Fiscal Stimulus, Distortionary Taxation, and Financial Frictions

Radu Puslenghea

November 12, 2014

Abstract

I quantify fiscal multipliers in a New Keynesian model with credit constrained households, housing, and distortionary taxation. My findings suggest that increases in government spending have a larger economic stimulus effect compared to tax instruments (lump-sum, labor, and capital income tax). The output fiscal multiplier for government expenditures can exceed unity, on impact, in highly leveraged economies. The consumption response of the credit constrained households plays a key role. These agents have a large marginal propensity to consume, due to their high degree of impatience, and they will increase their spending after a positive transitory income shock. The model also predicts a drop in the house price, induced by the increase in the real interest rate, as a result of higher government debt. This effect reduces the borrowers’ net worth and the volume of credit they can access, which in turn creates a drop in their consumption. Therefore, the expansionary impact of fiscal policy in this class of models will be relatively weaker when compared to a framework with standard rule-of-thumb agents, who do not have access to capital markets. As an empirical test, I use a regime-switching SVAR model to study the impact of government spending shocks on output, consumption and house prices under two credit regimes (difficult and relaxed). The results show a reduced policy effect in the bad state of the world which is compatible with the idea of an asset price transmission channel.

Keywords: Fiscal Policy, Fiscal Multiplier, Credit Constraint, DSGE modeling, VAR

JEL Classification: E21; E62; H31; H63; C32

*I would like to thank Chris Otrok, Toshi Mukoyama for their guidance, support, and helpful advice. I also want to thank Latchezar Popov, Sophie Osotimehin, Aaron Butz, Bingbing Dong, and Raju Huidrom for their useful comments and advice. All errors are mine.
1 Introduction

The onset of the Financial Crisis in the late 2007 that culminated in a Global Recession has forced policymakers throughout the world to critically reevaluate the toolkits at their disposal. The academic debate regarding the potential stabilization role of fiscal policy has started picking up momentum again, especially as key interest rates were gradually cut back towards zero which limited the scope of future monetary interventions.

Empirically, the topic has received considerable attention in the past decade. The seminal contribution of Blanchard and Perotti (2002) has encouraged the development of a diverse and extensive body of related literature, often built around the SVAR framework proposed by the two authors. Nevertheless, at least until the last economic crisis, the use of theoretical DSGE models was significantly less well represented in the study of fiscal policy.

An important downside of the standard New Keynesian model based on a single type of representative agent is that it cannot replicate the positive response of private consumption after an expansionary government spending shock - a common result in the empirical studies.

The reason is that households are forward looking, so the Ricardian equivalence principle will hold in this scenario. The representative agents associate present fiscal stimulus with higher future taxes, which imposes a negative wealth effect. Thus, they will respond by increasing labor supply and reducing consumption.

Gali et al. (2007) proposed a solution to the conundrum, by introducing, so called, rule-of-thumb (RoT) consumers in a canonical DSGE model. This approach, which is in line with the work of Campbell and Mankiw (1991), is able to reconcile empirical evidence and generates a crowding-in effect on consumption in response to positive fiscal shocks, if prices are sticky and the share of the liquidity constrained agents is large enough (around 25 percent in Gali et al. 2007).

The assumption, while tractable, has the notable disadvantage that it does not account at all for credit conditions or credit market imperfections. The ROT agents are by definition insensitive to changes in the real interest rates, since do not engage in intertemporal consumption smoothing - a mechanism which makes them very responsive to transitory income. Furthermore, they do not have access to the capital market, which also insulates them from financial developments and thus leaves out a potentially meaningful policy transmission channel.

1These agents do not save and simply consume their entire (labor) income every period. Many models currently used for policy analysis incorporate this feature: SIGMA (FRB), NAWM (ECB), QUEST III (EC), etc.
As the recent financial crisis that originated in the US suprime mortgage market has shown, a worsening in financial conditions can significantly reduce credit availability at the aggregate level. In particular, the reduction in the volume of credit appeared to have a particularly severe effect on the private sector, in addition to its expected negative supply side impact.

The drop in private consumption, consistent with the existence of credit constrained households, accelerated the economic decline and resulted, in many countries, in prolonged and deep economic recessions. This empirical evidence thus offers additional support to the idea of a financial amplification mechanism that ties credit conditions to movements in private consumption and, implicitly, output. Importantly, such a channel would also hold implications regarding the conduct of fiscal policy, as the government financing needs are non-neutral with respect to the credit market.

From a theoretical point of view, the role of financial frictions as a business cycle amplification mechanism has been firmly established in the literature, starting with the seminal contributions of Kiyotaki and Moore (1997) and Bernanke, Gertler, and Gilchrist (1999). In this class of models a balance-sheet credit channel links, via asset prices, the wealth of borrowers to both private consumption and investment spending, significantly heightening their response to exogenous shocks, thus giving rise to a "financial accelerator".

The motivation for credit constraints varies, but most researchers follow either BGG (1999), who assume a moral hazard problem, or Kyiotaki and Moore (1997) who consider a limited enforceability problem. The two mechanisms are qualitatively different, since the first influences the cost of credit (through an external finance premium), while the second affects directly the availability of credit (collateral requirement) which is in line with the empirical evidence mentioned above.

In this paper I study the effects of discretionary fiscal policy in a New Keynesian framework that features housing investment and allows for credit constrained households along the lines of Kiyotaki and Moore (1997). The model is based on Iacoviello and Neri (2010), which has been shown to match well the cyclical properties and long-run behavior of housing and non-housing variables alike.

The assumption that a subset of the population is subject to collateral requirements is particularly relevant, as it creates an endogenous amplification mechanism that links housing

---

2 An alternative approach is to introduce financial frictions by giving financial intermediaries an ability to change credit conditions without a change in borrower creditworthiness, like in Meh and Moran (2004).

3 In particular, both housing prices and housing investment appear strongly procyclical, volatile and sensitive to monetary shocks, in line with the empirical evidence. For details see Iacoviello and Neri (2010).
wealth to non-housing consumption. Compared to a standard DSGE model, this results in an additional transmission channel for policy that reflects conditions on the demand side of the credit market.

In my analysis I consider how credit conditions, and particularly the level of private indebtedness, seen both as an intensive margin of borrowing (loan-to-value ratio), as well as an extensive margin (share of borrowers in total population) affect the response of private consumption, investment and output to fiscal stimulus in an economy featuring distortionary taxation.

My findings, based on present value fiscal multipliers, suggest that increases in government spending are more effective at stimulating output than reductions in taxes. The existence of credit constrained households insures a positive net response of aggregate consumption (around 0.12 on impact) which is in line with the empirical evidence. The borrowers’ high marginal propensity to consume plays a key role here, as it makes these agents very responsive to changes in their transitory income, in a similar manner to their RoT counterparts.

The effect is strong enough to offset, in the short run, the drop in savers’ consumption, due to the negative wealth effect imposed by higher expected future taxes, and produces a Keynesian multiplier for output (1.03 on impact) under the baseline calibration. The output multipliers decline at longer horizons as a result of the crowding out of private investment and a fall in aggregate consumption. The latter is compounded by a decline in housing prices which reduces the borrowers’ net worth and consumption multipliers become negative after approximately five quarters.

Increases in government transfers and labor tax cuts have quantitatively similar effects on output, with impact multipliers of around 0.17. In both cases, fiscal stimulus generates an increase in the consumption of credit constrained agents who respond to a higher, albeit transitory, level of income. At longer horizons, multipliers become negative, as the increase in interest rates crowds out investment, depresses housing prices and raises credit costs for borrowers. In this framework capital tax cuts have a largely negative effect on output as savers reallocate their financial resources towards investment, and away from the impatient

---

4 Villaverde (2010) comes to a similar conclusion in the context of DSGE model with financial frictions based on BGG(1999)


6 Consistent with this finding, Agnello and Sousa (2011) provide empirical evidence, based on a panel vector auto-regressive (PVAR) approach, on the link between positive fiscal shocks and a decline in housing prices.
households, which brings down aggregate consumption.

Regarding the importance of credit conditions, the loan-to-value ratio appears to play the key role in terms of the expected expansionary effect of fiscal measures. This parameter is directly tied to the borrowers’ credit limit, as it determines the value of the housing stock which is allowed as collateral. Thus it affects the consumption amplification mechanism, which accounts for the initial positive response of aggregate consumption to fiscal stimulus.

Consistent with the findings of Gali et al. (2007), in an environment where prices are more rigid, increases in government spending result in larger output multipliers. The smaller increase in the expected real interest rate reduces the negative response in the savers’ current consumption, while also slowing the decline of housing prices. This helps conserve the borrowers’ net worth, as well as, their consumption level. The same argument can be made for a lower degree of persistence in the fiscal shock as the change in interest rates is expected to be shorter lived.

Policy experiments have shown that a sufficiently large value of the LTV ratio (of around 0.80) is necessary in order to generate output multipliers above unity. This is true even when one assumes a large share of credit constrained agents (0.5). In general, policy effects scale up with the size of credit constrained population.

A worsening in the quality of credit conditions modeled by a drop in the loan-to-value ratio (a forced deleveraging like in a credit crunch) or a reduction in the volume of private credit (modeled as a decrease in the share of borrowers) will reduce the expansionary effects of fiscal stimulus. Using a regime switching SVAR which controls for two credit regimes, I find evidence that under the bad state of the world the expansionary effects of policy are reduced, as opposed to normal or (more) relaxed financial conditions.

The rest of the paper is organized as follows. The next two sections introduce the model and provide details on the calibration. Section four discusses the main set results and their sensitivity to alternative specifications, section five introduces an empirical exercise based on a regime switching SVAR that focuses on the link between fiscal policy and financial conditions. Finally, the last section concludes.

### 2 The Model

This section presents a closed economy framework, based on Iacoviello and Neri (2010), which I extend to include a government sector that raises revenue via distortionary taxation (on capital and labor revenue) and redistributes income through transfers. The model
also features two production sectors, heterogeneity in the households’ discount factors and financial frictions in the form collateral constraints tied to the value of the housing stock. The economy is populated by two types of households which, based on their respective discount factor, can be classified as patient (savers) and impatient (borrowers). The savers work, consume, accumulate housing and pay taxes. They own the entire capital stock, as well as, the production firms and use their savings to supply funds to the impatient households and to the government, financing the public debt.

Similarly, the borrowers work, consume, pay labor income taxes, receive transfers and accumulate housing. As opposed to savers, the impatient households only accumulate the required net worth to finance the down payment on their homes and are assumed to be up against their housing collateral constraint in the equilibrium.

On the supply side, the non-housing sector combines capital and labor to produce consumption and capital for both sectors, while the housing sector produces new homes using capital, labor and land.

Besides financial frictions and housing, the model also features price and wage stickiness, monopolistic competition and habit formation in consumption. These types of rigidities are typically considered in models used for policy analysis, such as Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2007), and make the results comparable to previous findings in the literature.8

Finally, the model economy includes a monetary authority and a government sector. The central bank controls the supply of currency and conducts monetary policy using the (short term) nominal interest rate as an instrument, while the government finances its spending through taxation and borrowing.

7Differently from Andres, Bosca and Ferri (2012) the housing stock is variable in this economy, thus fluctuations in the supply of housing influence the price of housing and, implicitly, the role of collateralized debt. A model with a fixed housing supply will tend to overstate the changes in house prices, which given the financial amplification mechanism may have a large impact in the aggregate. I am also considering distortionary taxes, as opposed to lump-sum taxation. As Drautzburg and Uhlig (2011) point out the effects of fiscal policy can differ significantly at longer horizons depending on the assumed tax structure. Furthermore, Leeper et. al (2009) argue, based on a posterior odds comparison for their estimated model, that the data clearly prefers a model with a more complex fiscal sector.

8Iacoviello and Neri (2010) employ this framework to explore quantitatively the nature of the shocks hitting the housing market, as well as, the size of spillovers from this market to the rest of the economy. They find that the model explains well the cyclical properties and the long-run behavior of both housing and nonhousing variables. Moreover, housing prices and housing investment appear to be strongly procyclical, volatile, and very sensitive to monetary shocks.
2.1 Households

The economy is populated by two types of households, patient and impatient, each of mass 1, that derive utility from consumption, leisure, and housing services. The economic size of each group is given by their corresponding wage share. This is fixed across groups, due to the assumed production function, with a constant elasticity of substitution, and it is $\alpha$ for borrowers and $1 - \alpha$ for lenders, respectively.

The household $z \in [0,1]$, of type $i$, maximizes the following expected utility:

$$E_0 \sum_{t=0}^{\infty} (\beta_i)^t \left( \ln(c_{i,t} - \epsilon_i c_{i,t-1}) + j_t \ln h_{i,t} - \frac{1}{1 + \eta_i} \left( (n_{i,c,t})^{1+\xi_i} + (n_{i,h,t})^{1+\xi_i} \right)^{\frac{1+\xi_i}{1+\eta_i}} \right), \quad (1)$$

where $i = 1, 2$ denotes the type of the household (patient or impatient) differentiated by its time-discount factor $\beta_1$ and $\beta_2$, respectively. The other factors, $c, h, n_c$, and $n_h$ represent (composite) consumption, housing, hours worked in the consumption sector and housing sector, respectively.

The positive parameters $\xi_i$ represent the inverse elasticity of substitution across hours in the two sectors and allow for less than perfect labor mobility across sectors as in Horvath (2000). The inverse Frish elasticity of labor supply is given by $\eta_i$, while $\epsilon \in [0,1]$ is the habit parameter.

The term $j_t$ describes a housing preference shock intended to capture, in a reduced form, cyclical variations due to resource availability for housing purchases (relative to the other goods), as well as, institutional changes that may impact preferences.

The composite consumption is defined as a Dixit-Stiglitz aggregator of the final good varieties:

$$c_t = \left( \int_0^1 c_t(\tau) \frac{\epsilon_p^{-1}}{\epsilon_p} d\tau \right)^{\frac{\epsilon_p}{\epsilon_p-1}} \quad (2)$$

where $\epsilon_p$ represents the intertemporal elasticity of substitution and $\tau$ denotes variety.

Also, the demand for each variety $\tau$ is given by:

$$c_t(\tau) = \left( \frac{P_t(\tau)}{P_t} \right)^{-\epsilon_p} c_t, \quad (3)$$

The corresponding consumer price index has the property that minimizes the cost of a bundle of final good varieties yielding $c_t$ units of composite consumption and is given by:
\[ P_t = \left( \int_0^1 P_t(\tau)^{1-\epsilon} d\tau \right)^{1/(\epsilon_p - 1)}, \]  

where \( P_t(\tau) \) denotes the price for variety \( \tau \).

Following Davis and Heathcote (2005), the log-log specification for consumption and housing in the period utility accounts for the stable nominal share of expenditures on housing goods, while the disutility of labor \((\epsilon \geq 0, \eta \geq 0)\) suggests some sector specificity and a smaller response in relative hours as a result of wage differentials.

### 2.1.1 Patient Households (Savers)

The patient households are characterized by a higher propensity to save, so in equilibrium they will supply loans to the impatient households and the government sector. They own the retail firms (being entitled to dividends, paid as a lump-sum) and all the capital which they rent out, selling any remaining undepreciated capital. The savers also accumulate housing, from which they derive utility services. They owe taxes on their labor and capital income and receive a lump-sum transfer.

The period budget constraint is given by:

\[
c_{1,t} + k_{c,t} - (1 - \delta_{kc})k_{c,t-1} + k_{h,t} - (1 - \delta_{kh})k_{h,t-1} + q_t h_{1,t} + b_{1,t} + b_{g,t} = (1 - \tau_t^l) \left( \frac{w_{1,c,t} n_{1,c,t}}{X_{1,wc,t}} + \frac{w_{1,h,t} n_{1,h,t}}{X_{1,wh,t}} \right) \\
+ (1 - \tau_t^k) \left( R_{c,t} k_{c,t-1} + R_{h,t} k_{h,t-1} \right) + \frac{R_{t-1} b_{1,t-1}}{\pi_t} + \frac{R_{t-1} b_{g,t-1}}{\pi_t} + q_t (1 - \delta_h) h_{1,t-1} + Z_{1,t} + Div_{1,t}, \quad (5) \]

where \( c_{1,t} \) denotes (composite) consumption at \( t \), \( h_{1,t} \) are housing holdings priced at \( q_t \), \( k_{c,t} \) represents consumption sector capital, \( k_{h,t} \) is housing sector capital. Also, the real rental rates for the consumption and housing business capital are \( R_{c,t} \) and \( R_{h,t} \), respectively, while \( \delta_{kc}, \delta_{kh}, \) and \( \delta_h \) represent depreciation rates for the capital and housing stock.

Nominal (private) loans are given by \( b_{1,t} \), \( b_{g,t} \) are government bonds, \( \pi_t = P_t/P_{t-1} \) is the gross inflation rate, \( n_{1,c,t} \) and \( n_{1,h,t} \) are hours worked in the consumption and housing sectors, respectively, \( w_{1,c,t} \) and \( w_{1,h,t} \) denote real wages, while \( X_{1,wc,t} \) and \( X_{1,wh,t} \) are wage markups due to monopolistic competition.
Finally, $\tau_l^t$ and $\tau_k^t$ are current tax rates, $Z_{1,t} = (1-\alpha)Z_t$ represents household transfers/lump-sum taxes (normalized by the economic size of the group) and $Div_{1,t}$ are lump-sum profits, both from the ownership of firms and labor unions.

### 2.1.2 Impatient Households

Impatient households discount the future at a higher rate than the patient households ($\beta_2 < \beta_1$) and they are subject to a borrowing constraint given as a fraction of the value of their housing stock. The budget constraint for the impatient households and the borrowing limit are given below:

$$c_{2,t} + q_{h,t}(h_{2,t} - (1-\delta_h)h_{2,t-1}) = (1-\tau_l^t) \left( \frac{w_{2,h,t}n_{2,h,t}}{X_{2,wh,t}} + \frac{w_{2,c,t}n_{2,c,t}}{X_{2,wc,t}} \right) - \frac{R_{t-1}b_{2,t-1}}{\pi_t} + b_{2,t} + Z_{2,t} + Div_{2,t},$$

(6)

$$b_{2,t} \leq mE_{t} \frac{q_{h,t+1}\pi_{t+1}h_{2,t}}{R_{t}}$$

(7)

where $m$ is the loan-to-value ratio for the household which is consistent with the practice in the mortgage market to limit the amount lent to a fraction of the value of the asset. Alternatively, $(1-m)$ can be interpreted as the cost that lenders need to pay in order to repossess the asset in case of default.

### 2.2 Production Sector

The production sector in this economy consists of perfectly competitive wholesale firms that produce consumption goods and housing, and a continuum of monopolistically competitive final good firms activating at the retail level in the consumption sector.

---

9 Under uncertainty the concavity of the objective function, in some states of the world, can induce the impatient households to self insure - borrow less than their credit limit. In particular this could happen after a sufficiently long spell of positive shocks. Such an occurrence would invalidate an approximation around the deterministic state, because the borrowing constraint does not bind. However as Iacoviello (2005) has argued based on partial equilibrium evidence, under a reasonable parametrization, evidence from non-linear simulations suggests that uncertainty is "small enough" relative to the degree of impatience to rule out non-binding credit constraints.
2.2.1 Wholesale Consumption Goods Producers

The firms that manufacture the wholesale consumption goods are endowed with a Cobb-Douglas production technology and are assumed to be perfectly competitive. These firms use labor and capital as production inputs as follows:

\[ Y_t = \left( A_{c,t} \left( n_{1,c,t}^{1-\alpha} n_{2,c,t}^\alpha \right) \right)^{1-\mu_c} (k_{c,t-1})^{\mu_c}, \]  

where \( A_{c,t} \) represents productivity in the consumption sector, \( \alpha \) is the labor income share of the patient households, and \( \mu_c \) is the share of capital in the production of consumption goods.

2.2.2 Housing Producers

Similarly to the wholesale firms, the housing producers are assumed to be perfectly competitive, with a Cobb-Douglas technology that combines labor and capital into new housing goods. Their production function is given bellow:

\[ IH_t = \left( A_{h,t} \left( n_{1,h,t}^{1-\alpha} n_{2,h,t}^\alpha \right) \right)^{1-\mu_h} (k_{h,t-1})^{\mu_h}, \]  

where \( A_{h,t} \) is a shock to the marginal efficiency of producing housing and \( \mu_h \) is the share of capital in the housing sector.

2.2.3 Retailers

In the consumption sector, there is a continuum of measure one of retail firms, owned by the savers, that buy the wholesale goods \( Y_t \) at a competitive price \( P_{w,t} \), differentiate it at no cost, and then sell it at a mark-up \( X_t = P_t / P_{w,t} \) to the consumers.\(^{10}\) The households then costlessly bundle these goods via the CES aggregator into homogeneous consumption \( c_{i,t} \) and investment.

Each firm is subject to Calvo price rigidity and in any given period it has a probability, \( 1 - \theta_{\pi} \) to optimally reset the price for its product. If a firm does not get to adjust the price, it will simply index it to the inflation rate in the previous period with elasticity \( \iota_{\pi} \).

\(^{10}\)Iacoviello and Neri (2010) argue that price rigidities in the housing sector appear as unrealistic, given that for these expensive goods there is a large incentive to negotiate the price and also because most homes are priced for the first time when they are sold.
Firms choose $\tilde{P}_t$ to maximize the expected present value of their real profits, as follows:

$$\sum_{k=0}^{\infty} \theta^k E_t \{ \Lambda_{t+k} \left( \frac{\tilde{P}_t}{P_{t+k}} - \frac{X_t}{X_{t+k}} \right) Y_{t+k}^d(\tau) \} = 0.$$  (10)

where $\Lambda_{t+k} = \beta \frac{C_{1,t}}{C_{1,t+k}}$ is a stochastic discount factor and $X_t$ is the markup.

Since on average, a fraction $\theta\pi$ of firms cannot reset their prices, and those that do, will choose the same price, the evolution of the aggregate price level is given by:

$$P_t = (\theta\pi (P_{t-1})^{1-\epsilon_p} + (1-\theta\pi)(\tilde{P}_t)^{1-\epsilon_p})^{1/(1-\epsilon_p)}.$$  (11)

The consumption-sector Phillips curve is given by:

$$\ln \pi_t - \tau \pi \ln \pi_{t+1} = \beta (E_t \ln \pi_{t+1} - \tau \pi \ln \pi_t) - \epsilon_\pi \ln (X_t/X),$$  (12)

where $\epsilon_\pi = \frac{(1-\theta\pi)(1-\beta\theta\pi)}{\theta\pi}.$

### 2.3 Wage Rigidity

The model features wage rigidity, as in Erceg et al. (2000), for both types of households and sectors\footnote{Christiano et al. (2005) argue that the critical nominal friction in their model is wage rigidity. They find that a model that only includes price rigidities cannot generate persistent movements in output unless the price contracts have a very long duration, while a model with nominal wage rigidities does not have this problem. Iacoviello and Neri (2010) confirm that the presence of price and wage rigidities in their model is necessary to account for the volatility of housing investment. Without such mechanisms in place the housing investment sector is disconnected from the monetary and inflation disturbances.}. Therefore there are four labor unions in this economy, to which households supply homogeneous labor services\footnote{One for each household and sector pairing.}. In turn, the labor services are differentiated by these unions and the wages are set following a Calvo scheme with partial indexation to past inflation. Finally, the unions offer the labor services to wholesale labor packers who combine them, at no cost, into the homogeneous labor composites.

For a given type of household (patient or impatient) and sector (consumption or housing) each union is a monopolistically competitive supplier of differentiated labor services, which allows them to set their own wage. In any given period $t$ a union in sector $j = c, h$ (regardless...
of the type of labor), has a probability $\theta_{w_j}$ of not being able to optimally reset its nominal wage, in which case it indexes the wage to past inflation with elasticity $\iota_{w_j}$. Alternatively, it chooses a new wage such that the union’s future expected average marginal revenue will equal the average marginal cost of supplying labor.

The four wage equations, derived in a similar fashion to the consumption sector Philips curve, are given by:

\[
\begin{align*}
\ln \omega_{c,t} - \iota_{w_c} \ln \pi_{t-1} &= \beta(E_t \ln \omega_{c,t+1} - \iota_{w_c} \ln \pi_t) - \epsilon_{w_c} \ln \left( \frac{X_{w_c,t}}{X_{w_c}} \right) \\
\ln \omega'_{c,t} - \iota_{w_c} \ln \pi_{t-1} &= \beta'(E_t \ln \omega'_{c,t+1} - \iota_{w_c} \ln \pi_t) - \epsilon'_{w_c} \ln \left( \frac{X_{w_c,t}}{X_{w_c}} \right) \\
\ln \omega_{h,t} - \iota_{w_h} \ln \pi_{t-1} &= \beta(E_t \ln \omega_{h,t+1} - \iota_{w_h} \ln \pi_t) - \epsilon_{w_h} \ln \left( \frac{X_{w_h,t}}{X_{w_h}} \right) \\
\ln \omega'_{h,t} - \iota_{w_h} \ln \pi_{t-1} &= \beta'(E_t \ln \omega'_{h,t+1} - \iota_{w_h} \ln \pi_t) - \epsilon'_{w_h} \ln \left( \frac{X_{w_h,t}}{X_{w_h}} \right)
\end{align*}
\]

where $\omega_{i,t} = \frac{w_{i,t} \pi_t}{w_{i,t-1}}$ is the nominal wage inflation for each sector/household pair.

### 2.4 Monetary Authority

The monetary policy is conducted by a central bank. This monetary authority is assumed to be endowed with a commitment technology that insures time consistency of monetary policy decisions and, thus, the announced policy is fully credible for the private sector.

The monetary policy is given by a linear interest rate rule stated here in terms of log deviations from the deterministic steady-state level of the following form:

\[
\dot{R}_t = \alpha_r (1 - \alpha_r) \hat{\pi}_t + \alpha_y (1 - \alpha_r) \hat{Y}_t + \alpha_r \dot{R}_{t-1} + u_{r,t} \quad (13)
\]

where $\alpha_r$ corresponds to the degree of interest rate smoothing, $\alpha_x$ measures the responsiveness of interest rate deviations of inflation from its steady state level, $\alpha_y$ is the output gap coefficient, and $u_{r,t}$ represents a zero-mean i.i.d monetary shock with variance $\sigma_r^2$. For any variable $x_t$, we have that $\hat{x}_t \equiv \ln \left( \frac{x_t}{x_0} \right)$, where $x$ represents the non-stochastic steady state

\footnote{Many policy rules define the output gap in terms of deviations from its natural level, but that requires the policymaker to know, besides the deterministic steady state of the economy, the joint distribution of all shocks driving the economy and their current realizations.}

\footnote{Without inertia ($\alpha_R = 0$), it has to be the case that $\alpha_\pi > 1$ to insure local determinacy. With inertia $\alpha_R = 1$, $\alpha_\pi > 0$}
value of $x_t$.

2.5 Government Sector

The government in this economy balances expenditures (public spending and transfers) against tax revenues and net borrowing using the following budget constraint:

$$G_t + b_{g,t-1} \frac{R^g_t}{\pi_t} + Z_t = b_{g,t} + \tau_t \left( \frac{w_{1,c,t}m_{1,c,t}}{X_{1,w,t}} + \frac{w_{1,h,t}m_{1,h,t}}{X_{1,w,h,t}} \right)$$

$$+ \tau_t \left( \frac{w_{2,h,t}n_{2,h,t}}{X_{2,w,h,t}} + \frac{w_{2,c,t}n_{2,c,t}}{X_{2,w,c,t}} \right) + \tau_t^k \left( R_{c,t}k_{c,t-1} + R_{h,t}k_{h,t-1} \right)$$

(14)

2.6 Aggregation

The goods market includes consumption, business investment (in consumption and housing sectors) and government spending, thus:

$$Y_t = c_{1,t} + c_{2,t} + I_t + G_t$$

(15)

where $I_t = IK_{c,t} + IK_{h,t}$ is business investment with $IK_{c,t} = k_{c,t} - (1 - \delta_{kc})k_{c,t-1}$ representing investment in the consumption goods sector and $IK_{h,t} = k_{h,t} - (1 - \delta_{kh})k_{h,t-1}$ being investment in the housing sector.

The market clearing condition for the housing market implies that:

$$H_t - (1 - \delta_h)H_{t-1} = IH_t,$$

(16)

where $H_t = h_{1,t} + h_{2,t}$ denotes the aggregate stock of housing and $IH_t$ is current period aggregate investment in housing goods.

Finally, the credit market clears when:

$$b_{1,t} + b_{2,t} + b_{g,t} = 0$$

(17)

2.7 Exogenous processes

The model is perturbed by eight exogenous processes. Four of them, the housing preference shock, productivity in consumption sector, and housing, respectively, $\chi_t = \{j_t, A_{c,t}, A_{h,t}\}$ follow an AR(1) process described bellow.
\[ \ln(\chi_t) = \rho \ln(\chi_{t-1}) + \varepsilon_{\chi_t}, \]  
(18)

where \( \varepsilon_{\chi_t} \sim N(0, \sigma_{\varepsilon_{\chi}}^2) \), \( 0 < \rho \chi < 1 \).

The monetary shock \( u_{r,t} \) is assumed to be zero-mean i.i.d with variance \( \sigma_r^2 \). The remaining four refer to the government tax and expenditure processes and are based on Leeper, Plante and Traum (2009) and Butz(2012). These rules are described below in log-linear form:

\[ \log(\tau^I_t) = \rho_{\tau^I} \log(\tau^I_{t-1}) + (1 - \rho_{\tau^I})(\tau^I_{ss} + \phi_{\tau^I} \hat{b}_{t-1,g}) + v^I_t \]
\[ \log(\tau^k_t) = \rho_{\tau^k} \log(\tau^k_{t-1}) + (1 - \rho_{\tau^k})(\tau^k_{ss} + \phi_{\tau^k} \hat{b}_{t-1,g}) + v^k_t \]
\[ \log(z_t) = \rho_z \log(z_{t-1}) + (1 - \rho_z)(z_{ss} - \phi_z \hat{b}_{t-1,g}) + v^z_t \]
\[ \log(g_t) = \rho_g \log(g_{t-1}) + (1 - \rho_g)(g_{ss} - \phi_g \hat{b}_{t-1,g}) + v^g_t \]  
(19)

where the positive parameters \( \phi_z, \phi_g, \phi_{\tau^k}, \text{ and } \phi_{\tau^I} \) represent debt automatic stabilizers to enforce government solvency.

### 3 Calibration

The calibration of the model follows Iacoviello (2005) and Iacoviello and Neri (2010) and it aims to match certain dimensions of the US economy for the period 1965Q1-2008Q1\(^{15}\). The time period is assumed to be one quarter. In Tables 1 and 2, I give the calibrated values used for the core structural parameters that govern preferences, technology, policy, price and wage stickiness, as well as, the various exogenous processes.

For the patient household, the discount factor \( \beta_1 \) is assumed to be 0.99, which corresponds to an approximately 4% steady state annual interest rate. The borrowers exhibit a stronger preference for present consumption and thus have a discount factor \( \beta_2 \) of 0.95. A high enough degree of impatience is required for these agents in order to insure that their credit limit is binding in the steady state.

\(^{15}\)Because in this paper I am not accounting for the zero lower bound effect on the interest rate, I leave out the post-crisis period.
The weight of housing $j$ in the utility function is set at 0.12 which accounts for a ratio between the residential stock and GDP of approximately 1.35. Also, the consumption habit parameters $\epsilon_1$ and $\epsilon_2$ are 0.32 and 0.58, respectively. The larger value for the impatient agents is required in order to match the persistence of consumption in aggregate data, since these agents cannot engage in inter-temporal consumption smoothing via savings.

The labor income share of the credit constrained households ($\alpha$) is set at 20 percent which, as Iacoviello and Neri document, is large enough to generate a positive response of consumption to house prices. This value is in line with estimates from the literature such as Traum and Yang that give a value of 18 percent, or Jappelli (1990) with 20 percent for the share of constrained households.

Price stickiness ($\theta_\pi$) is 0.83 which corresponds to a price reoptimization frequency of around six quarters. Regarding wage stickiness, the adjustment schedule is similar for both sectors with $\theta_{wc} = \theta_{wh} = 0.80$. Wage indexation is higher in the housing sector, with $\tau_{wh} = 0.40$, compared to consumption goods production $\tau_{wc} = 0.08$.

In production, the depreciation rate for housing $\delta_h = 0.01$ suggests a ratio of residential investment to total output of approximately 6%. The depreciation rates for the consumption and housing sectors, respectively, ($\delta_{kc} = 0.025$ and $\delta_{kh} = 0.03$) give a ratio between non-residential and GDP of 27%, while the ratio of business capital to annual GDP is approximately 2.1. The labor supply elasticity ($\eta$) is assumed to be same for both types and is set at 1.75.

As baseline, the loan-to-value parameter (LTV) $m$ is set at 0.85, based on observed values for homebuyers using data from the Finance Board’s Monthly Survey of Rates on Conventional Single-Family Non-farm Mortgage Loans. In my policy experiments I am also considering alternative values for LTV ranging from 0.75 to 0.95.

Regarding the policy parameters, the values for the Taylor Rule coefficients are standard and they match the estimated values in Iacoviello and Neri (2010) i.e. $r_R = 0.59$, $r_\pi = 1.44$, $r_Y = 0.52$.

The fiscal stabilizers $\phi_g$, $\phi_{tr}$, $\phi_{\tau_k}$, and $\phi_{\tau_l}$ have values between 0.05 and 0.40 following Leeper et. al (2009). All shocks are quite persistent with autocorrelation coefficients ranging between 0.80 and 0.95. Their specific values are detailed in Table 2. The share of government spending to output in steady state $g_{ss}$ is fixed at 9.2% to match the average in the data. Similarly the share of transfers $z_{ss}$ is 10.14%, while the tax rates using the approach given in Jones (2002) are 22.3% for labor and 18.4% for capital.\footnote{A description of the data and methodology for computing the tax rates is included in the Appendix}
4 Results

4.1 Model Dynamics

In this section I present the model’s dynamic responses to expansionary fiscal shocks in all of the four fiscal instruments considered (government spending, transfers, labor and capital income taxes). The impulse response functions are included in the Appendix, Figures 1 through 4. Regarding its cyclical properties, the model appears to replicate quite well both the variables correlations and their volatility (HP filtered) as shown in Tables 3 and 4.

The economy is described by the baseline calibration and operates under a simple, current-looking Taylor-type rule, that matches the estimated policy function by Iacoviello and Neri (2010) for the period considered. More precisely,

\[ \hat{R}_t = 1.44\hat{\pi}_t + 0.52\hat{Y}_t + 0.59\hat{R}_{t-1} \]  

(20)

Government spending - a temporary, one percent, increase in government consumption has an expansionary effect on both output and aggregate consumption. The difficulty of Neoclassical and New Keynesian models with a standard representative agent to generate a positive consumption response to changes in government spending is well documented in the literature\textsuperscript{17}. In the absence of credit or liquidity constraints, the households, who are forward looking, will associate the fiscal stimulus with higher future taxes which creates a negative wealth effect. Therefore, consistent with consumption smoothing, they will respond by increasing labor effort and decreasing current consumption in favor of additional savings to pay for their expected future tax obligations.

In the current framework the positive co-movement between government spending and consumption is driven by the response of the impatient households. These agents, due to their high discount rate, have a large marginal propensity to consume and already hold debt up to the value of their collateral. The increase in their transitory income, which is equivalent to additional borrowing at the prevailing interest rate, will allow them to expand consumption. The higher inflation also erodes the value of their outstanding debt (denominated in nominal terms), which has a further positive impact on the consumption response. Overall the effect is significant enough to offset the drop in the consumption of the patient for approximatively five quarters.

\textsuperscript{17}See for example Hall (2009) for a comprehensive review of the literature
Because the stimulus is debt financed, government debt will rise putting upward pressure on the real interest rate. This will crowd out private investment, and the consumption of the savers, while also decreasing house prices. The drop in house prices, reduces the value of the collateral and tightens the credit limit for borrowers forcing them to scale down their consumption at longer horizons. Over time, this will bring both aggregate consumption and output down.

_Transfers_ - compared to a change in government expenditures an increase in transfer payments results in a smaller output response (roughly one fifth), but a significantly larger increase in aggregate consumption. While the patient agents do not respond much since they are anticipating higher future taxes, the borrowers raise their consumption more than proportionately. Furthermore, the increase in the real interest rate is less than in the previous scenario which accounts for both a smaller crowding out of investment and a smaller decline in house prices. The latter effect does not constrain the consumption of the impatient agents as much as in the first scenario, so the positive effect will persist for a longer time.

_Labor taxes_ - a reduction in the labor income tax works very similarly to an increase in transfer payments. In both cases the positive response of aggregate consumption is largely borne out by the impatient households who are very sensitive to changes in transitory income. These agents would like to access more credit for additional consumption, but cannot do so because of the collateral requirement. In terms of the output impact, the two policy actions have comparable effects. A major difference, though, is the response of real wages which will fall in the wake of a labor tax cut. At longer horizons, the drop in labor income will have a negative impact on consumption expenditures (especially for the borrowers as their only source of income). Nevertheless, due to the wealth effect induced by higher consumption, the reduction in real wages will be smaller than in a model without credit constraints.

_Capital taxes_ - finally, a cut in the tax on capital revenues induces the savers to reallocate their financial resources from lending towards investment. Together with the increase in public debt, this will reduce the volume of credit available to the impatient agents, which accounts for a sharp drop in their consumption in the short run. At the same time, inflation will drop, increasing the debt burden (nominal debt contracts), but house price will rise which boosts the value of the collateral - an offsetting effect. Nevertheless, the overall impact on output and aggregate consumption appears to be negative but small.
4.2 Present Value Multipliers

In line with the related literature on fiscal policy, I summarize the quantitative effects of fiscal shocks by calculating and reporting present-value multipliers for aggregate output, consumption, and investment\(^{18}\). The results are included in tables 5 through 8, for various time horizons, up to twenty quarters.

The use of present value multipliers takes into account the dynamics induced by fiscal innovations, while also discounting macroeconomic effects in the future. As documented by Uhlig (2009) relying exclusively on impact multipliers can be misleading. Nevertheless, they are still a useful comparison point, given their widespread use in empirical studies like Blanchard and Perotti (2002), Forni, Monteforte, and Sessa (2009) and others.

More specifically, the present value multiplier of additional output induced by a policy innovation is given by the ratio between the discounted sum of changes in GDP over a \(k\)-period horizon (using the discount factor of the lenders which fixes the steady state level of the interest rate) and government spending calculated in the same way\(^{19}\).

Therefore,

\[
\text{Multiplier}(k) = \frac{\mathbb{E}_t \sum_{j=0}^{k} \left( \prod_{i=0}^{j} R_{t+i}^{-1} \right) \Delta Y_{t+j}}{\mathbb{E}_t \sum_{j=0}^{k} \left( \prod_{i=0}^{j} R_{t+i}^{-1} \right) \Delta G_{t+j}}
\]

(21)

In this framework, with heterogeneous agents, the impact multiplier \((k = 1)\) for government spending is greater than one, as a result of crowding in of private consumption borne out by increased demand from the impatient households (borrowers). The initial shift out in aggregate demand due to a higher level of government expenditures is followed by an increase in labor demand, which in turn raises household income and allows for additional consumption. The positive effect on aggregate consumption is large enough to offset in the short run the crowding out of private investment and account for a larger positive response in output.

As Gali et al. (2007) have showed, by allowing for a large enough share of rule of thumb consumers (around 25 %), elastic labor supply and price rigidities, it is possible to have a positive response of consumption to fiscal shocks. The problem with the assumption of liquidity constrained agents is that they do not have access to the financial market and cannot engage in intertemporal consumption smoothing, which may exaggerate the response

\(^{18}\)See for example Mountford and Uhlig (2009).

\(^{19}\)For tax instruments I consider the change in tax revenue instead.
of consumption and output to fiscal actions.

In contrast, in the current framework with credit constrained households, under the baseline calibration, the net (impact) effect of government spending on aggregate consumption appears positive, but smaller (0.12), which is enough for a Keynesian multiplier on output (1.03). These values are in range of the results from empirical (VAR) studies like Blanchard and Perotti (2002), Ramey (2008) who report multipliers of around 1.

Models with liquidity constrained households frequently give sensibly larger values of around 1.5, like Gali et al. (2007). Results based on real business cycle models (Fatas and Mihov (2001), Uhlig (2009)) are uniformly smaller (0.6).

At longer horizons, as the crowding out of private investment by government spending starts to take effect, output declines and the multipliers go down gradually but remain positive up to the twenty quarters mark. Aggregate consumption ends up falling as well, the multipliers becoming negative in this case after approximatively six quarters. Furthermore, the fall in consumption is accelerated by a decline in house prices, induced by fiscal stimulus.

The output multipliers associated with an increase in government transfers are small (around 0.17) and positive on impact and then for approximately twelve quarters. At longer horizons they become negative, as the positive economic effects induced by increased consumption (mainly by borrowers which respond to changes in transitory income) begin to wear off.

Furthermore, there appears to be crowding out of private investment due to the increase in the interest rate, which further weakens the expansionary effects. Still the long term implications for aggregate investment are likely ambiguous. The increase in transfers payments leads to both higher public debt and taxes (through the debt stabilizing component of the fiscal process considered here). The lenders anticipating this negative wealth effect, will likely consider reallocating more resources into investment, to offset a drop in their consumption (habit formation also plays a role here).

Quantitatively, the short run output multipliers for a decrease in the labor tax are not very different from those observed for the government transfer shock. The mechanism behind these policies is similar, since they both affect household income and thus consumption.

The main difference appears at longer horizons, as the output multipliers remain positive in the case of the labor tax cut thanks to a less severe crowding out of private investment. Eventually, real wages start to decline, as well as prices, which tends to have a negative

---

20 The increase in the interest rate, has a negative effect on the credit conditions for the impatient agents, reducing the amount they can borrow.
effect on the borrowers consumption by reevaluating their debt obligations. Together with the automatic stabilizers this will bring down consumption multipliers over time.

Finally, lower capital taxes have a weak and largely negative effect on output. While they do create incentives for additional investment by savers, this comes at the expense of consumption for both types of agents as lenders reallocate their financial resources.

Also the increase in public debt, triggers through the automatic stabilizers cuts in government consumption and transfers which will further reduce aggregate consumption, particularly through their effects on the credit constrained agents as described above.

Overall, the initial increase in investment turns out to be insufficient to offset the drop in consumption, so output falls. The decline in aggregate income leads, at longer horizons, to an eventual drop in investment spending. This result is sensitive to the particular debt stabilizing behavior assumed in the fiscal processes used.

4.3 Sensitivity Analysis

4.3.1 Fiscal Stimulus and Credit Conditions

This section explores in more detail the implications that financial frictions, modeled in this framework as a collateral constraint on private borrowing, have regarding the effectiveness of fiscal stimulus.

In particular, I consider a temporary, one percent, increase in government expenditure, since as the present value multipliers results have showed, this type of policy action has the largest effect on aggregate output, thus setting an upper threshold on the expected impact. Furthermore, there is also a wealth of related empirical results, coming from the VAR literature, which can offer a useful comparison point.

There are two main dimensions that describe credit conditions in the economy. First, the loan-to-value (LTV) ratio represents an intensive margin on private borrowing, by directly determining the amount of debt at household level and, second, the (economic) fraction of credit constrained households, which can be seen as an extensive margin and is controlled by the labor income share parameter $\alpha$.

The results of the policy experiment are presented in Figure 5 which gives the impact fiscal multipliers, as a function of the share of borrowers, for two possible values of the LTV parameter: $m_1 = 0.85$, which matches the baseline model calibration, and $m_2 = 0.75$, a
more conservative value based on data.\footnote{According to data from the Federal Housing and Finance Agency from their Survey of Rates and Terms on Conventional Single-Family Non-farm Mortgage loans (table 19), the average LTV ratio is 75.6 between 1973 and 2008.}

Intuitively, as the loan-to-value ratio increases, the borrowing constraint on the impatient agents is relaxed, which allows them to borrow and consume more. Also, for a larger share of credit constrained agents, the impact on aggregate consumption goes up as well. This puts upward pressure on wages, raises household income and ultimately leads to a more expansionary fiscal effect.

The LTV parameter directly affects the financial amplification mechanism in the model and a sufficiently large value is required to generate output multipliers larger than unity. In fact, in the conservative case, the output multipliers, while positive, are below unity even for a large fraction of constrained households (close to half), simply because the consumption of the impatient agents does not increase enough to offset the crowding out effect imposed on the savers’ consumption and private investment.

Fiscal expansions lead to a drop in house prices under all scenarios. This is due to the increase in the real interest rate which creates added incentives for savers to engage in inter-temporal consumption smoothing and depresses the housing market. The negative wealth effect associated with higher expected future taxes, forces these households to cut current consumption. In turn the marginal utility of consumption relative to housing will rise, which determines a fall in house prices.

Furthermore, this reduces the borrowers’ net worth, by decreasing the value of their housing stock (the credit collateral) and forces them to scale back consumption. Overall the expansionary effects of the fiscal package will be reduced at longer horizons and the loss in output has a further negative impact on real estate prices.

In general, when borrowers want to expand consumption, they also need to build up their collateral stock which creates demand for housing goods and raises their price. This effect however will be weakened when the credit availability is reduced, so on average house prices will be lower in a deleveraged economy (like in the wake of a credit crunch). This mechanism is also the reason why the drop in house prices is larger in response to the government spending shock, under the low LTV relative to baseline.

The model therefore predicts (when accounting for the asset price transmission channel) that under difficult financial conditions debt financed fiscal stimulus has a reduced response on output and, if credit frictions are significant enough, the response of aggregate consump-
tion can be in fact negative. In the last section of the paper I revisit this finding from an empirical angle.

4.3.2 Fiscal Multipliers, Nominal Rigidities, and the Persistence of Fiscal Shocks

The role of price rigidities is well established in both the business cycle literature and in the models typically used for monetary policy analysis (King and Watson 1995, Erceg et al., 2000, Christiano et al. 2005, Smets and Wouters 2007 to name just a few). Also, as Harms (2002), Gali et al. (2007), Fernandez-Villaverde et al. (2012) among others have documented, shock persistence has important implications regarding the aggregate economic effects of fiscal packages (either expansionary or for consolidation). Therefore it is informative to also consider the role of these key structural parameters in the current framework.

In principle, a higher degree of price stickiness requires a smaller adjustment in the expected real interest rate, as the response of inflation is more sluggish. This effect, on the one hand, helps reduce the drop in current consumption for savers and, on the other hand, dampens the decline in housing prices. Since house prices directly determine the borrowers net worth, they implicitly set the amount of credit these agents can access and, thus, will prevent a sharper negative adjustment in their consumption.

Figure 6 shows present value output multipliers calculated up to a twenty quarters horizon. I consider three values of the price stickiness parameter, while keeping the rest of the baseline calibration unchanged. In line with the intuition outlined above, the simulation shows an increase in output multipliers at all horizon when prices become more rigid.

The effects of wage stickiness are showcased in Figure 7. When wages are more flexible, labor income can raise faster in response to an increase in labor demand, induced by higher aggregate demand. In turn as discussed above, higher labor income supports an increase in aggregate consumption and thus output. There appears to be a trade off though; while the short run multipliers are in fact larger, the economy will spend less time operating above potential when wages adjust rapidly and the duration of the expansion will be reduced. This accounts for lower economic growth.

Consistent with the findings of Gali et al. (2007), the degree of persistence in fiscal shocks (here government spending) affects household choices mainly through its effects on the real interest rate and the relative prices in the economy. For instance, in the case of an expansionary fiscal shock, with a highly persistent government expenditure process, the households will expect higher public spending for longer.

22
This in turn will imply higher interest rates and lower house prices, forcing both types of agents to be more conservative in their spending decisions. The net effect will be a drop in aggregate consumption and output resulting in lower fiscal multipliers for both variables. The results are summarized in Figure 8.

4.3.3 Fiscal Multipliers and Government Debt Financing

In line with Leeper et. al (2009), I consider several alternative scenarios for public debt financing, as well as the effects of a stronger response in fiscal instruments to debt. The results of these policy experiments are presented in Figures 9 through 11.

The choice of how to finance the public debt appears to be particularly important especially at longer horizons. In particular, an over reliance on capital taxes imposes a large cost on society in terms of growth potential. A sharp rise in the capital tax, reduces investment spending significantly in the short and medium run, which stymies the productive capabilities of the economy in the long run. The output multipliers change sign and become negative, when only capital taxes are used to pay off debt, after approximatively thirty five quarters.

This pattern does not occur, though, when the government relies on labor taxes. In the short run, the output multipliers are marginally smaller, but they remain positive up the forty quarters mark, which is consistent with a smaller negative adjustment in investment spending in this case.

Finally, a more aggressive stance in the repayment of public debt tends to reduce output multipliers at all horizons when labor taxes are used. A larger increase in the labor tax in response to debt will, on one hand, have a significant negative effect on the consumption of constrained agents for which is the main source of income. This will erode over time the effect of fiscal stimulus. On the other hand, by increasing the disutility of labor, the number of hours worked will drop, which will have a negative impact on economic growth and translate into smaller long run multipliers.

When only capital taxes respond to debt, the degree of debt stabilization appears to have a nonlinear effect. A faster response to debt, tends to decrease the short run output multipliers by decreasing private investment, also the short increase in interest rates, has a negative impact on house prices and thus borrowers’ consumption. At the same time, once the public debt has been paid off, the relaxation of credit conditions allows for an increase in investment and output which account for larger long run multipliers.
Credit Conditions and Government Spending Shocks - Evidence from a Nonlinear SVAR

This section provides some empirical insight regarding the role of financial conditions on the effects of fiscal stimulus. I employ a regime switching SVAR framework that controls for two financial regimes. One is characterized by difficult (tight) credit conditions, while the other refers to a scenario where access to credit is easy (relaxed credit conditions).

Following Auerbach and Gorodnichenko (2012), I estimate a Smooth Transition Vector Autoregressive model (STVAR) in which the transition between the two regimes is done in a continuous fashion. A logistic function is used to model the probability of being in one regime versus the other. The state of nature is characterized by an appropriate index variable. In this particular case the switch variable will be an index for aggregate financial conditions.

The STVAR is a more general specification of the Threshold VAR approach and it has the benefit of allowing for a larger number of observations to be used in estimation (particularly in the extreme regime). Intuitively, an STVAR can be understood as a weighted average of two piecewise linear combinations of the endogenous variables, each corresponding to one regime. The weights are given by the probability of being in that particular regime and are determined by the logistic function, based on the values of the index variable.

The model is specified as follows:

\begin{align}
(1) \quad & X_t = [1 - F(z_{t-1})] \Pi_R (L) X_{t-1} + F(z_{t-1}) \Pi_T (L) X_{t-1} + u_t, \\
(2) \quad & u_t \sim N(0, \Omega_t), \\
(3) \quad & \Omega_t = \Omega_R [1 - F(z_{t-1})] + \Omega_T F(z_{t-1}), \\
(4) \quad & F(z_{t-1}) = \frac{\exp(-\gamma z_t)}{1 + \exp(-\gamma z_t)}, \gamma > 0, \\
(5) \quad & \text{var}(z_t) = 1, E(z_t) = 0.
\end{align}

I use log-transformed, 1973:Q1-2007:Q4, quarterly data and consider the following endogenous variables: government spending (which includes consumption and gross investment), tax receipts (less transfer payments to businesses and individuals), output, total private consumption and an index of house prices.

All variables are converted in real terms using the GDP deflator (2005 chained dollars) and are expressed in per capita terms, with the exception of the house price index. The starting date of the sample was determined by data availability for the financial conditions index (the switch variable between the two regimes). The sample excludes the crisis period.
to avoid potential distortions induced by structural changes in the conduct of monetary policy (Zero Lower Bound).

The parameters $\Pi_R(L)$ and $\Pi_T(L)$ represent lag polynomials of degree four written for both regimes ($R =$ relaxed credit, $T =$ tight financial conditions), while $\Omega_R$ and $\Omega_T$ are the corresponding covariance matrices for disturbances.\footnote{The number of lags was chosen based on the Akaike information criterion. Similar values have been chosen in the literature: Blanchard and Perotti (2002), Auerbach and Gorodnichenko (2012).}

The regime switch variable $z_t$ is the Adjusted National Financial Conditions Index (ANFCI) published by the Federal Reserve Bank of Chicago. It provides information on the status of aggregate financial conditions, while controlling for the contribution of the business cycle. In order to insure scale invariance, it was normalized to have mean zero and variance equal to one. Figure 12 presents the index over the considered sample.

In order to isolate a component of financial conditions uncorrelated with economic conditions, the variation in the individual indicators attributable to economic activity and inflation has been removed. To this purpose, a three-month moving average of the Chicago Feds National Activity Index (CFNAI) and three-month percent change in the Personal Consumption Expenditures (PCE) were used by the source.

Finally, $F(\cdot)$ is a weighting function that takes values in the $(0, 1)$ interval depending on the index variable. The parameter $\gamma$ is positive by convention and controls the curvature of the weighting function. While it can be estimated jointly with the other VAR parameters, it is costly to do so in terms of degree of freedoms (due to the reduced number of observations in the tight credit regime). Instead I calibrate the parameter so the frequency of the bad state of the world is around 33 percent to match the data. Figure 13 plots the calibrated weight function over the sample.

Identification is based on a Cholesky decomposition with government spending ordered first, followed by taxes, output, consumption and house prices along the lines of Blanchard and Perotti (2002). That is $X_t = [G_t \ T_t \ Y_t \ C_t \ H_t]'$. This order reflects the fact that discretionary fiscal policy is not likely to react to an output change within a quarter due to implementation lags. Or in other words, that shocks in tax revenue, output, private consumption and house prices do not have a contemporaneous effect on the government spending, while house prices respond contemporaneously to all other variables.

The model is estimated using maximum likelihood methods. The 90% confidence intervals and the impulse responses are generated using an MCMC based method developed by Chernozhukov and Hong (2003). Figures 14 through 18 describe the impulse response of
the VAR variables to a 1% unanticipated shocks to government spending. The black line is generated from a linear VAR that does not control for credit regimes and is included as a comparison point. The red line is the response in the tight credit regime, while the blue line refers to the case when credit conditions are relaxed.

The results suggest that in the short run, credit conditions may play an important role in the economy’s response to fiscal stimulus. When credit conditions are difficult, increases in government spending have a reduced effect on output, while the response of private consumption is negative. There is also a sharp decline in house prices. These findings are qualitatively compatible with the existence of a credit channel, the crowding out of private borrowing, and of a financial amplification mechanism tied to credit constrained households, as outlined in the theoretical DSGE model.

In contrast, in a relaxed credit regime, fiscal stimulus appears more effective, leading to a positive response in both output and private consumption, along the lines of the existing empirical literature. House prices will also increase on impact, suggesting a less negative impact on private borrowing. This finding can again be reconciled with the existence of credit constrained agents who will be able to expand their consumption relatively more under this scenario, as the collateral constraint they are facing will be less severe due to overall better credit terms.

Agnello and Sousa (2011) using a panel VAR (PVAR) for 10 industrialized countries (including the U.S.) also document a negative response of asset prices (stocks and housing) to expansionary fiscal policy. They find this consistent with a deterioration of credit conditions due to the government’s increased financing needs. According to their results the response of house prices is persistent, while the effect on stock prices appears transitory, suggesting that policy makers might find it difficult to stabilize both markets using a single policy instrument.

At longer horizons, the effectiveness of fiscal stimulus appears to increase in a tight credit regime and decline under relaxed credit conditions. This pattern could be explained by the reallocation of financial resources towards investment and away from the credit constrained households (as their credit worthiness declines in the difficult credit environment) and the other way around under more relaxed credit conditions.

Afonso et al. (2011), who use a threshold VAR to study the effects of fiscal policy on output under two different financial stress regimes, arrive at a similar result. They find that in a high financial stress regime increases in government spending are contractionary.

23 The Appendix includes a sketch of the estimation procedure.
on impact, but overall the output rate of growth will be higher relative to the low stress regime.

6 Concluding Remarks

In a New Keynesian framework that features credit constrained households, distortionary taxation and private debt tied to the value of the housing stock, increases in government expenditures can be a more effective economic stimulus instrument compared to tax reductions.

In the short run, the output response associated with government spending features a Keynesian multiplier (1.03), conditional on a sufficiently large degree of leverage in the model economy (around 0.85 under the baseline calibration). The central mechanism behind this finding is the consumption response for credit constrained agents, which rises on impact due to a high marginal propensity to consume that makes them responsive to changes in transitory income.

The increase in aggregate consumption is large enough to offset the corresponding drop associated with the patient agents (savers) who exhibit a Ricardian behavior. The model is thus able to replicate the positive short run comovement between private consumption and government spending observed empirically (Perotti 2008, Ramey 2011, etc).

Quantitatively, both output and consumption multipliers appear smaller at all horizons than those typically reported in the DSGE models that incorporate rule-of-thumb agents (ROT). This literature frequently give values of around 1.5 or larger (Gali et. al (2007), Monacelli and Perotti (2008), Romer and Bernstein (2009)).

In the current framework all agents have access to the financial markets which dampens the response of consumption for the constrained agents relative to their ROT counterparts. Furthermore, the use of housing as collateral, introduces an additional transmission channel for policy via changes in housing prices which will affect credit availability to households and limit the response of output.

The loan-to-value ratio plays a key role in terms of the expected expansionary effect of fiscal measures. This parameter is directly tied to the borrowers’ credit limit, as it determines the value of the housing stock which is allowed as collateral. Policy experiments have shown that a sufficiently large value of the LTV ratio (of around 0.80) is necessary in order to
generate output multipliers above unity. In general, policy effects scale up with the size of credit constrained population.

A worsening in the quality of credit conditions modeled by a drop in the loan-to-value ratio (a forced deleveraging like in a credit crunch) or a reduction in the volume of private credit (modeled as a decrease in the share of borrowers) will reduce the expansionary effects of fiscal stimulus.

Using a regime switching SVAR which controls for two credit regimes, I find evidence that under the bad state of the world the expansionary effects of policy are reduced, as opposed to normal or (more) relaxed financial conditions. The empirical results show a negative impact for government spending on private consumption and house price when credit conditions are difficult. This result is compatible with the existence of a credit channel, as outlined in the theoretical model that links the government financing needs to the private terms of credit via a collateral mechanism tied to the value of housing goods.
7 Appendix

7.1 Tables

Table 1: Calibrated Structural Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta_1 )</td>
<td>0.99</td>
<td>( \eta_2 )</td>
<td>1.75</td>
</tr>
<tr>
<td>( \beta_2 )</td>
<td>0.95</td>
<td>( \xi_1 )</td>
<td>0.66</td>
</tr>
<tr>
<td>( \mu_c )</td>
<td>0.35</td>
<td>( \xi_2 )</td>
<td>0.97</td>
</tr>
<tr>
<td>( \mu_h )</td>
<td>0.1</td>
<td>( \alpha )</td>
<td>0.20</td>
</tr>
<tr>
<td>( \delta_h )</td>
<td>0.01</td>
<td>( r_x )</td>
<td>1.44</td>
</tr>
<tr>
<td>( \delta_{kc} )</td>
<td>0.025</td>
<td>( r_Y )</td>
<td>0.52</td>
</tr>
<tr>
<td>( \delta_{kh} )</td>
<td>0.03</td>
<td>( \theta_\pi )</td>
<td>0.83</td>
</tr>
<tr>
<td>( X, X_{wc}, X_{wh} )</td>
<td>1.15</td>
<td>( t_\pi )</td>
<td>0.69</td>
</tr>
<tr>
<td>( \epsilon_1 )</td>
<td>0.85</td>
<td>( \theta_{wc} )</td>
<td>0.80</td>
</tr>
<tr>
<td>( \epsilon_2 )</td>
<td>0.32</td>
<td>( t_{wc} )</td>
<td>0.08</td>
</tr>
<tr>
<td>( \epsilon_3 )</td>
<td>0.58</td>
<td>( \theta_{wh} )</td>
<td>0.80</td>
</tr>
<tr>
<td>( \eta_1 )</td>
<td>1.75</td>
<td>( t_{wh} )</td>
<td>0.4</td>
</tr>
<tr>
<td>( \phi_g )</td>
<td>0.23</td>
<td>( \phi_{tr} )</td>
<td>0.5</td>
</tr>
<tr>
<td>( \phi_{\tau_l} )</td>
<td>0.049</td>
<td>( \phi_{\tau_k} )</td>
<td>0.39</td>
</tr>
</tbody>
</table>

Table 2: Shock Processes Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \rho_{AC} )</td>
<td>0.95</td>
</tr>
<tr>
<td>( \rho_{AH} )</td>
<td>0.99</td>
</tr>
<tr>
<td>( \rho_j )</td>
<td>0.96</td>
</tr>
<tr>
<td>( \rho_g )</td>
<td>0.80</td>
</tr>
<tr>
<td>( \rho_{tr} )</td>
<td>0.85</td>
</tr>
<tr>
<td>( \rho_{\tau_l} )</td>
<td>0.85</td>
</tr>
<tr>
<td>( \rho_{\tau_k} )</td>
<td>0.90</td>
</tr>
<tr>
<td>( \sigma_{AC} )</td>
<td>0.01</td>
</tr>
<tr>
<td>( \sigma_{AH} )</td>
<td>0.0193</td>
</tr>
<tr>
<td>( \sigma_j )</td>
<td>0.0416</td>
</tr>
<tr>
<td>( \sigma_R )</td>
<td>0.0034</td>
</tr>
<tr>
<td>( \sigma_g )</td>
<td>0.0136</td>
</tr>
<tr>
<td>( \sigma_{tr} )</td>
<td>0.0145</td>
</tr>
<tr>
<td>( \sigma_{\tau_l} )</td>
<td>0.0163</td>
</tr>
<tr>
<td>( \sigma_{\tau_k} )</td>
<td>0.0196</td>
</tr>
</tbody>
</table>
Table 3: Business Cycle Properties - Correlations

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>Corr (Model)</th>
<th>Corr (Data)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C,GDP</td>
<td>0.8613</td>
<td>0.88</td>
</tr>
<tr>
<td>IK,GDP</td>
<td>0.8844</td>
<td>0.75</td>
</tr>
<tr>
<td>IH, GDP</td>
<td>0.638</td>
<td>0.78</td>
</tr>
<tr>
<td>Q,GDP</td>
<td>0.6827</td>
<td>0.58</td>
</tr>
<tr>
<td>Q,C</td>
<td>0.6062</td>
<td>0.48</td>
</tr>
<tr>
<td>Q,IH</td>
<td>0.4721</td>
<td>0.41</td>
</tr>
</tbody>
</table>

Table 4: Business Cycle Properties - Standard deviations

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>Standard Deviation percent (Model)</th>
<th>Standard Deviation percent (Data)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>1.62</td>
<td>1.22</td>
</tr>
<tr>
<td>IK</td>
<td>4.17</td>
<td>4.87</td>
</tr>
<tr>
<td>IH</td>
<td>8.69</td>
<td>9.97</td>
</tr>
<tr>
<td>Q</td>
<td>2.20</td>
<td>1.87</td>
</tr>
<tr>
<td>GDP</td>
<td>2.27</td>
<td>2.17</td>
</tr>
<tr>
<td>R</td>
<td>0.32</td>
<td>0.32</td>
</tr>
</tbody>
</table>

Table 5: Present Value Multipliers for an Increase in Government Spending

<table>
<thead>
<tr>
<th>Quarters</th>
<th>Output</th>
<th>Consumption</th>
<th>Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.035</td>
<td>0.122</td>
<td>-0.087</td>
</tr>
<tr>
<td>4</td>
<td>0.847</td>
<td>0.043</td>
<td>-0.197</td>
</tr>
<tr>
<td>8</td>
<td>0.636</td>
<td>-0.035</td>
<td>-0.328</td>
</tr>
<tr>
<td>12</td>
<td>0.527</td>
<td>-0.072</td>
<td>-0.401</td>
</tr>
<tr>
<td>20</td>
<td>0.353</td>
<td>-0.134</td>
<td>-0.511</td>
</tr>
</tbody>
</table>

Notes: The multipliers are calculated for output, aggregate consumption and investment. The fiscal shock is a 1% transitory increase in government spending that is debt financed. All fiscal instruments adjust to stabilize debt. Time is measured in quarters.
Table 6: Present Value Multipliers for an Increase in the Government Transfer

<table>
<thead>
<tr>
<th>Quarters</th>
<th>Output</th>
<th>Consumption</th>
<th>Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.171</td>
<td>0.186</td>
<td>-0.016</td>
</tr>
<tr>
<td>4</td>
<td>0.113</td>
<td>0.162</td>
<td>-0.048</td>
</tr>
<tr>
<td>8</td>
<td>0.056</td>
<td>0.127</td>
<td>-0.072</td>
</tr>
<tr>
<td>12</td>
<td>0.026</td>
<td>0.093</td>
<td>-0.067</td>
</tr>
<tr>
<td>20</td>
<td>-0.015</td>
<td>0.068</td>
<td>-0.082</td>
</tr>
</tbody>
</table>

Notes: The multipliers are calculated for output, aggregate consumption and investment. The fiscal shock is a 1% transitory increase in government transfers that is debt financed. All fiscal instruments adjust to stabilize debt. Time is measured in quarters.

Table 7: Present Value Multipliers for a Decrease in the Labor Tax

<table>
<thead>
<tr>
<th>Quarters</th>
<th>Output</th>
<th>Consumption</th>
<th>Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.181</td>
<td>0.202</td>
<td>-0.021</td>
</tr>
<tr>
<td>4</td>
<td>0.158</td>
<td>0.176</td>
<td>-0.018</td>
</tr>
<tr>
<td>8</td>
<td>0.135</td>
<td>0.151</td>
<td>-0.017</td>
</tr>
<tr>
<td>12</td>
<td>0.114</td>
<td>0.126</td>
<td>-0.011</td>
</tr>
<tr>
<td>20</td>
<td>0.072</td>
<td>0.081</td>
<td>-0.008</td>
</tr>
</tbody>
</table>

Notes: The multipliers are calculated for output, aggregate consumption and investment. The fiscal shock is a 1% transitory decrease in labor tax that is debt financed. All fiscal instruments adjust to stabilize debt. Time is measured in quarters.

Table 8: Present Value Multipliers for a Decrease in the Capital Tax

<table>
<thead>
<tr>
<th>Quarters</th>
<th>Output</th>
<th>Consumption</th>
<th>Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.011</td>
<td>-0.021</td>
<td>0.011</td>
</tr>
<tr>
<td>4</td>
<td>-0.016</td>
<td>-0.037</td>
<td>0.021</td>
</tr>
<tr>
<td>8</td>
<td>-0.024</td>
<td>-0.056</td>
<td>0.032</td>
</tr>
<tr>
<td>12</td>
<td>-0.047</td>
<td>-0.063</td>
<td>0.017</td>
</tr>
<tr>
<td>20</td>
<td>-0.054</td>
<td>-0.071</td>
<td>0.015</td>
</tr>
</tbody>
</table>

Notes: The multipliers are calculated for output, aggregate consumption and investment. The fiscal shock is a 1% transitory decrease in labor tax that is debt financed. All fiscal instruments adjust to stabilize debt. Time is measured in quarters.
Figure 1: Impulse response to a 1 percent increase in government expenditures. X-axis measures quarters, Y-axis (times 100) measures percentage deviations from steady state.
Figure 2: Impulse response to a 1 percent increase in government transfers. X-axis measures quarters, Y-axis (times 100) measures percentage deviations from steady state.
Figure 3: Impulse response to a 1 percent cut in the labor income tax. X-axis measures quarters, Y-axis (times 100) measures percentage deviations from steady state.
Figure 4: Impulse response to a 1 percent increase in the capital income tax. X-axis measures quarters, Y-axis (times 100) measures percentage deviations from steady state.
Figure 5: Fiscal Impact Multipliers as a Function of the Share of Credit Constrained Agents. X-axis measures the share of borrowers (as a %) starting with baseline value.
Figure 6: Output Present Value Multipliers as a Function of Price Rigidity ($\theta_p$). X-axis measures the calculation horizon (in quarters).
Figure 7: Output Present Value Multipliers as a Function of Wage Rigidity ($\theta_w$). X-axis measures the calculation horizon (in quarters).
Figure 8: Output Present Value Multipliers as a Function of Government Spending Shocks Persistence ($\rho_g$). X-axis measures the calculation horizon (in quarters).
Figure 9: Output Present Value Multipliers under Alternative Debt Financing Schemes. X-axis measures the calculation horizon (in quarters).
Figure 10: Output Present Value Multipliers when only Labor Taxes adjust to Debt. Parameter \( \mu \) is a scaling factor of the debt stabilizing component. X-axis measures the calculation horizon (in quarters).
Figure 11: Output Present Value Multipliers when only Capital Taxes adjust to Debt. Parameter $\mu$ is a scaling factor of the debt stabilizing component. X-axis measures the calculation horizon (in quarters).
Figure 13: Weight function $F(z_t)$ 1973:Q1 - 2007:Q4. X-axis measures time (in quarters).
Figure 14: Gov. Spending Impulse Response Function to a 1% Gov. Spending Shock with 90% CI (linear VAR - black line, Tight Credit - red line, Relaxed Credit - blue line). X-axis measures time (in quarters).
Figure 15: Housing Price Impulse Response Function to a 1% Gov. Spending Shock with 90% CI (linear VAR - black line, Tight Credit - red line, Relaxed Credit - blue line). X-axis measures time (in quarters).
Figure 16: Output Impulse Response Function to a 1% Gov. Spending Shock with 90% CI (linear VAR - black line, Tight Credit - red line, Relaxed Credit - blue line). X-axis measures time (in quarters).
Figure 17: Private Consumption Impulse Response Function to a 1% Gov. Spending Shock with 90% CI (linear VAR - black line, Tight Credit - red line, Relaxed Credit - blue line). X-axis measures time (in quarters).
Figure 18: Tax Revenue Response Function to a 1% Gov. Spending Shock with 90% CI (linear VAR - black line, Tight Credit - red line, Relaxed Credit - blue line). X-axis measures time (in quarters).
7.3 Estimation Procedure

The model is estimated using maximum likelihood methods following the approach given in Auerbach and Gorodnichenko (2012). The log-likelihood function is described by:

\(\log L = \text{const} - \frac{1}{2} \sum_{t=1}^{T} \log |\Omega_t| - \frac{1}{2} \sum_{t=1}^{T} u_t' \Omega_t^{-1} u_t\)

where \(u_t = X_t - (1 - F(z_{t-1})) \Pi_R(L) X_{t-1} - F(z_{t-1}) \Pi_T(L) X_{t-1}\).

The vector of the model parameters is given by \(\Psi = \{\gamma, \Omega_T, \Omega_R, \Pi_T(L), \Pi_R(L)\}\).

Conditional on \(\{\gamma, \Omega_T, \Omega_R\}\) the model will be linear in the lag polynomials \(\{\Pi_T(L), \Pi_R(L)\}\) which can then be estimated with weighted least squares. The weights are given by \(\Omega_t^{-1}\) and the estimates of \(\{\Pi_T(L), \Pi_R(L)\}\) must minimize \(\frac{1}{2} \sum_{t=1}^{T} u_t' \Omega_t^{-1} u_t\).

Let:

\(W_t = [(1 - F(z_{t-1}))X_{t-1} F(z_{t-1})X_{t-1} \ldots (1 - F(z_{t-1}))X_{t-p}F(z_{t-1})X_{t-p}]\)

represent the full vector of regressors, \(\Pi = [\Pi_T \Pi_R]\), \(u_t = X_t - \Pi W_t\) and the objective function is given by:

\((A2) \frac{1}{2} \sum_{t=1}^{T} (X_t - \Pi W_t)' \Omega_t^{-1} (X_t - \Pi W_t)\).

or equivalently:

\[\frac{1}{2} \sum_{t=1}^{T} (X_t - \Pi W_t)' \Omega_t^{-1} (X_t - \Pi W_t) = \text{trace} \left[ \frac{1}{2} \sum_{t=1}^{T} (X_t - \Pi W_t)' \Omega_t^{-1} (X_t - \Pi W_t) \right]\]

\[= \frac{1}{2} \sum_{t=1}^{T} \text{Trace} [(X_t - \Pi W_t')(X_t - \Pi W_t)'] \Omega_t^{-1}].\]

Taking the first order condition with respect to \(\Pi\) and applying the \(\text{vec}\) operator gives:

\[\text{vec} \left( \sum_{t=1}^{T} W_t' X_t \Omega_t^{-1} \right) = \text{vec} \left[ \sum_{t=1}^{T} W_t' W_t \Pi' \Omega_t^{-1} \right] = \sum_{t=1}^{T} \text{vec}[W_t' W_t \Pi' \Omega_t^{-1}].\]
Or equivalently:

\[
(A3) \quad vec\Pi' = \left( \sum_{t=1}^{T} \left[ \Omega^{-1}_t \otimes W'_t W_t \right] \right)^{-1} vec \left( \sum_{t=1}^{T} W'_t X_t \Omega^{-1}_t \right).
\]

The procedure iterates on \( \{\gamma, \Omega_T, \Omega_R\} \) (which yields \( \Pi \) and the likelihood) until an optimum is reached. Allowing for a homoscedastic error term (i.e. \( \Omega_t = \text{constant} \)) gives standard VAR estimates.

To address the fact that the model is highly non-linear in parameters which makes optimization challenging and to simplify inference, Auerbach and Gorodnichenko (2012) use a Markov Chain Monte Carlo (MCMC) approach.

The method was originally developed by Chemozhukov and Hong (2003) and in this case it helps find a global optimum and generate empirical distributions for the model parameters. The Metropolis-Hastings algorithm constructs chains of length \( N \) and is succinctly summarized below:

Step 1: Draw \( \Theta^{(n)} \), a candidate vector of parameter values for the chain’s \( n+1 \) state.

\[ \Theta^{(n)} = \Psi^{(n)} + \psi^{(n)} \]

where \( \Psi^{(n)} \) is the current \( n \) state of the model parameter vector, \( \psi^{(n)} \) is an i.i.d. vector of shocks from \( N(0, \Omega_{\psi}) \), and \( \Omega_{\psi} \) is diagonal.

Step 2: The \( n+1 \) state of the chain is given by:

\[ \Psi^{(n+1)} = \begin{cases} 
\Theta^{(n)}, \text{probability : } \min\{1, \exp[\log L(\Theta^{(n)}) - \log L(\Psi^{(n)})]\} \\
\Psi^{(n)}, \text{otherwise}
\end{cases} \]

where \( L(\Psi^{(n)}) \) is the value of the objective function at the current state of the chain and \( L(\Theta^{(n)}) \) is the value of the objective function using the candidate parameter vector.

The starting value of \( \Psi^{(0)} \) is computed as follows. The vector of endogenous variables \( X_t \) is regressed on lags of \( X_t, X_t z_t, X_t z_t^2 \). The residual is then used to fit equation (3), while \( \Omega_T \) and \( \Omega_R \) are estimated by MLE. These estimates are used to construct starting values for the lag polynomials \( \{\Pi_T(L), \Pi_R(L)\} \) based on equation (A3).

The initial \( \Omega_{\psi} \) is calibrated to about one percent of the parameter value and then adjusted on the fly for the first 20,000 draws to generate 0.3 acceptance rates of candidate draws, as
in Gelman et al. (2004). The number of draws is set at 100,000 and the first 20,000 are dropped as burn-in.

The generated chain of parameter values $\{\Psi^{(n)}\}_{n=1}^N$ is also used to construct confidence intervals for the impulse responses. A number of 1,000 draws (with replacement) are made from $\{\Psi^{(n)}\}_{n=1}^N$ and impulse responses are calculated for each of these.

The parameters $\{\Pi_T(L), \Pi_R(L)\}$ are drawn directly from $\{\Psi^{(n)}\}_{n=1}^N$, while the covariance matrix of residuals in regime $s = \{T, R\}$ is drawn from $N(\text{vec}(\Omega_s), \Sigma_s)$.

$$\Sigma_s = 2[(D_n^T D_n)^{-1} D_n] \{\text{var}(\text{vec}(\Omega_s)) \otimes \text{var}(\text{vec}(\Omega_s))\} [(D_n^T D_n)^{-1} D_n]'$$

$D_n$ is the duplication matrix, and var(vec($\Omega_s$)) is computed from $\{\Psi^{(n)}\}_{n=1}^N$. The 90 percent confidence bands are computed as the 5$^{th}$ and 95$^{th}$ percentiles of the generated impulse responses.

### 7.4 Fiscal Data Description

My construction of the fiscal data follows Leeper et. al (2009). The main data source are the National Income and Product Accounts Tables from the National Bureau of Economic Research. To convert nominal series into real terms I used the GDP deflator for Personal Consumption Expenditures (Table 1.1.4, line 2). Where appropriate variables were divided by a population index (LNS10000000 from the Bureau of Labor Statistics) and then log transformed.

For capital and labor taxes, I calculate an average personal income tax, following Jones (2002):

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

where $IT$ is personal income tax revenue calculated as the sum between federal income taxes $FIT$ and state and local income taxes $SIT$ (Table 3.2, line 3). $W$ is wages and salaries (Table 1.12, line 3). $PRI$ is proprietor income (Table 1.12, line 9 ). $CI$ denotes capital income which is defined as half of proprietor’s income, rental income (Table 1.12, line 12), corporate profits (Table 1.12, line 13) and net interest (Table 1.12, line 18).

Average labor income tax is:

$$\tau^l = \frac{\tau^p(W + PRI/2 + CSI)}{EC + PRI/2}$$
where $CSI$ denotes total contributions to government social insurance (Table 3.2, line 11) and $EC$ denotes compensation of employees (Table 1.12, line 2).

The average capital income tax rate is calculated as:

$$\tau^k = \frac{\tau^p CI + CT}{CI + PT}$$

where $CT$ is taxes on corporate income (Table 3.2, line 7) and $PT$ is property taxes (Table 3.3, line 8).

The capital and labor tax revenues are calculated as the product between the corresponding average tax rate and its tax base.

Government Consumption. Government consumption includes current government expenditures (Table 3.2, line 20) and government net purchases of non-produced assets (Table 3.2 line 44), minus government consumption of fixed capital (Table 3.2 line 45).

Transfers. The transfer payment is defined as net current transfers, net capital transfers, and subsidies (Table 3.2, line 32), minus the tax residual. Net current transfers are current transfer payments (Table 3.2, line 22) minus current transfer receipts (Table 3.2, line 16). Net capital transfers are capital transfer payments (Table 3.2, line 43) minus capital transfer receipts (Table 3.2, line 39). The tax residual is defined as current tax receipts (Table 3.2 line 2), contributions for government social insurance (Table 3.2, line 11), income receipts on assets (Table 3.2, line 12), and current surplus of government enterprises (Table 3.2, line 19) minus total tax revenue (consumption, labor, and capital tax revenues).

Government debt is based on data from the Dallas Federal Reserve Bank series and is calculated as previous debt plus interest payments (Table 3.2, line 29), government consumption, and transfers minus Seignorage (change in the monetary base) (AMBSL from the St. Louis Federal Reserve Bank), as well as capital and labor tax revenue.
References


