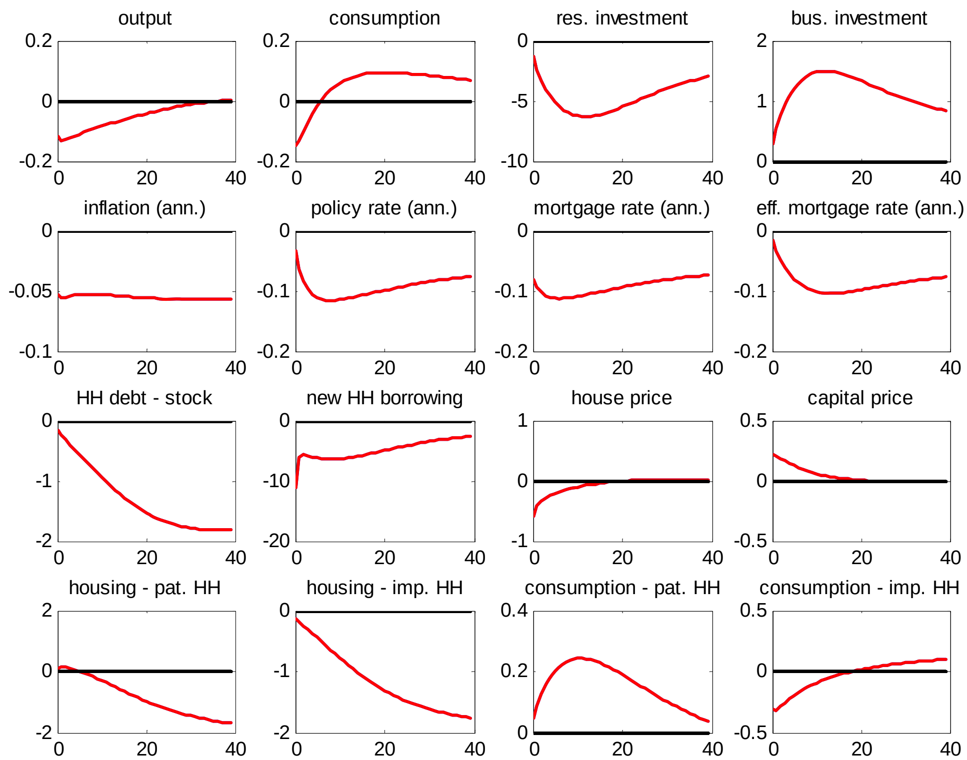

Figure 8: Impulse responses to a 0.22 pp (annual) persistent increase in the property tax rate (i.e. τ_p increases from 0.014 /4 to 0.0162/4).

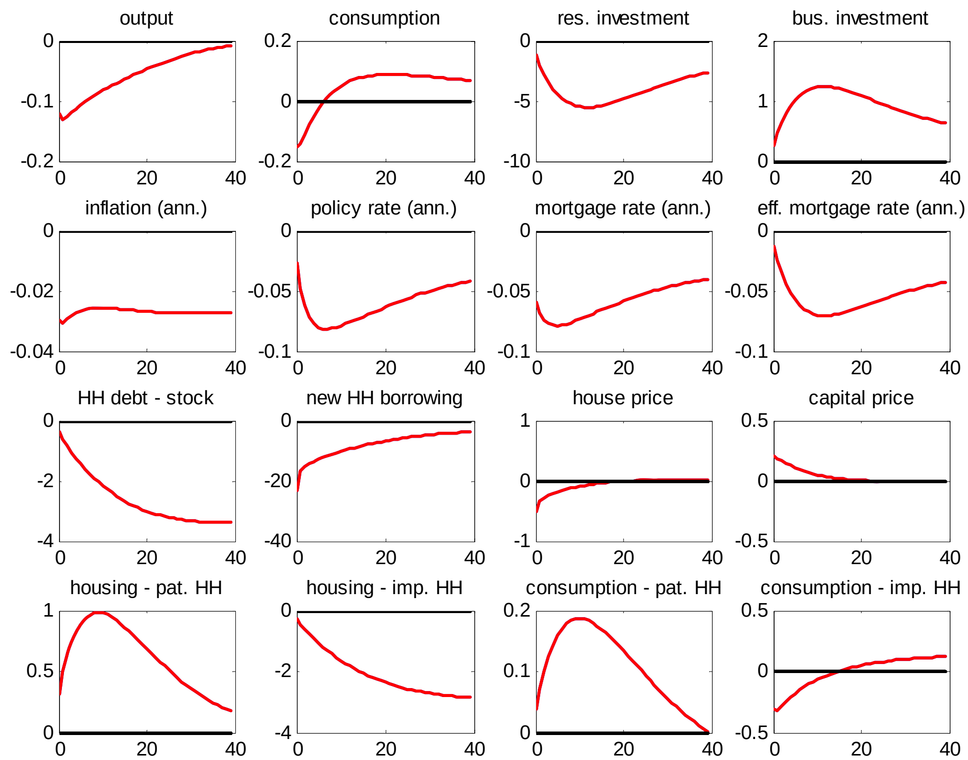

Figure 9: Impulse responses to a 30 percent persistent decline in the tax deductibility of mortgage interest (i.e. I_m is reduced from 1 to 0.7).

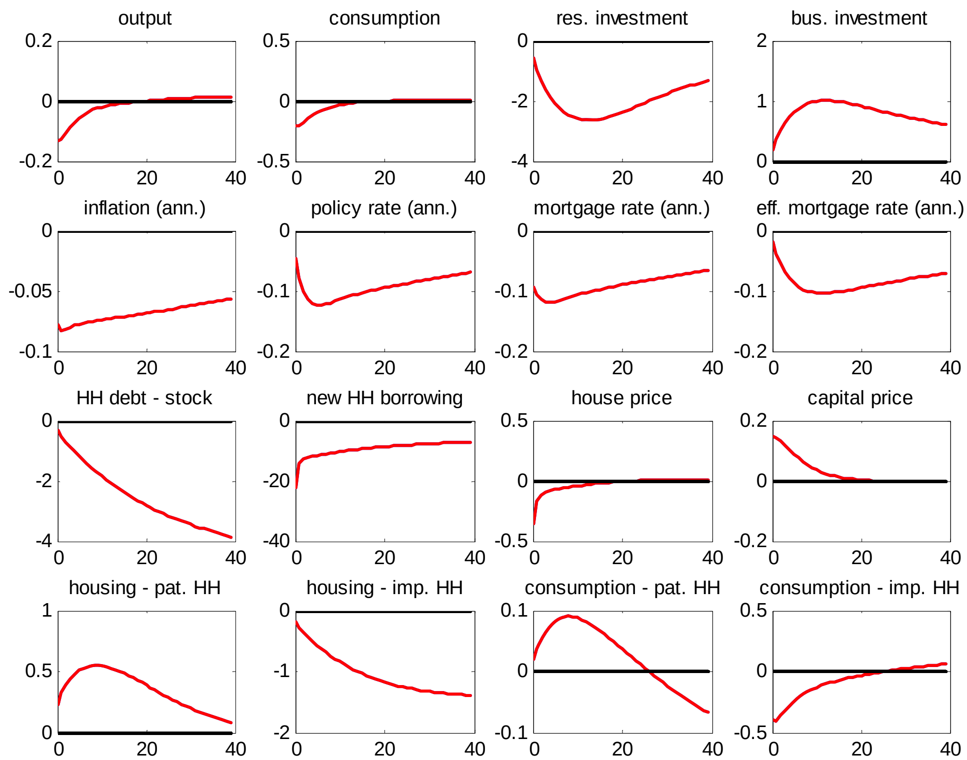

Figure 10: Impulse responses to a 5 pp persistent decline in the regulatory LTV on new mortgage loans (i.e. ϕ decreases from 0.91 to 0.86).

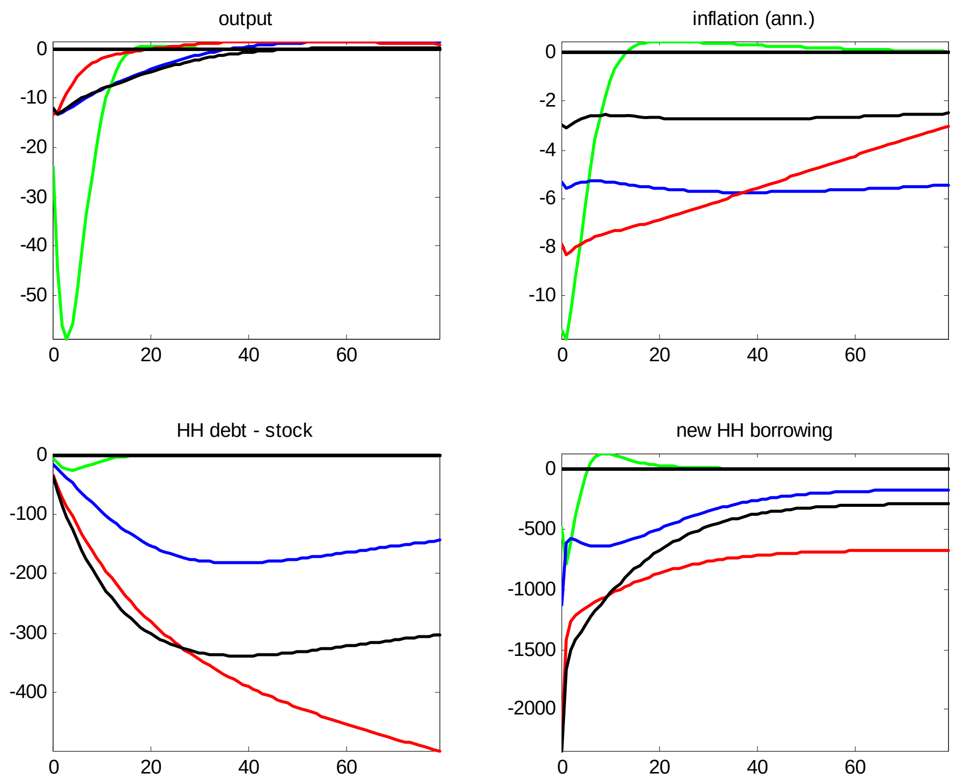

Figure 11: Comparing the effects of the four policies (green solid line = monetary policy; blue dash line = property tax; black dash and dotted line = mortgage deduction; red solid line = regulatory LTV).