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Abstract

We show that DSGE models with housing and collateralized borrowing predict a fall in house prices following positive government spending shocks. By contrast, we show that house prices in the US rise persistently after identified positive government spending shocks. We clarify that the incorrect house price response is due to a general property of DSGE models—approximately constant shadow value of housing—and that modifying preferences and production structure cannot help in obtaining the correct house price response. 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; Government spending shocks

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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 US 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 persistent 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 even by 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 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 estimate the effect of government spending shocks on house prices in the US economy using a structural VAR approach pioneered by Blanchard and Perotti (2002). We augment the VAR with forecast errors of the growth rate of government spending as in Auerbach and Gorodnichenko (2012), to account for the potential timing mismatch between private agents' anticipation of government spending and actual spending, as highlighted in Ramey (2011).

Our main empirical finding is that real house prices rise persistently after a positive government spending shock.[4] The increase in house prices is statistically significant and peaks between 5 and 8 quarters in the specification that accounts for anticipation effects. This result is robust to disaggregating total government spending to consumption and investment spending, to different subsamples in the data, and to a variety of specification checks.

In sharp contrast to the empirical evidence, we highlight that real house prices *fall* in a DSGE model with housing after a positive government spending shock. We demonstrate this counterfactual result relative to the SVAR evidence by introducing government spending shocks in the Iacoviello and Neri (2010) model of housing, with (patient) lenders and (impatient) borrowers, and housing production. This framework is a natural starting point for studying the dynamic effects of shocks on house prices 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 – a property that was shown by Barsky, House, and Kimball (2007) to produce a counterfactually negative comovement in durable goods consumption vis-à-vis nondurables following a monetary policy shocks.[6] In this paper, we show that the same property also produces a counterfactually negative comovement in house prices for a government spending shock. 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 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 the future marginal utility of housing. Increased government spending financed by either increasing taxes or by household bond-holdings, lowers the present value of disposable income. The reduced current income causes an increase in the shadow value of lenders' income, and a fall in current consumption. Since the shadow value of housing remains approximately constant, it follows that the relative price of housing must fall. Thus, the quasi-constancy property combined with the increased shadow value of lenders' income after a temporary government shock explains the response of house prices in the model.

We argue that this counterfactual decline in house prices is a general result for existing DSGE models by showing that a number of extensions to the baseline model that modify production structure and preferences, do not alter this property. Specifically, we consider modifications to the baseline model such as restricting housing supply, introducing nominal stickiness in housing production, non-separable preferences, Edgeworth complementarity between private and public consumption, and deep habits in consumption and government spending. We find that these mechanisms are unable to break the quasi-constancy property, or prevent a rise in the shadow value of income following a government spending shock. Rather, we find that these mechanisms provide a positive consumption response by changing the relationship between consumption and the shadow value of income. Since the latter still rises, the counterfactual decline in house prices remains a feature of a broad class of DSGE models of housing.

Finally, we consider a more direct way to have an increase in the shadow value of income through monetary policy accommodation of government spending shocks. The particular specification is similar to that in Nakamura and Steinsson (2014) 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 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 on real house prices 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 baseline DSGE model of housing. Section 4 provides an explanation of why house prices fall in the model. Section 5 summarizes the findings of a variety of modifications of the baseline model. Section 6 considers accommodative monetary policy. Section 7 concludes.

2 Empirical Evidence

In this section, we use a structural VAR setup to establish the empirical regularity that real house prices rise in aggregate U.S. data following a positive shock to government spending.

Our point of departure is a quarterly VAR with six variables as follows:

$$\mathbf{X}_t = \alpha_0 + \alpha_1 t + \alpha_2 t^2 + A(L)\mathbf{X}_{t-1} + e_t \tag{1}$$
$$\mathbf{X_t} = \begin{bmatrix} G_t & T_t & Y_t & C_t & Q_t & R_t \end{bmatrix}'$$

Where, G_t is real total government expenditure and investment, T_t is total tax receipts less transfer payments, Y_t is real total output, C_t is real total private consumption less consumption on housing and utilities, Q_t is the real median price of new houses, and R_t is the real Fed Funds rate. We consider the first four variables above in real log per-capita terms, and include a linear and quadratic trend in the VAR specification in (1), to be consistent with the literature (see, e.g. Blanchard and Perotti 2002, Ramey 2011). Variables T_t and Q_t are transformed into real terms by deflating nominal values by the GDP deflator. The real Fed Funds rate is calculated by deducting annualized one quarter ahead realized inflation, calculated using the GDP deflator, from the nominal Fed Funds rate. The Appendix contains a detailed description of the series that we used.

Our baseline identification follows the seminal contribution of Blanchard and Perotti (2002) and identifies fiscal shocks 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 endogenous policy response, a quarter would have passed. 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.[7] 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, e.g., Fatas and Mihov 2001, Galí, López-Salido and Vallés 2007) in demonstrating that increases in government spending raise output, consumption and wages.

Ramey (2011), however, argues that if fiscal shocks are anticipated by private agents, the above identification scheme will be misleading. 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.

To account for any such anticipation effects, we follow Auerbach and Gorodnichenko (2012) and augment our benchmark VAR specification with information on expectations of future spending to control for the forecastable component of actual government spending. Specifically we consider $\hat{\mathbf{X}}_t = \begin{bmatrix} FE_t^G & G_t & T_t & Y_t & C_t & Q_t & R_t \end{bmatrix}'$, where FE_t^G is the forecast error from private sector forecasts of the growth rate of government spending.[8] The unanticipated shock, then, is identified as the innovation in the forecast error itself, rather than an innovation to G_t.

The data for the baseline specification span from the third quarter of 1966 through the third quarter of 2010, where both the start and end dates are restricted by availability of the forecast error variable.

Figure 1 shows the impulse responses of a one standard deviation shock to government spending.

The first column collects impulse responses to government shocks identified via Cholesky ordering as in Blanchard and Perotti (2002), while the second column corresponds to the Auerbach and Gorodnichenko (2012) identification through shocks to private sector forecast errors on government spending. The responses of all the variables are expressed in standard-deviations from their respective means.

Clearly, following a positive unanticipated government spending shock, both consumption and house prices rise in a persistent manner regardless of the presence of anticipation effects. In particular, the response for house prices are both economically and statistically significant.

This finding of increasing real house prices following a positive shock to government spending is robust to a slew of reasonable variations of our baseline specification. In particular, this result is robust to (a) the exclusion of linear and quadratic time trends in specification (1), (b) doubling the lag length, (c) correcting for heteroskedasticity and autocorrelation in the error terms of the VAR system, (d) considering various subsamples of the data, (e) the exclusion of output, consumption or interest rate variables from the VAR system, (f) alternative ordering of the variables other than government spending, (g) deflating the nominal house prices with the PCE deflator or the CPI index, and (h) alternate measures of house prices.[9] Importantly, the result of an increasing real house price is also robust to identifying government spending shocks using the Ramey and Shapiro (1998) military dummies.[10] Figures 2 and 3 show the results from these robustness exercises.

To summarize, empirical evidence suggests that real house prices rise in a persistent manner after a positive government spending shock. We now turn to a DSGE model of housing 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 production based on Iacoviello and Neri (2010), and determine the effects on government spending shocks on real house prices as our baseline case. The simpler case of fixed housing supply, as in Iacoviello (2005), is embedded within this setup and considered in the robustness exercises. The baseline setup features two types of representative households: patient lenders and impatient borrowers, and two production sectors: the non-housing sector produces (non-durable) consumption and investment goods, while the housing sector produces new homes.

3.1 Households

The two types of agents in the economy are characterized by different rates of time preference. A fraction, $0 < \alpha < 1$, of the population are impatient agents who discount the future at a rate higher than patient agents. The size of the total population is normalized to one. Both agents receive utility from consuming a non-durable good, and from the service flows of the stock of housing they own. Both supply labour to the housing and nonhousing production sectors. Patient agents are net lenders. They hold government debt, and own physical capital which they rent out to the production sector. Impatient agents are net borrowers. 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 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

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

where $j = \ell$ for the patient-lenders and $j = b$ for the impatient-borrowers. The variables c_t, h_t, n_t, and n_t^h denote non-durable consumption, housing services, and labour supplied to the nonhousing and housing production sectors, respectively.[11]

The parameters β_j, Υ^j, and η denote the discount factor, the weight of housing in the utility function, and the inverse Frisch elasticity of labour supply, respectively.

Patient-lenders maximize their utility subject to the following budget constraint:

$$\begin{aligned} c_t^\ell + q_t h_t^\ell + i_t + i_t^h + b_t^g + b_t &= w_t n_t^\ell + w_t^h n_t^{h\ell} + \left(1 - \delta^h\right) q_t h_{t-1}^\ell + r_t k_{t-1} + r_t^h k_{t-1}^h + d_t^\ell \\ &\quad + \frac{r_{t-1}^n b_{t-1}^g}{\pi_t} + \frac{r_{t-1}^n b_{t-1}}{\pi_t} - \tau_t^\ell \end{aligned} \tag{2}$$

where q_t is the relative price of housing stock, k_t and k_t^h represent capital rented out to the nonhousing and housing production sectors, r_t and r_t^h are the real rental returns on the two types of capital, and i_t and i_t^h represent gross investment on the two types of capital. 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^n/π_{t+1}, where r_t^n is the nominal interest rate and π_{t+1} is the gross inflation rate. Finally, τ_t^ℓ is a lump-sum tax imposed by the government on patient-lenders.

The capital accumulation processes for the two sectors are given as

$$k_t = (1-\delta^{kc})k_{t-1} + \phi\left(\frac{i_t}{k_{t-1}}\right)k_{t-1} \tag{3}$$

$$k_t^h = (1-\delta^{kh})k_{t-1}^h + \phi_h\left(\frac{i_t^h}{k_{t-1}^h}\right)k_{t-1}^h \tag{4}$$

Where δ^{kc} is the depreciation rate of capital in the nonhousing sector, $\phi(.)$ 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. δ^{kh} and $\phi_h(.)$ correspond to similar expressions for the housing sector.

Impatient borrowers face the following budget constraint:

$$c_t^b + q_t h_t^b + \frac{r_{t-1}^n b_{t-1}}{\pi_t} = w_t n_t^b + w_t^h n_t^{hb} + q_t\left(1-\delta^h\right)h_{t-1}^b + b_t - \tau_t^b \tag{5}$$

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

$$b_t \leq mE_t\left\{\frac{q_{t+1}h_t^b\pi_{t+1}}{r_t^n}\right\} \tag{6}$$

which says that the real debt services 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.

Denoting the Lagrange multipliers on the constraints (2), (3), and (4) as λ_{1t}^ℓ, λ_{2t}^ℓ and λ_{3t}^ℓ, 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, respectively, as follows:

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

where ψ_t and ψ_t^h, defined as $\lambda_{2t}^\ell/\lambda_{1t}^\ell$ and $\lambda_{3t}^\ell/\lambda_{1t}^\ell$, represent the marginal value of capital in the nonhousing and housing sectors in terms of the consumption, with (2), (3), and (4) satisfied at the optimum.

Denoting the Lagrange multipliers on the constraints (5) and (6) as λ_{1t}^b and λ_{2t}^b, the first-order-conditions for the impatient-borrowers that characterize the optimal choices of their consumption, labour supply, housing, and borrowing are, respectively, as follows:

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

with (5) and (6) satisfied at the optimum.

3.2 Nonhousing Production Sector and Nominal Rigidities

To introduce price rigidities in the nonhousing sector, we assume a two-step production and pricing process in the New Keynesian tradition. There is a perfectly competitive final goods firm that produces non-durable consumption good, y_t, from a continuum of intermediate goods, $x_t(s)$, with $s \in [0,1]$, purchased at price $p_t(s)$ from monopolistically competitive intermediate firms, using the Dixit-Stiglitz aggregator function:

$$
y_t = \left(\int_0^1 x_t(s)^{\frac{\epsilon-1}{\epsilon}} dx\right)^{\frac{\epsilon}{\epsilon-1}}
$$

Both final and intermediate good producing firms are owned by the patient households. The final goods firm's profit maximization problem leads to the following input demand function:

$$
x_t(s) = \left(\frac{p_t(s)}{p_t}\right)^{-\epsilon} y_t
$$

Intermedite goods firms choose capital and labour to minimize the cost of production while facing the following production technology:

$$y_t(s) \;\; = \;\; k_{t-1}(s)^{\gamma} n_t(s)^{1-\gamma}$$

where total labour demand,

$$n_t(s) \;\; = \;\; \alpha n_t^{\ell}(s) + (1-\alpha)\, n(s)_t^b$$

Intermediate goods firms also set nominal prices in a monopolistically competitive environment, subject to the standard Calvo (1983) friction, taking as given the input demand function above. Each firm faces a probability $(1-\theta)$ of choosing an optimal price at each period. This setup generates the familiar log-linearized New Keynesian Phillips Curve:

$$\hat{\pi}_t = \beta_\ell \hat{\pi}_{t+1} - \frac{(1-\theta)\,(1-\beta_\ell \theta)}{\theta} \hat{mc}_t$$

where variables with hats denote logged deviation from their respective steady-states, and mc_t denotes the marginal cost of the representative intermediate firm.

3.3 Housing Production Sector

There are no nominal rigidities in the housing market.[12] A representative firm produces new homes Y_t^h using total capital and labour available to the housing sector and a Cobb-Douglas technology:

$$Y_t^h \;\; = \;\; \left(K_{t-1}^h\right)^{\mu} \left(N_t^h\right)^{(1-\mu)}$$

It then sells newly produced homes at price q_t. The firm's optimal choices determine the demand for capital, K_t^h, and labour, N_t^h, specific to the housing sector. Total housing stock available to the two types of households to purchase and hold each period equals the existing undepreciated stock of housing plus new homes produced by the housing sector.

$$H_t = (1 - \delta_h) H_{t-1} + Y_t^h$$

3.4 Fiscal and monetary policies

We follow Galí, López-Salido and Vallés (2007) for the fiscal policy specifications. The government faces the following budget constraint 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. 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). 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's nominal interest rate. This rule is given as

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

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

3.5 Aggregation

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

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

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

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

Finally, the aggregate resource constraint in the non-housing and housing sectors are given as:

$$\begin{aligned}
Y_t &\approx \left(K_{t-1}\right)^\gamma \left(N_t\right)^{1-\gamma} = C_t + \phi\left(\frac{I_t}{K_{t-1}}\right) K_{t-1} + \phi_h \left(\frac{I_t^h}{K_{t-1}^h}\right) K_{t-1}^h + G_t \\
Y_t^h &\approx \left(K_{t-1}^h\right)^\mu \left(N_t^h\right)^{1-\mu} = H_t - (1-\delta_h)\, H_{t-1}
\end{aligned}$$

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

3.6 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 equation (7) around a steady state with zero debt and primary balanced budget.[13]

The model is set in a quarterly frequency. The calibration of the model is based closely on the empirical findings in Iacoviello and Neri (2010). The discount factors of the patient-lenders and the impatient-borrowers are set to 0.99 and 0.97, respectively. This ensures that the borrowing constraint is binding in equilibrium. The inverse elasticity parameters in the labour market, η and ξ are set to 0.5 and 0.8, which fall within the bounds of estimated results of Iacoviello and Neri (2010).

For the non-housing sector, the capital share of output, γ, is set to 0.35, and the depreciation rate of capital, δ^{kc}, is set to 0.025. We assume a steady-state price markup of 0.15, implying a steady-state marginal cost, mc, of $\frac{1}{1.15} \approx 0.87$. We set the Calvo price-adjustment frequency to 0.83, implying that prices are re-optimized on average once every 6 quarters. 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.

For the housing sector, the capital share of output, μ, is set to 0.2, and the depreciation rate of capital, δ^{kh}, is set to 0.03. The benchmark value of $\frac{qH}{4 \times GDP} = 1.36$ is taken from Iacoviello and Neri (2010), and 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). The benchmark loan-to-value ratio is set at 0.85. We set the housing-sector productive capital to GDP ratio following Iacoviello and Neri (2010) as $\dfrac{K^h}{4 \times GDP} = 0.04$.

We set the Taylor rule parameter measuring the response of the monetary authority to inflation, ϱ_π, to 1.5, and the parameter for the response to ouput, ϱ_y, to 0.5—values commonly used in the literature. We match the benchmark values of the fiscal response parameters to those in Galí, López-Salido and Vallés (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 $\frac{c^\ell}{GDP} = \frac{c^b}{GDP} = \frac{C}{GDP} = 65\%$ and $\frac{qh^\ell}{GDP} = \frac{qh^b}{GDP} = \frac{qH}{GDP}$. The first can be easily achieved by assuming different levels of steady-state lump-sum taxes.[14] The latter can be achieved by setting different values for the weight of housing in utility. We set the steady-state non-residential investment share of GDP to 13%, and residential investment share of GDP to 7% following U.S. data. This, along with a steady-state consumption share of GDP of 65%, implies a steady-state government share of GDP of 15%.

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.[15] 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. An online appendix summarizes the benchmark model and the calibration values. We use Dynare to solve the model.[16]

4 The effects of government spending shocks on house prices

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 a general property of the DSGE model of housing—the approximately constant shadow value of housing for lenders. The property of near-constant shadow value of long-lived goods was first pointed out in Barsky, House, and Kimball (2007) as the source of a counterfactually negative comovement in durable goods consumption vis-à-vis nondurables following a monetary policy shock. In this paper, we demonstrate that the same property generates a counterfactual decline in house prices following a government spending shock.

Housing is a long-lived good and provides a service-flow for many periods in the future. 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

$$\begin{aligned} \hat{v}_t^\ell \equiv \hat{\lambda}_{1t}^\ell + \hat{q}_t &= (\beta_\ell - 1) E_t \left[\sum_{s=0}^{\infty} \beta_\ell^s \hat{h}_{t+s}^\ell \right] \qquad (7) \\ &\approx 0 \qquad (8) \end{aligned}$$

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 equation (8). 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 the future marginal utility of housing (i.e., the $\hat{h}_{t+s}^\ell = 0$ as s increases).

Now, the intuition for why house prices decrease is as follows. Government spending is financed by taxes and bonds. Thus, increased government spending means lowered present value of disposable income. The shadow value of lenders' income rises after a temporary (positive) government spending shock, i.e., $\hat{\lambda}_{1t}^\ell > 0$. This means that real house prices must decrease, $\hat{q}_t < 0$, as the shadow value of housing is approximately constant.

As shown if Figure 4, current consumption falls, $\hat{c}_t^\ell < 0$. There are three forces that are behind this fall in lenders' consumption. First, a temporary fall in after-tax income causes a small negative income effect, and pushes consumption down. Second, as government spending increases output and inflation, the central bank's monetary policy implies an increase in the real interest rate which raises λ_{1t}^ℓ relative to λ_{1t+1}^ℓ from the Euler equation, resulting in a fall in current consumption.

Third, the decline in the relative price of housing lowers income for the lenders from lending to borrowers, reinforcing the negative income effect.

It is important to note that this result does not depend on the structure of the labour market. Following Galí, López-Salido and Vallés (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 results remain the same.[17] Moreover, Andrés, Boscá, and Ferri (2012) introduce job search 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.[18] Thus, relative to the SVAR evidence reported in section 2, the counterfactual response of house prices 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 equation (7), 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

$$\begin{aligned} \hat{v}_t^b \equiv \hat{\lambda}_{1t}^b + \hat{q}_t &= (\beta_b - 1)\, E_t \sum_{s=0}^{\infty} \beta_b^s \hat{h}_{t+s}^b \\ &+ m(\beta_\ell - \beta_b) E_t \sum_{s=0}^{\infty} \beta_b^s \left(\hat{\lambda}_{2t+s}^b + \hat{\pi}_{t+1+s} - \hat{r}_{t+s}^n + \hat{q}_{t+1+s} + \hat{h}_{t+s}^b \right) \end{aligned} \tag{9}$$

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 $\hat{\lambda}_{2t+s}^b (> 0)$.

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 in addition to the decrease in the present value of disposable income, 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.[19]

5 Modifications

From section 4, it is evident that house prices fall after a positive government spending shock because the shadow value of lenders' income rises. In this section we draw on the literature and consider five relevant modifications of the benchmark model to explore whether any of them can deliver a positive response of house prices to government spending shocks.[20] These are: (a) fixed housing (Iacoviello 2005), (b) sticky house prices (Barsky, House, and Kimball 2007), (c) non-separable (GHH) preferences (see, e.g., Greenwood, Hercowitz, and Huffmann 1988, Monacelli and Perotti 2009, Bilbiie 2009, Kilponen 2012), (d) Edgeworth complementarity between government and private spending (see, e.g., Bouakez and Rebei 2007, Fève, Matheron, and Sahuc 2013), and (e) deep-habits (see, e.g., Ravn, Schmitt-Grohé, and Uríbe 2006, Zubairy 2010, Jacob 2010).

Figure 5 summarizes the results for these five cases. We find that none of these modifications break the quasi-constancy property highlighted in section 4. The shadow value of income always rises for lenders, and consequently, house prices always fall after a government spending shock. Any positive response in consumption, then, is generated by changing the relationship between consumption and the shadow value of income.[21]

6 Monetary policy accommodation

The findings in the previous sections reveal that neither modifications to preferences along the lines considered in existing literature, nor including sticky house prices can reconcile the house price response in the DSGE model. We now consider 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 (2014). Specifically, we consider an augmented policy rule of the form

$$\hat{r}_t^n = \rho_r \hat{r}_{t-1}^n + (1-\rho_r)(\varrho_\pi \hat{\pi}_t + \varrho_y \hat{y}_t + \varrho_g \hat{g}_t), \quad 0 < \rho_r < 1, \varrho_\pi > 1, \varrho_y > 0, \varrho_g < 0 \tag{10}$$

A motivation for the assumption $\varrho_g < 0$ in (10), is given in the empirical response of real interest rates to government spending shocks in Figure 1. Real interest rates fall regardless of whether anticipated effects have been accounted for. This, therefore, provides direct evidence to motivate the accommodative monetary policy specification (10) and it can be viewed as a channel that contributes to the observed decline in the real interest rate.[22]

Figure 6 shows the results when $\varrho_g = -1$. We choose this value to illustrate that under strong monetary policy accommodation, house prices and total consumption can rise after a positive government spending shock. 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 1-3. Our findings suggest that accounting for house price movements and developing a stronger propagation mechanism for government spending shocks in a DSGE model of housing is a fruitful area for future work.

7 Conclusion

We showed that a broad class of DSGE models with housing and collateralized borrowing predict house prices to fall after positive government spending shocks. The quasi-constant shadow value of lenders' housing and a rise in the shadow value of lenders' income after a positive government spending shock are the key reasons for this result. By contrast, we present evidence that real house prices in the US rise following positive government spending shocks, estimated using a structural vector autoregression methodology that accounts for anticipated effects. We clarify that modifying the production structure or preferences alone 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. Even with monetary accommodation, however, the model does not deliver the persistent rise in house prices 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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Notes

[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.

[4]We are aware of only one previous study by Afonso and Sousa (2008) who examined the effects of government spending shocks on US 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 Andrés, Boscá, and Ferri (2012) who augment the fixed housing setup of Iacoviello (2005) 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 and Perotti (2009).

[7]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 US and Cloyne (2012) for the UK.

[8]We use the series constructed by Auerbach and Gorodnichenko (2012) by splicing two separate one-quarter-ahead forecasts of governments expenditure as follows: (i) from the Survey of Professional Forecasters (SPF), available from 1982 onwards and (ii) forecasts prepared by the Federal Reserve Board staff for the meetings of the Federal Open Market Committee (Greenbook), available from 1966 through 2004.

[9]In particular, we consider the Shiller (2015) historic home price index.

[10]Note, however, that the sample considered in the appendix figure runs from 1963Q1 through 2014Q1. This allows 3 military dummies: in 1965Q1, 1980Q1 and 2001Q3.

[11]We assume that housing services are proportional to housing stock and normalize the constant of proportionality 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.

[12]Following Iacoviello and Neri (2010), our benchmark formulation rules out price rigidities for a number of reasons. First, housing is relatively expensive on a per-unit basis. As such, housing transactions usually involve significant degree of negotiations among buyers and sellers that would make the price relatively flexible. Second, most homes are priced for the first time when they are sold, and as such do not conform to a Calvo-type rigidity.

[13]Note that hatted variables are expressed in percentage deviations, i.e., deviations from their steady state values, normalized by their respective steady state levels. 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 $\tilde{X}_t = \frac{X_t - X}{GDP}$ where GDP is steady-state level of total output in the two sectors.

[14]See the discussion in Galí, López-Salido and Vallés (2007).

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

[16]See Dynare Reference Manual, Version 4 by Adjemian et al. (2011) and http://www.dynare.org/.

[17]Available upon request.

[18]See Figures 2, 3, and 4 in Andrés, Boscá, and Ferri (2012). Since Andrés, Boscá, and Ferri (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.

[19]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, López-Salido and Vallés (2007).

[20]We provide the details of model derivations in an online appendix available at http://http-server.carleton.ca/ hashkhan/.

[21]The appendix provides analytical details for these results.

[22]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).

Data description

All data used in the benchmark specification are publicly available for download from the FRED database. The FRED mnemonics are given below

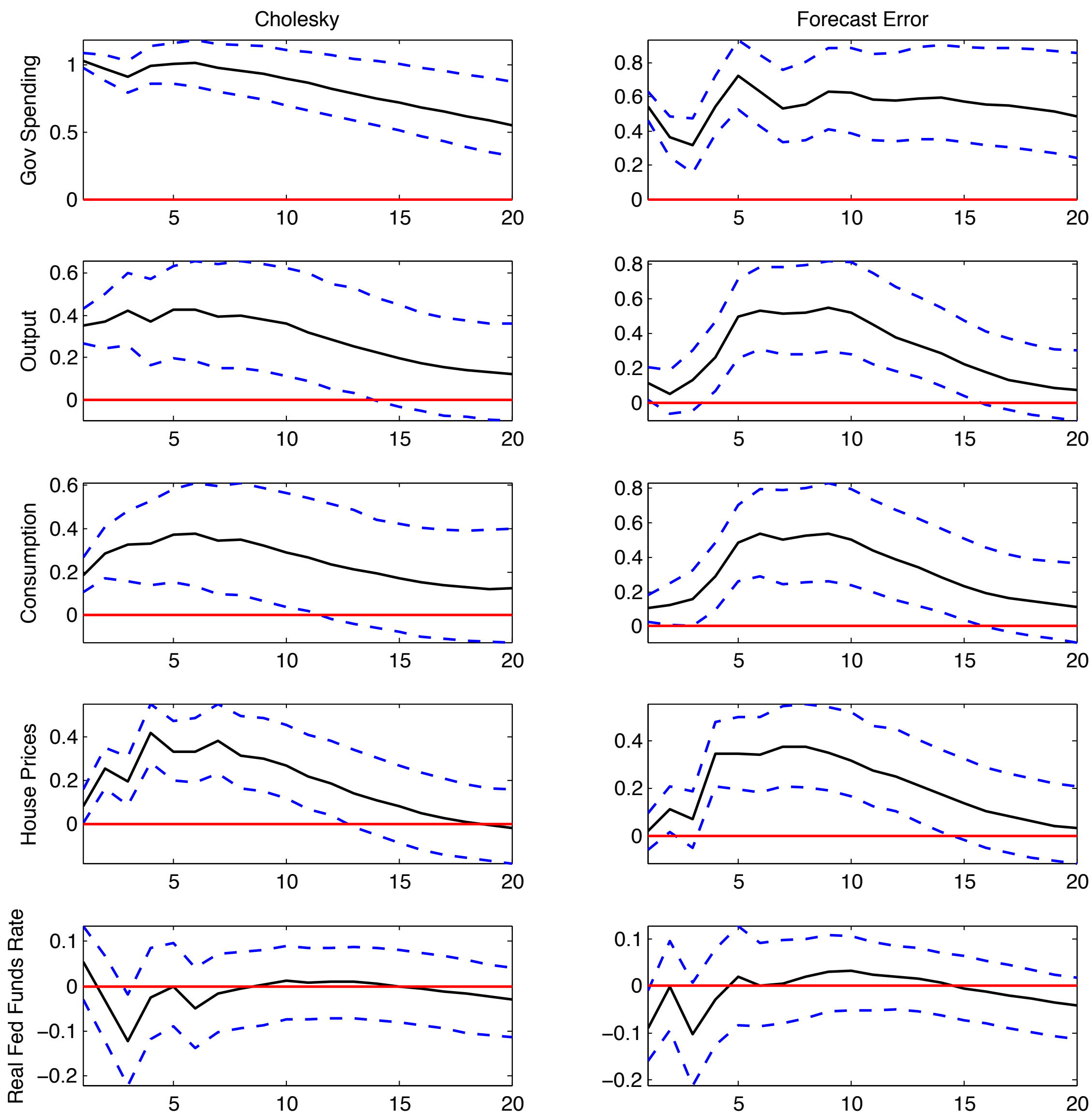
- G_t = Government consumption expenditures and gross investment (`GCEC96`, seasonally adjusted, Chained 2009$)
- T_t = Government Current Tax Receipts (`W054RC1Q027SBEA`) + Government Income Receipts on Assets (`W058RC1Q027SBEA`) + Government Current Transfer Receipts (`W060RC1Q027SBEA`) - Government Current Transfer Payments (`A084RC1Q027SBEA`) - Government Interest Payments (`A180RC1Q027SBEA`) - Government Subsidies (`GDISUBS`). T is nominal, converted to real after dividing by the GDP deflator (`GDPDEF`, seasonally adjusted, 2009=100).
- Y_t = Real Gross Domestic Product (`GDPC1`, seasonally adjuste, Chained 2009$)
- C_t = Real private consumption expenditure (`PCECC96`, seasonally adjusted, Chained 2009$) - Real personal consumption expenditure on housing and utilities (`DHUTRX1Q020SBEA`, seasonally adjusted, Chained 2009$)
- Q_t = Median Sales Price for New Houses Sold in the United States (`MSPNHSUS`). This series is then seasonally adjusted and deflated by the GDP deflator above.
- R_t = Effective Fed Funds Rate (`FEDFUNDS`) - one quarter ahead annualized quarter-over-quarter inflation in the GDP deflator.

The first four series are converted to per capital using the census bureau civilian population (all ages) estimates.[23]

Table 1: Parameter values and steady-state ratios

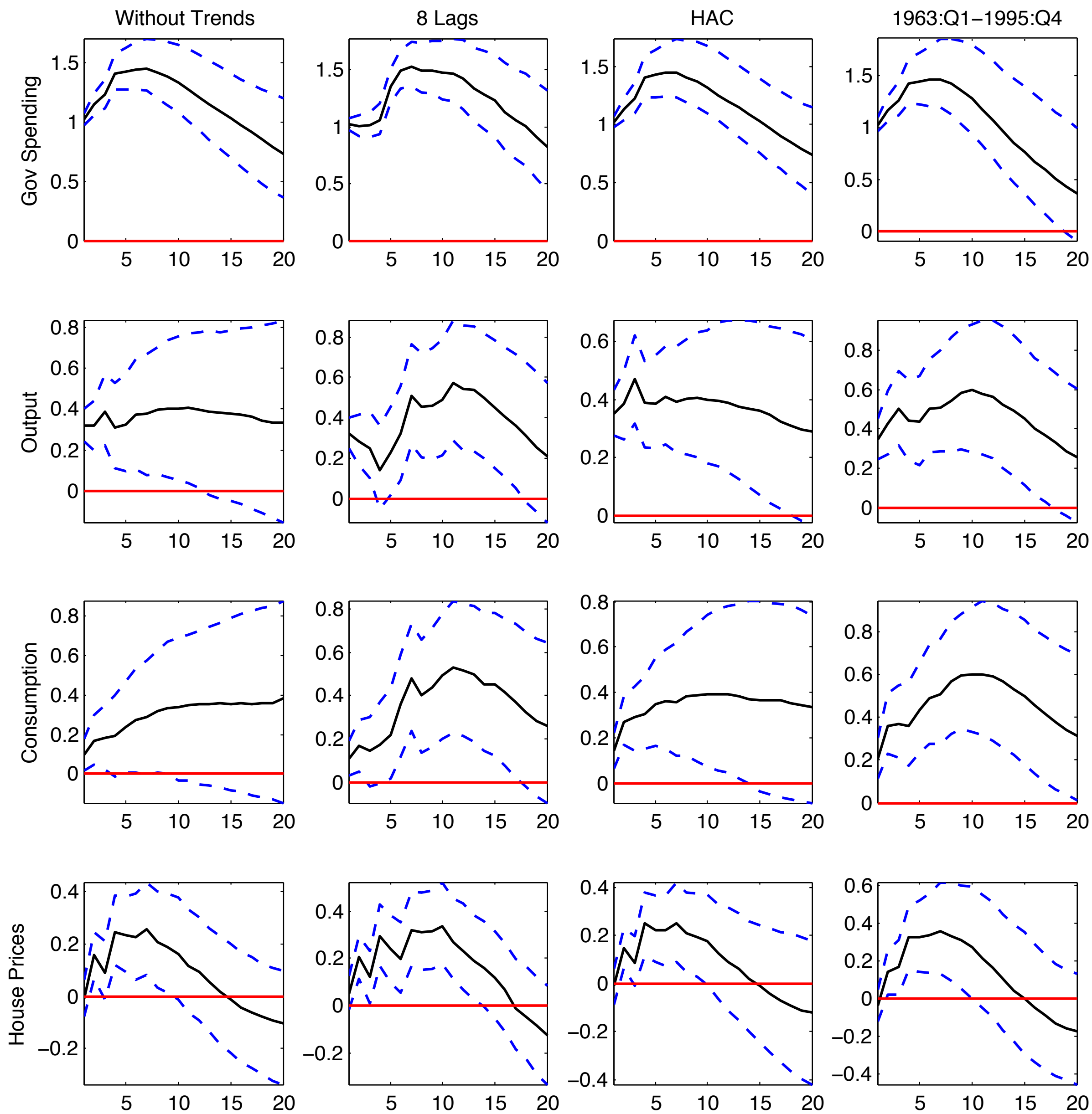
Parameter	Description	Value
β_ℓ	Patient-lenders' discount factor	0.9925
η	Inverse elasticity of labour supply	0.5
ξ	Inverse elasticity of labour substitution across sectors	0.8
δ	Depreciation rate of non-housing sector capital	0.025
δ^h	Depreciation rate of housing sector capital	0.01
$\phi''(\delta)$	Capital adjustment cost for non-housing sector	-14.25
$\phi''_h(\delta^h)$	Capital adjustment cost of housing sector	-10.75
β_b	Impatient-borrowers' discount factor	0.97
m	Loan-to-value ratio	0.85
α	Share of patient lenders in the economy	0.5
γ	Capital share of non-housing output	0.35
μ	Capital share of housing output	0.2
ϵ	Dixit-Stiglitz aggregation parameter	7.67
θ	Calvo price-adjustment frequency	0.83
ϱ_r	Interest rate persistence in Taylor rule	0.8
ϱ_π	Taylor rule response to inflation	1.5
ϱ_y	Taylor rule response to output gap	0.5
ϱ_g	Tax response to government spending	0.1
ϱ_b	Tax response to government debt	0.33
ρ_g	Persistence parameter for government shock	0.8
$\frac{C}{GDP}$	Consumption share of GDP	0.65
$\frac{I}{GDP}$	Business invesment share of GDP	0.13
$\frac{q \times Y^H}{GDP}$	Housing investment to GDP	0.07
$\frac{G}{GDP}$	Government share of GDP	0.15
$\frac{q \times H}{4 \times GDP}$	Housing wealth	1.36
$\frac{K^H}{4 \times GDP}$	Housing sector capital	0.04

Figure 1: **Impulse responses of key variables to a government spending shock**



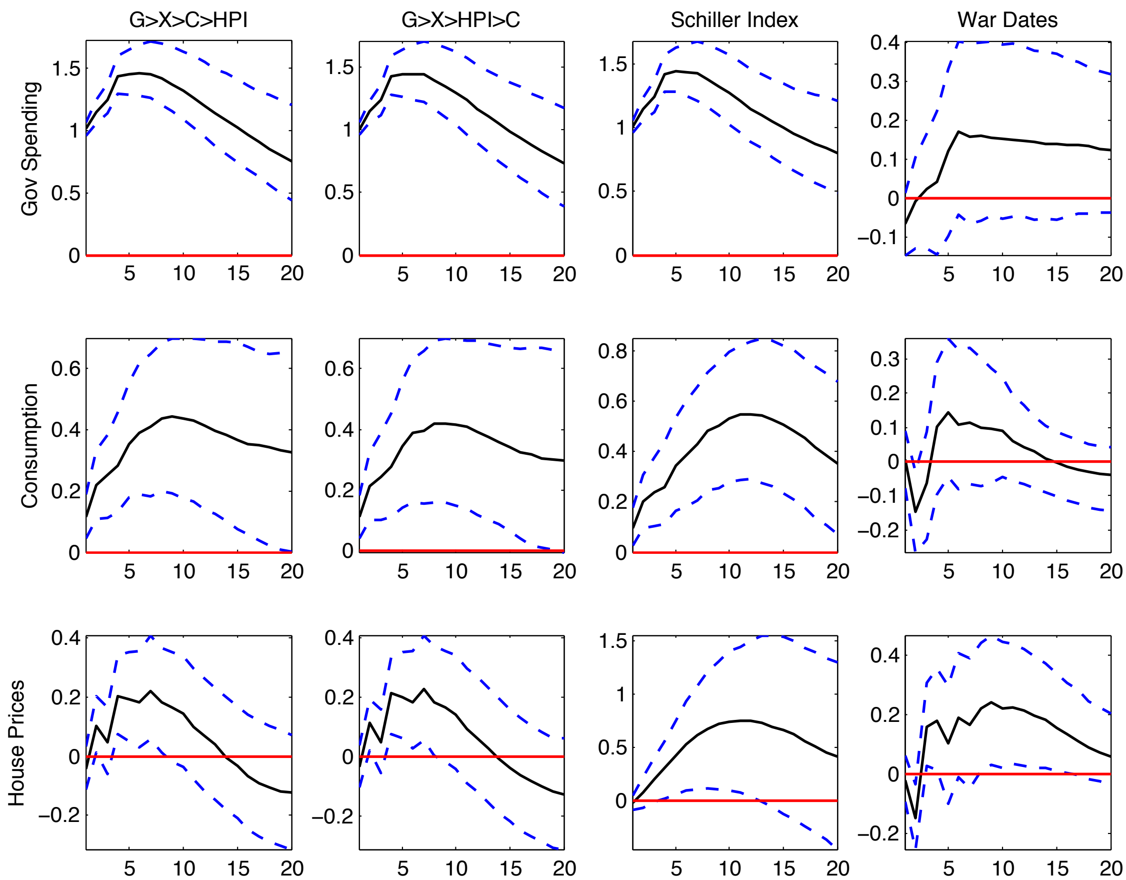
Notes: Broken blue lines correspond to the 16th and 84th percentile confidence bands calculated from from 1000 Monte Carlo simulations. The first column represents shocks identified using Cholesky ordering with Government Spending ordered first, as in Blanchard and Perotti (2002). Second column represents shocks identified via private-sector forecast errors of government spending, as in Auerbach and Gorodnichenko (2012).

Figure 2: **Impulse responses of key variables to a government spending shock – robustness**



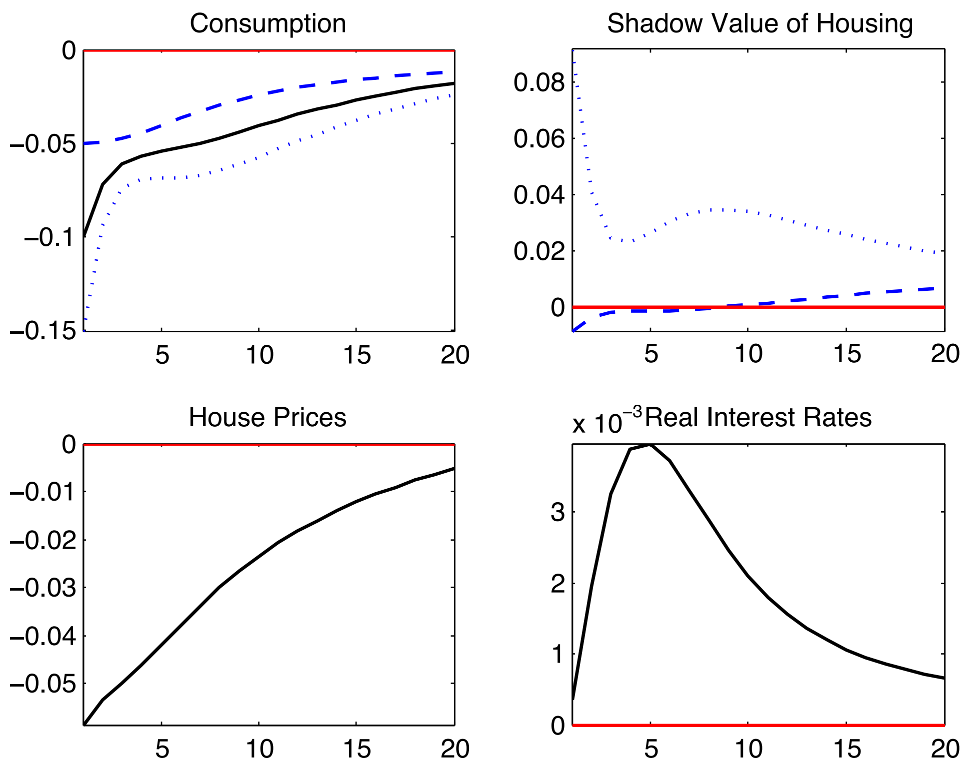
Notes: Broken blue lines correspond to the 16th and 84th percentile confidence bands calculated from from 1000 Monte Carlo simulations. Column 1 excludes linear and quadratic time trends from the baseline specification. Column 2 increases the lag length from 4 to 8. Column 3 considers the Newey-West estimator for heteroskedasticity and autocorrelation-consistent standard errors. Column 4 stops the sample at 1995.

Figure 3: **Impulse responses of key variables to a government spending shock – robustness *(contd.)***



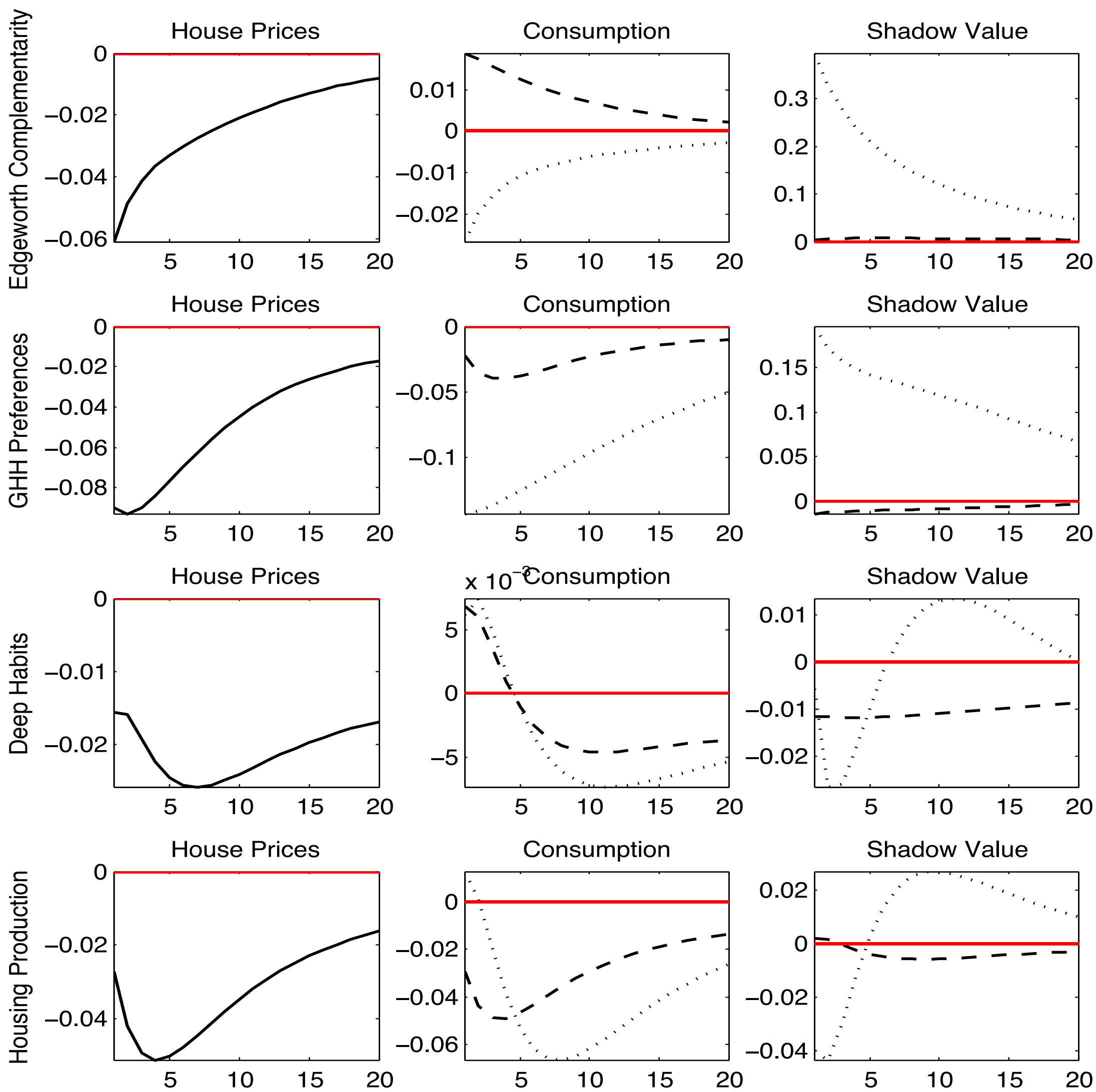
Notes: Broken blue lines correspond to the 16th and 84th percentile confidence bands calculated from from 1000 Monte Carlo simulations. All VAR specifications in this figure exclude the output and interest rate variables from the baseline specification. Column 1 orders the variables as G>X>C>Q. Column 2 orders them as G>X>Q>C. Column 3 considers the Shiller (2015) house price index, deflated by the GDP deflator. Column 4 identifies government shocks as shocks to Ramey and Shapiro (1998) and Ramey (2011) military date dummies.

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



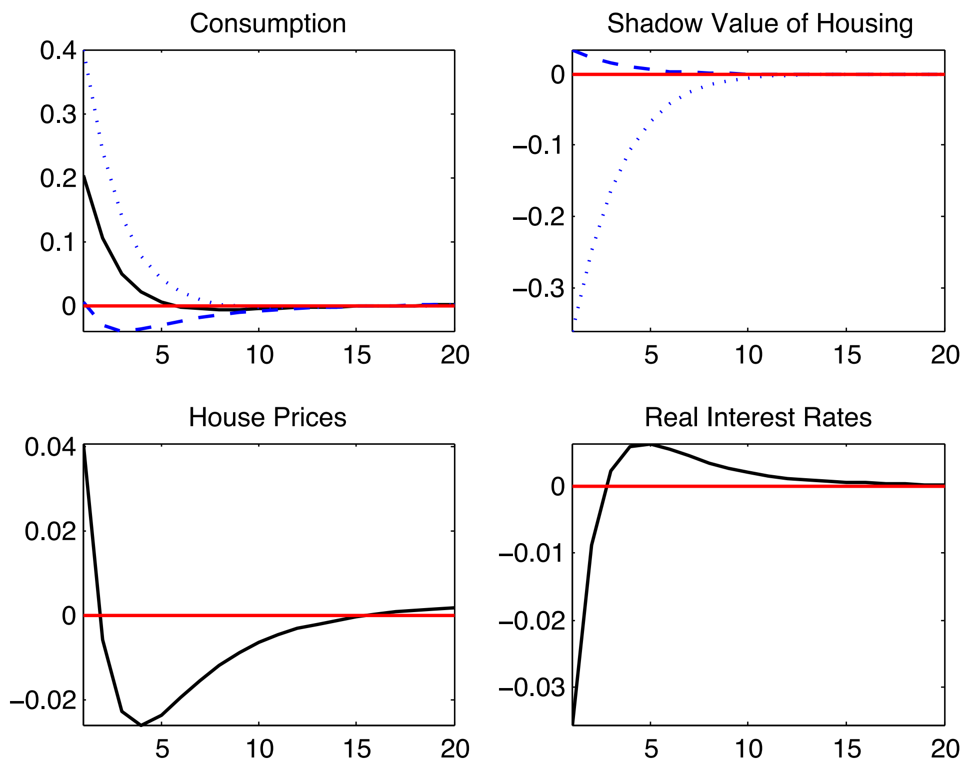
Notes: For the responses of shadow value of housing and consumption, the dashed line is for lenders and dotted line is for borrower, respectively.

Figure 5: **Effects of government spending shocks: modifications of the baseline DSGE model**



Notes: Row 1 for fixed housing, Row 2 for sticky house prices in a model with housing production, Row 3 for GHH preferences, Row 4 for Edgeworth complementarity, and Row 5 for deep habits. For the responses of shadow value of housing and consumption, the dashed line is for lenders and dotted line is for borrower, respectively.

Figure 6: **Effects of a positive government spending shock in the baseline 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, respectively.