Non-linear Effects of Fiscal Policy: The Role of Housing Wealth and Collateral Constraints*

Dimitrios Bermperoglou†

December, 2015

Abstract

This paper investigates how housing wealth dynamics and collateral constraints jointly matter for the non-linear transmission of fiscal policy shocks. A DSGE model with housing investment and occasionally binding collateral constraints reveals a non-linear pattern of responses to fiscal shocks: positive government consumption shocks are more expansionary during times that housing wealth is relatively high and the collateral constraint is slack, while tax cuts are more expansionary during times that housing wealth is low and the collateral constraint binds. The key mechanism is a collateral channel that is in effect when the collateral constraint binds, while it is absent when the constraint is slack. Moreover, this collateral channel buffers government spending stimuli while boosts tax cut stimuli. Empirical evidence, using a threshold VAR model, confirms theoretical predictions.

JEL classification: C24, C32, E44, E62, H31.
Keywords: Fiscal policy, Threshold Vector Autoregression models, Nonlinear analysis, Ocasionally binding collateral constraints, Financial frictions, Housing.

*I am indebted to my PhD advisor, Evi Pappa, and Luca Gambetti for their thorough guidance and support. I also thank IDEA professors and colleagues for their helpful comments and discussions. All remaining errors are mine. Financial support from the Spanish Ministry of Economy and Competitiveness is gratefully acknowledged.

†University of Lausanne. Correspondence: Département d'économétrie et économie politique (DEEP), Faculté des HEC, Bâtiment Internef , Université de Lausanne, CH - 1015 Lausanne. E-mail: dimitrios.bermperoglou@unil.ch

1 Introduction

The burst of 2008 financial crisis and the subsequent recession have revived a hot debate in policy circles and academic research on whether countercyclical fiscal policy is effective in stimulating private activity during times of financial stress. This debate is partly based on the theoretical intuition that, during periods of adverse financial conditions, private agents are more likely to become liquidity constrained thus finding it hard to optimally smoothen their consumption along time. In turn, fiscal shocks will have relatively more pronounced effects on private demand during bad times. The seminal work of Perotti (1999) is one of the first attempts to document state-dependent effects of fiscal policy related to financial conditions, such as the number of liquidity constrained consumers in an economy and the level of public debt. Similarly, Tagkalakis (2008) directly controls for financial conditions. Both papers support the view that fiscal policy is more effective in stimulating private activity during times characterized by adverse financial conditions. They base their analysis on the assumption that during bad times the fraction of liquidity constrained (hand-to-mouth) households increases, thus raising the marginal propensity to consume in the economy. As a result, fiscal expansions raise disposable income and strongly trigger private consumption during bad times. In the same spirit, Gali et al. (2007) propose a model with *rule-of-thumb consumers* that are excluded from financial markets in order to replicate the positive response of private consumption after fiscal expansions. On the other hand, Canzoneri et al. (2012) provide a theory of state-dependent fiscal multipliers by postulating an ad-hoc positive relationship between the output gap and the interest rate spreads' elasticity to output. This mechanism plays the role of a financial accelerator for fiscal shocks; it speeds up reductions in spreads and economic recovery during recessions, while it implies only modest effects on spreads and output during normal times.

However, the theoretical literature discussed above has so far neglected a critical aspect: the increasing role of *collateralized credit*. Last decades financial markets have been developed rapidly and a greater fraction of people have gained access to credit. Commercial banks have provided massive credit to households which is collateralized by their existing housing property. What is more, figure 1 shows that house prices and real estate wealth in the US have experienced at least four boom-bust cycles in the last decades. Such sharp house price and wealth deviations from trend could seriously affect collateral capacity and the tightness of collateral constraints. A serious implication is that the transmission of fiscal policy shocks might be different between times that collateral constraints are tight and times that constraints become laxer or slack[1]. What is more, collateral constraints may not only matter as an initial condition for the transmission of fiscal shocks, but the endogenous reaction of the collateral to the shocks could also play a role. In particular, fiscal shocks may affect house prices, collateral capacity and borrowing limits. In turn, tighter or laxer borrowing limits could affect the volume of credit provided to households, and thus impact on their demand for consumption and investment. As models with collateral constraints become more and more appealing for policy analysis today, we should know what they imply for the transmission of fiscal policy[2].

The present paper attempts to fill the gap in the literature discussed above. In particular, we investigate how housing wealth dynamics and collateral constraints jointly matter for the non-linear transmission of fiscal policy shocks. A DSGE model with housing investment and *occasionally binding collateral constraints* reveals a non-linear pattern of responses to fiscal shocks. Most importantly, the implications are distinct from what existing non-linear models predict: fiscal policy may be relatively less effective in stimulating the economy during bad times (times of low housing wealth and tight credit). In the second part, we test the model's predictions in the data, providing empirical evidence of state-dependent effects of fiscal policy.

More analytically, in the first part we consider a *New Keynesian model* with heterogeneous households (savers and borrowers) and a two-sector production (non-durable goods and housing) similar to the models of Iacoviello and Neri (2010) and Guerrieri and Iacoviello (2013). The non-durable production sector features monopolistic competition and Calvo-type price rigidities. Borrowers are collateral-constrained, and the debt limit is determined by the their expected housing wealth. Incorporating housing investment and an occasionally binding collateral constraint into an otherwise standard DSGE model offers a critical link between housing wealth fluctuations and the tightness of collateral constraints, thus defining two distinct regimes/states of the economy: when housing wealth is low collateral capacity is also low and the collateral constraint binds, while when housing wealth and the collateral capacity rise substantially the collateral constraint may become slack. The theoretical exercise consists of simulating the two distinct environments/regimes and calculating the model's responses to a government consumption and

[1] This idea has been first introduced by Guerrieri and Iacoviello (2013) for the non-linear effects of house price shocks.

[2] Roeger and in't Veld (2009) and Andrés et al. (2012) analyze fiscal policy in models with collateral constraints but they restrict to linear analysis.

an income tax rate shock within each regime. The purpose is to document any non-linearities that arise across regimes.

The predictions of the theoretical model with respect to the fiscal shocks are the following; positive government consumption shocks have more pronounced and expansionary effects on output and private consumption in times characterized by high housing wealth and a slack collateral constraint rather than times of low wealth and a binding constraint. On the contrary, tax shocks are more effective in stimulating the economy when housing wealth is relatively low and the collateral constraint binds. The key mechanism is that when the constraint binds there is an extra transmission channel that comes from the valuation effects on the collateral (*collateral channel*). In particular, if the collateral constraint binds, then variations in the credit supplied to households are proportional to variations in the collateral capacity (borrowing limit). At the same time, positive government consumption shocks lead to lower real house prices, thus lower collateral value. As a result, government consumption shocks cause both collateral capacity and credit supplied to households to fall. The latter has a contractionary impact on households' consumption and investment. However, this negative effect of the collateral channel on private demand is absent when the collateral constraint is slack. For tax shocks the opposite holds; tax cuts induce an increase in real house prices and collateral capacity. When the constraint is slack, variations in collateral capacity are irrelevant for households' responses. However, when the constraint binds, then the credit supplied to households becomes proportional to their collateral capacity. Therefore, a tax cut will raise both collateral capacity and credit, thus inducing further expansionary effects on private demand for consumption and investment. Overall, an environment of low housing wealth and a binding collateral constraint implies *a collateral channel for the transmission of fiscal shocks that buffers government spending stimuli and boosts tax cut stimuli.*

In the next step, the paper attempts to reconcile theory with empirics. We estimate a *threshold VAR model*, and we identify government consumption and personal income tax shocks in order to track the effects of those shocks on several macrovariables. The VAR estimates are conditioned to a threshold variable that approximates housing wealth, and this is a house price index.

The main findings of the VAR estimation confirm theory; positive government consumption shocks have more pronounced and expansionary effects on output and private consumption during times that housing wealth is relatively high (above the threshold), while tax cuts are more expansionary during times that housing wealth is relatively low (below the threshold). Furthermore, positive spending shocks cause real house prices to fall, while tax cuts drive house prices up.

The results of this paper have significant policy implications. Given that the effectiveness of fiscal policy is not independent of the prevailing credit conditions, then nonlinear empirical studies should become the guidance for policy impact assessments. According to the results of this paper, linear estimates of fiscal multipliers may overestimate the effectiveness of government spending shocks and underestimate the effectiveness of tax shocks during times of financial stress.

The rest of the paper is organized as follows. Section 2 elaborates on the theoretical model while section 3 discusses the theoretical results. Section 4 consists of the empirical analysis. Section 5 provides some more discussion and sensitivity analysis that attempts to reconcile theory with empirics. In section 6 we make a direct comparison of the effectiveness of the two fiscal instruments (spending versus tax shocks). Finally, section 7 concludes.

2 The Model

The model follows Iacoviello and Neri (2010) and Guerrieri and Iacoviello (2013). We build a New Keynesian two-sector model with heterogeneous households and collateral constraints. Specifically, there are two types of households in the economy, the patient households of population size $1 - \omega$ and the impatient households of size ω. The two types of households only differ in their time preference rate; impatient households have a lower time preference rate, thus discounting the future more heavily than the patient households. This heterogeneity leads to a positive amount of debt held by the impatient households in equilibrium. The maximum debt that they can hold is restricted by a collateral constraint similar to the setup in Kiyotaki and Moore (1997) and Iacoviello (2005). In the production side, there are perfectly competitive firms that either produce an intermediate good as input for the production of non-durable retail goods, or they produce houses. The non-durable retail goods are produced by monopolistic competitive firms that face sticky prices *á la* Calvo. In addition, there is a monetary policy authority that sets interest rates according to a Taylor rule and, finally, a government that manages public expenses and tax revenue.

2.1 Patient Households (Savers)

The problem of patient households is quite standard. They maximize their lifetime utility subject to their budget constraint. In particular, they maximize:

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, h_t, n_{c,t}, n_{h,t}) \tag{1}$$

with respect to their non-durable consumption c_t, housing stock h_t and hours worked in the non-residential and residential sector $n_{j,t}$ with $j \in \{c, h\}$, subject to the budget constraint (expressed in terms of the non-durable retail good prices):

$$c_t + q_t h_t + b_t \leq (1 - \tau_t^n) \left[w_{c,t} n_{c,t} + w_{h,t} n_{h,t} \right] + q_t (1 - \delta) h_{t-1} + \frac{R_{t-1} b_{t-1}}{\pi_t} + \Xi_t - T_t \tag{2}$$

where $c_t, q_t, h_t, b_t, R_t, \pi_t, \Xi_t$ and T_t are respectively the non-durable consumption, real house prices, the housing stock, total savings in form of non-contingent bonds, the interest rate, the gross inflation rate, the profits from the monopolistic competitive firms that households own and the lump-sum taxes. Finally, τ_t^n is the labor income tax rate and $w_{j,t}$ is the real wage rate paid in the sector $j \in \{c, h\}$.

We use the following functional form for the utility, first proposed by Greenwood et al. (1988) and subsequently used by Monacelli and Perotti (2008) for fiscal policy analysis[3]:

$$U(c_t, h_t, n_{c,t}, n_{h,t}) = \frac{(X_t - \Phi N_t^{\varphi})^{1-\sigma} - 1}{1 - \sigma} \tag{3}$$

$$\text{where } X_t \equiv \left[(1 - \alpha_t)^{\frac{1}{\eta}} c_t^{\frac{\eta-1}{\eta}} + \alpha_t^{\frac{1}{\eta}} h_t^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{4}$$

$$N_t \equiv \left(n_{c,t}^{1+\nu} + n_{h,t}^{1+\nu} \right)^{\frac{1}{1+\nu}} \tag{5}$$

[3] Monacelli and Perotti (2008) adopt a non-separable utility in consumption and hours in order to replicate a positive response of private consumption after fiscal expansions, which is typically observed in the empirical literature.

where $\Phi > 0$ is a disutility parameter related to labor, φ is the inverse of the Frisch elasticity of labor supply, and α_t is a preference parameter for housing that follows an AR(1) process with a zero-mean, white-noise shock ε_t^{α}.

2.2 Impatient Households (Borrowers)

Impatient households face a similar problem. They maximize their lifetime utility being constrained by the budget constraint and an extra collateral constraint. Specifically, they maximize:

$$E_0 \sum_{t=0}^{\infty} \widetilde{\beta}^t U\left(\widetilde{c}_t, \widetilde{h}_t, \widetilde{n}_{c,t}, \widetilde{n}_{h,t}\right) \tag{6}$$

subject to the budget constraint:

$$\widetilde{c}_t + q_t \widetilde{h}_t + \frac{R_{t-1}\widetilde{b}_{t-1}}{\pi_t} \leq (1-\tau_t^n)\left[w_{c,t}\widetilde{n}_{c,t} + w_{h,t}\widetilde{n}_{h,t}\right] + q_t(1-\delta)\widetilde{h}_{t-1} + \widetilde{b}_t - \widetilde{T}_t \tag{7}$$

and a collateral constraint that limits their debt up to a certain portion of their expected real estate wealth[4]:

$$\widetilde{b}_t \leq \theta E_t \frac{q_{t+1}\widetilde{h}_t \pi_{t+1}}{R_t} \tag{8}$$

2.3 Production

There are two types of perfectly competitive firms: the first belong to the sector "c" and produce intermediate goods as inputs for the production of non-durable retail goods, while the second type belong to the sector "h" and produce houses. Any type of firms $j \in \{c, h\}$ use a linear technology:

$$y_t^j = A_t N_t^j \tag{9}$$

[4] This constraint specification was first proposed by Kiyotaki and Moore (1997). We use a modified version of the collateral constraint introduced by Iacoviello (2005) and subsequently used in Iacoviello and Neri (2010) and Guerrieri and Iacoviello (2013).

where A_t is an aggregate technology parameter that follows an AR(1) process and N_t^j are the total hours supplied by the households to the sector j. Firms maximize profits subject to their technology process:

$$\max_{N_t^j} \left\{ z_t^j A_t N_t^j - P_t^c w_t^j N_t^j \right\} \tag{10}$$

where z_t^j is the price of the goods or houses produced. Note that real wage w_t^j is defined as the nominal wage deflated by the non-durable retail goods price P_t^c.

2.4 Retailers

There is a continuum of monopolistically competitive retailers in the sector of non-durable goods, indexed by i on the unit interval. Retailers buy intermediate goods and differentiate them with a technology that transforms one unit of intermediate good into one unit of retail good. Note that the relative price of intermediate goods, z_t^c/P_t^c, coincides with the real marginal cost faced by the retailers, mc_t. Let y_{it}^c be the quantity of output sold by retailer i. Final non-durable goods can be expressed as:

$$y_t^c = \left[\int_0^1 (y_{it}^c)^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{11}$$

where $\varepsilon > 1$ is the constant elasticity of demand for intermediate goods. The retail good is sold at its price, $p_t^c = \left[\int_0^1 (p_{it}^c)^{1-\varepsilon} di \right]^{\frac{1}{1-\varepsilon}}$. The demand for each intermediate good depends on its relative price and aggregate demand:

$$y_{it}^c = \left(\frac{p_{it}^c}{p_t^c} \right)^{-\varepsilon} y_t^c \tag{12}$$

Following Calvo (1983), we assume that in any given period each retailer can reset her price with a fixed probability $1 - \chi$. Hence, the price index is:

$$p_t^c = \left[(1-\chi)(p_t^*)^{1-\varepsilon} + \chi (p_{t-1}^c)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}} \tag{13}$$

The firms that are able to reset their price, p_{it}^*, choose it so as to maximize expected profits given by:

$$E_t \sum_{s=0}^{\infty} \chi^s \Lambda_{t+s} (p_{it}^* - mc_{t+s}) y_{it+s}^c$$

The resulting expression for p_{it}^* is:

$$p_{it}^* = \frac{\varepsilon}{\varepsilon - 1} \frac{E_t \sum_{s=0}^{\infty} \chi^s \Lambda_{t+s} mc_{t+s} y_{it+s}^c}{E_t \sum_{s=0}^{\infty} \chi^s \Lambda_{t+s} y_{it+s}^c} \tag{14}$$

2.5 Monetary Policy

There is an independent monetary authority that sets the nominal interest rate according to a simple Taylor rule:

$$R_t = R_{t-1}^{\rho_\pi} (\pi_t^c)^{(1-\rho_\pi)\phi_\pi} \tag{15}$$

where π_t^c is the gross inflation rate of the non-durable good's retail price, ρ_π is a coefficient measuring inertia in interest rate setting and ϕ_π measures the "aggressiveness" of monetary policy to fight inflation.

2.6 Government

Government's income consists of tax revenue, while expenditures consist of consumption purchases. The government deficit in real terms is defined as:

$$DF_t = g_t - \tau_t^n (w_t^c N_t^c + w_t^h N_t^h) - T_t \tag{16}$$

where g_t is public consumption, and τ_t^n is the labor income tax rate. The government budget constraint is given by:

$$\frac{R_{t-1}^{-1} b_{t-1}^G}{\pi_t} + DF_t = b_t^G \tag{17}$$

where b_t^G denotes government bonds sold to patient households. For the two fiscal instruments we assume the exogenous processes:

$$x_t = (1 - \boldsymbol{\varrho}_x)\overline{x} + \boldsymbol{\varrho}_x x_{t-1} + \varepsilon_t^x \tag{18}$$

where $x \in \{\log(g), \tau^n\}$, ρ_x determines the persistence of the processes, and ε_t^x is a zero-mean, white-noise disturbance. Finally, to ensure determinacy of equilibrium and a non-explosive solution for debt (see e.g. Leeper (1991)), we assume a debt-targeting rule for the lump-sum taxes of the form:

$$T_t = \overline{T} \exp(\zeta_{ß}(ß_t - \overline{ß})) \tag{19}$$

where $\overline{ß}$ is the steady state level of debt to GDP ratio, $ß_t = \frac{B_t^G}{y_t}$.

2.7 Market Clearing

In equilibrium all markets clear. The equilibrium in the non-durable goods market implies the aggregate resource constraint:

$$y_t^c = (1-\omega)\, c_t + \omega \widetilde{c}_t + g_t \tag{20}$$

Similarly, the equilibrium in the real estate market requires:

$$y_t^h = (1-\omega)\left(h_t - (1-\delta)h_{t-1}\right) + \omega\left(\widetilde{h}_t - (1-\delta)\widetilde{h}_{t-1}\right) \tag{21}$$

Also, the labor markets in the non-durable good sector and the residential sector should clear in equilibrium:

$$N_t^c = (1-\omega)\, n_{c,t} + \omega \widetilde{n}_{c,t} \tag{22}$$

$$N_t^h = (1-\omega)\, n_{h,t} + \omega \widetilde{n}_{h,t} \tag{23}$$

If all markets above clear then the bond market also clears by Walras' law. Finally, we define total output produced as the sum of non-residential output and residential investment:

$$y_t = y_t^c + q \cdot y_t^h \tag{24}$$

where q is the price of houses expressed in non-durable retail goods prices.

2.8 Calibration and Solution

The model period is a quarter. We parameterize the model such that we target several statistics for the US economy. Specifically, we set the steady state value of the preference variable α equal to 0.1 in order to target the residential investment-to-GDP ratio which is approximately 5% for the US. The time preference rate of patient households is set to 0.99 which implies an annual interest rate of 4%, close to the average Fed Funds rate. The discount rate for impatient households is set lower at 0.98 in order to ensure positive debt in equilibrium. In addition, the values of several fiscal variables are set according to data. Government consumption amounts for 20% of the US GDP, the deficit/GDP ratio is set to 1% and the debt/GDP ratio 50%.

Following Monacelli and Perotti (2008) we set φ so that it implies a Frisch labor supply elasticity equal to 1.25, while the labor disutility parameter Φ is set such that the hours worked by households correspond to 1/3 of their time. The specific aggregator for hours worked by a household in the utility function permits for a varying level of substitutability or complementarity. When ν is zero the hours of the two sectors are perfect substitutes. However, we set ν to 0.7 which implies an imperfect substitutability as in Iacoviello and Neri (2010). It is assumed that the housing investment depreciates at an annual rate of 4% and as a result δ is set to 0.01. The retail sector of non-durable goods is characterized by sticky prices that cannot change for three quarters and consequently the stickiness parameter χ is set to 0.67. A summary of all parameters are presented in table 1 of appendix B.

In order to solve the model with an occasionally binding collateral constraint we follow Guerrieri and Iacoviello (2015) who present a novel piecewise linear solution. Specifically, there are two regimes characterized by whether the constraint binds or not. In the steady state the constraint always binds. When a shock hits the economy, the constraint may become slack but it is expected to revert and bind again in the future. Within a given regime the solution is linear so that there are two linear policy rules, one for each regime. The policy rules are derived from a first-order approximation of the log-linearized version of the model. The system of equations that describe the model are given in appendix A.

3 Theoretical Results

3.1 State-Dependent Responses

In order to compute the state-depedent responses to the fiscal shocks we simulate two regime-specific environments: an environment characterized by a binding collateral constraint and an environment characterized by a slack collateral constraint. As first described in Guerrieri and Iacoviello (2013), a model with housing investment and a collateral constraint provides a direct link between housing wealth fluctuations and the tightness of the constraint. Specifically, the model's implication is as follows: when housing wealth is relatively low, the value of housing collateral and borrowing limits are also low, and consequently the collateral constraint binds; however, when housing wealth increases substantially after a series of shocks, then the collateral value and borrowing limits may increase so much that the collateral constraint becomes slack. To this end, we proceed in three steps. First, we hit the economy with a series of house preference shocks that directly affect house prices and housing wealth, and hence dictate a fixed regime (either a binding or a slack collateral constraint) throughout the impulse response horizon. We save the responses of all variables. In the second step, we compute the same set of responses after the same shock process but further adding the fiscal shock under investigation. We save the new set of responses. Finally, we subtract the responses obtained in the first step from the responses obtained in the second step, and the result is the marginal contribution of the fiscal shock to the variables' dynamics.

The benchmark results are presented in figures 3 and 4. All shocks considered are expansionary, and all variables and their corresponding responses are measured in real terms. Figure 3 shows the responses to a 1% of GDP increase in government consumption. The (blue) solid lines represent responses when the economy is simulated to be in an environment of low housing wealth and a binding collateral constraint while the (red) dashed lines stand for an environment of relatively high housing wealth and a slack constraint. The abbreviation "S" in the variables' names denotes savers while "B" denotes borrowers. Let first consider the effects of spending shocks on house prices. The patient households' first order condition with respect to housing (equation A.2) , written in a more concise form where $U_{h,t}$ is the marginal utility of housing and $U_{c,t}$ the marginal utility of consumption, is:

$$U_{h,t} - U_{c,t}q_t + E_t\left[\beta(1-\delta)U_{c,t+1}q_{t+1}\right] = 0 \tag{25}$$

If we iterate it forward, it can be restated as:

$$U_{c,t}q_t = \underbrace{E_t\left[\sum_{j=1}^{\infty}\left[\beta(1-\delta)\right]^j U_{h,t+j}\right]}_{\approx\ \text{constant}} \tag{26}$$

The left-hand-side term $U_{c,t}q_t$ represents the shadow value of housing, which optimally should be equal to the discounted present value of marginal utilities of the service flow of housing (right-hand-side term). As it is widely discussed in the literature[5], the right-hand-side term term is almost constant because δ is small and $U_{h,t+j}$ is a smooth process. As a result, any variations in the marginal utility of consumption $U_{c,t}$ should be matched by analogous adjustments in the real house price q_t , and vice versa, in order to satisfy the optimal demand decision for housing. A positive shock to government consumption expands demand for labor, hours worked rise and so does the marginal utility of consumption. Therefore, equation 26 requires that the real house price must fall. This effect on house prices should be common in both regimes (i.e. when the collateral constraint is either slack or binding).

According to the benchmark parameterization, the output multiplier reaches 0.2 when the collateral constraint binds, while it reaches around 2 when the constraint becomes slack. This result comes from the response of total private consumption, which is negative when the constraint binds while it is positive when the constraint is slack. The reasoning goes as follows. After a government spending expansion, total working hours increase due to a positive labor supply and a positive labor demand effect. In addition, due to the assumption of a non-separable utility, the increasing hours worked raise the marginal utility of consumption and lead patient and impatient households to increase their consumption. As a result total consumption and output tend to increase. Those effects should be common in both regimes. However, the binding constraint regime implies a further *collateral channel* that alters the transmission of fiscal policy. In particular, the fall in house prices after the shock erodes impatient households' collateral value, and hence they are forced to borrow and spend less according to what their collateral constraint

[5] See Barsky et al. (2007) for a detailed analysis.

dictates. If this negative effect on consumption caused by the collateral channel is stronger than the positive effect induced by the increase in hours and the marginal utility of consumption, then private consumption of borrowers will fall, as indeed does here. What is more, this collateral channel plays the role of a financial accelerator which reinforces the decline in house prices and private debt. For this reason, when the collateral constraint binds house prices fall by much more than when the constraint is slack. This fact has serious implications for the behavior of patient households as well. Specifically, house prices fall so much that equation 26 would require a substantial increase in the marginal utility of consumption. The latter is achieved through a decline in patient households' consumption. Note that the sharp fall in real house prices also leads to a substitution effect; patient households will desire to substitute consumption of non-durables with relatively cheaper housing. Overall, when the collateral constraint is binding for borrowers aggregate private consumption falls, while when the constraint is slack aggregate consumption increases. Residential investment typically is crowded out in both cases, but does not contribute that much to the asymmetric behavior of output. As a result, the non-linear behavior of private consumption is the main source of asymmetries. To sum up, *government spending shocks are more effective in stimulating output when housing wealth is relatively high and the collateral constraint is slack* rather than the rest times.

Figure 4 shows the responses after a 1 percentage point cut in the labor income tax rate. As expected, the shock is expansionary in both regimes but the expansion of output is more pronounced in the binding constraint regime. The reasoning goes as follows. Let first consider the regime that the collateral constraint is slack. A cut in the labor income tax rate encourages labor supply, and total hours worked increase. The increase in hours of both patient and impatient households will raise their marginal utility of consumption and, consequently, consumption increases. In addition, residential investment and subsequently house prices increase due to a fall in the interest rate. As a result, total output increases by 0.4% on impact. However, when the collateral constraint is binding the implications are different. The increase in real house prices implies an increase in the value of collateral for borrowers, thus a relaxation of the borrowing limit and a proportional increase in the credit extended to households. This positive effect on borrowers' resources will be reflected on higher demand for consumption and residential investment. The significant increase in house prices will force patient households to substitute non-durable goods for housing, and consequently investment of patient households falls while their consumption increases. Overall, given a binding collateral constraint, total consumption rises by 1.3% and output rises by 1.1%. As a result, *tax cuts are more effective in stimulating the economy in times of low housing wealth and binding collateral constraints* rather than the rest times.

The next sections are devoted to (i) a non-linear empirical analysis in order to test the model's predictions in the data and (ii) a sensitivity analysis of the model which attempts to reconcile theory and empirics.

4 Empirical Analysis

4.1 The Threshold VAR Model

In this step, we estimate the non-linear effects of fiscal policy on output and its components after government consumption and income tax shocks in order to test whether data reveal a similar pattern of the state-dependent effects of fiscal policy that we received in the theoretical analysis. We consider a threshold VAR (TVAR) model following Koop et al. (1996) and Balke (2000). Such a model has the advantage of capturing non-linear dynamics conditioned to a transition (threshold) variable that is observable and endogenous to the system. Moreover, this threshold variable can be endogenous in the VAR system. Specifically, the threshold VAR model we estimate is:

$$y_t = A_1(L)y_{t-1} + B_1(L)x_t + I\left[z_{t-1} \geq z^*\right] \cdot (A_2(L)y_{t-1} + B_2(L)x_t) + u_t \tag{27}$$

where y_t is the vector of endogenous variables, x_t the vector of exogenous variables, and z is the transition (threshold) variable that determines two distinct regimes. $I[\cdot]$ is an indicator function that equals 1 when variable z_{t-1} is above a threshold value z^* and 0 otherwise. The regression model also contains a deterministic trend and regime-specific constants. The model parameters $A_1(L)$, $B_1(L)$, $A_2(L)$, $B_2(L)$, z^*, the deterministic term coefficients and the error covariance matrix are estimated using the Conditional Ordinary Least Squares estimator proposed by Tsay (1998).

4.2 Data

We use quarterly, seasonally adjusted data of the US for the period 1963q1-2007q4. The series come from the NIPA tables. The benchmark model contains six endogenous variables: the log of real per capita government consumption, the net (of transfers) tax revenue, the gross domestic product, house prices, an interest rate and a sixth variable. To economize in degrees of freedom, the last variable rotates between the private consumption of non-durables and services, and the residential investment. In order to identify exogenous tax shocks, we also consider a measure of average personal income tax shocks as exogenous variable. The exogenous shocks are constructed in Mertens and Ravn (2013) and more details are provided in the next section. The fiscal variables, GDP, consumption and investment are in log per capita terms and deflated by the GDP deflator, while house prices are in logarithms and deflated by the GDP deflator. All variables except for the interest rate are linearly detrended. According to information criteria we set the lag length of the VAR to two.

Concerning the threshold variable z_{t-1} we use real house prices. House prices mainly drive housing wealth. What is more, figure 1 shows that house prices strongly comove with private sector's real estate wealth, having a correlation of 0.95. As a result, house prices could be considered as a reliable proxy for collateral fluctuations and the tightness of collateral constraints. As benchmark house prices we use the median house price index of the US Census Bureau described in appendix A.

4.3 Identifying the Shocks

A key challenge in this framework is the identification of the fiscal shocks. Many identification approaches have been suggested in the past and still there is no conclusive empirical work on determining the best way of identifying fiscal shocks in the data. To recover government spending shocks we use a recursive identification according to the SVAR literature, as in Blanchard and Perotti (2002) and Fatas and Mihov (2001). This identification method assumes that the reduced VAR residuals are a linear combination of structural uncorrelated shocks, and that government spending cannot be contemporaneously affected by any other variable in the system. When using quarterly data it is reasonable to assume that public spending decisions cannot be revised within a quarter and thus cannot react to current economic conditions. Those two assumptions are satisfied if i) the contemporaneous matrix that links the VAR errors with the structural shocks is given by the Cholesky factor of the estimated VAR error covariance matrix, and ii) government consumption is ordered first in the VAR system. Then, given the estimated Cholesky factor and the estimated VAR residuals, one can recover the government spending shocks.

Concerning the identification of the personal income tax shocks one should be more careful because the tax revenue are affected by the economic cycle, prices and other factors, and, as a result, it is much more difficult to isolate the discretionary exogenous component of the changes in tax revenue. The most popular approach so far to overcome this problem has been a narrative identification using official budget records, news press records and other official documents that report exogenous policy decisions and their estimated or actual net effects on tax liabilities. The seminal work of Romer and Romer (2010) introduces this framework for the US and several other papers further contribute to expand this approach in terms of methodology (Favero and Giavazzi (2012), Mertens and Ravn (2013) and Perotti (2012)) or in terms of country sample (Cloyne (2013)). In particular, Mertens and Ravn (2013) construct narrative average personal income tax and corporate income tax shocks, and they consider them as instruments for the observed average income tax series. Using a novel GMM framework the authors estimate the effects of the distinct tax revenue components on the US output. In a similar vein, Favero and Giavazzi (2012) use the narrative tax revenue shocks constructed by Romer and Romer (2010), but the authors treat the shocks as an exogenous variable in a fiscal VAR model. The methodology of Favero and Giavazzi (2012) seems very suitable for our empirical framework, and as a result we use the narrative personal income tax shocks of Mertens and Ravn (2013) as an exogenous variable x_t in the threshold VAR model (equation 27). The average personal income tax shocks are plotted in figure 2 and they are defined as the change in the personal income tax liabilities between two consequtive quarters divided by the personal taxable income of the previous period.

4.4 Empirical Results

4.4.1 Benchmark Results

Figures 11a and 11b present the impulse response functions of output, private consumption, residential investment and real house prices after an 1% of GDP increase in government consumption and 1 percentage point cut in personal income tax rate respectively[6]. The left columns represent the regime where house prices are below the threshold at the time that the shock hits, while the right columns represent a regime where house prices are above the threshold value. The estimated threshold value (trend deviation of house prices) in this specification is approximately 0.004. To make the comparison between the two regimes more clear, tables 2 and 3 presents the 1-year and 3-year annualized cumulative responses of output, consumption and residential investment to the two shocks, and the peak responses. The benchmark results are given in the first block of those tables (under the label "Benchmark model").

According to figure 11a, the effects of government consumption shocks are highly non-linear; when house prices are above the estimated threshold the spending shock has an expansionary and lasting effect on output and private consumption. Specifically, output significantly increases for twelve quarters with a peak at 1.88% in the sixth quarter, while private consumption increases persistently throughout the horizon with a peak at 1.76%. On the other hand, in the low house price regime (left column), responses switch sign after the first quarter. In particular, a fiscal expansion makes output and private consumption fall significantly and persistently. Notably, output responses follow the pattern of private consumption responses in both regimes. Also, real house prices fall persistently in both states. Residential investment significantly falls in the low house price regime, thus being in accordance with what theory predicts, while it does not move significantly in the other regime. The same conclusions can be reached according to table 2. In the regime that house prices lie above the threshold (in table notation: regime II), both the one-year and three-year cumulative responses of output are significant and equal to 1.25% and 4.12% respectively. The cumulative responses of private consumption are also significant and with values very close to those of output. However, when house prices are relatively low (in table notation: regime I) the three-year cumulative response is significant and equal to -3.90%.

Figure 11b similarly reveals non-linear patterns of the responses to tax shocks. In the regime characterized by low house prices, the tax effects are more pronounced comparably to

[6] At this step, the computed impulse responses ignore any endogenous feedback of the system to the threshold variable. In other words, the benchmark impulse responses assume that the economy can stay in a given regime for a sufficient number of periods and there is no endogenous regime shift. This framework can be equally seen as an analysis of fiscal policy in two boundary scenarios, one referring to a protracted period of high house prices (e.g. financial boom) and the other referring to a protracted period of low house prices (e.g. financial crisis). This type of impulse responses are useful for two reasons. First of all, it is easier to compare the two regimes and assess their distinct implications for the tranmission of the fiscal shocks. Secondly, they can be directly comparable with the theoretical results. However, in the robustness section we also compute impulse responses that allow for endogenous regime shifts.

the high price regime. In particular, in an environment of low house prices, a 1 percentage point cut in the average personal income tax rate induces an increase in output by approximately 0.9% on impact. Output peaks in the third quarter at a maximum value of 1.58%, and the increase remains persistent for fourteen quarters. In contrast, in the regime characterized by high house prices, the response of output is weaker and not significantly different from zero. The responses of private consumption and residential investment have almost the same pattern; a 1 percentage point tax cut yields a peak response of private consumption around 1.49% in the third quarter in an environment of low house prices , while responses are buffered and not statistically significant when house prices are above the threshold. Similarly, residential investment significantly increases with a peak response at around 10.54% in the third quarter when house prices are below the threshold, while it does not move significantly in the other regime. Finally, real house prices significantly and persistently increase throughout the horizon in both regimes. Similar conclusions can be reached according to table 3. In the regime that house prices lie below the threshold (regime I), both the one-year and three-year cumulative responses of output are significant and equal to 1.60% and 4.06% respectively. The cumulative responses of private consumption are also significant and equal to 1.04% and 3.47%. Residential investment's cumulative responses over one and three years are also significant. However, when house prices are relatively high (regime II) neither the cumulative responses nor the peak responses of all three variables are statistically significant. Notably, the estimates of output in the low house price regime are very close to the ones that Mertens and Ravn (2013) report for income tax rate shocks in a linear model. In particular, the authors report a peak response of GDP by 1.8% at the third quarter.

4.4.2 Robustness Analysis

The threshold variable A first issue is whether the empirical results are sensitive to alternative threshold definitions. As a benchmark case, we considered the median price for new, single-family houses sold (including land) provided by the US Census Bureau. The first exercise here is to use a shorter series of house prices available from the Bank for International Settlements starting in 1970 and referring to residential property prices of existing dwellings. These series are derived from the Corelogic database and are constructed using the weighted-repeat sales methodology proposed by Case and Shiller. A second alternative definition of house prices we are going to consider is the median price for all houses provided by the US Census Bureau. We repeat the benchmark TVAR regression using the two alternative threshold variables in place of the benchmark house prices. The TVAR model remains the same at all other aspects. Exact definitions of the variables are provided in appendix A.

Figures 12a and 13a refer to the responses to spending shocks for the two alternative threshold definitions. The responses convey a message similar to the benchmark result: positive spending shocks are more expansionary with respect to private consumption and output during times of relatively high house prices (figures 12a and 13a, right columns), while responses become weaker or even switch sign during times of relatively low house prices (left columns). Residential investment may fall or not move significantly when house prices are relatively low, while it may increase or not react when house prices exceed the threshold. Similarly, the cumulative and peak responses of output and private consumption are quite high and mostly significant in the regime defined by high house prices (regime II, second and third block of table 2) while the cumulative responses in the low price regime are barely significant and turn negative (regime I, second and third block of table 2).

Figures 12b and 13b refer to the responses to tax shocks for the two alternative threshold definitions. As before, the benchmark result remains robust across threshold definition: tax cuts are more expansionary on output and consumption during times characterized by low house prices rather than in times of high house prices. Table 3 (second and third block) conveys the same message. The cumulative and peak responses of all variables are significant and high in the regime defined by low house prices (regime I), while they are very low and barely significant in the high price regime (regime II).

Controlling for expectations Another important aspect is the timing of fiscal policy and the implications for the proper identification of government spending shocks. In particular, the seminal work of Ramey (2011) highlights that fiscal policy measures are often pre-announced or expected by individuals. In such a case, a shock considered at a certain point in time actually has already affected economic decisions of agents well before, at the point it was announced or simply expected by the public. According to Ramey (2011), failing to distinguish between the expected component and the truly unexpected component of a fiscal policy shock will result to bias in the estimates. Therefore, we re-estimate the TVAR model adding the forecast series of real government expenditure provided by the Survey of Professional Forecasters. The forecast series is ordered first in the TVAR since it is a predetermined variable in the system. All rest variables are ordered as in the benchmark TVAR model. This ordering permits to purge government spending series from their expected component, and to estimate the effects of the truly unexpected spending shocks. The responses of macrovariables to unexpected government spending shocks are shown in figure 14, while cumulative and peak responses are provided in the fourth block of table 2 (under the label "Anticipation effects"). The responses are quite close to the benchmark ones, and hence they confirm our main conclusions.

SVAR-based tax shocks In the benchmark specification we consider tax shocks identified using a narrative approach since this method seems to be the most reliable way of obtaining truly exogenous changes in taxes. This part robustifies benchmark estimations using SVAR-based tax shocks. In particular, we construct average income tax rate series following the approach of Jones (2002). Details on the construction of the tax rate series are provided in the appendix A. The alternative VAR specification contains the following endogenous variables: the log of real per capita government consumption, the constructed average tax rate series, the gross domestic product, house prices, an interest rate and a sixth variable which again rotates between the private consumption and the private residential investment. The tax rate variable is ordered last in the VAR in order to purge it from any endogenous response to other variables like output or interest rates.

The results of the alternative TVAR model are shown in figure 15. The responses of output, consumption and house prices bear striking similarities to the benchmark estimations. If house prices lie below the threshold when a tax rate cut hits, output and consumption significantly increase with a peak at 1.56% and 1.37% respectively. However, if house prices exceed the threshold at the moment a tax shock hits the system, then output and consumption barely respond. House prices significantly increase in both regimes, while residential investment initially increases only in the low price regime. According to table 3 (fourth block) the one- and three-year cumulative responses of output, consumption and investment are significantly high when house prices lie below the threshold (regime I), while they are low and not different from zero when house prices exceed the threshold (regime II). Overall, the benchmark results remain robust under the alternative identification method.

Generalised Impulse Responses The benchmark impulse responses ignore any endogenous feedback of the system to the threshold variable. In other words, the benchmark impulse responses assume that the economy can stay in a given regime for a sufficiently large number of periods and there is no endogenous regime shift. This framework can be equally seen as an analysis of fiscal policy in two boundary scenarios, one referring to a protracted period of high house prices (e.g. financial boom) and the other referring to a protracted period of low house prices (e.g. financial crisis). This type of impulse responses are useful for two reasons. First of all, it is easier to compare the two regimes and assess their distinct implications for the tranmission of the fiscal shocks. Secondly, they can be directly comparable with the theoretical results. However, at this point it would be useful to compute *generalised impulse response functions (GIRFs)* that allow for endogenous regime shifts and test whether our benchmark result remains robust.

Impulse responses to a shock may depend on several factors: initial conditions (values) of one or more variables, the variables' history, the size and the direction of current and future shocks. All those factors together determine how far from the threshold value the transition variable lies and how often it crosses the threshold. In turn, the frequency and the pattern of the regime shifts is what determines the generalised impulse responses. In other words, the GIRFs represent a kind of marginal effects of shocks when history, the size and direction of current and future shocks are all averaged out.

The TVAR is reestimated and GIRFs are computed. The responses with respect to the government consumption shock are presented in figure 16a. When house prices are below the threshold, output, private consumption and residential investment does not significantly react to a government consumption shock. On the other hand, in the regime defined by high house prices, output and private consumption increase with a peak at 0.79% and 0.81% in the fifth quarter respectively. House prices robustly fall in both regimes.

Responses to tax shocks (figure 16b) also remain robust. A one percentage point cut in the personal income tax induces a significant increase in output, private consumption, residential investment and house prices in the regime defined by low house prices. On the contrary, responses of all variables are more buffered in the regime defined by high house prices.

5 Back to the model: Squaring theory and empirics

Both the theoretical model and the empirical analysis are in accordance that housing wealth is a significant factor that dictates two distinct regimes and differentiates the transmission mechanism of fiscal shocks across the regimes. In the theory, fluctuations of house prices and housing wealth make a collateral constraint occasionally binding and thus imply heterogeneous dynamics depending on whether the constraint is binding or slack when the fiscal shock hits the economy. Similarly, in the empirical model house prices directly define two distinct regimes. The aim of this section is to explain which assumptions or parameters in the theoretical model are crucial for matching theoretical responses with empirical ones.

5.1 The role of (non)separable utility

In the theoretical model we have assumed a utility function that is non-separable in consumption and hours. Monacelli and Perotti (2008) first proposed such a specification of the utility in fiscal policy analysis in order to replicate the positive response of private consumption after fiscal expansions that is typically reported by the structural VAR literature. But how much crucial is such an assumption in our framework? Indeed, non-separability seems to play an important role for matching theoretical and empirical responses. To see why, we repeat the theorerical analysis with a model that assumes a separable utility. The responses of both specifications (separable and non-separable) after a government spending shock are presented in figure 5a for the case that the collateral constraint binds and in figure 5b for the case that the constraint is slack. When the collateral constraint binds and the economy is hit by a positive government consumption shock (figure 5a) non-separability implies a relatively more contractionary effect on consumption and hence a less expansionary effect on output than what separability implies for the given shock and regime. This happens because, given a government spending shock and the subsequent expansion of hours worked, non-separability implies an increase in the marginal utility of consumption by more than what would be the case in the separable utility model. Therefore, according to equation 26, a non-separable utility model requires a relatively sharper decline in the real house price, which in turn leads to a stronger negative collateral effect and more contractionary impact on private demand for consumption and housing. What is more, comparing figures 5a and 11a (left column), the responses of the non-separable utility model are closer to the empirical responses where actually both output and consumption contract. On the other hand, when the collateral constraint is slack and the economy is hit by a positive government consumption shock (figure 5b) non-separability implies a relatively more expansionary effect on consumption and output than what separability implies for the given shock and regime. The reason is that with non-separable utility a spending shock induces an increase in the marginal utility of consumption and triggers private consumption, while separability does not imply such an effect on the marginal utility of consumption. Instead, in the case of a separable utility any increase in the marginal utility of consumption that is required in order to satisfy the Euler equations A.4 and A.10 can be only achieved through reductions in private consumption. Most importantly, comparing figures 5b and 11a (right column), the responses of the non-separable case are closer in value to the empirical responses, where both output and consumption expand and, particularly, output multipliers exceed the unity. The separable utility specification cannot generate strong expansions and output multipliers higher than one.

Now we turn our attention to the role of (non)separability for tax shocks. The responses of both specifications (separable and non-separable) after a tax rate cut are presented in figure 6a, for the case that the collateral constraint binds, and in figure 6b, for the case that the constraint is slack. In both states of collateral constraints (both figures 6a and 6b) non-separability implies a relatively more expansionary effect on consumption and output than what separability does. The reasoning goes as before; with non-separable utility a tax cut induces an expansion in hours and a subsequent increase in the marginal utility of consumption which further stimulates private consumption and output. Comparing figures 6a and 11b (left column), the responses of the non-separable utility model are closer in value to the empirical responses where both output and consumption significantly expand. The separable utility specification can generate only weaker expansions.

Above all, we conclude that the non-separable utility model generates responses that better matches the empirical patterns. However, there are still some more discrepancies between the theoretical and empirical results. Next subsections suggest how results could further improve by modifying some other aspects of the model.

5.2 The role of the shock persistence

The theoretical analysis concluded that positive government consumption shocks increase output in both regimes, and that the response is more buffered in the environment characterized by low housing wealth and a binding collateral constraint. However, in the empirical part, output significantly falls in the analogous regime of low housing wealth. The shock persistence, ρ_g and ρ_τ, is a possible explanation for this discrepancy. In particular, an increase in the persistence of a shock to deficit-financed spending implies a stronger negative wealth effect due to much higher taxes in the future. In turn, this negative wealth effect will force households to cut back consumption. If the negative response of private consumption dominates the positive response of public consumption, then it could be the case that output falls. As a result, the higher the persistence of the shock, the more likely for output to fall after a fiscal expansion. To test that, figure 7a show the responses for various values of the shock persistence after a positive government consumption shock in the regime defined by a binding collateral constraint (left column) and a regime defined by a slack collateral constraint (right column). As expected, in the binding constraint regime (left column) higher shock persistence implies more negative responses of private consumption. Especially when the shock persistence is 0.95 then the deep fall in private consumption dominates, and therefore output falls as well. Furthermore, higher shock persistence implies flatter and more persistent responses of all variables in the regime defined by a slack collateral constraint (right column). The flatter and more persistent responses in high values of ρ_g are similar to the empirical responses in the analogous regime. Overall, a higher shock persistence, about 0.95, yields theoretical responses that are closer to the empirical ones for both regimes. Notably, the estimated lag coefficient of an AR(1) process for the government spending is around 0.94. This result further confirms our view that shock persistence may be the factor that make our benchmark output responses be slightly different than the empirical ones. Hence, once applying the estimated shock persistence in the model, theoretical responses improve. What is more, the benchmark result remains robust to alternative values of shock persistence: spending shocks have relatively more expansionary effects on output and private consumption in the slack constraint regime rather than the binding constraint regime.

Similar conclusions can be derived for the responses after tax shocks, shown in figure 7b. A higher tax shock persistence implies stronger responses of house prices, consumption, investment and output in both regimes. This helps to improve the match between the theoretical and empirical responses in the regime characterized by low housing wealth (compare left columns of figures 7b and 11b). Furthermore, the benchmark result remains robust to alternative values of shock persistence: tax cuts are more expansionary in the tight credit regime.

5.3 The role of monetary policy

The response of monetary policy to stabilize prices after fiscal shocks is another important factor that affects the transmission of shocks. In particular, both the sensitivity of the policy rate to inflation (i.e. the Taylor rule coefficient ϕ_π) and the Taylor rule inertia (coefficient ρ_π) determine the extent to which interest rates react to fiscal shocks, thus the extent of crowding-out of private demand. To test for the role of monetary policy, we consider three different monetary policy stance specifications: an accommodative policy ($\phi_\pi = 1.1, \rho_\pi = 0.8$), the benchmark policy ($\phi_\pi = 1.5, \rho_\pi = 0.5$), and an aggressive policy ($\phi_\pi = 2.5$, $\rho_\pi = 0$). Figures 8a and 8b present the responses for spending shocks and tax shocks in the regime defined by a binding collateral constraint (left columns) and a regime defined by a slack collateral constraint (right columns). According to figure 8a, a more aggressive monetary policy (high ϕ_π and low ρ_π) induces more contractionary (or less expansionary) effects of government spending shocks on output and private consumption in both regimes. This is quite intuitive because spending expansions put upward pressure on inflation. If the policy rate is very sensitive to inflation and exhibits no inertia, then it rises substantially and generates a contractionary effect on consumption and output. Most importantly, an aggressive monetary policy improves the match between empirical and theoretical responses, especially in the low housing wealth regime where constraints are more likely to bind: as monetary policy becomes more aggressive with no inertia, fiscal expansions through spending induce a stronger interest rate response and a bigger crowding-out of private demand. The latter dominates and finally output falls.

On the other hand, according to figure 8b, tax cuts induce a decline in inflation and a lower interest rate as a response to the former. The negative response of interest rates after tax cuts is the reason why tax cuts induce stronger expansionary effects when the monetary policy is more aggressive. As before, varying the level of monetary policy aggressiveness does not make much difference for the comparison of the two regimes, and instead confirms our benchmark result: tax cuts are more expansionary in the tight credit regime.

6 A policy instrument comparison

As the previous analysis shows, the effectiveness of fiscal policy will depend on the prevailing credit conditions. In particular, the analysis suggests that spending policies are highly effective in stimulating private demand in times of loose credit, while tax policies are highly effective in doing so in times of tight credit. However, it would be also interesting to know whether, for instance, in times of tight credit a tax policy is still preferable to a spending policy. The present framework permits us to make a direct comparison between the two fiscal instruments. To do so, we rescale the tax rate shock to correspond to a 1% of GDP cut in income tax revenue while the spending shock corresponds to a 1% of GDP increase in the government consumption. Figure 9 makes a direct assessment for the effectiveness of spending shocks against tax shocks for the regime characterized by low housing wealth and a binding collateral constraint. Output multiplier equals 0.2 for the spending shock while it is 1.7 for the tax shock. This discrepancy comes from the fact that tax cuts stimulate private demand for consumption and investment while spending increases crowd-out both. Those effects are further reinforced by the presence of the *collateral channel*. In particular, tax cuts induce an increase in real house prices, an increase in the value of collateral and a proportional positive wealth effect that stimulates consumption and investment of borrowers. In contrast, after positive government spending shocks real house prices fall, the value of collateral declines and the credit supplied to borrowers contracts. This effect worsens the crowding-out of private consumption and investment. Therefore, government spending shocks cannot be so expansionary as tax cuts during times of tight credit.

However, the opposite holds during periods of loose credit. According to figure 10, government spending shocks imply an output multiplier around 2 while a tax cut implies a multiplier around 0.6. The difference in the effectiveness of the two instruments comes from the following reasons. Both positive government consumption shocks and tax cuts will increase hours worked which will subsequently drive the marginal utility of consumption up. To restore equilibrium, households increase consumption, and output expands. However, the increase in hours after tax cuts is not so pronounced as the increase in hours after the positive spending shocks. This is reasonable because positive spending shocks imply (i) a negative wealth effect, thus increasing labor supply and (ii) a direct demand effect that increases labor demand, and overall the hours worked increase substantially. On the other hand, tax cuts directly imply only a labor supply effect. Therefore, total hours worked increase more after spending expansions rather than tax cuts. In turn, the marginal utility of consumption, consumption itself and output increase by more after spending expansions rather than tax cuts. As a result, in times of loose credit, spending-based fiscal stimuli are more effective than tax-based stimuli of equal size.

7 Conclusion

This paper investigates how housing wealth dynamics and collateral constraints jointly matter for the non-linear transmission of fiscal policy shocks. To this end, a DSGE model with housing investment and occassionally binding collateral constraints is proposed and studied. The effects of fiscal shocks are found to be highly non-linear in such a model. In particular, positive government spending shocks have more pronounced and expansionary effects on output and private consumption when housing wealth is relatively high and the collateral constraint is slack rather than in rest times. On the contrary, tax cuts are more expansionary in times of low housing wealth and a binding collateral constraint rather than in rest times. The key mechanism is that when the collateral constraint binds an extra transmission channel emerges that comes from house price movements and the subsequent valuation effects on the housing collateral. This collateral channel buffers government spending stimuli while boosts tax cut stimuli.

A threshold VAR model also reveals significant state-dependent effects of fiscal shocks conditional on housing wealth, and confirms the theoretical model's predictions. Moreover, the data are in favor of a model with non-separable utility in consumption and hours, since, in contrast to a sepable utility model, it generates responses that are closer to the empirical ones. In addition, higher shock persistence and a more aggressive monetary policy stance seem to improve the model's performance comparably to data.

The model also has important implications for the relative efficiency of spending policies versus tax policies. In particular, income tax shocks are more expansionary on output and private demand than government consumption shocks in times of tight credit. On the contrary, spending shocks are more effective in stimulating private demand and output than tax shocks in times of loose credit. This result is highly policy relevant; during times of tight credit and low housing wealth, such as the period that followed the 2008 financial crisis, a tax-based stimulus would be more recommendable than a spending-based stimulus. However, for countries that have implemented fiscal consolidation programs in the aftermath of the financial crisis, spending-based austerities would be less harmful to output and private demand than tax-based austerities.

References

Andrés, J., J. Boscá, and F. Ferri, 2012. "Household Leverage and Fiscal Multipliers," Banco de España Working Papers 1215, Banco de España.

Balke, N.S., 2000. "Credit and Economic Activity: Credit Regimes and Nonlinear Propagation of Shocks," *The Review of Economics and Statistics*, MIT Press, vol. 82(2), pages 344-349, May.

Barsky, R. B., C. L. House, and M. S. Kimball, 2007. "Sticky-Price Models and Durable Goods," American Economic Review, American Economic Association, vol. 97(3), pages 984-998, June.

Blanchard, O., and R. Perotti, 2002. "An Empirical Characterization Of The Dynamic Effects Of Changes In Government Spending And Taxes On Output," *The Quarterly Journal of Economics*, MIT Press, vol. 117(4), pages 1329-1368, November.

Calvo, G., 1983. "Staggered Pricing in a Utility Maximizing Framework," *Journal of Monetary Economics*, 12, 383-96.

Canzoneri, M., F. Collard, H. Dellas, and B. Diba, 2012. "Fiscal Multipliers in Recessions," Diskussionsschriften dp1204, Universitaet Bern, Departement Volkswirtschaft.

Cloyne, J., 2013. "Discretionary Tax Changes and the Macroeconomy: New Narrative Evidence from the United Kindom ", *American Economic Review* 103(4), 1507-28.

Fatas, A., and I. Mihov, 2001. "The Effects of Fiscal Policy on Consumption and Employment: Theory and Evidence," CEPR Discussion Papers No 2760.

Favero, C., and F. Giavazzi, 2012. "Measuring Tax Multipliers: The Narrative Method in Fiscal VARs," *American Economic Journal: Economic Policy*, American Economic Association, vol. 4(2), pages 69-94, May.

Galí J., López-Salido, D., and J. Vallés, 2007. "Understanding the Effects of Government Spending on Consumption," *Journal of the European Economic Association*, 5(1),

Greenwood, J., Hercowitz, Z. and Huffman, G. W, 1988. "Investment, Capacity Utilization, and the Real Business Cycle," *American Economic Review*, vol. 78(3), pages 402-17, June.

Guerrieri, L., and M. Iacoviello, 2013. "Collateral Constraints and Macroeconomic Asymmetries," International Finance Discussion Papers, Board of Governors of the Federal Reserve System (U.S.) 1082

Guerrieri, L., and M. Iacoviello, 2015. "OccBin: A Toolkit for Solving Dynamic Models With Occasionally Binding Constraints Easily," *Journal of Monetary Economics*, March, vol. 70, pages 22-38.

Iacoviello, M., 2005. "House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle," *American Economic Review*, American Economic Association, vol. 95(3), pages 739-764, June.

Iacoviello, M., and S. Neri, 2010. "Housing Market Spillovers: Evidence from an Estimated DSGE Model," *American Economic Journal: Macroeconomics*, American Economic Association, vol. 2(2), pages 125-64, April.

Roeger, W., and J. in 't Veld, 2009. "Fiscal Policy With Credit Constrained Households," European Economy - Economic Papers 357, Directorate General Economic and Financial Affairs (DG ECFIN), European Commission.

Jones, J. B., 2002. "Has Fiscal Policy Helped Stabilize the Postwar U.S. Economy?," *Journal of Monetary Economics*, Elsevier, vol. 49(4), pages 709-746, May.

Kiyotaki, N., and J. Moore, 1997. "Credit Cycles," *Journal of Political Economy*, University of Chicago Press, vol. 105(2), pages 211-48, April.

Koop, G., M. H. Pesaran, and S. M. Potter, 1996. "Impulse Response Analysis in Nonlinear Multivariate Models," *Journal of Econometrics*, Elsevier, vol. 74(1), pages 119-147, September.

Leeper, E., 1991. "Equilibria under Active and Passive Monetary and Fiscal Policies," *Journal of Monetary Economics*, 27, 129-147.

Mendoza, E.G., Razin, A., and L.L. Tesar, 1994. "Effective Tax Rates in Macroeconomics: Cross-country Estimates of Tax Rates on Factor Incomes and Consumption," *Journal of Monetary Economics* 34, 297–323.

Mertens, K., and M. O. Ravn, 2013. "The Dynamic Effects of Personal and Corporate Income Tax Changes in the United States," *American Economic Review*, vol. 103(4), pages 1212-47, June.

Monacelli, T., and R. Perotti, 2008. "Fiscal Policy, Wealth Effects and Markups," CEPR Discussion Papers 7099, C.E.P.R. Discussion Papers.

Perotti, R., 1999. "Fiscal Policy In Good Times And Bad," *The Quarterly Journal of Economics*, MIT Press, vol. 114(4), pages 1399-1436, November.

Perotti, R., 2012. "The Effects of Tax Shocks on Output: Not So Large, but Not Small Either." *American Economic Journal: Economic Policy*, 4(2): 214-37.

Ramey, V., 2011. "Identifying Government Spending Shocks: It's all in the Timing," *The Quarterly Journal of Economics*, vol. 126(1), pages 1-50.

Romer, C. D., and D. H. Romer, 2010. "The Macroeconomic Effects of Tax Changes: Estimates Based on a New Measure of Fiscal Shocks," *American Economic Review*, American Economic Association, vol. 100(3), pages 763-801, June.

Tagkalakis, A., 2008. "The Effects of Fiscal Policy on Consumption in Recessions and Expansions," *Journal of Public Economics*, Elsevier, vol. 92(5-6), pages 1486-1508, June.

Tsay, R. S., 1998. "Testing and Modeling Multivariate Threshold Models," *Journal of the American Statistical Association*, Vol. 93, No. 443, pp. 1188-1202.

APPENDIX A

Data Definitions and Sources

Government consumption: Consumption expenditures, Item 18, Table 3.1. Government Current Receipts and Expenditures, Source: Bureau of Economic Analysis.

Government wage consumption: Compensation of general government employees, Item 4, Table 3.10.5. Government Consumption Expenditures and General Government Gross Output, Source: Bureau of Economic Analysis.

Income tax revenue: Personal current taxes, Item 3, Table 3.1. Government Current Receipts and Expenditures, Source: Bureau of Economic Analysis.

Output: Gross domestic product, Item 1, Table 1.1.5. Gross Domestic Product, Source: Bureau of Economic Analysis.

Consumption: Personal consumption expenditures of non-durables and services, Items 5+6, Table 1.1.5. Gross Domestic Product, Source: Bureau of Economic Analysis.

Investment: Residential investment, Item 13, Table 1.1.5. Gross Domestic Product, Source: Bureau of Economic Analysis.

House prices: Median price for new, single-family houses sold (including land). Source: US Census Bureau.

Alternative house prices1: Residential property prices, existing dwellings, per dwelling. Source: National sources, BIS Residential Property Price database. http://www.bis.org/statistics/pp.htm.

Alternative house prices2: Median price for all houses. Source: US Census Bureau.

Interest rate: FED Funds Rate, Item: FEDFUNDS, Source: FRED.

Narrative shocks to the average personal income tax rate, Source: Mertens and Ravn (2013)

Average labor income tax rate: Own calculations.

Construction of average tax rates

The approach to construct average tax rates on labor income follows Mendoza et al. (1994) and Jones (2002). The source of data are NIPA tables (www.bea.gov).

The average personal income tax rate is calculated as:

$$\tau^p = \frac{IT}{W + PRI/2 + CI}$$

$$\text{where} \quad CI \equiv PRI/2 + RI + CP + NI$$

and IT denotes total income taxes (table 3.1: line 3), W denotes wages and salaries (table 1.12: line 3), CI denotes the capital income, PRI denotes the proprietor's income (table 1.12: line 9), RI denotes the rental income (table 1.12: line 12), CP denotes corporate profits (table 1.12: line 13) and NI denotes the net interest (table 1.12: line 18).

The labor tax rate is subsequently calculated as:

$$\tau^n = \frac{\tau^p\,(W + PRI/2) + CSI}{EC + PRI/2}$$

where CSI denotes contributions to social insurance (table 3.1: line 7) and EC denotes compensation of employees (1.12: line 2).

Equilibrium Conditions of the Model

- Patient Households

$$\lambda_t = (X_t - \Phi N_t^{\varphi})^{-\sigma} \left(\frac{(1-\alpha_t)X_t}{c_t} \right)^{\frac{1}{\eta}} \tag{A.1}$$

$$(X_t - \Phi N_t^{\varphi})^{-\sigma} \left(\frac{\alpha_t X_t}{h_t} \right)^{\frac{1}{\eta}} - \lambda_t q_t + E_t \left[\beta(1-\delta)\lambda_{t+1} q_{t+1} \right] = 0 \tag{A.2}$$

$$(X_t - \Phi N_t^{\varphi})^{-\sigma} \Phi \varphi N_t^{\varphi-\nu-1} n_{j,t}^{\nu} = \lambda_t (1-\tau_t^n) w_{j,t} \qquad \text{for any} \quad j \in \{c, h\} \tag{A.3}$$

$$\lambda_t = \beta E_t \left[\lambda_{t+1} \frac{R_t}{\pi_{t+1}} \right] \tag{A.4}$$

$$\text{where } X_t \equiv \left[(1-\alpha_t)^{\frac{1}{\eta}} c_t^{\frac{\eta-1}{\eta}} + \alpha_t^{\frac{1}{\eta}} h_t^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{A.5}$$

$$\text{and} \quad N_t \equiv \left(n_{c,t}^{1+\nu} + n_{h,t}^{1+\nu}\right)^{\frac{1}{1+\nu}} \tag{A.6}$$

- Impatient Households

$$\widetilde{\lambda}_t = (\widetilde{X}_t - \widetilde{\Phi}\widetilde{N}_t^{\varphi})^{-\sigma}\left(\frac{(1-\alpha_t)\widetilde{X}_t}{\widetilde{c}_t}\right)^{\frac{1}{\eta}} \tag{A.7}$$

$$(\widetilde{X}_t - \widetilde{\Phi}\widetilde{N}_t^{\varphi})^{-\sigma}\left(\frac{\widetilde{\alpha}_t\widetilde{X}_t}{\widetilde{h}_t}\right)^{\frac{1}{\eta}} - \widetilde{\lambda}_t q_t + E_t\left[\widetilde{\beta}(1-\delta)\widetilde{\lambda}_{t+1}q_{t+1}\right] + \mu_t\theta E_t\left[\frac{q_{t+1}\pi_{t+1}}{R_t}\right] = 0 \tag{A.8}$$

$$(\widetilde{X}_t - \widetilde{\Phi}\widetilde{N}_t^{\varphi})^{-\sigma}\widetilde{\Phi}\varphi\widetilde{N}_t^{\varphi-\nu-1}\widetilde{n}_{j,t}^{\nu} = \widetilde{\lambda}_t(1-\tau_t^n)w_{j,t} \qquad \text{for any } \ j \in \{c,h\} \tag{A.9}$$

$$\widetilde{\lambda}_t = \widetilde{\beta}E_t\left[\widetilde{\lambda}_{t+1}\frac{R_t}{\pi_{t+1}}\right] \tag{A.10}$$

$$\widetilde{c}_t + q_t\widetilde{h}_t + \frac{R_{t-1}\widetilde{b}_{t-1}}{\pi_t} \leq (1-\tau_t^n)\left[w_{c,t}\widetilde{n}_{c,t} + w_{h,t}\widetilde{n}_{h,t}\right] + q_t(1-\delta)\widetilde{h}_{t-1} + \widetilde{b}_t - \widetilde{T}_t \tag{A.11}$$

$$\widetilde{b}_t \leq \theta E_t\frac{q_{t+1}\widetilde{h}_t\pi_{t+1}}{R_t} \tag{A.12}$$

$$\text{where } X_t \equiv \left[(1-\alpha_t)^{\frac{1}{\eta}} c_t^{\frac{\eta-1}{\eta}} + \alpha_t^{\frac{1}{\eta}} h_t^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{A.13}$$

$$\text{and} \quad N_t \equiv \left(n_{c,t}^{1+\nu} + n_{h,t}^{1+\nu}\right)^{\frac{1}{1+\nu}} \tag{A.14}$$

- Intermediate Firms in the Non-durable Goods Sector

$$y_t^c = A_t N_t^c \tag{A.15}$$

$$w_{c,t} = mc_t \tag{A.16}$$

- Firms in the Housing Sector

$$y_t^h = A_t N_t^h \tag{A.17}$$

$$w_{h,t} = q_t \tag{A.18}$$

- Retailers in the Non-durable Goods Sector

  Combining and log-linearizing equations 13 and 14 results to a typical Philipps curve:

$$\pi_t^c = \frac{(1-\chi)(1-\beta\chi)}{\chi}\widehat{mc}_t + \beta E_t\left[\pi_{t+1}^c\right] \tag{A.19}$$

- Taylor Rule

$$R_t = R_{t-1}^{\rho_\pi}(\pi_t^c)^{(1-\rho_\pi)\phi_\pi} \tag{A.20}$$

- Government

$$DF_t = g_t - \tau_t^n(w_{c,t}N_t^c + w_{h,t}N_t^h) - T_t \tag{A.21}$$

$$\frac{R_{t-1}^{-1}b_{t-1}^G}{\pi_t} + DF_t = b_t^G \tag{A.22}$$

$$T_t = \overline{T}\exp(\zeta_{ß}(ß_t - \overline{ß})) \tag{A.23}$$

- Market Clearing Conditions and Aggregation

$$y_t^c = (1-\omega)\,c_t + \omega\widetilde{c}_t + g_t \tag{A.24}$$

$$y_t^h = (1-\omega)\,(h_t - (1-\delta)h_{t-1}) + \omega\left(\widetilde{h}_t - (1-\delta)\widetilde{h}_{t-1}\right) \tag{A.25}$$

$$N_t^c = (1-\omega)\,n_{c,t} + \omega\widetilde{n}_{c,t} \tag{A.26}$$

$$N_t^h = (1-\omega)\, n_{h,t} + \omega \widetilde{n}_{h,t} \tag{A.27}$$

$$y_t = y_t^c + q \cdot y_t^h \tag{A.28}$$

- Shock processes

$$\log x_t = (1-\boldsymbol{\varrho}_x) \log \overline{x} + \boldsymbol{\varrho}_x \log x_{t-1} + \varepsilon_t^x \quad x \in \{g, \tau^n, a, A\} \tag{A.29}$$

- Given the shock processes A.29, the equilibrium conditions and rest definitions A.1-A.28 define a system that can be solved for all endogenous state and control variables: c, $\widetilde{c}$, h, $\widetilde{h}$, n_c, n_h, $\widetilde{n_c}$, $\widetilde{n_h}$, X, $\widetilde{X}$, N, $\widetilde{N}$, N^c, N^h, λ, $\widetilde{\lambda}$, y^c, $y^h_,$ y, w_c, w_h, q, π^c, R, DF, b^G, $\widetilde{b}$, T_t.

APPENDIX B

Tables

Table 1: Benchmark calibration

Parameters		Values
ω	Size of impatient households	0.4
β	Discount factor of patient households	0.99
$\widetilde{\beta}$	Discount factor of impatient households	0.98
$\overline{\alpha}$	Steady state housing preference	0.1
φ	Parameter relevant to the Frisch elasticity	2
ν	Elasticity of substitution across labor types	0.7
δ	Housing depreciation rate	0.01
θ	Maximum loan to value ratio	0.9
ε	Elasticity of substitution for non-durable goods	6
η	Elasticity of substitution between non durables - housing	1
σ	Inverse of elasticity of substitution in consumption	1
χ	Price stickiness in the non-durable goods sector	0.67
$\zeta_{ß}$	Debt elasticity of lump-sum taxes	0.02
ϕ_{π}	Taylor rule coefficient	1.5
ϱ_{π}	Taylor rule inertia	0.5
ϱ	Persistence of shocks	0.85
Steady state target values		
n_c+n_h	Total hours worked by a household	1/3
π	Gross inflation rate	1
	Annual interest rate	0.04
$\frac{y^h}{y}$	Residential investment to GDP ratio	0.06
$\frac{g}{y}$	Public consumption to GDP ratio	0.20
$\overline{ß}$	Public debt to GDP ratio	0.50
$\frac{DF}{y}$	Public deficit to GDP ratio	0.01

	Output		Private Consumption		Residential Investment	
	Regime I	Regime II	Regime I	Regime II	Regime I	Regime II
	Benchmark model					
T=1	-0.62	1.25*	-0.57*	1.42*	-3.02	3.24
T=3	-3.90*	4.12*	-4.13*	4.30*	-12.50	7.94
Peak	0.57	1.88*	0.34	1.76*	-0.98*	6.11
	Alternative threshold variable (BIS prices)					
T=1	-0.22	0.04	-0.47	0.93*	-8.35*	1.26
T=3	-0.65	3.69*	-1.83	5.18*	-20.09*	19.77*
Peak	0.68	1.98*	0.30	2.23*	6.80	11.19*
	Alternative threshold variable (US Census prices)					
T=1	-0.56	0.60*	0.03	0.59	0.83	1.70
T=3	-4.58*	2.80*	-2.65*	2.45*	5.52	7.27
Peak	0.54	1.24*	0.44	1.01	5.20	4.19
	Anticipation effects					
T=1	-0.56	0.95*	-0.39	1.40*	-5.48	2.51
T=3	-1.89	3.51*	-2.28	4.76*	-14.98	-4.08
Peak	0.91	1.63*	0.24	1.85*	-0.74	4.10
	Generalised Impulse Response Functions					
T=1	-0.17	0.76*	-0.24	0.78*	-1.32	2.21
T=3	-1.01	2.01*	-1.35	1.76*	-0.95	7.16
Peak	0.69	0.79*	0.40	0.81*	1.66	6.27

Table 2: Annualized cumulative responses of output (columns 1-2), consumption (columns 3-4) and residential investment (columns 5-6) to a 1% of GDP increase in government consumption.

An asterisk * denotes one standard error statistical significance.

	Output		Private Consumption		Residential Investment	
	Regime I	Regime II	Regime I	Regime II	Regime I	Regime II
	Benchmark model					
T=1	1.60*	0.02	1.04*	0.08	10.92*	-0.50
T=3	4.06*	0.21	3.47*	0.01	25.90*	1.05
Peak	1.58*	0.16	1.49*	0.08	10.54*	1.45
	Alternative threshold variable (BIS prices)					
T=1	2.06*	0.50	1.20*	0.31	-5.72*	4.13
T=3	2.44*	0.43	2.56*	0.00	2.47	2.70
Peak	2.01*	0.48	1.37*	0.29	8.43*	4.15
	Alternative threshold variable (US Census prices)					
T=1	1.10*	0.21	0.88*	0.26	7.21*	-1.35
T=3	3.02*	0.79	2.75*	0.58	11.21*	0.13
Peak	1.21*	0.36	1.28*	0.28	9.14*	0.85
	SVAR-based tax shocks					
T=1	0.75*	0.17	0.65*	0.09	4.32*	0.43
T=3	2.71*	0.49	2.51*	-0.17	4.45	-3.69
Peak	1.56*	0.75*	1.37*	0.22	7.69*	2.24
	Generalised Impulse Response Functions					
T=1	1.26*	0.81*	0.78*	0.20	10.05*	6.94*
T=3	2.00*	0.48	1.38*	-0.27	19.00*	4.98
Peak	1.21*	0.87*	0.97*	0.31	9.19*	7.13*

Table 3: Annualized cumulative responses of output (columns 1-2), consumption (columns 3-4) and residential investment (columns 5-6) to a one percentage point cut in the personal income tax rate.

An asterisk * denotes one standard error statistical significance.

Figures

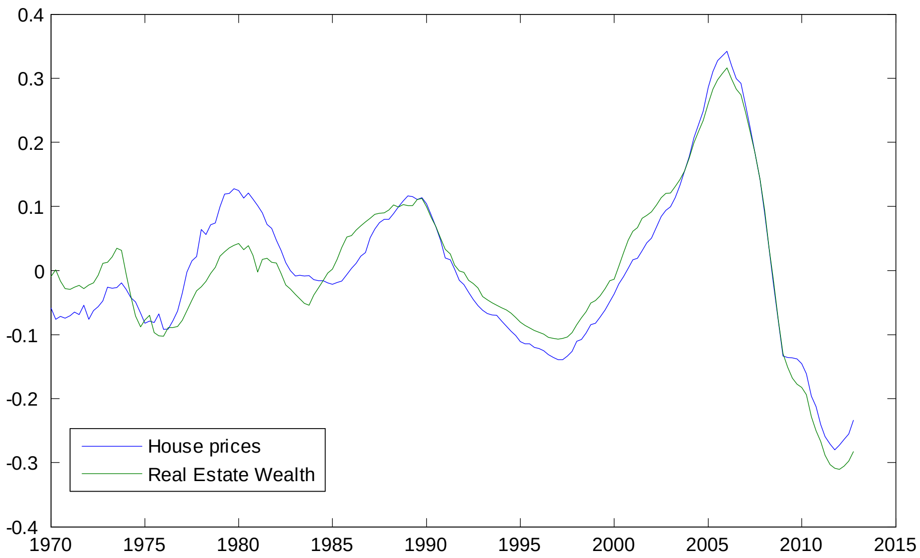

Figure 1: Real house prices and real estate wealth of households (Detrended series)

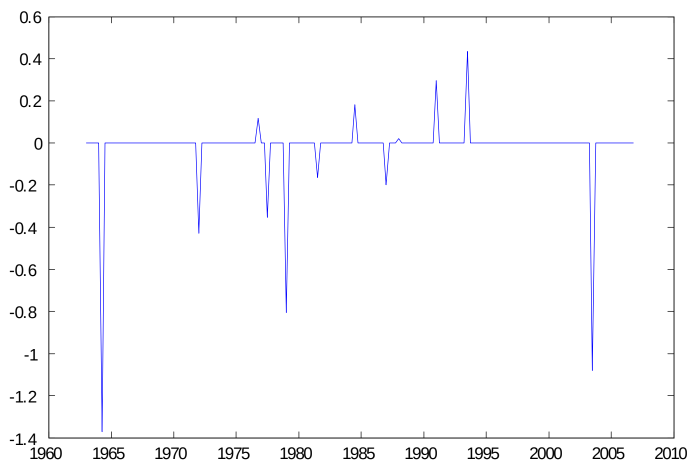

Figure 2: The narrative measure of personal income tax rate shock. (Source: Mertens and Ravn (2013))

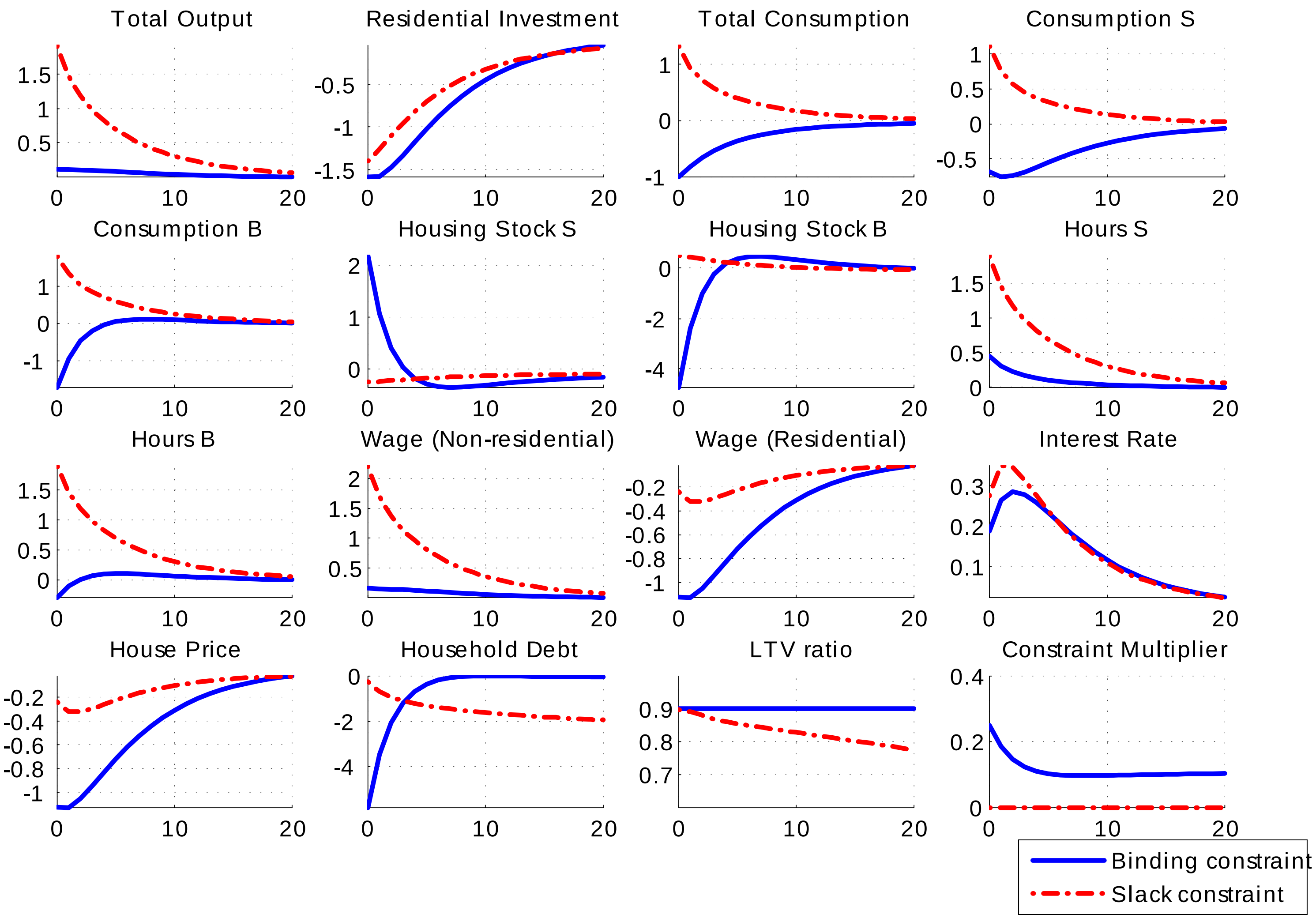

Figure 3: Regime-dependent responses to a government consumption increase equal to 1% of GDP. Binding versus slack collateral constraint. "S": Savers, "B": Borrowers.

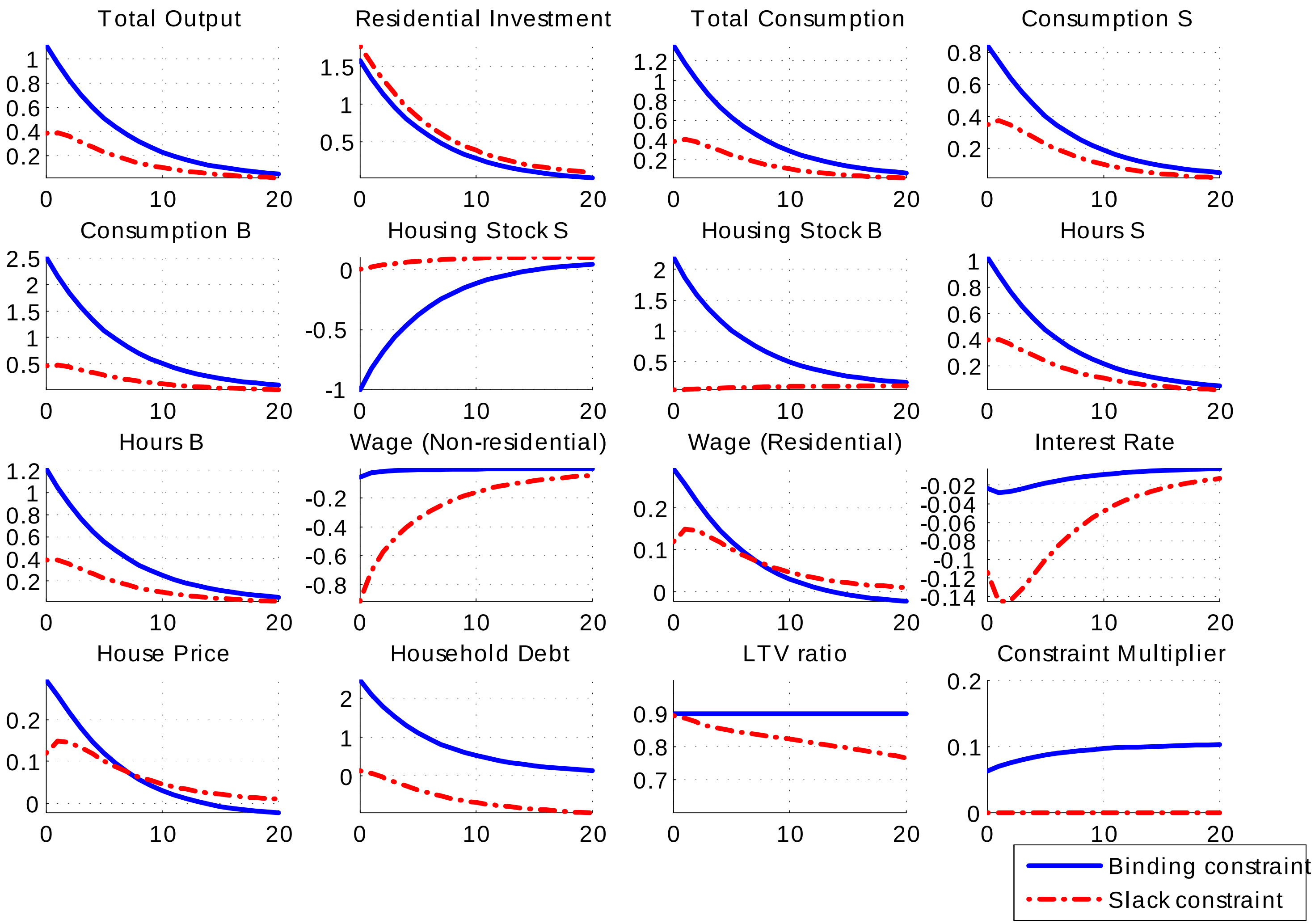

Figure 4: Regime-dependent responses to a 1 percentage point cut in the income rax rate. Binding versus slack collateral constraint. "S": Savers, "B": Borrowers.

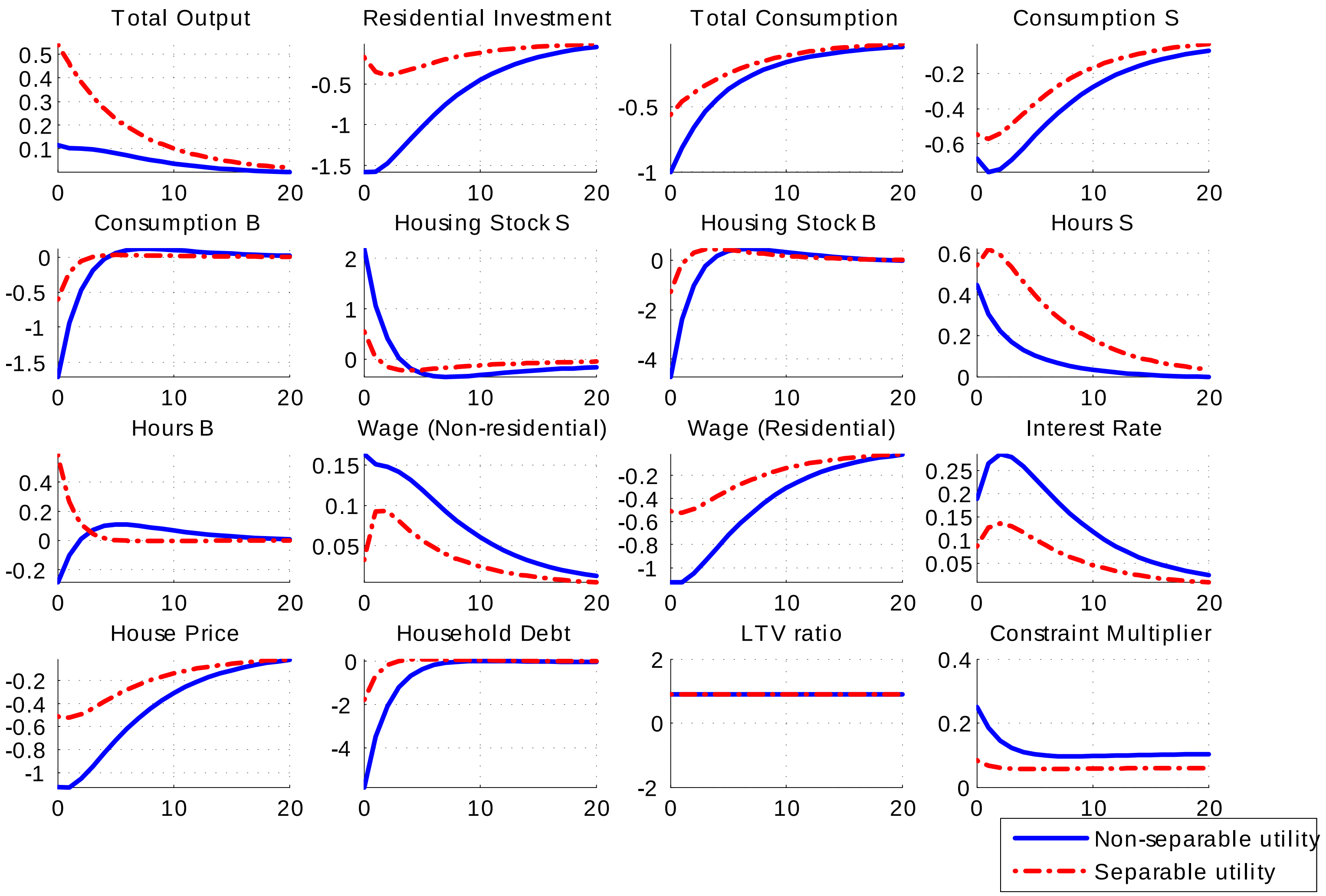

Figure 5a: Responses to a government consumption increase equal to 1% of GDP when the collateral constraint binds. Separable utility versus non-separable utility. "S": Savers, "B": Borrowers.

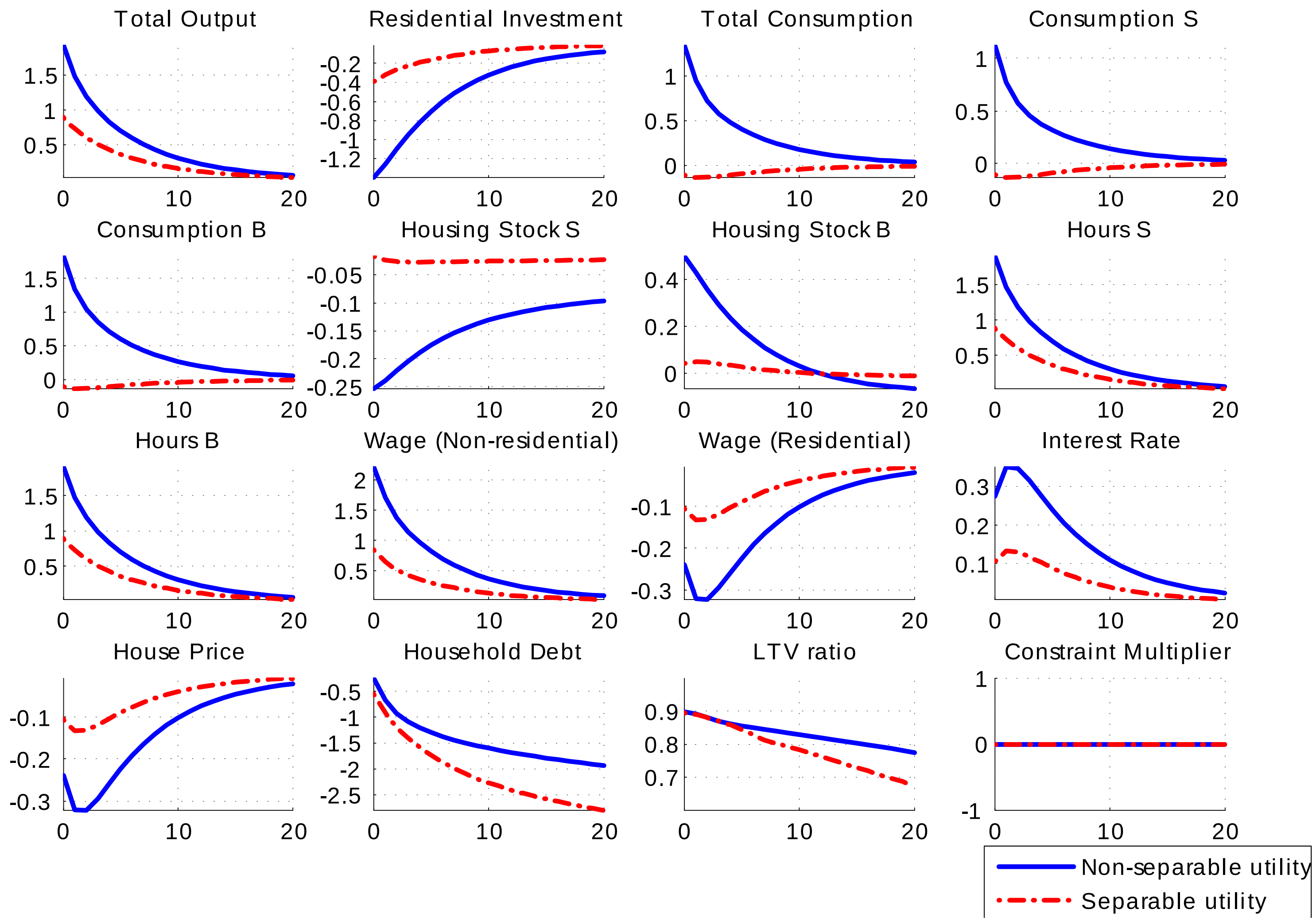

Figure 5b Responses to a government consumption increase equal to 1% of GDP when the collateral constraint is slack. Separable utility versus non-separable utility. "S": Savers, "B": Borrowers.

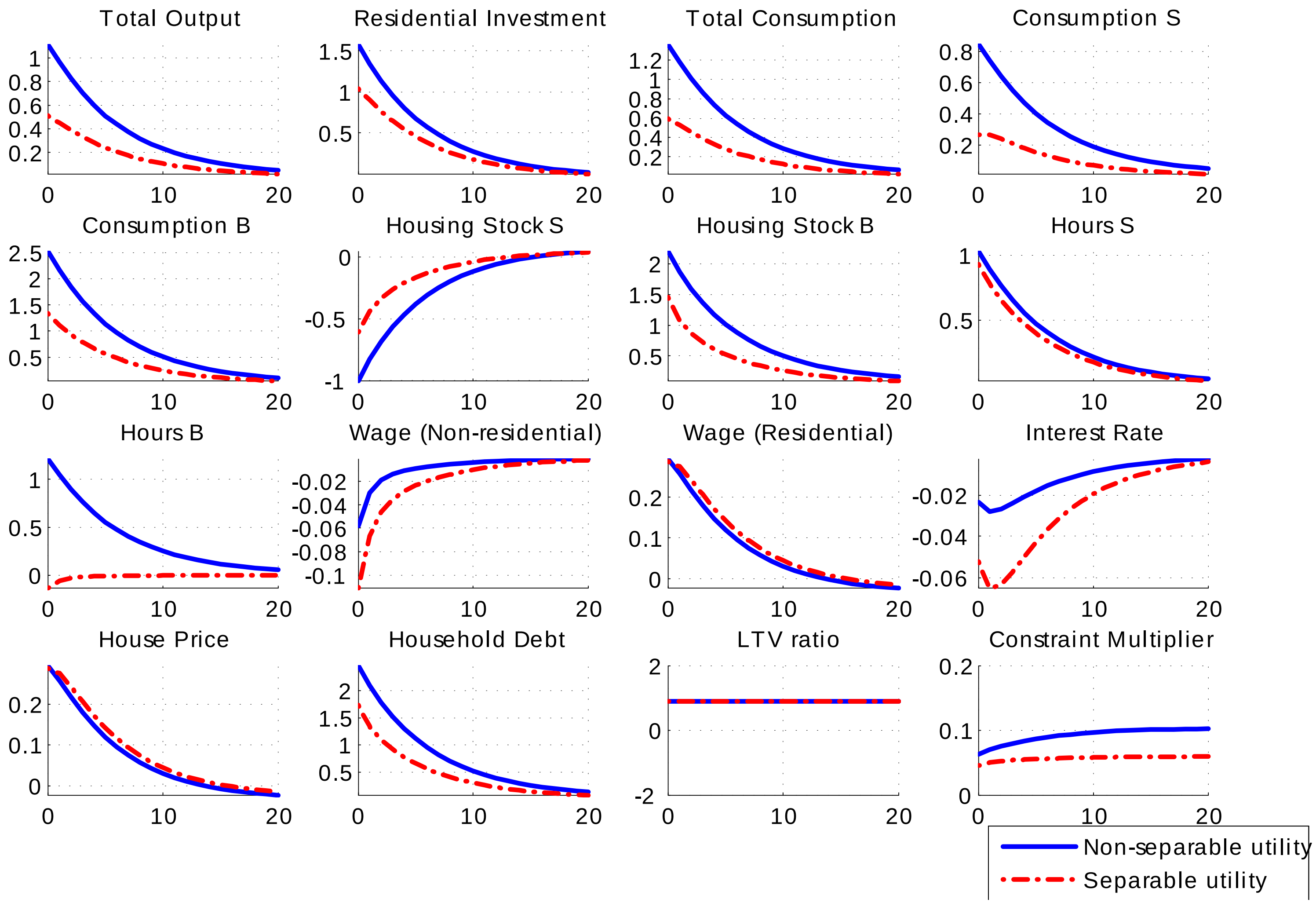

Figure 6a: Responses to a 1 percentage point cut in the income rax rate when the collateral constraint binds. Separable utility versus non-separable utility. "S": Savers, "B": Borrowers.

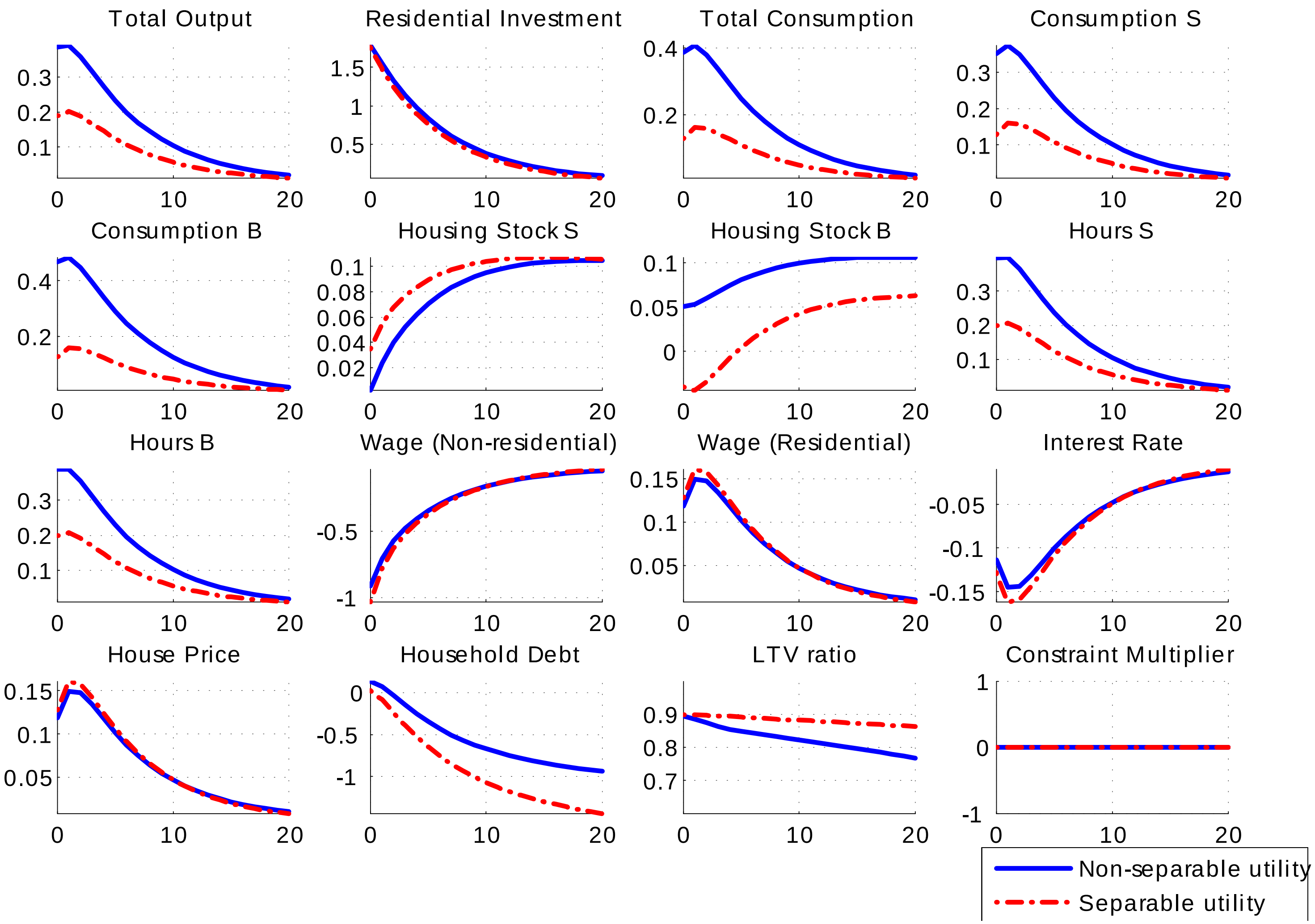

Figure 6b: Responses to a 1 percentage point cut in the income rax rate when the collateral constraint is slack. Separable utility versus non-separable utility. "S": Savers, "B": Borrowers.

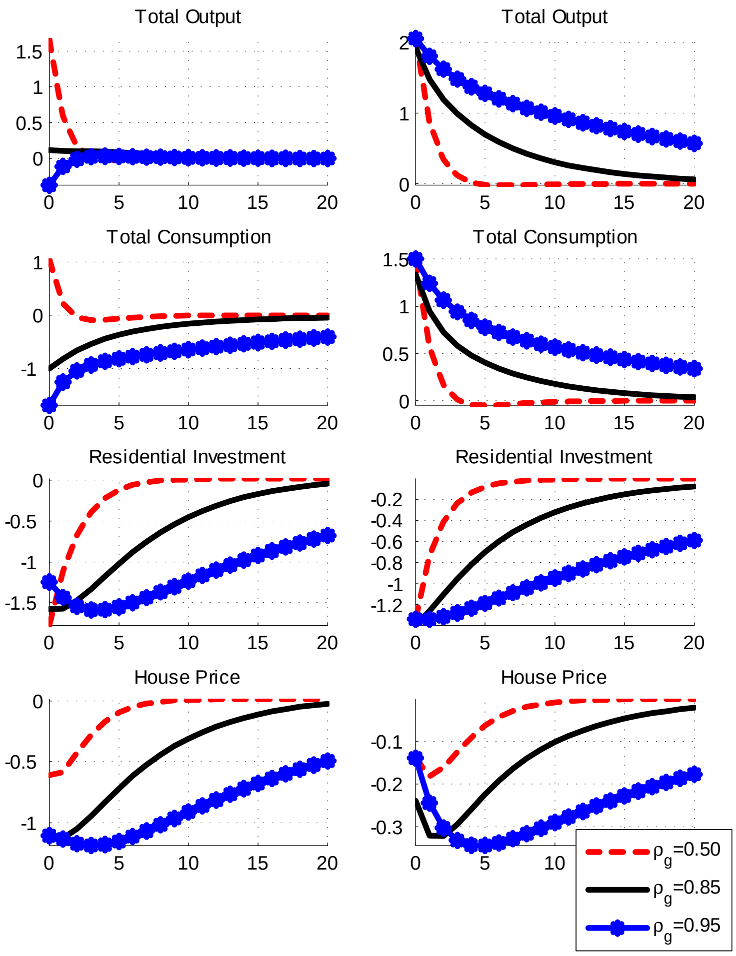

Figure 7a: Responses to a government consumption increase equal to 1% of GDP. Sensitivity analysis with respect to the shock persistence, ϱ_g. Binding collateral constraint (left column) versus slack constraint (right column).

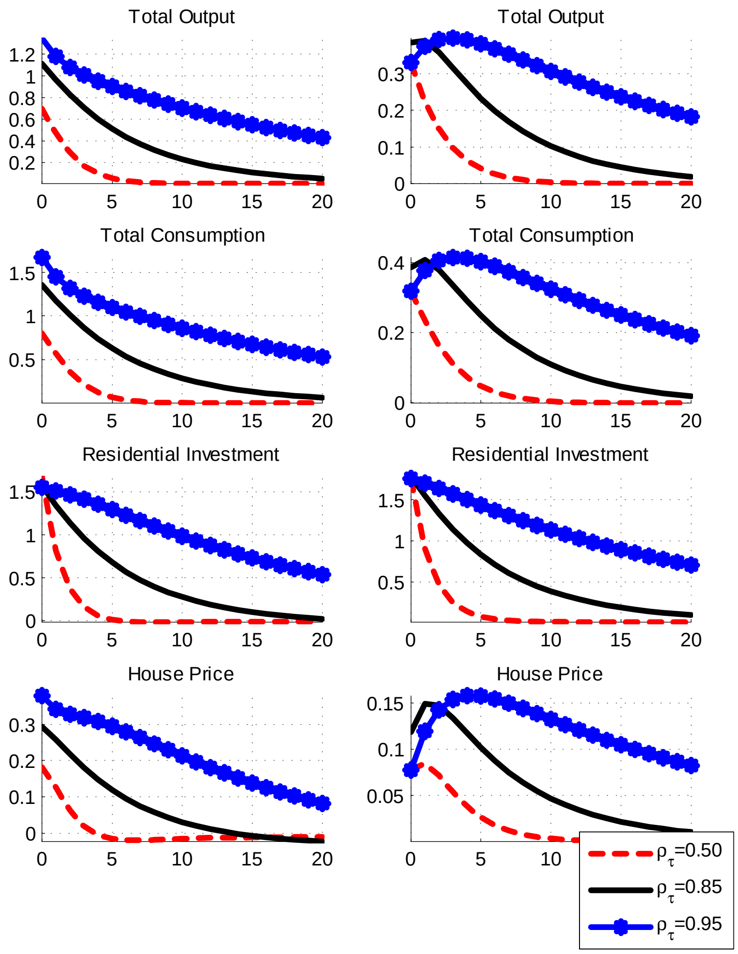

Figure 7b: Responses to a one percentage point cut in the labor income tax rate. Sensitivity analysis with respect to the shock persistence, ϱ_τ. Binding collateral constraint (left column) versus slack constraint (right column).

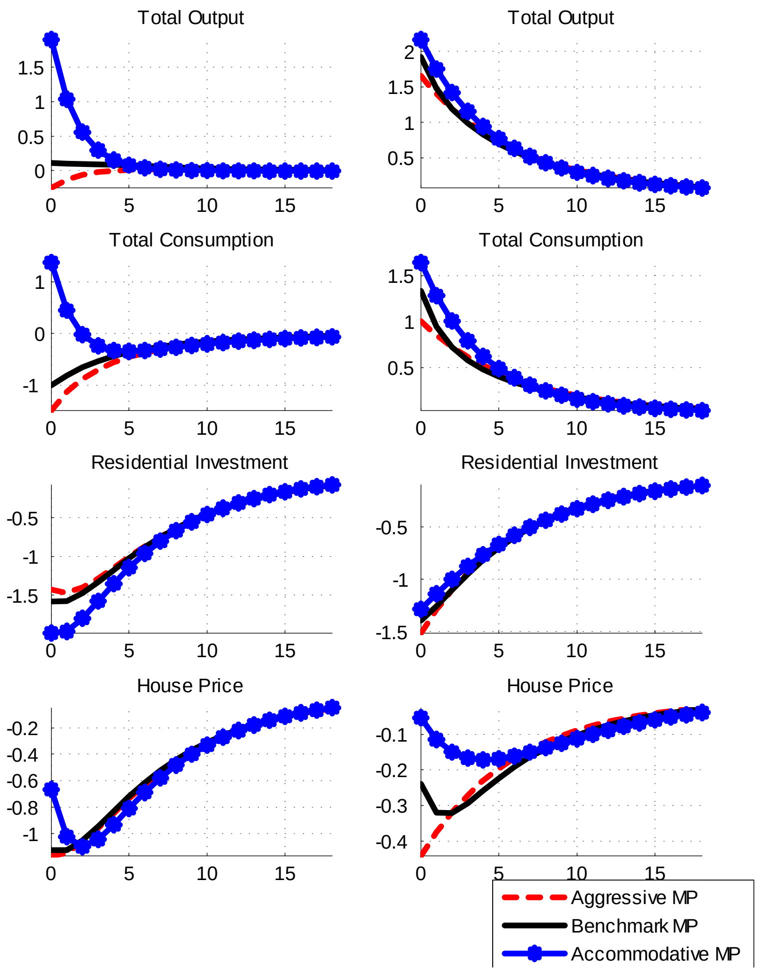

Figure 8a: Responses to a government consumption increase equal to 1% of GDP. Sensitivity analysis with respect to the monetary policy stance, ϕ_{π}, ρ_{π}. Binding collateral constraint (left column) versus slack constraint (right column).

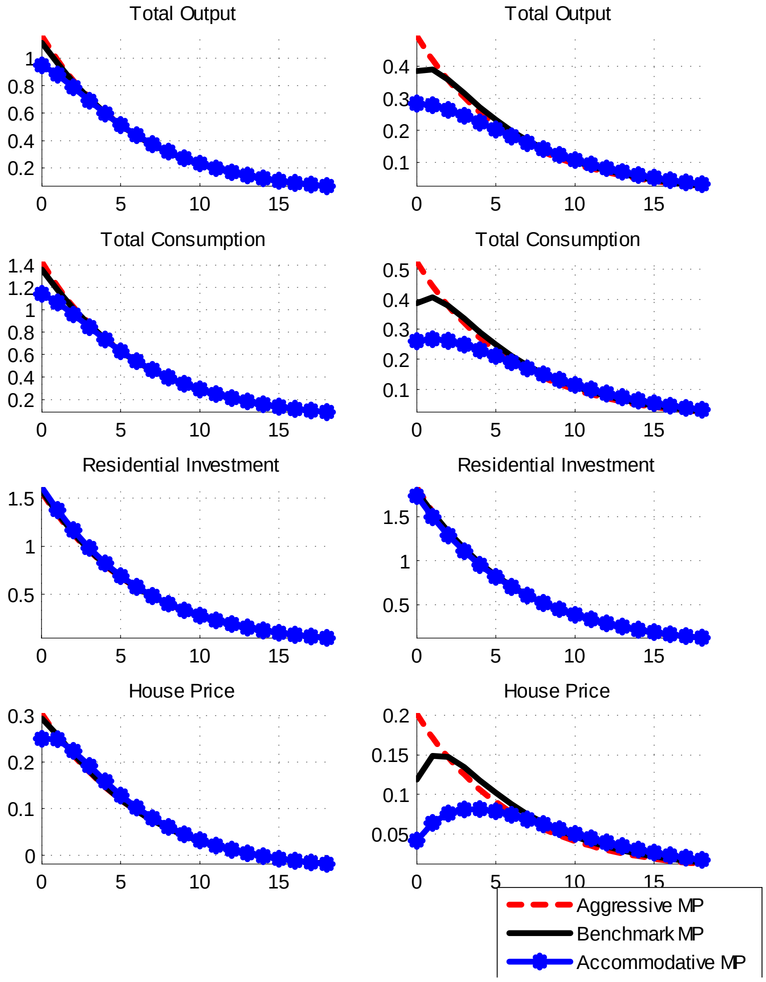

Figure 8b: Responses to a one percentage point cut in the labor income tax rate. Sensitivity analysis with respect to the monetary policy stance, ϕ_π, ρ_π. Binding collateral constraint (left column) versus slack constraint (right column).

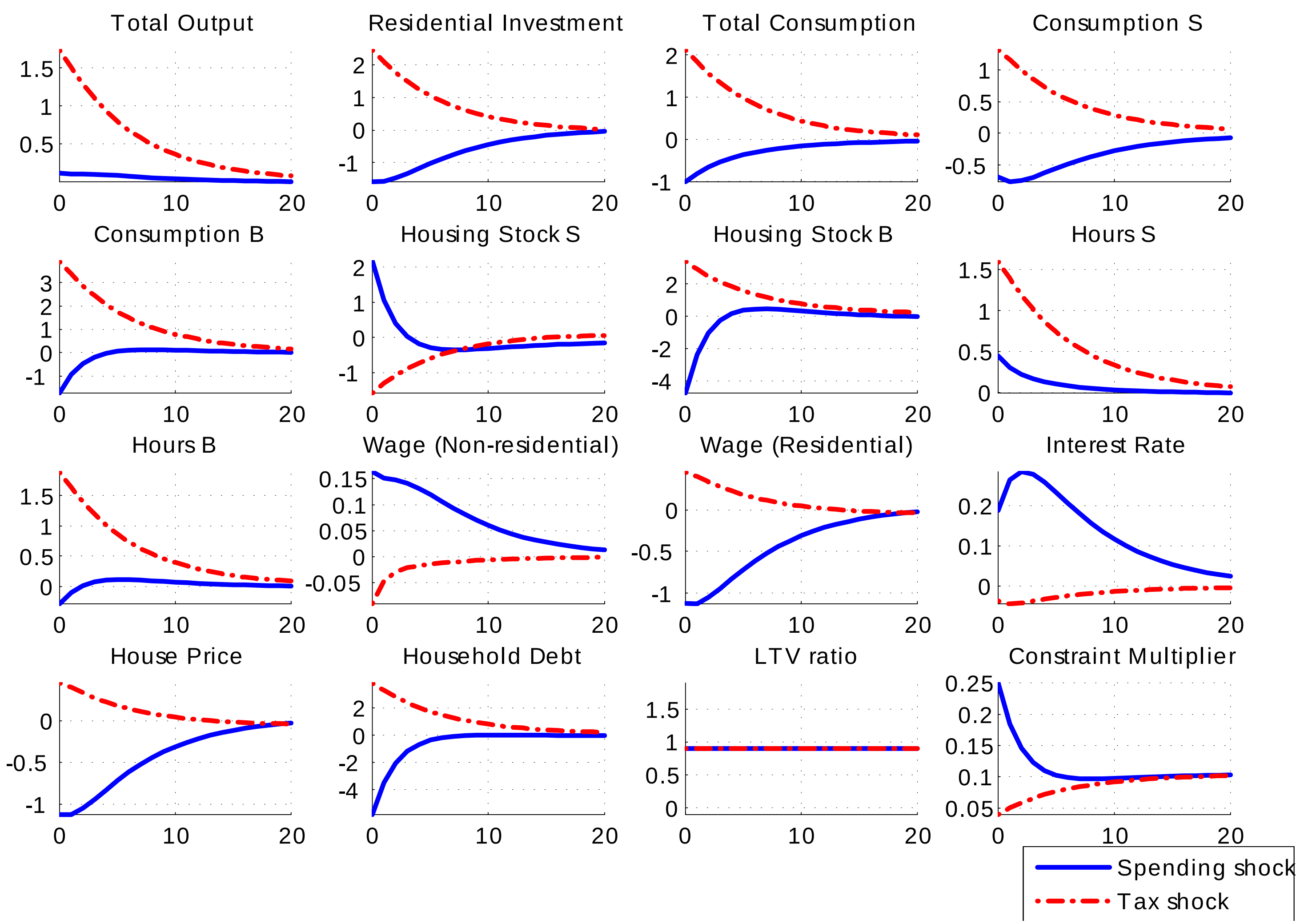

Figure 9: Responses to a government consumption increase versus an income tax revenue cut equal to 1% of GDP. Binding collateral constraint. "S": Savers, "B": Borrowers.

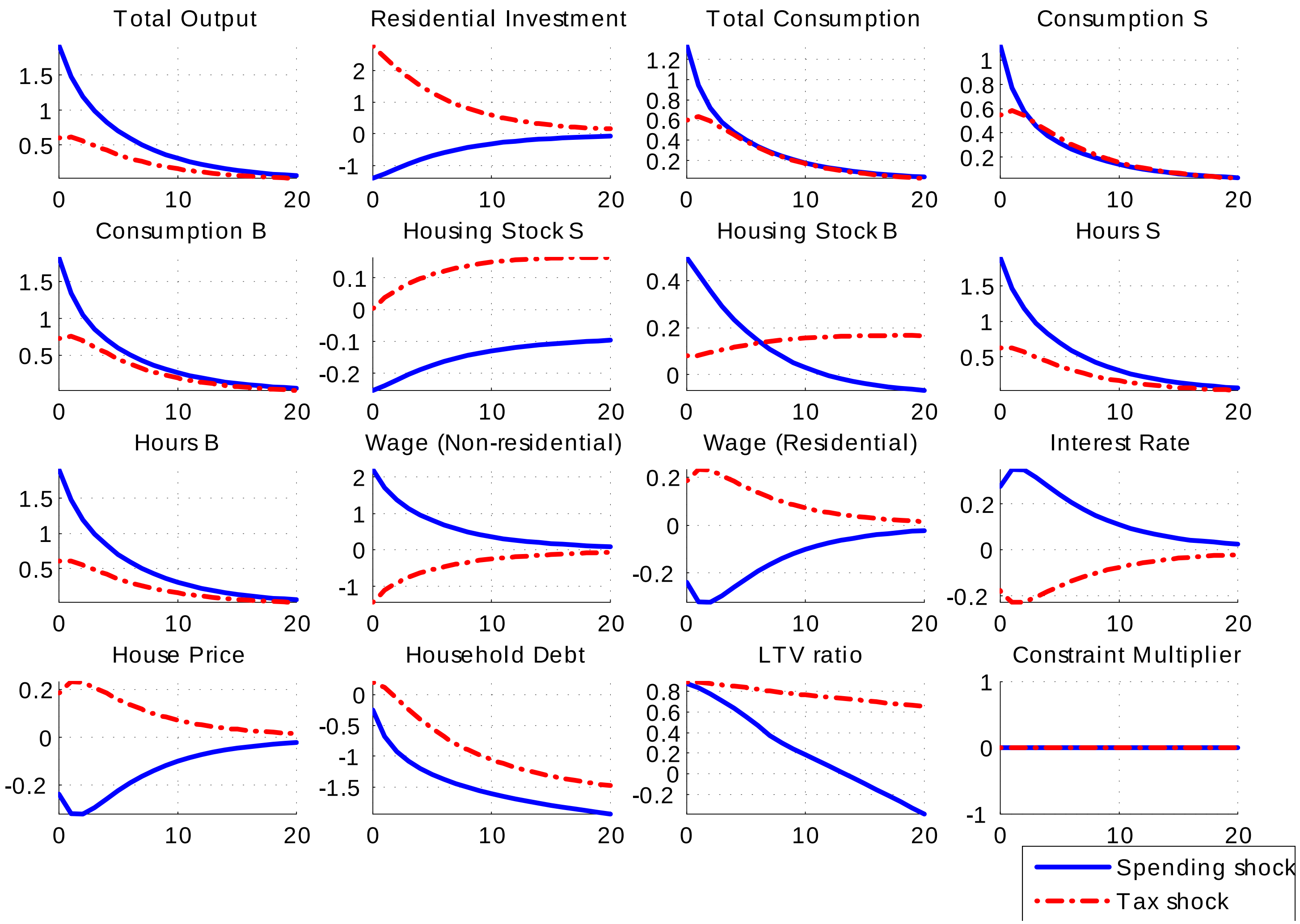

Figure 10: Responses to a government consumption increase versus an income tax revenue cut equal to 1% of GDP. Slack collateral constraint. "S": Savers, "B": Borrowers.

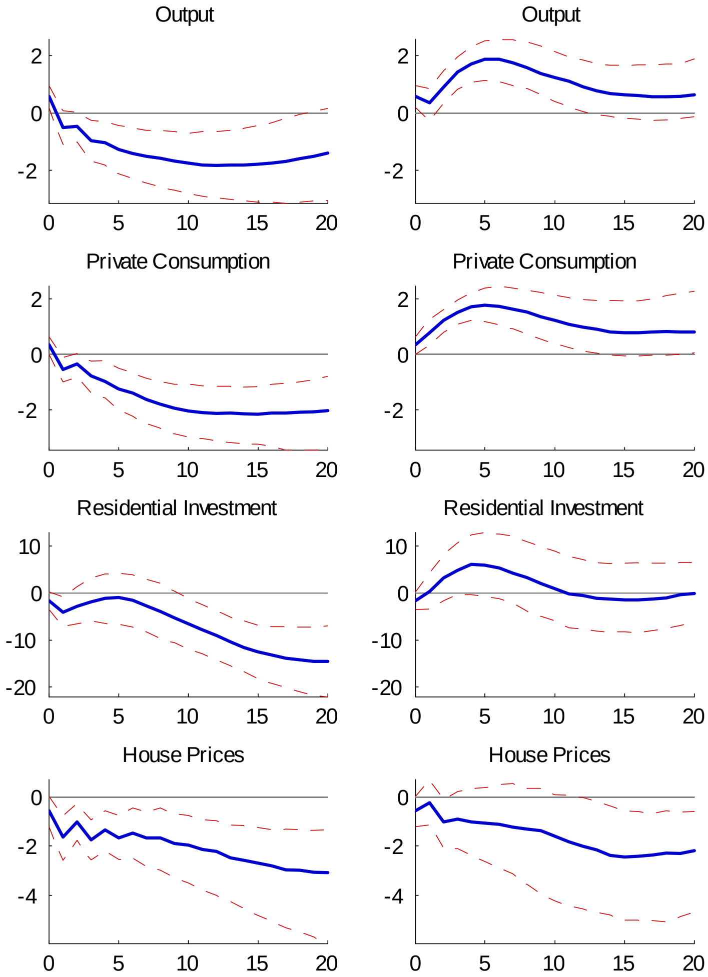

Figure 11a: Regime-dependent responses to a government consumption shock equal to 1% of GDP. Low house price regime (left column) versus high house price regime (right column).

Figure 11b: Regime-dependent responses to one percentage point cut in the average personal income tax rate. Low house price regime (left column) versus high house price regime (right column).

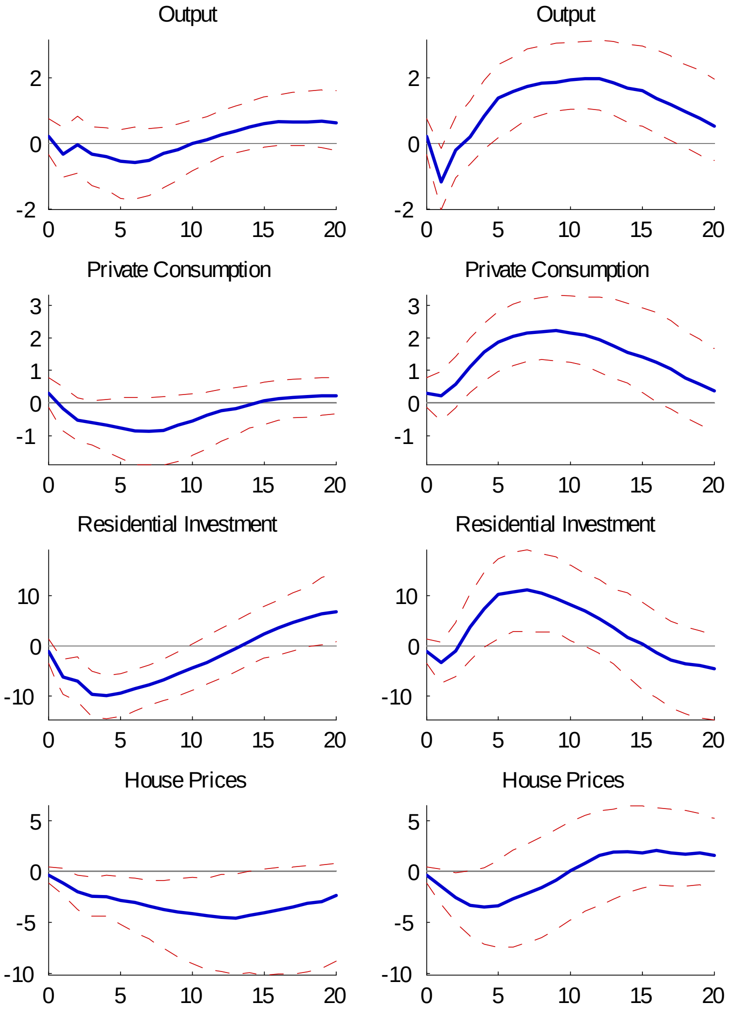

Figure 12a: Regime-dependent responses to a government consumption shock equal to 1% of GDP. Low house price regime (left column) versus high house price regime (right column). Alternative house price series (BIS prices).

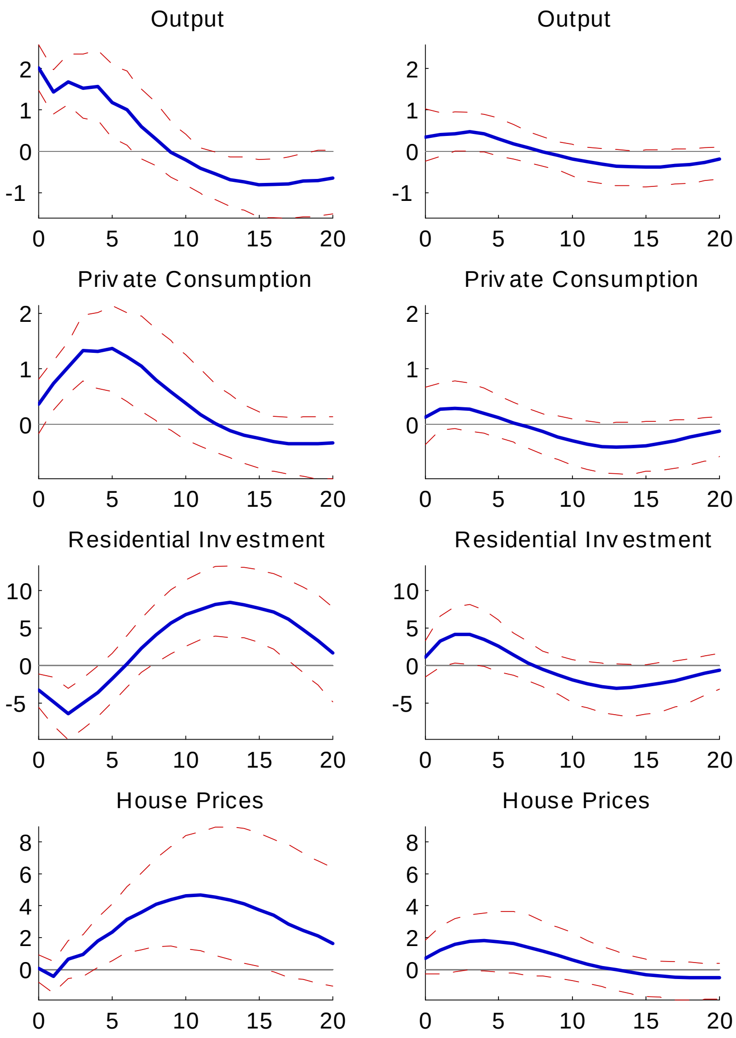

Figure 12b: Regime-dependent responses to one percentage point cut in the average personal income tax rate. Low house price regime (left column) versus high house price regime (right column). Alternative house price series (BIS prices).

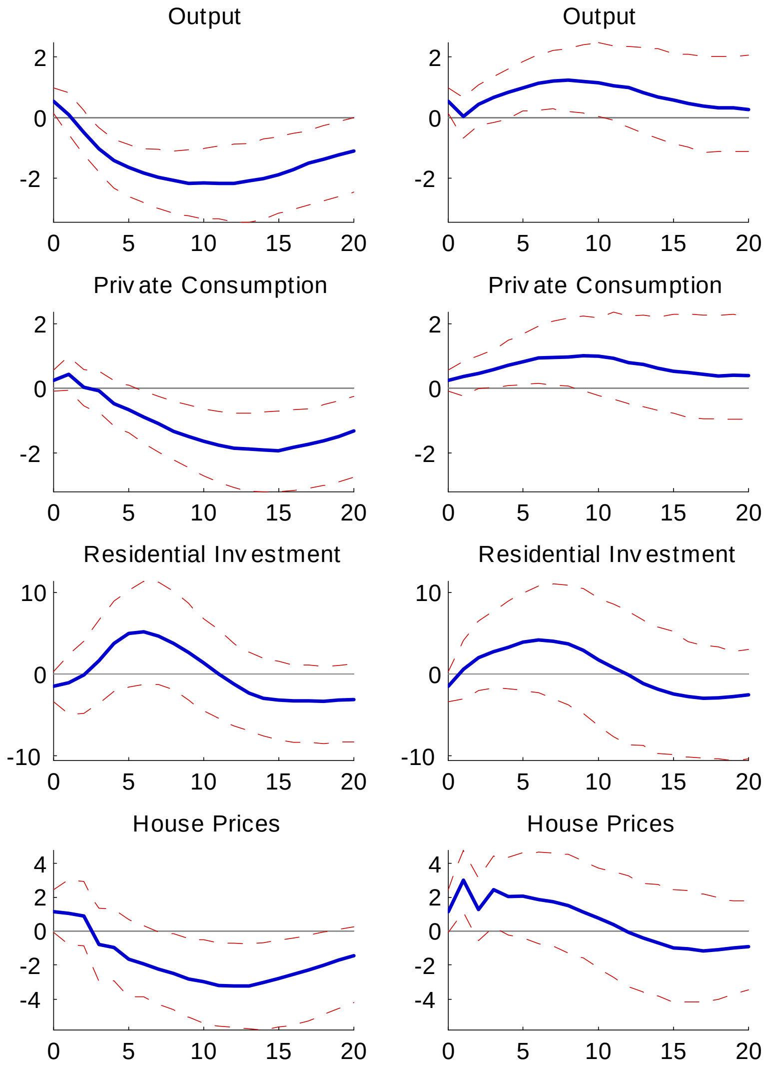

Figure 13a: Regime-dependent responses to a government consumption shock equal to 1% of GDP. Low house price regime (left column) versus high house price regime (right column). Alternative house price series (US Census prices).

Figure 13b: Regime-dependent responses to one percentage point cut in the average personal income tax rate. Low house price regime (left column) versus high house price regime (right column). Alternative house price series (US Census prices).

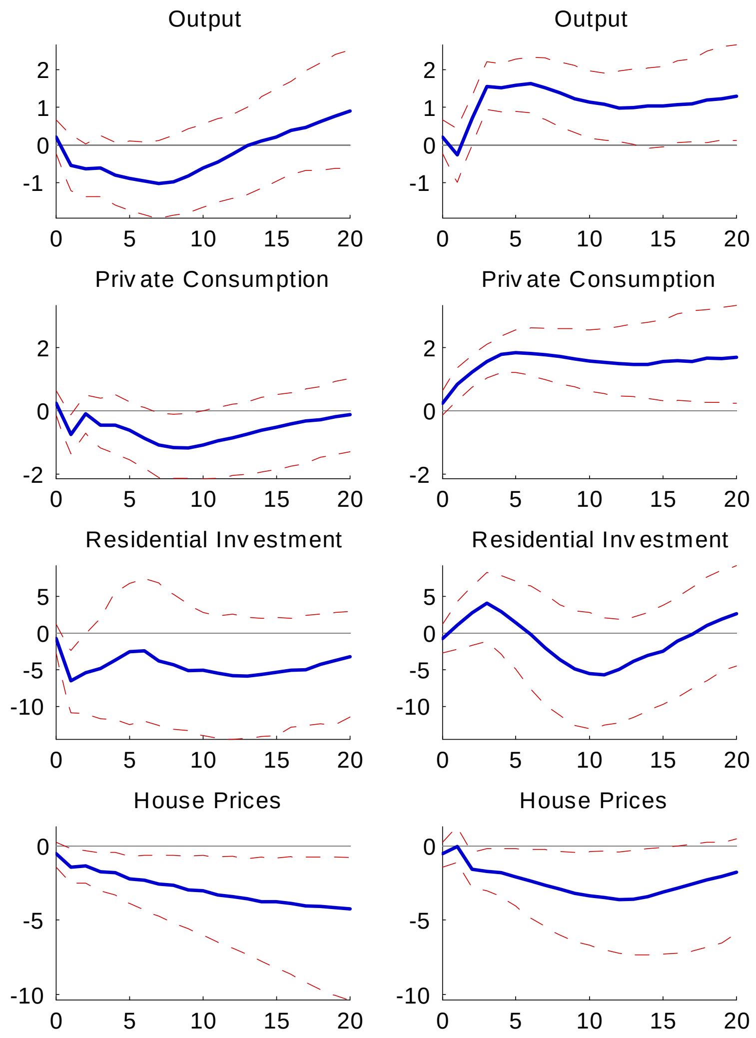

Figure 14: Regime-dependent responses to an unexpected government consumption shock equal to 1% of GDP. Controlling for anticipation effects. Low house price regime (left column) versus high house price regime (right column).

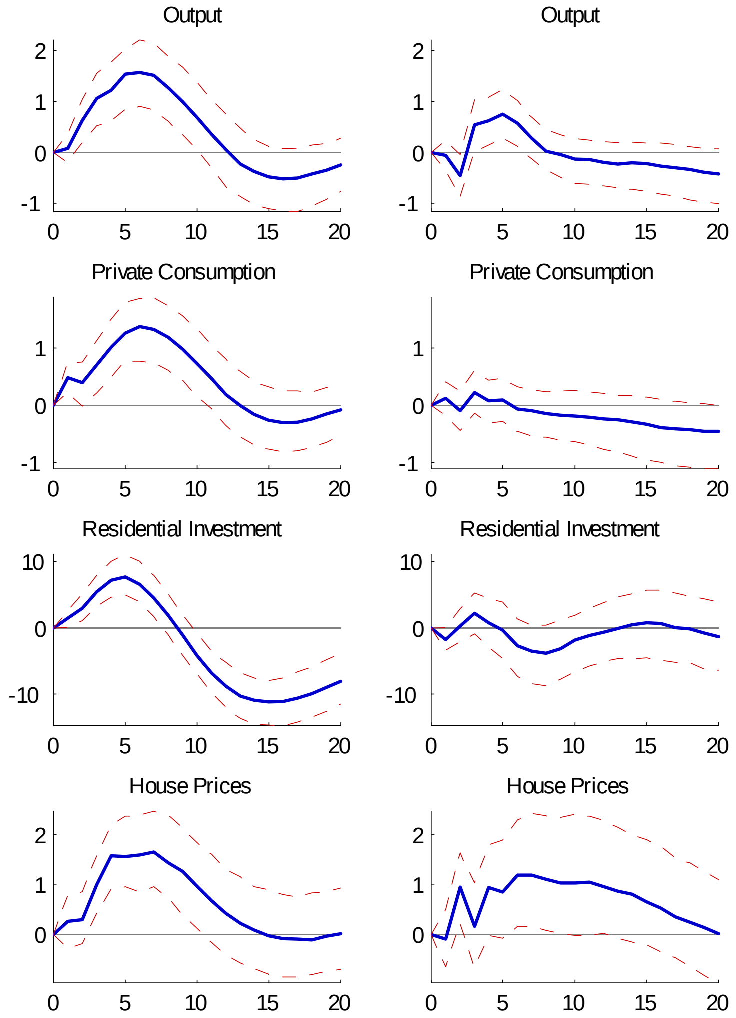

Figure 15: Regime-dependent responses to one percentage point cut in the average personal income tax rate. Low house price regime (left column) versus high house price regime (right column). SVAR-based tax shocks.

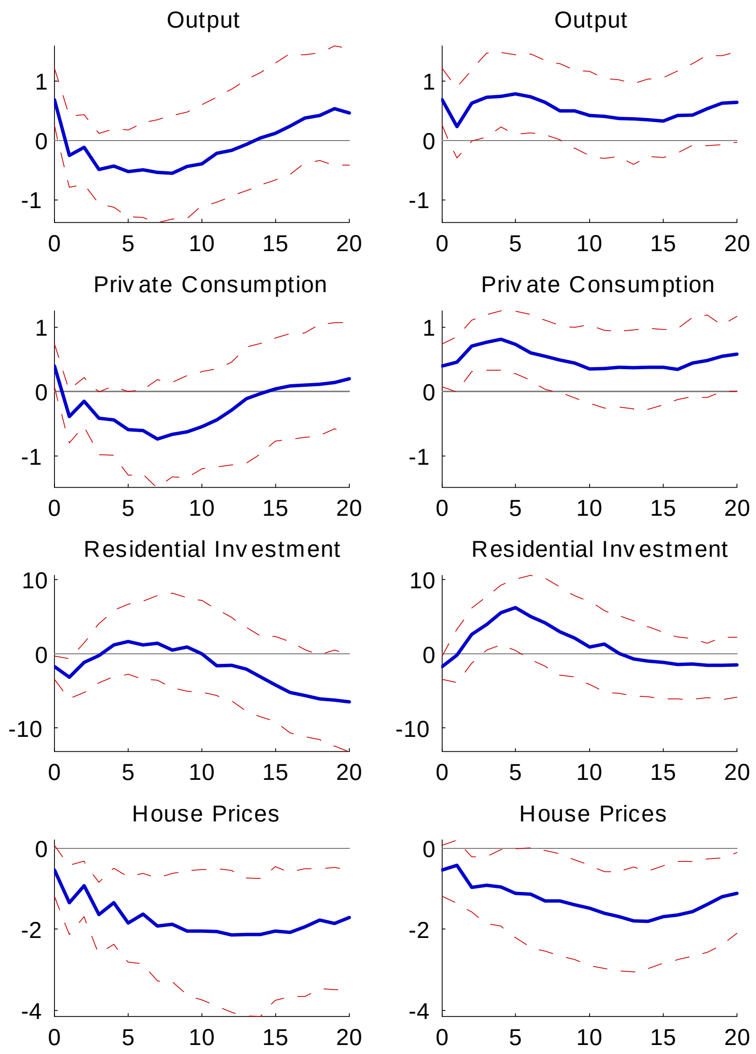

Figure 16a: Generalised impulse responses to a government consumption shock equal to 1% of GDP. Low house price regime (left column) versus high house price regime (right column).

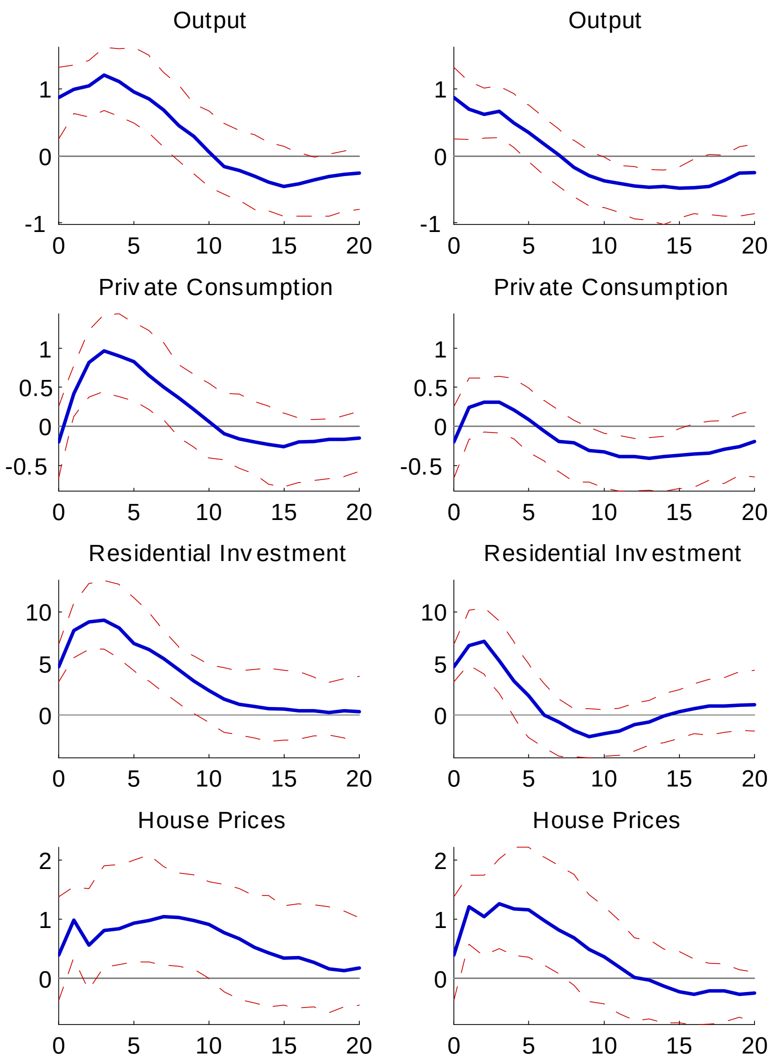

Figure 16b: Generalised impulse responses to one percentage point cut in the average personal income tax rate. Low house price regime (left column) versus high house price regime (right column).