CEP 13-10

"House Prices, Consumption, and Government Spending Shocks"

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December 2013

CARLETON ECONOMIC PAPERS

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House Prices, Consumption, and Government Spending Shocks*

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First draft: December 2012
Revised: December 20, 2013

Abstract

We highlight that a broad class of DSGE models with housing and collateralized borrowing predict a fall in both house prices and consumption following positive government spending shocks. By contrast, we show that house prices and consumption in the U.S. rise persistently after identified positive government spending shocks, using a structural vector autoregression methodology and accounting for anticipated effects. We clarify that modifying preferences alone, as previously suggested in the literature, does not help in obtaining the correct house price response. We then show that only when monetary policy strongly accommodates government spending shocks, the impact effects on house prices and total consumption are positive. The model, however, does not deliver the persistent rise in house prices and consumption as evident in the data. Properly accounting for the empirical evidence on government spending shocks and house prices using a DSGE model, therefore, remains a significant challenge.

JEL classification: E21, E44, E62

Key words: House prices; Consumption; Government spending

*We thank Hafedh Bouakez, Miguel Casares, Yuriy Gorodnichenko, Matteo Iacoviello, David Romer, and Johannes Wieland for very helpful discussions and comments. An earlier version of the paper was presented at the Canadian Economic Association Meetings (Calgary, 2012). The views in this paper do not reflect those of the Bank of Canada.

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1 Introduction

House price changes determine the amount of funds that financially constrained homeowners can borrow against the value of their homes for current consumption. If fiscal policies affect house prices, they can provide a channel for influencing private consumption, and hence aggregate demand in the economy. This is important in the context of the U.S. economy for two reasons. First, the slow recovery following the 2008 financial crisis has coincided with a renewed interest in determining the effects of fiscal policy and a better understanding of its transmission mechanism.[1] Second, the weakness in the housing market continues to be a major concern for economic recovery. Although the federal spending allotment of $14.7 billion under the American Recovery and Reinvestment Act (ARRA) of 2009 and housing policies under the Making Home Affordable Program may have slowed the decline in house prices, it is estimated that in the first quarter of 2013, 19.8% of mortgaged homes were worth less than their outstanding mortgage amounts.[2] For both reasons, empirical evidence on the effects of fiscal policies on house prices and consumption can help inform policy on the housing market. At the same time, models used for policy analysis should reflect this evidence. Surprisingly, however, neither has such evidence been adequately established, nor has the effects of discretionary fiscal policy on house prices been properly studied. Our paper attempts to fill this gap.

The objectives of this paper are twofold: First, to determine the effects of government spending shocks on house prices empirically, and second, to examine whether dynamic stochastic general equilibrium (DSGE) models with housing can account for these effects as DSGE models are widely used in informing policy.[3]

We employ the Blanchard and Perotti (2002) approach and identify government spending shocks using U.S. data, and examine their effects on house prices and consumption. As emphasized by Ramey (2011), however, this approach misses the timing of anticipated government spending and gives a result different from the narrative approach of Ramey and Shapiro (1998). To account for

[1] See, for example, Romer (2011).

[2] CoreLogic Report (June 2013) and Sengupta and Tam (2009).

[3] The nexus between the housing market and the macroeconomy has received renewed interest from both academics and policy makers. See Iacoviello (2010) for a recent perspective and Leung (2004) for an early review.

anticipated effects in the identification of shocks, we follow Auerbach and Gorodnichenko (2012) and include forecast errors for the growth rate of government spending in the VAR system. Our main empirical finding is that house prices rise in a persistent manner after a positive government spending shock.[4] The increase in house prices is statistically significant and peaks between 5 and 8 quarters in the baseline specification that accounts for anticipation effects.

In sharp contrast to the empirical evidence, house prices *fall* in a DSGE model with housing after a positive government spending shock. We highlight this counterfactual result relative to the SVAR evidence by introducing government spending shocks in the Iacoviello (2005) model of housing, with (patient) lenders and (impatient) borrowers. Both types of agents make housing purchases and receive utility from housing services. Housing also serves as a collateral in borrowing funds. The borrowers, however, face a collateral constraint which limits their borrowing to a certain fraction of the expected value of their housing stock. This framework is a natural starting point for studying the dynamic effects of shocks on house prices and consumption and has been widely used in the literature for this purpose.[5]

Why do house prices fall after positive government spending shocks in the model? The intuition follows from the approximately constant shadow value of housing for lenders. Housing is a long-lived good and provides a service-flow for many periods in the future. The property of near-constant shadow value of long-lived goods was first pointed out in Barsky et al. (2007) in the context of durable goods and permanent monetary policy shocks.[6] In a lender-borrower DSGE model, the shadow value of housing for the lender, defined as the product of the relative price of housing and marginal utility of consumption, is determined by the expected infinite sum of discounted marginal utility of housing. Two key features make the shadow value of housing approximately

[4]We are aware of only one previous study by Afonso and Sousa (2008) who examined the effects of government spending shocks on U.S. house prices. Although they do not control for expectations in the identification of shocks, our findings are still consistent with theirs. As it turns out, controlling for expectations has a big effect on the timing of the peak response of consumption to government spending shock. They also do not explore the implications for DSGE models of housing which is one of the objectives of our paper.

[5]A recent example is Andres et al. (2012) who augment the Iacoviello (2005) model with search and matching frictions to study the size of fiscal multipliers in response to government spending shocks.

[6]More recently, Sterk (2010) highlights the role of the quasi-constancy property to re-examine the extent to which credit frictions can resolve the lack of comovement between durable and non-durable consumption in New Keynesian models following a monetary tightening, as studied by Monacelli (2009).

constant. First, the marginal utility of housing depends on the stock of housing. Housing flows do not contribute much to the variation in this stock and thus it remains close to its steady state. Second, temporary government spending shocks exert little influence on future marginal utility of housing. A positive government spending shock has a negative wealth effect on lenders as they expect an increase in future taxes. This causes them to cut current consumption, thereby raising the marginal utility of consumption. Since the shadow value of housing remains approximately constant, it follows that the relative price of housing must fall.

Two additional price and income effects magnify the increase in the marginal utility of lenders' consumption. First, as government spending increases output and inflation, the central bank's monetary policy implies an increase in the real interest rate which lowers current consumption. This price effect arises independent of the type of preferences. Second, the decline in the relative price of housing lowers housing asset income for the lenders and exerts an additional negative income effect.

Aggregate consumption in the model also falls after a positive government spending shock. For lenders, current consumption falls as explained above. For borrowers, the fall in the current and expected price of housing constrains consumption for two reasons. First, their initial housing stock is less valuable and, second, the expected real value of their collateral falls. These effects resemble the ones discussed in Callegari (2007) who shows that in the presence of durable goods, a positive government spending shock no longer leads to an increase in consumption as in a model with rule-of-thumb consumers considered in Galí et al. (2007).

Given the strong link between consumption and the shadow values of income and housing, it is easy to imagine that a rise in consumption following a government spending shock would solve the problem of the counterfactual decline in house prices automatically. To explore whether this is true, we examine three extensions of the baseline model which have been previously considered in the literature to make the response of consumption to government spending shocks consistent with the SVAR evidence. We clarify why these preference modifications are not successful and that the fall in house prices after a positive government spending shock remains a robust property of the DSGE framework. The extensions include Edgeworth complementarity between private and public consumption (Feve et al. (2013), Bouakez and Rebei (2007)), non-separable preferences (Greenwood et al. (1988)), and deep habits (Ravn et al. (2006)). We also consider a case with flexible housing supply to demonstrate that the counterfactual fall in house prices does not depend on housing supply being fixed. In addition to these extensions, we consider monetary policy accommodation of government spending shocks. The particular specification is similar to that in Nakamura and Steinsson (2013) and allows the possibility of a fall in the real interest rate which provides an incentive to increase current consumption, and hence, offset the negative wealth effect. We present evidence that both nominal and real interest rates fall after a positive government spending shock to motivate accommodative monetary policy as a channel that contributes to this decline in the real interest rate. For strong accommodation, house prices and total consumption increase after a positive government spending shock. But the model does not deliver the persistent rise in house prices and consumption as evident from the SVAR findings, and, therefore, accounting for the observed evidence remains a significant challenge for DSGE models of housing.

The rest of the paper is organized as follows. Section 2 presents the empirical evidence. Section 3 presents a benchmark DSGE model of housing and discusses the effects of government spending shocks on house prices, consumption, and other model variables. Section 4 presents a number of extensions of the benchmark model. Section 5 considers accommodative monetary policy. Section 6 concludes.

2 Empirical Evidence

The point of departure for our empirical analysis is the seminal paper by Blanchard and Perotti (2002), which examines the effect of fiscal shocks in a structural VAR with government spending, revenues and output. Changes in fiscal variables – government purchases and tax revenues – can result from discretionary policy action or automatic responses to innovations in output.[7] Fiscal shocks are then identified by assuming that discretionary fiscal responses do not occur within the same quarter as any innovation in output. By the time policy-makers realize that a shock has affected the economy, and go through the planning and legal processes of implementing an appropriate policy response, a quarter would have passed. Non-discretionary responses, on the

[7]For example, an exogenous increase in output may result in an increase in total tax revenues if the tax base increases and tax rates remain the same.

other hand, can be identified through spending or revenue elasticities of output either estimated using institutional information or through auxiliary regressions. In this setting, any innovation to fiscal variables that are not predicted within the VAR system are interpreted as unexpected shocks to spending or revenues.

Since we are interested in estimating the effects of government spending shocks only (and not the effects of taxes on output), the timing assumption essentially reduces to a Cholesky-ordering of the VAR with government spending ordered first.[8] Specifically, this implies that other shocks in the system do not affect government spending within a quarter, while government spending affects the remaining variables in the same quarter. This approach has been widely used (see Galí et al. (2007), Fatas and Mihov (2001)) in demonstrating that increases in government spending raise output, consumption and wages. We start by following these earlier studies and estimating a quarterly VAR in $\mathbf{X_t} = \begin{bmatrix} G_t & T_t & Y_t & C_t & Q_t \end{bmatrix}'$ with four lags, a constant, and linear and quadratic time trends as follows:

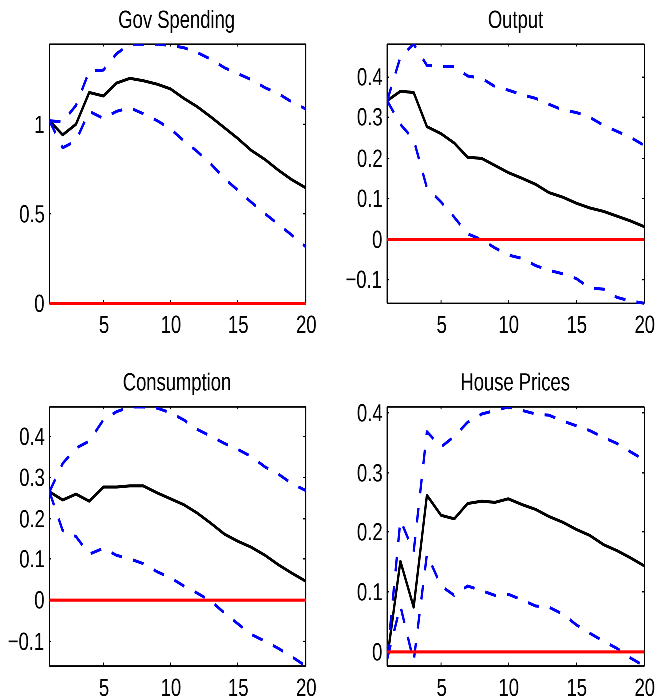
$$\mathbf{X}_t = \alpha_0 + \alpha_1 t + \alpha_2 t^2 + A(L)\mathbf{X}_{t-1} + e_t$$

Here, $A(L)$ is a lag polynomial of degree 4, G_t is government consumption and gross investment, T_t is government tax receipts less transfer payments, Y_t is output, C_t is total private consumption less consumption of housing services and utilities, and Q_t is an index of the median price of new houses. All variables are deflated by the GDP deflator. All variables, except Q_t, are expressed in log per-capita terms. The data span from the third quarter of 1963 through the last quarter of 2007. The start date is limited by the availability of house prices, and the end date set to exclude the 2008 financial crisis. Government spending shocks are then identified as a Cholesky-ordered innovation to G_t. Figure 1 shows the impulse responses of a one standard deviation shock to government spending in this baseline VAR specification, along with Monte Carlo confidence intervals. The responses of all the variables are expressed in standard-deviations from their respective means. Clearly, following a positive government spending shock, both consumption and house prices rise in a persistent manner.

Ramey (2011), however, argues that if fiscal shocks are anticipated by private agents, the

[8] For the effects of taxation on output, see Romer and Romer (2010) and Mertens and Ravn (2012), who provide evidence on the aggregate effects of tax shocks in the U.S. and Cloyne (2013) for the U.K.

Figure 1: **Impulse responses of key variables to a government spending shock, controlling for anticipation effects**



Notes: Government spending shock is identified as a Cholesky-ordered shock to the forecast error. Confidence bands show the 16th and 84th percentile of the related distribution from 1000 Monte Carlo simulations.

above identification scheme will be misleading. The timing of the shock plays a crucial role in identification. Alongside decision lags, there may be implementation lags in realizing fiscal policy. Often, governments announce their intended spending in advance, and the actual spending occurs in a staggered manner over a longer period of time. Private agents, then, would anticipate government spending well in advance and adjust their optimal consumption behaviour accordingly, while the econometrician would only see the effect of the policy when actual spending increases. If, contrary to the finding of Blanchard and Perotti (2002), private consumption were to decline upon the announcement of future increases in spending, a mis-timed VAR analysis would only capture the return of consumption to steady state, and not the initial decline. Thus, the econometrician will mistakenly infer that consumption rises following a spending increase.[9]

The anticipation problem arises because private agents have access to more information than the econometrician, which allows them to develop a forecast of government spending that the econometrician does not observe.[10] We consider two approaches that can help account for the anticipation effects and also mitigate the invertibility problem. First, we include variables containing private sector forecasts of future spending in the VAR specification. Following Auerbach and Gorodnichenko (2012), we control for the forecastable components by including in the VAR a variable that captures forecasted government spending from two sources: (i) the Survey of Professional Forecasters (SPF) and (ii) forecasts prepared by the Federal Reserve Board staff for the meetings of the Federal Open Market Committee (Greenbook). The SPF forecasts are available from 1982 onward, while the Greenbook forecasts are available from 1966 through 2004. We take the variable used in Auerbach and Gorodnichenko (2012) generated by splicing the two series to create a continuous forecast series starting in 1966.[11] The variable contains forecasts made in period $t-1$ for the period-t spending value. We augment the baseline VAR by considering $\hat{\mathbf{X}}_t = \begin{bmatrix} FE_t^G & G_t & T_t & Y_t & C_t & Q_t \end{bmatrix}'$, where FE_t^G is the forecast error for the growth rate of government spending. The unanticipated shock, then, is identified as the innovation in the forecast error itself, rather than an innovation to G_t.

Second, following Forni and Gambetti (2011), we estimate a factor-augmented VAR (FAVAR) with 110 variables, 13 static factors, 4 lags and 6 structural shocks.[12] We identify government

[9] Using narrative records of government accounts, Ramey and Shapiro (1998) and Ramey (2011) identify spending shocks as dates when a large amount of national defence spending was announced and find that consumption declines following a positive fiscal shock. The anticipation issue is emphasized in Ramey (2011) by showing that lagged defence spending dates Granger cause the VAR shocks identified by Blanchard and Perotti (2002), suggesting that their identification scheme misses information already available to private agents. Auerbach and Gorodnichenko (2012) also finds that a sizeable fraction of innovations identified by VAR is predictable. Specifically, they find that residuals from projecting private sector forecasts of government spending growth on lags of variables included in the VAR is positively correlated with residuals from projecting actual government spending growth on the same variables. If the VAR innovations were unexpected, then the two residuals should be unrelated.

[10] As discussed in Leeper et al. (2011), this issue can cause an invertibility problem, in that, it may not be possible to recover the structural shocks facing private agents from the identified shocks. Finding ways to address this issue is an area of ongoing research. See, for example, Dupor and Han (2011), Forni and Gambetti (2011), and Sims (2012).

[11] We thank Yuriy Gorodnichenko for providing us with the data on government spending forecasts.

[12] The dataset is almost identical to Forni and Gambetti (2011), with few exceptions, and is described in a separate appendix available upon request. All data are in quarterly frequencies and cover the period from 1963:1 through 2007:4.

spending shocks by imposing the following sign restrictions on the impulse response functions: total government spending, federal government spending, total government deficit, federal government deficit and output all increase in the fifth quarter following the shock. Imposing the restriction a few quarters after the impact period allows for anticipation effects. This strategy, however, does not allow us to differentiate between an expected and an unexpected shock.

Figure 2 shows the impulse responses of a shock to the one-step-ahead forecast error of government spending in the expectation-augmented VAR specification.[13] The differences in the shape of the IRF's suggest that expectations do play a role in determining the effects of government spending shocks. While in the baseline case (Figure 1), the largest effect of an increase in spending occurs in the first period, we see that the largest effect on output and consumption occurs about 5 quarters after the spending shock impact (Figure 2). Even after controlling for expectations, however, house prices clearly increase in a persistent manner following an unanticipated government spending shock.

Figure 3 shows the impulse responses for the FAVAR specification along with one-standard error boot-strapped confidence bands. The FAVAR specification also confirms that house prices and consumption increase following a government spending shock.

To summarize, empirical evidence suggests that house prices rise in a persistent manner after a positive government spending shock. We now turn to a DSGE model to examine channels through which government spending shocks may affect house prices, and account for the observed evidence.

3 A DSGE Model with Housing

We consider a DSGE model with housing based on Iacoviello (2005) with an exogenous fixed supply of housing and determine the effects on government spending shocks on house prices in this model.[14]

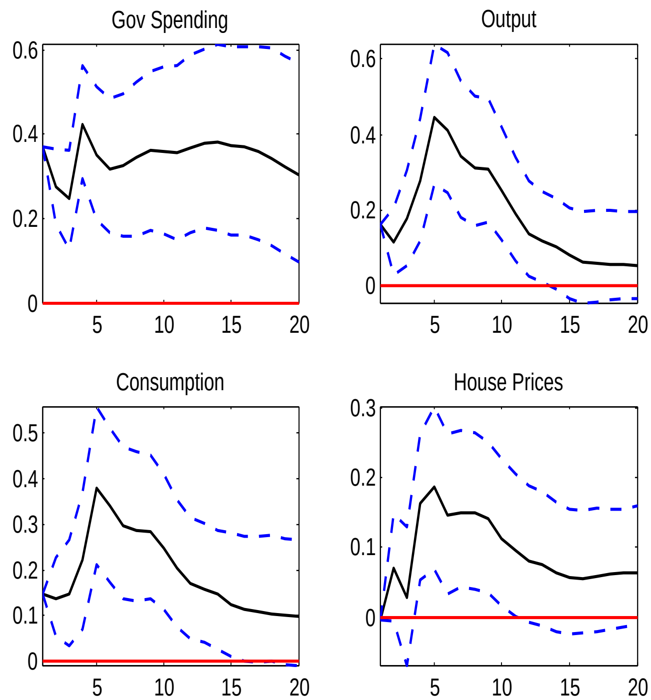
3.1 Households

There are two types of agents in the economy characterized by their different rates of time preference. The size of the total population is normalized to one. A fraction, $0 < \alpha < 1$, of the population

[13]The shock gives a 0.4*standard deviation increase in actual government spending on impact.

[14]As we show in the next section, introducing housing production as in Iacoviello and Neri (2010) does not change the conclusions obtained relative to the fixed supply case.

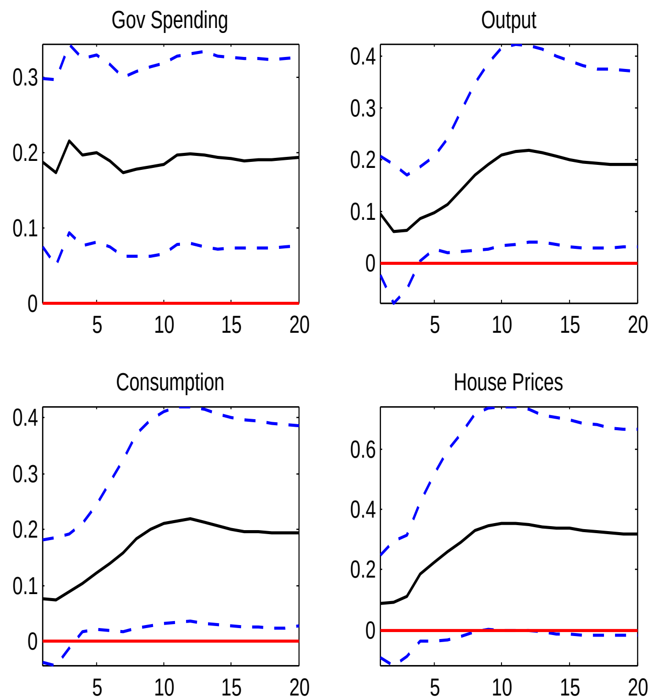
Figure 2: **Impulse responses of key variables to a government spending shock, controlling for anticipation effects**



Notes: The VAR specification includes one-step-ahead forecast errors from private sector forecasts of government spending (Auerbach and Gorodnichenko (2012)). Government spending shock is identified as a Cholesky-ordered shock to the forecast error. Confidence bands show the 16th and 84th percentile of the related distribution from 1000 Monte Carlo simulations.

are impatient agents who discount the future at a rate higher than patient agents. Both agents receive utility from consuming a non-durable good, from the services of the stock of housing they own, and from leisure. In addition, only the patient agents hold government debt, and own physical capital which they rent out to the production sector. Both agents supply labour services to the production sector. In this setting, patient households are net lenders and impatient households are net borrowers in the steady state. Due to the presence of financial frictions, the borrowers face a constraint on the amount they can borrow in each period by using their stock of housing as collateral. As in Iacoviello (2005), the amount of uncertainty in the economy is small enough

Figure 3: **Impulse responses of key variables to a government spending shock from a FAVAR specification**



Notes: Government spending shock identified using sign restrictions specifying an increase in total and federal government spending, deficits and read output on the 5th quarter following the shock. Bootstrapped confidence bands show the 16th and 84th percentile of the related distribution

such that for borrowers, the effect of impatience on borrowing always dominates the precautionary motive for self-saving and consequently the collateral constraint is always binding in equilibrium.

The optimization problems of patient-lenders and impatient-borrowers are to maximize the expected discounted lifetime utility given by

$$E_0 \sum_{t=0}^{\infty} \beta_j^t \left[\ln c_t^j + \Upsilon^j \ln h_t^j - \frac{1}{1+\eta} \left(n_t^j \right)^{1+\eta} \right]$$

where $j = \ell$ for the patient-lenders and $j = b$ for the impatient-borrowers. The variables c_t, h_t, and n_t denote non-durable consumption, housing services, and labour supplied to the production sector, respectively.[15] The parameters β_j, Υ^j, and η denote the discount factor, the weight of housing in

[15]We assume that housing services are proportional to housing stock and normalize the constant of pro-

the utility function, and the inverse Frisch elasticity of labour supply, respectively.

The budget constraint facing a patient-lender is

$$c_t^\ell + q_t h_t^\ell + i_t + b_t^g + b_t = w_t n_t^\ell + q_t h_{t-1}^\ell + r_t k_{t-1} + d_t^\ell + \frac{r_{t-1}^n b_{t-1}^g}{\pi_t} + \frac{r_{t-1}^n b_{t-1}}{\pi_t} - \tau_t^\ell \tag{1}$$

where q_t is the relative price of housing stock, k_t is capital rented out to the production sector, r_t is the real rental return on capital, and i_t is gross investment. Alongside investing in capital, patient households own firms in the production sector from which they receive dividends, d_t^ℓ, lend an amount b_t (in real terms) to borrowers, and hold government debt b_t^g (in real terms), both for the same rate of real gross return r_{t-1}^n/π_t, where r_{t-1}^n is the nominal interest rate and π_t is the gross inflation rate. Finally, τ_t^ℓ is a lump-sum tax imposed by the government on patient-lenders. The capital accumulation process is given as

$$k_t = (1-\delta)k_{t-1} + \phi\left(\frac{i_t}{k_{t-1}}\right)k_{t-1} \tag{2}$$

Where δ is the capital depreciation rate, $\phi(.)$ denotes capital adjustment costs which are increasing, concave, and homogenous of degree zero in the rate of investment, with $\phi'(i/k) = 1$, and $\phi(i/k) = i/k$, implying zero costs in the steady state. The budget constraint facing the impatient-borrowers is

$$c_t^b + q_t h_t^b + \frac{r_{t-1}^n b_{t-1}}{\pi_t} = w_t n_t^b + q_t h_{t-1}^b + b_t - \tau_t^b \tag{3}$$

where τ_t^b is a lump-sum tax. The impatient-borrowers also face a collateral constraint

$$b_t \leq m E_t \left\{\frac{q_{t+1} h_t^b \pi_{t+1}}{r_t^n}\right\} \tag{4}$$

which says that the real debt service due next period cannot exceed a fraction $m \in [0,1]$ of the expected real value of the housing stock held as collateral. Since only a fraction $0 < m < 1$ of the expected discounted value of housing stock is available for borrowing, $(1-m)$ can be interpreted as a down-payment requirement, and m the loan-to-value (LTV) ratio.

portionality to one. This means that housing services are a depreciation weighted sum of the housing service flows. Since housing is durable by definition its depreciation is typically small implying a low flow-stock ratio. We assume a zero depreciation rate in the benchmark model. Allowing for a small positive depreciation does not affect any of the conclusions as shown in the appendix.

Denoting the Lagrange multipliers on the constraints (1) and (2) as λ_{1t}^{ℓ} and λ_{2t}^{ℓ}, respectively, the first-order necessary conditions for the patient-lenders which characterize the optimal choices of their consumption, labour supply, housing, investment, capital, lending and government bonds are as follows:

$$\begin{aligned}
\frac{1}{c_t^{\ell}} &= \lambda_{1t}^{\ell} \\
\frac{\left(n_t^{\ell}\right)^{\eta}}{w_t} &= \lambda_{1t}^{\ell} \\
\frac{\Upsilon^{\ell}}{h_t^{\ell}} &= \lambda_{1t}^{\ell} q_t - \beta_{\ell} E_t[\lambda_{1t+1}^{\ell} q_{t+1}] \\
1 &= \psi_t \phi' \left(\frac{i_t}{k_{t-1}}\right) \\
\psi_t &= \beta_{\ell} E_t \left[\frac{\lambda_{1t+1}^{\ell}}{\lambda_{1t}^{\ell}} \left(r_{t+1} + \psi_{t+1} \left((1-\delta)\phi\left(\frac{i_{t+1}}{k_t}\right) - \phi'\left(\frac{i_{t+1}}{k_t}\right)\frac{i_{t+1}}{k_t}\right)\right)\right] \\
1 &= \beta_{\ell} E_t \left[\frac{\lambda_{1t+1}^{\ell}}{\lambda_{1t}^{\ell}} \frac{r_t^n}{\pi_{t+1}}\right]
\end{aligned}$$

where ψ_t, defined as $\lambda_{2t}^{\ell}/\lambda_{1t}^{\ell}$, represents the marginal value of capital in terms of the consumption, or the Tobin's Q, with (1) and (2) satisfied at the optimum.

Denoting the Lagrange multipliers on the constraints (3) and (4) as λ_{1t}^{b} and λ_{2t}^{b}, respectively, the first-order-conditions for the impatient-borrowers that characterize the optimal choices of their consumption, labour supply, housing, and borrowing are as follows:

$$\begin{aligned}
\frac{1}{c_t^{b}} &= \lambda_{1t}^{b} \\
\frac{\left(n_t^{b}\right)^{\eta}}{w_t} &= \lambda_{1t}^{b} \\
\frac{\Upsilon^{b}}{h_t^{b}} &= \lambda_{1t}^{b} q_t - \beta_b E_t \left[\lambda_{1t+1}^{b} q_{t+1}\right] - \lambda_{2t}^{b} m E_t \left[\frac{q_{t+1}\pi_{t+1}}{r_t^n}\right] \\
\lambda_{1t}^{b} &= \beta_b E_t \left[\lambda_{1t+1}^{b} \frac{r_t^n}{\pi_{t+1}}\right] + \lambda_{2t}^{b}
\end{aligned}$$

with (3) and (4) satisfied at the optimum.

3.2 Firms

The production side in this model follows the standard New Keynesian approach which we describe in the appendix. There is a perfectly competitive final good sector in which firms produce a non-durable consumption good, y_t, using a continuum of intermediate goods, $x_t(s)$ with $s \in [0,1]$, produced by monopolistically competitive firms which face nominal price rigidities following the Calvo (1983) approach. Inflation dynamics in the model are characterized by the new Keynesian Phillips curve.

3.3 Fiscal and monetary policies

We follow Galí et al. (2007) for the fiscal policy specifications. The government faces a budget constraint of the form (in real terms):

$$\tau_t + b_t^g = \frac{r_{t-1}^n b_{t-1}^g}{\pi_t} + G_t$$

where τ_t is lump-sum tax revenue (which equals $(1-\alpha)\tau_t^\ell + \alpha\tau_t^b$) and G_t is government spending.[16] The government sets taxes according to the following fiscal rule

$$\tilde{\tau}_t = \varrho_b \tilde{b}_t^g + \varrho_g \tilde{g}_t$$

where $\tilde{g}_t \equiv \frac{G_t - G}{Y}$, $\tilde{\tau}_t \equiv \frac{\tau_t - \tau}{Y}$ and $\tilde{b}_t^g \equiv \frac{B_t - B}{Y}$ are deviations of the fiscal variables from a steady state with zero debt and balanced primary budget (normalized by steady-state level of output), respectively. Parameters ϱ_b and ϱ_g are weights assigned by the fiscal authority on debt and current government spending. Note that government debt is not modelled as discountable bonds, and pays nominal gross interest r_t^n each period. This form of government debt makes it easier to compare intertemporal decisions of households across different saving instruments. Government purchases are assumed to follow an exogenously determined auto-regressive process

$$\tilde{g}_t = \rho_g \tilde{g}_{t-1} + \varepsilon_t$$

where $0 < \rho_g < 1$ and ε_t is an i.i.d. government spending shock with variance σ_ε^2.

We assume that monetary policy is characterized by a Taylor rule with interest rate smoothing which determines the nominal interest rate in the economy as a function of inflation, output, and the previous period nominal interest rate. This rule is given as

$$\hat{r}_t^n = \varrho_r \hat{r}_{t-1}^n + (1-\varrho_r)(\varrho_\pi \hat{\pi}_t + \varrho_y \hat{y}_t)$$

[16] We have also considered distortionary labour taxes instead of lump-sum taxes, and have found house prices to decline. These results are available upon request.

where $\varrho_\pi > 1$ (i.e., the Taylor principle holds), $\varrho_y > 0$, and $0 < \varrho_r < 1$ are the policy rule parameters.

3.4 Aggregation

Aggregate consumption, labor and housing (all denoted in upper case) are weighted averages of the variables corresponding to patient-lenders and impatient-borrowers and are given as

$$\begin{aligned} C_t &= \alpha c_t^b + (1-\alpha)\, c_t^\ell \\ N_t &= \alpha n_t^b + (1-\alpha)\, n_t^\ell \\ H &= \alpha h_t^b + (1-\alpha)\, h_t^\ell \end{aligned}$$

Since capital is owned only by patient-lenders, aggregate investment and capital are given as

$$\begin{aligned} I_t &= (1-\alpha) i_t \\ K_t &= (1-\alpha) k_t \end{aligned}$$

Finally, the aggregate resource constraint is given as

$$C_t + I_t + \phi\left(\frac{I_t}{K_{t-1}}\right) K_{t-1} + G_t = Y_t \approx K_{t-1}^{\gamma} N_t^{1-\gamma}$$

where the aggregate production function holds up to a first-order approximation as shown in Woodford (2003). The economy is in equilibrium when all the first-order necessary conditions are satisfied and all the goods and factor markets clear.

3.5 Linearization, calibration, and model solution

We log-linearize the first-order optimality conditions of the households and firms, and the aggregate market clearing conditions around a steady state. We use hats on variables to denote the percentage deviations from their steady-state values, respectively. We linearize the government budget constraint (5) around a steady state with zero debt and primary balanced budget.[17]

[17] Note that hatted variables are expressed in percentage deviations, i.e., deviations from their steady state values, normalized by their steady state values. Government variables marked with a tilde, on the other hand, are deviations from their steady state values, normalized by the steady-state level of output. In other words, $\hat{X}_t = \ln X_t - \ln X \approx \frac{X_t - X}{X}$ and $\tilde{X}_t = \frac{X_t - X}{Y}$ where Y is steady-state level of output.

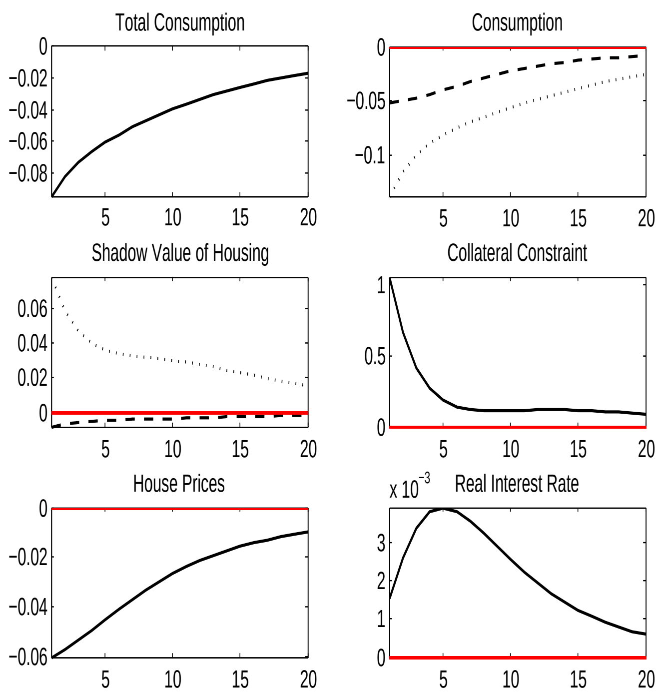
The model is set in a quarterly frequency. The discount factors of the patient-lenders and the impatient-borrowers are set to 0.9925 and 0.97, respectively. Iacoviello and Neri (2010) and Iacoviello (2005) consider this calibration value as it ensures that the borrowing constraint is binding in equilibrium. The captial share of output, γ, is set to 0.33, and the depreciation rate, δ, is set to 0.025. We assume a steady-state price markup of 0.15, implying a steady-state marginal cost, mc, of $\frac{1}{1.15} \approx 0.87$. The inverse of the Frisch-elasticity of labour supply, η, is set to 1. The elasticity of capital adjustment cost parameter, $\phi''(\frac{i}{k})$, is set to -14.25, to match the corresponding parameter estimated by Iacoviello and Neri (2010) using Bayesian methods. The benchmark value of $\frac{K}{Y}$ and $\frac{qH}{Y}$ is taken from Iacoviello and Neri (2010). The latter value corresponds to the total value of household real estate assets in the US, as specified in the Flow of Funds Account (B.100 line 4). We set the Calvo price-adjustment frequency to 0.75, corresponding to an average price duration of one year, and the Taylor rule parameter measuring the response of the monetary authority to inflation, ϱ_π, to 1.5, a value commonly used in the literature. We match the benchmark values of the fiscal response parameters to those in Galí et al. (2007), and set the tax response to government spending, ϱ_g, to 0.1, the tax response to outstanding government debt, ϱ_b, to 0.33, and the persistence of government shock, ρ_g, to 0.9.

The dynamics presented in this paper depend importantly on the different optimal responses of patient-lenders and impatient-borrowers to a government spending shock. The exposition of these differences in dynamics become easier if we start off the two households with identical consumption and housing levels. As such, we set $\frac{c^\ell}{Y} = \frac{c^b}{Y} = \frac{C}{Y} = 0.5$ and $\frac{qh^\ell}{Y} = \frac{qh^b}{Y} = \frac{qH}{Y}$. The first can be easily achieved by assuming different levels of steady-state lump-sum taxes.[18] The latter can be achieved by setting different values for the weight of housing in utility. Accordingly, we set Υ^ℓ to 0.0816 and Υ^b to 0.1102. The benchmark loan-to-value ratio is set at 0.85, following Iacoviello and Neri (2010), and the implications of changing this value is reported in the appendix. The main result that we highlight in this paper arises as long as the proportion of savers (Ricardian agents), $1-\alpha$, in the economy is positive.[19] The rule-of-thumb literature often sets the proportion of non-Ricardian agents to 0.5. We therefore set the benchmark value of α to 0.5 for ease of exposition. Table 1

[18]See the discussion in Galí et al. (2007).

[19]Iacoviello and Neri (2010) estimate the proportion of borrowers α to be 0.21, and consequently, the proportion of savers to be 0.79.

Figure 4: **Effects of a positive government spending shock in the benchmark DSGE model**



Notes: For the responses of shadow value of housing and consumption, the dashed line is for lenders and dotted line is for borrower.

summarizes the calibration values. We use Dynare to solve the model.[20]

3.6 The effects of government spending shocks on house prices and consumption

Figure 4 presents the effects of a one standard deviation positive shock to government spending for the benchmark calibration reported in Table 1. The relative price of housing falls immediately after a positive government spending shock. This response is in sharp contrast to the evidence presented in section 2 and the key finding that we wish to study from the perspective of a DSGE model.

Why does the relative price of housing fall after a positive government spending shock? The intuition follows from the approximately constant shadow value of housing for lenders. Housing

[20]See Adjemian et al. (2011) and http://www.dynare.org/.

is a long-lived good and provides a service-flow for many periods in the future. The property of near-constant shadow value of long-lived goods was first pointed out in Barsky et al. (2007) in the context of durable goods and temporary monetary policy shocks. We can define the shadow value of housing for the patient-lender as $v_t^\ell \equiv \lambda_{1t}^\ell q_t$ and, using the first-order-condition for optimal housing, express it in log-linearized form as

$$\hat{v}_t^\ell \equiv \hat{\lambda}_{1t}^\ell + \hat{q}_t = (\beta_\ell - 1) E_t \left[\sum_{s=0}^{\infty} \beta_\ell^s \hat{h}_{t+s}^\ell \right] \tag{5}$$

$$\approx 0 \tag{6}$$

There are two key features which make the deviations of shadow value of housing from its steady state, $\hat{v}_t^\ell$, approximately zero, as indicated in (6). First, the housing flows do not contribute much to the variation in the stock which means that the marginal utility of housing remains close to its steady state (i.e., the $\hat{h}_{t+s}^\ell$ terms are close to zero). Second, temporary government spending shocks have little influence on future marginal utility of housing (i.e., the $\hat{h}_{t+s}^\ell = 0$ as s increases). Now, a temporary positive government spending shock induces a negative wealth effect and causes the patient-lenders to reduce current consumption. This reduction in current consumption raises the marginal utility of consumption, $\hat{\lambda}_{1t}^\ell > 0$. Since the shadow value of housing is approximately zero, it implies that the the price of housing necessarily falls relative to its steady state value, i.e, $\hat{q}_t < 0$.

Two additional price and income effects magnify the increase in the marginal utility of lenders' consumption. First, as government spending increases output and inflation, the central bank's monetary policy implies an increase in the real interest rate which lowers current consumption. This price effect arises independent of the type of preferences. Second, the decline in the relative price of house lowers housing asset income for the lenders and exerts an additional negative income effect.

It is important to note that this result does not depend on the structure of the labour market. Following Galí et al. (2007), we consider a departure from competitive labour markets and set wages by unionized bargaining where marginal disabilities of labour supplies are equated among the two types of agents. The result remain the same.[21] Moreover, Andres et al. (2012) introduce job search

[21] Available upon request.

and unionized bargaining to provide a significant departure from the competitive labour market we consider here. Yet, even under that labour market structure they report that house prices fall.[22] Thus, relative to the SVAR evidence reported in section 2, the counterfactual response of housing to a government spending shock arises not only in the benchmark model but also in variants with a richer labour market structure.

In contrast to the patient-lenders, the shadow value of housing for the impatient-borrowers rises after the government spending shock. This rise reflects the desire to increase housing to use it as collateral for future consumption. From (5), we define the shadow value of housing to the impatient-borrower as $v_t^b \equiv \lambda_{1t}^b q_t$ and express it in log-linearized form (after simplifying the coefficients using steady state conditions) as

$$\begin{aligned} \hat{v}_t^b \equiv \hat{\lambda}_{1t}^b + \hat{q}_t &= (\beta_b - 1)\, E_t \sum_{s=0}^{\infty} \beta_b^s \hat{h}_{t+s}^b \\ &+ m(\beta_\ell - \beta_b) E_t \sum_{s=0}^{\infty} \beta_b^s \left(\hat{\lambda}_{2t+s}^b + \hat{\pi}_{t+1+s} - \hat{r}_{t+s}^n + \hat{q}_{t+1+s} + \hat{h}_{t+s}^b \right) \end{aligned} \tag{7}$$

The increase in the shadow value of housing, $\hat{v}_t^b > 0$, is driven by the sharp tightening of the current and expected future collateral constraints $\hat{\lambda}_{2t+s}^b (> 0)$, as shown in Figure 4.

Turning to the response of consumption, the patient-lenders' consumption always falls after a positive government spending shock as mentioned earlier. Consumption of the impatient-borrowers falls even further because on top of the negative wealth effect from increased future tax payments, the value of their collateral declines when house prices fall. This lowers their ability to borrow, which in turn, lowers consumption. Total consumption and investment are crowded out while output rises after the positive government spending shock.[23]

[22]See Figures 2, 3, and 4 in Andres et al. (2012). Since Andres et al. (2012) focus on studying fiscal multipliers, they do not examine whether the house price response to a positive government spending shock is consistent with empirical evidence as we do.

[23]These responses are consistent with those reported in Callegari (2007) who focuses on how in the presence of durable goods the response of consumption to government spending shock changes relative to when rule-of-thumb consumers are considered as in Galí et al. (2007).

4 Can house prices *rise* in a DSGE model with housing after a positive government spending shock?

From section 3, it is evident that house prices fall after a positive government spending shock because marginal utility of lenders' consumption rises due to a combination of negative wealth effects and the real interest rate effect. In this section we consider four extensions of the benchmark model to determine whether the modified model can deliver a positive joint response of house prices and consumption to government spending shocks. This is important for two reasons. First, regardless of the dynamics of house prices, consumption should rise following a government spending shock as it does in the data for a model to have meaningful implications for policy analysis. Second, given the strong relationship between consumption, the shadow value of income and that of housing, as explained earlier, it is reasonable to explore whether adopting a mechanism that allows consumption to rise following a government shock automatically imply a rise in house prices.

The first three extensions are different modifications of the preferences which have been previously considered in the literature to make the response of consumption to government spending shocks consistent with the SVAR evidence. Our motivation to consider them here is to clarify whether or not they are sufficient in overcoming the negative wealth effects and the real interest rate effect discussed in the previous section. The fourth adds housing production and nominal rigidities to the benchmark model to clarify if the fixed supply of housing is the source of the decline in house prices in the model.

4.1 Edgeworth complementarity between government and private spending

One potential channel through which government spending can influence house prices may be that government spending affects the quality of neighbourhoods in which new houses are built. For example, expenditure on roads, public parks, and civic amenities may make consumption and housing more desirable and may contribute to house price increases. To determine the consequences of this channel, we consider private consumption (both non-durable and housing) and government spending to be *Edgeworth complements* in the utility function. This means that an increase in government spending increases the marginal utility of both private consumption and housing, and hence creates an incentive for the agents to increase their demands. Clearly, this consideration provides a channel that can potentially dampen or even offset the negative wealth effect on consumption that underlies the problem discussed in section 3.6 above. Feve et al. (2013) have recently provided evidence that private consumption and government spending are Edgeworth complements in the U.S. economy. Previously, Bouakez and Rebei (2007) and Karras (1994) also found evidence for this property in the U.S. and international data, respectively.[24]

Consider the following preference structure for $j = \ell, b$

$$U(c_t^j, h_t^j, n_t^j; G_t) = \ln(c_t^j + a_c G_t) + \Upsilon^j \ln(h_t^j + a_h G_t) - \frac{1}{1+\eta}(n_t^j)^{1+\eta}$$

If $a_c < 0$ and $a_h < 0$ then consumption and housing are Edgeworth complements in utility with government spending, respectively. The first-order conditions of patient-lenders for optimal consumption and housing are

$$\frac{1}{c_t^\ell + a_c G_t} = \lambda_{1t}^\ell$$

$$\frac{\Upsilon^\ell}{h_t^\ell + a_h G_t} = \lambda_{1t}^\ell q_t - \beta_\ell E_t[\lambda_{1t+1}^\ell q_{t+1}]$$

After log-linearizing the above two equations we get

$$\left(\frac{-1}{1 + a_c\left(\frac{G}{c^\ell}\right)}\right)\hat{c}_t^\ell - \left(\frac{1}{1 + \frac{1}{a_c}\left(\frac{c^\ell}{G}\right)}\right)\hat{g}_t = \hat{\lambda}_{1t}^\ell$$

and

$$\frac{-1}{1 + a_h\left(\frac{G}{h^\ell}\right)}\hat{h}_t^\ell - \frac{1}{1 + \frac{1}{a_h}\left(\frac{h^\ell}{G}\right)}\hat{g}_t = \frac{1}{1-\beta_\ell}(\hat{q}_t + \hat{\lambda}_{1t}^\ell) - \frac{\beta_\ell}{1-\beta_\ell}E_t[\hat{q}_{t+1} + \hat{\lambda}_{1t+1}^\ell]$$

[24] A large body of literature has considered utility function specifications in which government spending and private consumption are either Edgeworth substitutes or complements. A few early examples include Barro (1981), Kormendi (1983), Aschauer and Greenwood (1985), and Bean (1986), McGrattan (1994), Karras (1994), Ni (1995), Ambler and Paquet (1996), Finn (1998), Amano and Wirjanto (1998), Linnemann and Schabert (82), Bouakez and Rebei (2007), and Feve et al. (2013). A utility specification where government spending enters the utility function but does not affect marginal utility of private consumption is considered in Baxter and King (1993).

This preference structure opens up the possibility of breaking the quasi-constancy property associated with durable housing. To illustrate this point, consider the case where only housing and government expenditures are Edgeworth complements (i.e. $a_c = 0$), so that the interpretation of λ_t^ℓ is the same as in the benchmark case.[25] The shadow value of housing is now given as

$$\hat{\lambda}_{1t}^\ell + \hat{q}_t = \frac{(\beta_\ell - 1)}{1 + a_h\left(\frac{G}{h^\ell}\right)} \underbrace{E_t \sum_{s=0}^{\infty} \beta_\ell^s \left(\hat{h}_{t+s}\right)}_{\approx 0} + \frac{(\beta_\ell - 1)}{1 + \frac{1}{a_h}\left(\frac{h^\ell}{G}\right)} \underbrace{E_t \sum_{s=0}^{\infty} \beta_\ell^s \left(\hat{g}_{t+s}\right)}_{\neq 0}, \quad a_h < 0 \tag{8}$$

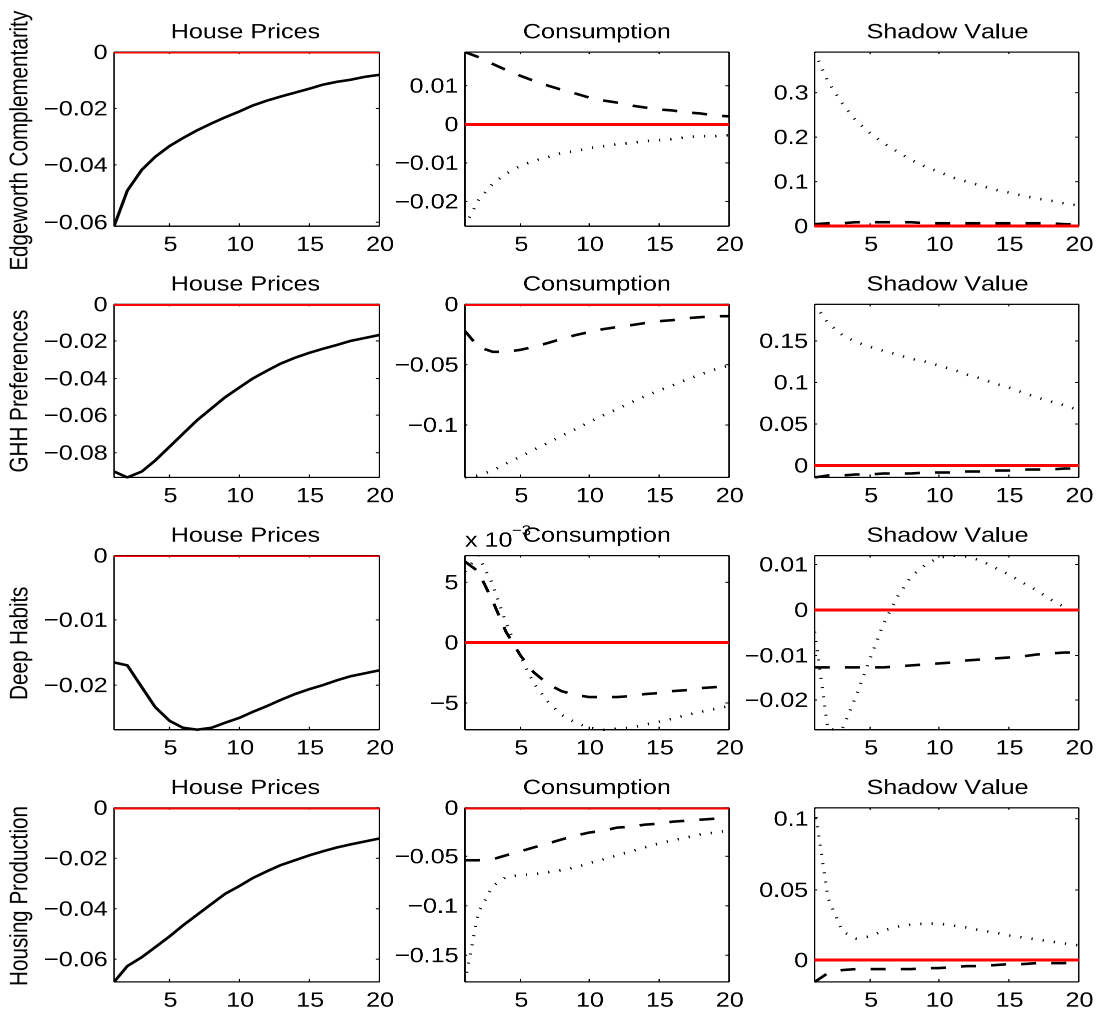
The right hand side of (8) shows that even if housing flows do not contribute much to the variation in the housing stock (and are approximately zero as in (5)) the variation in government purchases can contribute to the variation in the shadow value of housing.[26] Since $a_h < 0$, the shadow value of housing can increase after a positive government spending shock if the coefficient on the variation in government purchases is positive. This means that even if lender's consumption falls (hence $\hat{\lambda}_{1t}$ rises), q_t can still rise. And with $a_c < 0$, it is possible for the lender's consumption to rise as well.

Feve et al. (2013) estimate a value for $a_c^j = -0.95$. We find that this calibration value (for $j = \{\ell, b\}$) is insufficient to produce a rise in consumption following a government shock for either borrowers, or lenders. To illustrate our point in a clear fashion, we adopt a higher level of Edgeworth complementarity, e.g., $a_c^j = -1.5$, for which consumption for lenders can rise. As noted for the benchmark model, we choose the weight on housing Υ^j to obtain identical steady state housing level. Consequently, $\frac{h^\ell}{G} = \frac{h^b}{G} = \frac{H}{G}$. To calibrate H/G, we use the ratio of average housing wealth to total consumption, H/G, and government expenditure to consumption, G/C. The former is approximately 5 for the 1951-2006 period as calculated from the data in Ludvigson (2007). The latter is 0.15 in the U.S. data for the same time period.

Figure 5 (first row) shows the impulse responses for this calibration. Regardless of the fact that consumption of lenders is now positive, house prices fall. Note that the lender's shadow value of housing remains approximately zero. Thus the Edgeworth complementarity effect does not have a significant impact in breaking the quasi-constancy property. Rather, it simply changes the relationship between the marginal utility of consumption, λ_{1t}^j, and consumption relative to the

[25] Having $a_c < 0$ does not change either the intuition or the results in simulation for the point made here.
[26] Note that $\hat{g}_t = \frac{Y}{G}\tilde{g}_t$.

Figure 5: **Effects of government spending shocks: Special Preferences and Housing Production**



Notes: Row 1 for Edgeworth complementarity, Row 2 for GHH preferences + nominal rigidities, Row 3 for deep habits, and Row 4 for housing production+nominal rigidities. For the responses of shadow value of housing and consumption, the dashed line is for lenders and dotted line is for borrower.

benchmark model.[27]

[27]When either $a_h = 0$ or $a_c = 0$. The findings are similar to those in Figure 5. The rest of the model

4.2 Greenwood et al. (1988) preferences and nominal rigidities

Greenwood et al. (1988) (GHH) propose a special case of non-separable preferences which eliminate the wealth effects on labour supply. The key property of GHH preferences

$$U(c,n) = \underline{\mathrm{U}}(c - G(n))$$

is that the marginal rate of substitution of consumption for leisure is independent of consumption which implies that the labour supply relation depends only on the real wage. In the context of government spending shocks, Monacelli and Perotti (2009) show that assuming GHH preferences and nominal price stickiness can lead real wage and consumption to increase after a positive government spending shock.[28] As discussed above, the negative wealth effect on lenders which lowers their consumption is the reason why house prices fall in the model. Can GHH preferences and nominal price stickiness mitigate the negative wealth effect on lenders' consumption to allow an increase in house prices following a positive government spending shock? To answer this question, we consider GHH preferences over consumption, housing, and leisure

$$U(c_t^j, h_t^j, n_t^j) = \frac{1}{1-\gamma}\left[\left(x_t^j - \frac{(n_t^j)^{1+\eta}}{1+\eta}\right)^{1-\gamma} - 1\right], \quad j = \ell, b$$

where x_t^j is composite consumption which is an aggregate of non-durable consumption and housing given as

$$x_t^j = \left[(1-\psi_h^j)(c_t^j)^{1-\frac{1}{\rho}} + \psi_h^j(h_t^j)^{1-\frac{1}{\rho}}\right]^{\frac{\rho}{\rho-1}}$$

Parameter ρ is the elasticity of substitution between consumption and housing.[29] The labour supply

details are available upon request.

[28] Bilbiie (2009) provides a detailed general analysis of non-separable preferences and the conditions which allow for consumption to increase following a positive government spending shock. Cloyne (2011) considers the role of distortionary labour and capital taxes in the transmission of government spending shocks. Like Monacelli and Perotti (2009), both papers, however, consider only non-durable consumption. Kilponen (2012) considers non-separable preferences in the Iacoviello (2005) model to estimate a consumption Euler equation.

[29] Two recent papers have examined the role of non-separable preferences in resolving the Barsky et al. (2007) puzzle of lack of comovement between non-durable and durable consumption following a monetary shock. Kim and Katayama (2013) consider general non-separable preferences and Dey and Tsai (2011) consider GHH preferences.

relation is given as

$$n_t^j = \left[(1-\psi_h) w_t \left(\frac{x_t^j}{c_t^j} \right)^{1/\rho} \right]^{\frac{1}{\eta}}$$

Similar to Dey and Tsai (2011), the wealth effect on labour supply, n_t^j, is not eliminated as long as $\psi_h^j > 0$ (positive weight on housing in the utility function) and $\rho < \infty$ (i.e. consumption and housing are not perfectly substitutable). Since the negative wealth effect of government spending shock in the case of housing is even greater than in the case of non-durable consumption alone, the real wage and consumption can fall immediately after the positive government shock. Put differently, the combination of GHH preferences with sticky nominal prices of consumption is insufficient to deliver a positive consumption and real wage response to a government spending shock. The quasi-constancy property would imply that house prices also fall. Figure 5 (second row) shows house prices and consumption fall under the GHH preference specification.

4.3 Deep habits

Ravn et al. (2006) propose deep habits in consumer preferences as an alternative mechanism that can generate a positive response in private consumption following a government spending shock in an environment with imperfectly competitive product markets and flexible prices.[30] In contrast to superficial habits that are formed over the level of final consumption, deep habits imposes sluggishness in narrowly defined differentiated goods, over which monopolistically competitive firms have market power. This implies that the demand function facing firms has a price-elastic component that depends on lagged demand, as well as a price-inelastic component. Higher demand following increases in government spending raises the share of the price-elastic component, which in turn, induces firms to reduce the markup of price over marginal cost in a counter-cyclical manner. Since the markup and labour demand are negatively correlated, the latter rises, providing upward pressure on real wages. This effect makes households substitute leisure for consumption. As a result, consumption and wages both rise in the presence of deep habits. But, does this increase in

[30] Zubairy (2010a) extends these results to a sticky-price framework assuming Rotemberg (1982) adjustment costs. Jacob (2010) however, shows that the positive consumption response in a deep habits setting disappears if stickiness in prices are sufficiently high.

consumption result in rising house prices through the quasi-constancy property explained above? To answer this question, we impose deep habits in private and public consumption as in Zubairy (2010b) to the benchmark model, and consider a utility function for households given as

$$U\left(x_t^j, h_t^j, n_t^j\right) = \frac{1}{1-\sigma}\left[\left(\left(x_t^j\right)^{\psi_c}\left(h_t^j\right)^{\psi_h}\left(1-n_t^j\right)^{1-\psi_c-\psi_h}\right)^{1-\sigma} - 1\right], \quad j = \ell, b$$

where $\sigma \geq 0$ is the coefficient of relative risk aversion, and x_t^j is a composite of habit-adjusted consumption of a continuum of differentiated goods indexed by $i \in [0, 1]$,

$$x_t^j = \left[\int_0^1 \left(c_{i,t}^j - \theta s_{i,t-1}^j\right)^{\frac{\epsilon-1}{\epsilon}} di\right]^{\frac{\epsilon}{\epsilon-1}}$$

Here, $s_{i,t}^j$ denotes the stock of habit in consuming good i, whose evolution depends on a parameter ρ^c that measures the degree of habit formation as

$$s_{i,t}^j = \rho^c s_{i,t-1}^j + (1-\rho^c)\, c_{i,t}^j$$

The first-order condition for the patient-lender with respect to x_t^ℓ is

$$U_{x^\ell}(x_t^\ell, h_t^\ell, n_t^\ell) = \lambda_{1t}^\ell$$

where the Lagrange multiplier now represents the marginal utility of habit-adjusted consumption.[31] The shadow value of housing is given as

$$U_{x^\ell}(x_t^\ell, h_t^\ell, n_t^\ell)q_t = U_{h^\ell}(x_t^\ell, h_t^\ell, n_t^\ell) + \beta_\ell E_t\left[U_{x^\ell}(x_{t+1}^\ell, h_{t+1}^\ell, n_{t+1}^\ell)q_{t+1}\right]$$

Figure 5 (third row) shows the result. Although consumption rises, house prices still decline in this model. The reason is that marginal utility of habit-adjusted consumption, which gives the shadow value of housing, rises on impact. From the quasi-constancy property described in (5), it follows that house prices fall.

4.4 Housing production and nominal rigidities

We consider the DSGE model with housing production and depreciation with nominal rigidities developed by Iacoviello and Neri (2010) and introduce government spending shocks in that model.

[31] To save space we do not describe the rest of the model. The details are available upon request.

To save space we only report the results in Figure 5 (fourth row).[32] The findings are similar to those reported for the benchmark model in Figure 4. Thus, a fall in house prices after a positive government spending shock in the benchmark model is not driven by the assumptions of fixed supply of housing and no depreciation.

5 Monetary policy accommodation

The findings in the previous sections reveal that neither modifications to preferences along the lines considered in existing literature, nor including housing production, can reconcile the house price response in the DSGE model. We now consider a monetary policy accommodation of government spending shocks. That is, we allow monetary policy to respond directly to government spending shocks. This specification is similar to the one considered in Nakamura and Steinsson (2013). Specifically, we consider an augmented policy rule of the form

$$\hat{r}_t^n = \rho_r \hat{r}_{t-1}^n + (1-\rho_r)(\varrho_\pi \hat{\pi}_t + \varrho_y \hat{y}_t + \varrho_g \hat{g}_t), \quad 0 < \rho_r < 1, \varrho_\pi > 1, \varrho_y > 0, \varrho_g < 0 \tag{9}$$

To provide a motivation for the assumption $\varrho_g < 0$ in (9), we examine the empirical responses of both nominal and real interest rates to government spending shocks. The nominal interest rate is the effective federal funds rate and the real interest rate is the effective federal funds rate minus one period ahead actual inflation rate. We add these variables to the benchmark VAR specifications underlying Figures 1 and 2. Figure 6 (panels a and b) shows the results. When anticipated effects are not accounted for (panel a), both nominal and real interest rate fall on impact, reaching a low level after five quarters. With anticipated effects accounted for (panel b), the negative impact effect on both nominal and real interest rate is the largest and the responses are statistically significant. This evidence, therefore, provides direct evidence to motivate the accommodative monetary policy specification in 9 and it can be viewed as a channel that contributes to the observed decline in the real interest rate.[33].

Figure 7 shows the results when $\varrho_g = -1.5$. We choose this value to illustrate that under

[32]Note that Iacoviello and Neri (2010) consider the following set of shocks {housing preference, monetary policy, housing technology, non-housing technology, investment-specific, cost-push, inflation target}. They, however, do not consider government spending shocks. Since we are interested in studying the effects of government spending shocks only, we suppress the role of other shocks and certain features that Iacoviello

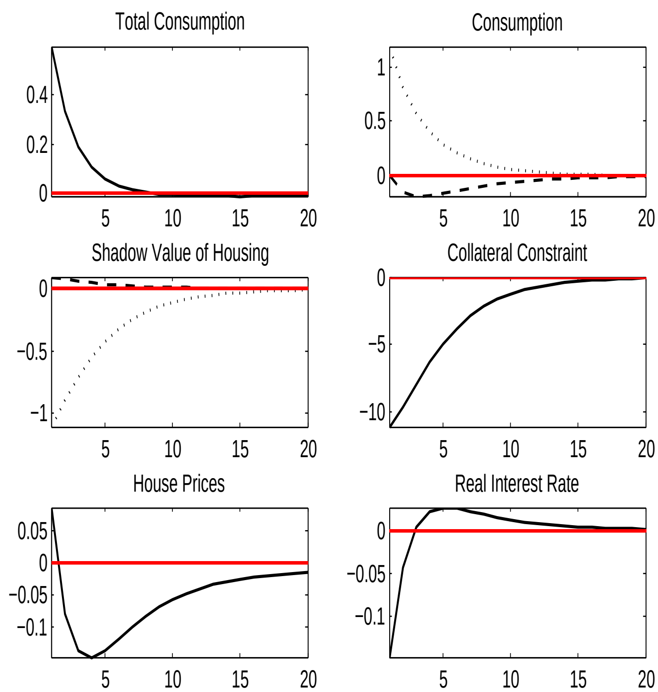
Figure 6: **Effects of government spending shocks on short-term nominal and real interest rates**

(a) Without anticipated effects

(b) With anticipated effects

Notes: The VAR specification in panel (b) includes one-step-ahead forecast errors from private sector forecasts of government spending (Auerbach and Gorodnichenko (2012)). Government spending shock is identified as a Cholesky-ordered shock to the forecast error. Confidence bands show the 16th and 84th percentile of the related distribution from 1000 Monte Carlo simulations.

Figure 7: **Effects of a positive government spending shock in the benchmark DSGE model with monetary accommodation.**



Notes: For the responses of shadow value of housing and consumption, the dashed line is for lenders and dotted line is for borrower.

strong monetary policy accommodation, house prices and total consumption can rise after a positive government spending shock. For mild degree of accommodation, however, the fall in the real interest rate is insufficient to offset the negative wealth effects and deliver a positive joint response of house prices and consumption. When both monetary accommodation and Edgeworth complementarity are present, a lower value $\varrho = -0.5$ can deliver a positive impact effect on house prices. It turns out that for GHH preferences and deep habits, even with monetary accommodation, $\varrho = -0.5$,

and Neri (2010) add to estimate their model.

[33] A further indirect motivation for augmented monetary policy rule comes from recent evidence presented in Melina and Villa (2013). They show that the spread between the 3-month bank prime loan rate and the T-bill rate falls significantly after a positive government spending shock. This reduction in bank spread can promote borrowing and can have an indirect expansionary effect on the economy. In a DSGE model with the banking sector, Gerali et al. (2010) show that the interest spread on retail loans depends positively on the policy rate. Although they do not consider government spending shocks, their model offers a theoretical mechanism that can rationalize the evidence in Melina and Villa (2013)

house prices continue to fall on impact. Finally, we also considered a specification where monetary policy responds to current house price movements along the lines considered in Iacoviello (2005). Since house prices fall in the model, this implies that the central bank lowers the nominal interest rate. However, this channel turns out also to be not sufficient to deliver a positive impact effect on house prices.

The findings reported in this section clarify that besides a strong monetary accommodation of government spending shocks it is, in general, difficult to obtain a positive house price response in a DSGE model of housing. A further challenge for this class of models is that they do not deliver hump-shaped responses to house prices and consumption in comparison to the identified responses in Figures 1 and 2. Our findings suggests that accounting for house price movements and developing stronger propagation mechanism for government spending shocks in a DSGE model of housing is fruitful area for future work.

6 Conclusion

We highlight that a broad class of DSGE models with housing and collateralized borrowing predict both house prices and consumption to fall after positive government spending shocks. The quasi-constant shadow value of lenders' housing and the negative wealth effect of future tax increases on their consumption are the key reasons for this prediction. By contrast, we present evidence that house prices and consumption in the U.S. rise following positive government spending shocks, estimated using a structural vector autoregression methodology that accounts for anticipated effects. We clarify that modifying preferences alone as previously suggested in the literature does not help in obtaining the correct house price response. We also show that only when monetary policy strongly accommodates government spending shocks, we obtain positive impact effects on house prices and total consumption. The model, however, does not deliver the persistent rise in house prices and consumption as evident from the SVAR findings. Properly accounting for the effects of government spending shocks on house prices, therefore, remains a significant challenge for DSGE models of housing.

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Data description

Tax Revenue: Current tax receipts + Income receipts on assets + Current transfer receipts - Current transfer payments - Interest payments - Subsidies. Source: Table 3.1. Government Current Receipts and Expenditures, Bureau of Economic Analysis.

Government Spending: Government consumption expenditures and gross investment. Source: Table 3.9.5. Government Consumption Expenditures and Gross Investment, Bureau of Economic Analysis.

Output: Gross domestic product. Source: Table 1.1.5. Gross Domestic Product, Bureau of Economic Analysis.

Consumption: Nondurable goods (Personal Consumption) + Services (Personal Consumption minus housing and utilities services consumption). Source: Table 1.1.5. Gross Domestic Product, Bureau of Economic Analysis.

The data are seasonally adjusted at annual rates. We transformed this into log real per capita terms by first normalizing the original data by Total Population: All Ages including Armed Forces Overseas (Quarterly Average, Source: Monthly National Population Estimates, US Department of Commerce: Census Bureau) and the GDP implicit price deflator (Seasonally adjusted, 2005=100, Source: Table 1.1.9. Implicit Price Deflators for Gross Domestic Product, Bureau of Economic Analysis) and then taking logarithm.

House Prices: Median price for new, single-family houses sold (including land). Monthly, US Census Bureau. Converted into quarterly frequency by taking simple average across months, and normalized by the average sales price for 2005.

A Appendix: To be made available online

A.1 The quasi-constancy property and the effect on house prices

We demonstrate that the quasi-constancy property shown in (5) and (6) and the decline in house prices after a positive government spending shock in not affected by the following three key features of the benchmark model.

A.1.1 The proportion of impatient-borrowers

Figure A.1 shows the responses of house prices, shadow values of housing, consumption, and housing demand when the share of impatient-borrowers, α, goes from zero to 80%. The responses are similar to the benchmark calibration. Both house prices and consumption fall after a positive government spending shock.

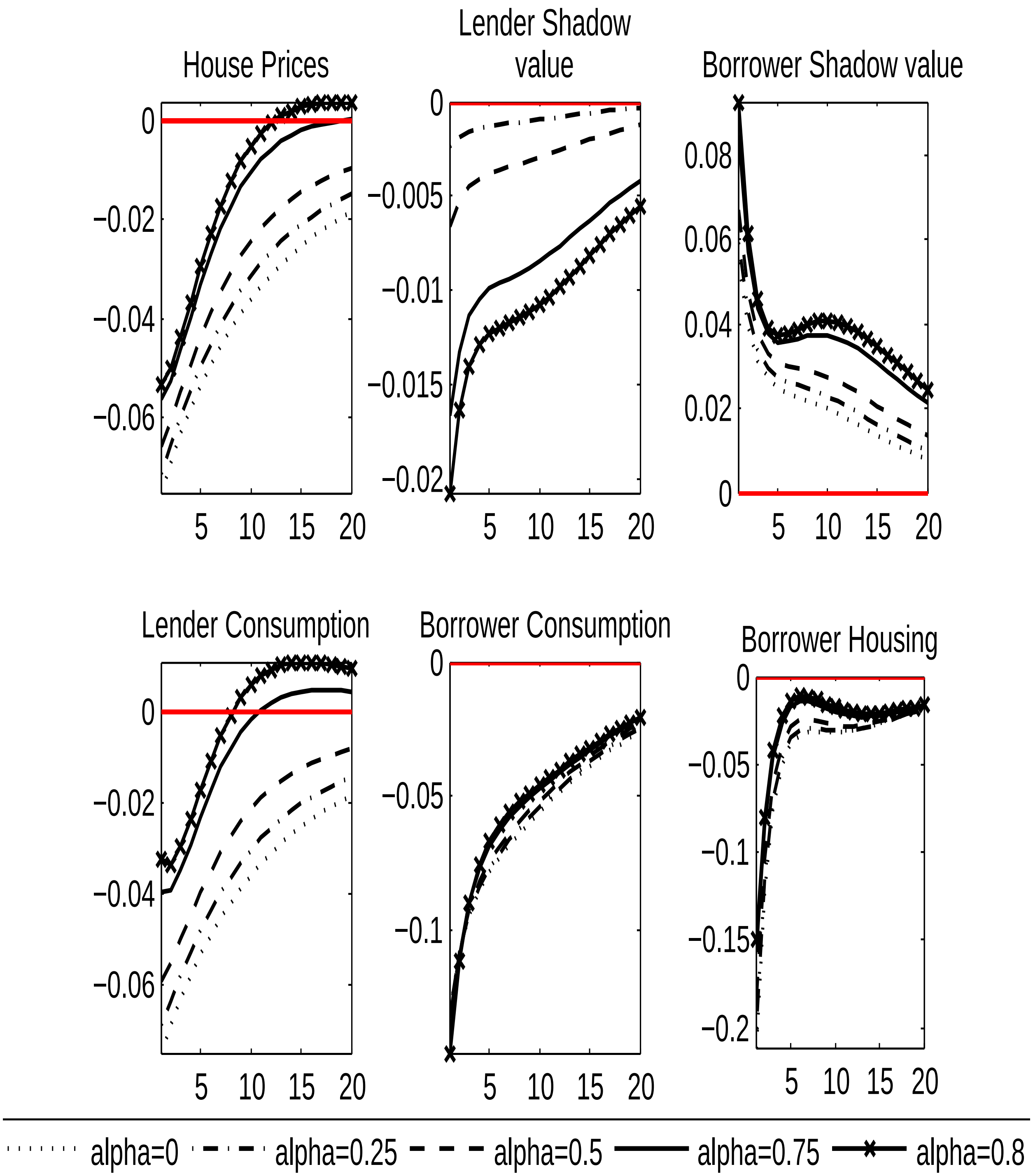
A.1.2 The loan-to-value ratio

Figure A.2 shows the results of relaxing the collateral constraint by increasing the loan-to-value ratio, m, from zero to 0.95. House prices fall in all the cases. Note that consumption response of the impatient-borrowers is even more negative when $m = 0.95$ relative to the benchmark calibration of 0.85. On the one hand these agents are able to secure more loans but on the other the interest payments on the loans are also higher which constrains their consumption.

A.1.3 Weight on housing in the utility function

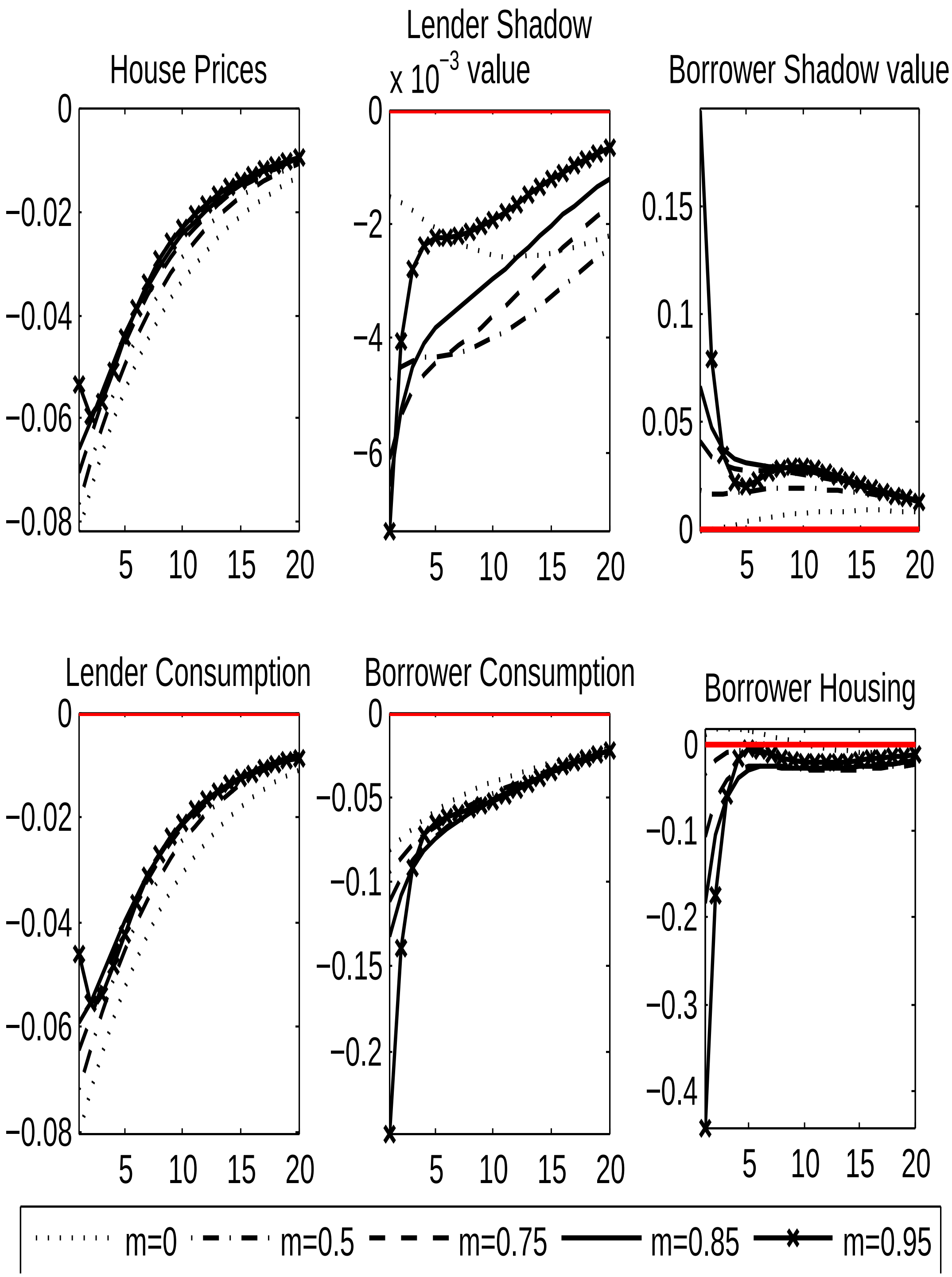
To demonstrate that housing assets are behind the negative consumption responses, we consider reducing the steady-state value of housing stock in the model. Note that this is akin to reducing the weight on housing in the utility function. In the benchmark case, where the housing stock-to-output ratio, $\frac{q^h H}{Y}$, is set to 5.44 which is the total value of household real estate assets in the U.S. The timing of the model implicitly assumes that both households sell their housing assets at the end of each period, and use the proceeds from this wealth, along with other income to purchase the optimal amount of housing and consumption goods in the next period. Calibrating to the total value of household real estate assets therefore makes sense. We, however, consider calibrations which produce a positive response of consumption. We first note that $\frac{q^h H}{Y}$ also determines the steady-state collateralized loans-to-GDP ratio. The alternative calibration uses single family residential mortgages outstanding in U.S. commercial bank balance sheets. We get a ratio that is roughly a tenth of the benchmark value. This can be justified by noting that not all housing assets are traded every period as the model implies, and should not have a direct effect on consumption levels. To capitalize on any increase in house prices, however, a borrower must instead re-mortgage her current housing stock. As such, the mortgage assets are a better guide for calibrating this ratio. As shown in Figure A.3, even under this alternative calibration of $\frac{q^h H}{Y} = 0.54$, both consumption and house prices decline following a positive government spending shock. Moreover, the lower the steady-state housing value-to-GDP ratio, the bigger the drop in house prices. It turns out that for substantially smaller value 0.013 relative to the baseline calibration of 5.44 and a slightly larger share of borrowers ($\alpha = 0.6$), the consumption response turns positive. However, at this extreme calibration, the decline in house prices is also the largest.

Figure A.1: **Effects of a positive government spending shock under different proportions of impatient-borrowers (α) in the benchmark model**



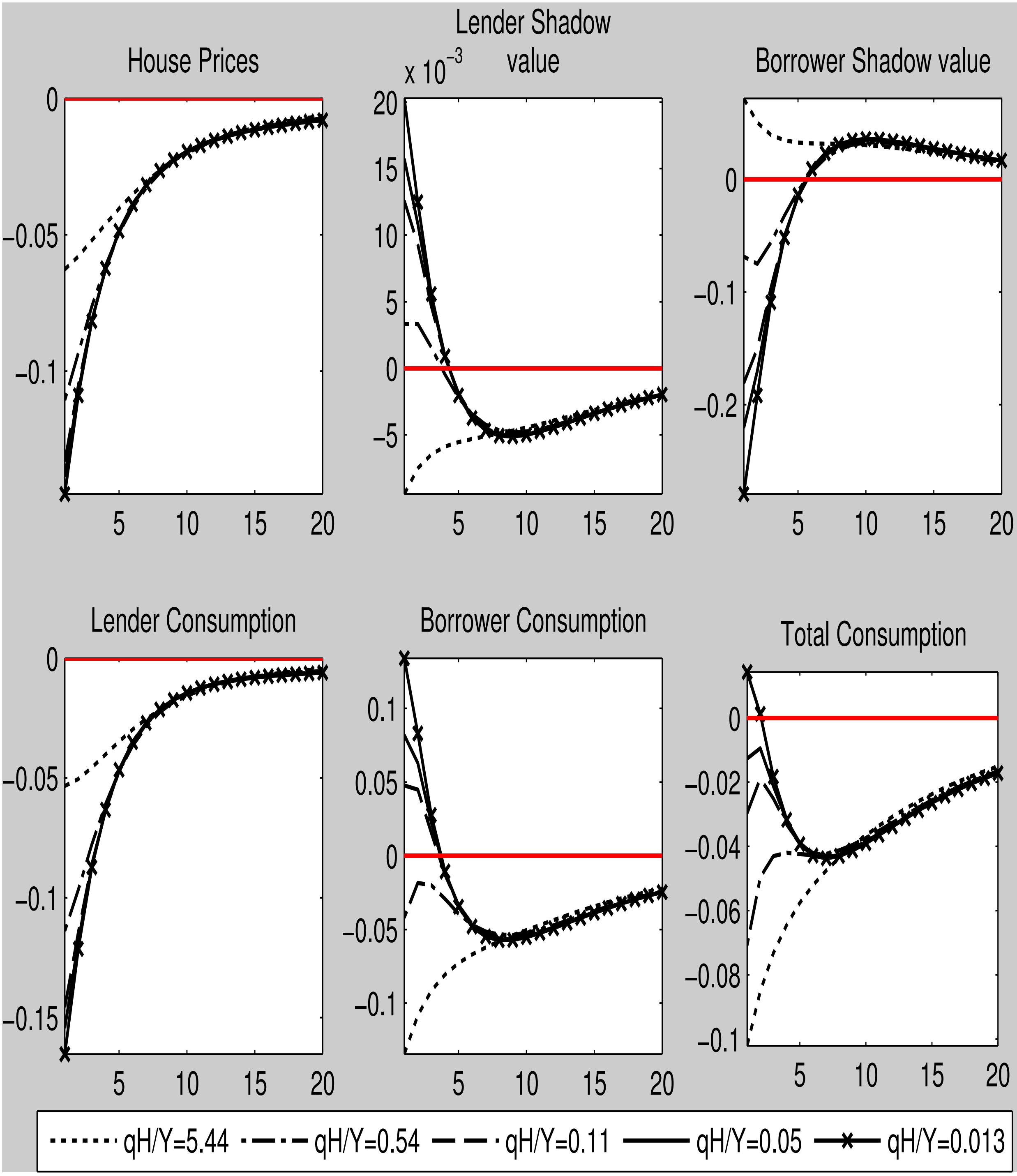
Notes: For the responses of shadow value of housing and consumption, the dashed-dotted line is for lenders and dotted line is for borrower.

Figure A.2: **Effects of a positive government spending shock under different loan-to-value ratios** (m)



Notes: For the responses of shadow value of housing and consumption, the dashed-dotted line is for lenders and dotted line is for borrower.

Figure A.3: **Response to a positive government spending shock under different housing value to output ratios**



Notes: For the responses of shadow value of housing and consumption, the dashed-dotted line is for lenders and dotted line is for borrower.

Table 1: Parameter and steady-state ratios

Parameter	Description	Value
α	Proportion of impatient-borrowers	0.5
β_ℓ	Patient-lenders' discount factor	0.9925
β_b	Impatient-borrowers' discount factor	0.97
η	Inverse Frisch-elasticity of labour supply	1
Υ^ℓ	Patient-lenders' utility weight on housing	0.0816
Υ^b	Impatient-borrowers' utility weight on housing	0.1102
γ	Output elasticity of capital	0.33
δ	Capital depreciation rate	0.025
θ	Calvo price-adjustment frequency	0.75
ϱ_r	Interest rate smoothing	0.8
ϱ_y	Taylor rule response parameter for output	0.15
ϱ_π	Taylor rule response parameter for inflation	1.5
ϱ_b	Fiscal respose parameter to outstanding government debt	0.33
ϱ_g	Fiscal response parameter to government spending	0.1
m	Loan-to-value ratio	0.85
ρ_g	Persistence parameter for government shock	0.9
$\phi''(\frac{i}{k})$	Capital adjustment cost parameter 1	-14.25
$\phi'(\frac{i}{k})$	Capital adjustment cost parameter 2	1
$\phi(\frac{i}{k})$	Capital adjustment cost parameter 3	δ
R	Steady-state interest rate	$\frac{1}{\beta_\ell}$
r	Steady-state return on capital	$\frac{1}{\beta_\ell} - (1-\delta)$
mc	Steady-state marginal cost	$\frac{1}{1.15}$
$\frac{wn}{Y}$	Steady-state wage earnings to output ratio	$(1-\gamma)\, mc$
$\frac{C}{Y}$	Steady-state consumption to output ratio	0.5
$\frac{K}{Y}$	Steady-state capital to output ratio	2.05×4
$\frac{qH}{Y}$	Steady-state housing value to output ratio	1.36×4
$\frac{b}{Y}$	Steady-state loans to output ratio	$m\beta_\ell \frac{qH}{Y}$