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Credit Crunch On Financial Intermediary

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Abstract

This paper proposes a speculative account of a DSGE model where the economy is under the strain of borrowers' default on their obligations to intermediary agents. The paper argues that macropruential policies help mitigate financial risks and reduce common exposures across markets. On the other hand, they may be inadequate in fostering a restoration of the economy after a crisis. This paper uses Bayesian estimations based on various data sets to simulate the Great Recession and to show the role of financial accelerator effects in the amplification and propagation of shocks. Facing the redistribution shock, banks have to recapitalize or deleverage in order to meet regulatory requirements. The portfolio change opens out the shock to the real side of the economy and starts a business cycle. This is similar to the climate of the Great Recession. The model does a good job of accounting for the behavior of key economic variables, especially housing prices during the Great Recession. It is able to capture the context of the home price double-dip after the closure of the crisis. On comparing different origin defaults, the paper indicates private defaults have more harsh economic impact rather than government defaults, in term of size of impacts, recovery time and welfare.

JEL classification:E32, E44, E62 .

Keywords: Private and Government default, Bank balance sheet, macroprudential policy.

1 Introduction

Comparing to those crises classified as real[1], two recent major crises had financial natures. The crisis of 2007-2009 evidences the integral role of financial intermediations and fric-

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[1]See Merz (1995) and Summers (2002)).

tions[2]. These two crises shared a common cause: a disturbance in the flow of resources between different agents of the economy. This anxiety can easily propagate to other agents and causes a business cycle.

The present paper characterizes a DSGE model to assess the dynamic impacts of bank's credit crunch initiated by borrowers' defaults on their obligations. The model incorporates borrowing constrained intermediaries, government, real estate and credit markets. The paper tries to answer two key questions. Firstly, what are the channels through them financial shocks propagate to the real side of the economy and how big are the impacts. Secondly, how do *macroprudential regulation tools* provide mechanisms to safeguard the economy and mitigate the impact of adverse shocks. In the first part, the paper provides a comparison between the business cycles initiated by different origins in the form of recovery time, size of impacts and welfare. The paper tries to build a reliable model to assess the aggregate impact of different financial shocks and makes a substrate to improve our understanding of financial business cycles. The model perfectly simulates the behavior of the economy before and after the Great Recession and captures the important features of the recent crisis such as the home price double-dip and the long recovery time. This structure can easily extend empirically to the real default cases such as private defaults (as is assessed in this paper in the case of the Great Recession) or government defaults e.g 1998 Russian financial crisis[3] (that Russia defaulted on its internal debt) or sovereign default e.g. the default of Greece[4].

The paper makes economic estimations based on various data sets to simulate the financial climate of the Great Recession. Using the estimation results, the paper compares the impact of different defaults. In the model, financial shocks i.e. defaults are initialized by two types of borrowers: Household and Government. Borrower households need credit in order to buy houses. A collateral constraint limits their borrowing to the expectation of the future house value. The government combines what it borrows with collected taxes, in order to cover its expenditure or expand public spending. Both these borrowers can default on their loans- and consume or expend more- and consequently, cause a credit shortage on financial intermediaries. The paper finds that although the government default negatively effects the aggregate economy, the household default has more severe implications. The recovery time of the latter is noticeably longer than the former and the same is true from the viewpoint of welfare. At the end, the paper presents

[2] The seminal works e.g. Bernanke (2009a), Bernanke (2009b) and Gorton (2010) well document the causes and the financial nature of the Great Recession.

[3] See Sturzenegger and Zettelmeyer (2008) and Duffie et al. (2003).

[4] See Borensztein and Panizza (2009) and Gennaioli et al. (2014).

the application of macroprudential tools in the case of debt-to-income ratio and liabilities-to-assets ratio. Applying macroprudential policies helps reduce externalities and market failures and protects the economy by reducing the volatilities. The paper reveals that with a stricter policy on the mortgage market through a cap on debt-to-income ratio, the economy wakes up faster but on the other hand, recovers slower.

The paper designs the model using the basic features of Iacoviello (2015) which estimates the impact of shocks in bank capital by household defaults. The banking structure, the context of the shocks and the credit crunch that the banking system is faced, are closely comparable in my model to his. However, in the creation of a model more sensitive to the nuances of a real economy, I use a DSGE model which includes government and renter households. The tax codes used in the present model are close to the actual US tax on income and property, including tax exemptions for mortgage and home owners. This type of model has been widely implemented in the previous literature e.g. Alpanda and Zubairy (2016). This rich macrofounded general equilibrium model, highlights inter-relations of the real economy and the credit market. The model remarkably simulates the behavior path of the economy from the beginning of the crisis until the economic crash.

The reason for the existence of bankers is twofold. Firstly, they facilitate transfers of assets between agents, secondly, they cater to facts in the real world. Households do not have the expertise required for direct investments. So the existence of intermediaries is technological and a real world application. There is an expansive body of literature which studies intermediary agents and varieties of capital constraints to include banks in the analysis. Gorton and Metrick (2010), Brunnermeier and Sannikov (2014) and Gersbach et al. (2015) use simple non-stochastic intermediary capital constraints to show the major role of financial intermediaries. Tchana (2012)'s model is an attempt to present a banking regulation in an overlapping-generations model and its effect on welfare. Mimir (2016) studies the role of financial shocks and credit frictions in a quantitative analysis à la Gertler and Karadi (2011) with a stochastic banking sector. Banks in those models act as zero profit organizations or accumulate net worth every period and consume all their net worth at the dead point. In contrast, the model of the present paper uses a stochastic representative banking sector which consumes every period, making it a more realistic representation and in closer adherence to empirical facts. In addition, the banking sector in the present paper faces a capital adequacy constraint that dynamically depends on banker's expectation on its stochastic future return assets, defaults and *liabilities-to-*

assets ratio set by a higher regulatory as a macroprudential policy tool.

Macroprudential policy tools are comprehensively proposed by a combination of regulators including the SEC, Federal Reserve, Basel Committee on Banking Supervision (BCBS), Financial Standards Board (FSB), Prudential Regulatory Authority (PRA) and the European Commission. They aim to provide a global model for the protection of banks and households against financial and real shocks. In the recent years, regulatories are more interested in study the effects of these tools. Lim et al. (2011) and Igan and Kang (2011) theoretically and empirically study the effectiveness and efficacy of macroprudential regulations. Simulating the behavior of the system after shocks, the present paper confirm the empirical findings of Claessens et al. (2013). However macroprudential tools are all protecting, they should be selected accurately. Some policies are more correspond to mitigate the vulnerabilities and some others are more apt to build up buffers. An efficient tool in boom periods could slow down the recovery of the economy during a recession. This paper designs the cap on debt-to-income ratio as a policy tool on borrower credit side à la Gelain et al. (2013).

The liabilities-to-assets ratio is the controversial subject as it has the same context of the capital requirement ratio (CRR). For instance, the required total CRR in Basel I and II was 8%. A mandatory capital conservation buffer in the form of dynamic macroprudential is presented in Basel III (2010) which adds 2.5% to the previous CRR so the required total capital increases up to 10.5% (Supervision, 2011). The present paper finds a higher liabilities-to-assets ratio reduces the volatility of house prices and protect the economy without slowing it down. Basel models are corroborated by an expansive body of empirical and theoretical evidence. For instance, Angelini et al. (2014) and Angelini et al. (2015) build a DSGE model à la Gerali et al. (2010) to show the functionality of Basel and countercyclical capital buffers in models with monetary policy. My model highlights the supporting role of the macroprudential policy tools to mitigate financial system vulnerabilitie. These policies address both the cross-sectional dimension of systemic risk and its temporal dimension and assist monetary policy by counteracting financial imbalances that pose systemic risks. Furthermore, in the view point of systemic perspective, macro-prudential policy can integrate microprudential policies and address the fallacy of composition[5].

One possible reason for household default is the tightening of collateral constraint,

[5] See Crockett (2000).

for instance, a drop in house prices [6]. The recent work, Lambertini et al. (2017) studies the interaction between risks in the mortgage market and the rate of delinquencies (or default) in a DSGE model. The present paper indicates the role of the price expectation in heating or slowing down the economy. It illustrates how the frictions in housing and capital investment market alongside future expectations make a double-dip in housing prices. The double-dip is pointed out in Case and Shiller (2003) and Case et al. (2003). The double-dip forms an economic setback, delays the recovery and is one of the reasons of long-lasting crisis.

The context of the government default in this paper is a reaction to positive government spending shocks by paying less back to banks and defaulting on the loans. This structure is in accordance with observable patterns in the global economy[7]. Government spending shocks are frequently studied in the literature. Ramey (2011), Bachmann and Sims (2012), Sims and Wolff (2013) and Forni and Gambetti (2016) either empirically or theoretically study the impact of government spending shocks in economic elements, welfare or channels by which government spending shocks affect the economy. However the impact of fiscal policy on housing and house prices remains unexplored. The present paper attempts to delve into this previously neglected area and show the impact of government spending shocks on housing. The recent work, Khan and Reza (2016), is an attempt at filling this gap in the research. They conduct an empirical VAR analysis to examine the effects of discretionary fiscal policy on house prices. They use the Blanchard and Perotti (2002) structural VAR approach and draw the conclude that house prices rise after a positive government spending shock. In contrast with the empirical findings, their DSGE model (à la Iacoviello and Neri (2010)) cannot capture the procyclical nayure of housing prices and counterfactually shows house prices fall after positive government spending shocks. They prove that this is a general property of DSGE models. My model confirms their findings and shows that even a model with intermediary agents cannot portey the procyclical aspect of the housing price, due to the constant shadow value of durable goods (Barsky et al., 2007). The model clearly shows the negative GDP response to positive government spending shocks.

[6] For other possible reasons, see Guerrieri et al. (2015).

[7] For instance, the Greek government-debt crisis. This led to a crisis of confidence, indicated by a widening of bond yield spreads and rising cost of risk insurance on credit default swaps compared to the other Eurozone countries. The country required bailout loans in 2010, 2012, and 2015 from the International Monetary Fund, Eurogroup, and European Central Bank, and negotiated a 50% haircut on debt owed to private banks in 2011. The Greek example is a perfect fit for the model proposed in this paper and a more indebt examination of its economy would make an interesting case-study for a supporting paper.

The following sections of this paper are organized as follows. Section 2 presents the model. Section 3 presents the estimation of the parameters using the calibration based on data and previous literature. Section 4 simulates the Great Recession using the estimated parameters and compare the accuracy of the model with the literature. Section 5 studies the impact of a stochastic shock on the bank asset side caused by private and government defaults and compares these two defaults. The effectiveness of different macroprudential policies and their protective mechanism are depicted in section 6. Section 7 offers a conclusion on the findings of this paper.

2 Model

The model is composed of four heterogeneous households (lenders, borrowers, renters and bankers) which each has a unit mass. Patient households are capital owners. Firms borrow this capital to produce non-housing goods. Patient households are, in addition, active in housing market. They sell and buy residential houses for personal uses and rental houses in order to rent to renter households. Patient households are lenders. They supply required credit for borrowers by making deposits in the banking sector. Bankers are expert investors and the owners of the banking sector. Bankers create credit for impatient households in the form of mortgages and for the government as government loans. Stochastic financial frictions are applied on impatient households and bankers. Government collects income and housing taxes and combine them with governmental loans to cover government expenditure and lump-sum transfers to all households except bankers.

2.1 Household

Superscribe P, I, R, B stand for Patient, Impatient, Renter households and Bankers, respectively. Any type of household has a unit measure of infinitely lived household.

2.1.1 Patient households

Patient household utility function is,

$$E_t \sum_{\tau=t}^{\infty} \beta_P^{\tau-t} \{\log c_\tau^P + \varphi_h \log h_{\tau-1}^P - \varphi_l \frac{(l_\tau^P)^{1+\iota}}{1+\iota}\} \tag{2.1}$$

where t presents time. $\beta_P < 1$ is the discount factor that is greater than the discount factor of other households. φ_h and φ_l present the relative importance of housing and labor participation in the utility function respectively, and ι is the inverse of the Frisch-elasticity of labor supply. l^P is the fraction of patient labor in the economy. The patient household's budget constraint is

$$(1+\tau_c)c_t^P + p_t^h h_t^{Ph} + i_t^k + d_t \leq \omega_t^P - \tau_t^P - AC_t^P \tag{2.2}$$

A representative patient household consumes c^P, buys residential and rental houses h^P and h^R respectively, at relative price p_t^h. The patient household is the owner of capital which is borrowed by firms in order to produce non-housing goods. After production, the undepreciated part of capital is returned to the household. The depreciation rates on housing and capital are δ_h and δ_k, respectively. The patient housing h^{Ph}, and capital investments i^k respectively are

$$h_t^{Ph} = [h_t^P - (1-\delta_h)h_{t-1}^P] + [h_t^R - (1-\delta_h)h_{t-1}^R] \tag{2.3}$$

$$i_t^k = k_t - (1-\delta_k)k_{t-1} \tag{2.4}$$

Deposit d is the saving of the patient household in banking sectors. Total income ω^P is composed of wage w^P, rent from renters at price p^R , return on deposit and capital with interest rate r and r^k respectively and the government transfer Γ^P,

$$\omega_t^P = w_t^P l_t^P + p_t^R h_{t-1}^R + (1+r_t)d_{t-1} + r_t^k k_{t-1} + \Gamma_t^P \tag{2.5}$$

The income tax for the patient household τ^P is composed of taxing on wage, rent, property, return on deposit and capital,

$$\begin{aligned}\tau_t^P = {}& \tau_w[w_t^P l_t^P + (p_t^R - \delta_h)h_{t-1}^R - \tau_p p_t^h(h_{t-1}^R + h_{t-1}^P)] + \tau_p p_t^h(h_{t-1}^P + h_{t-1}^R) \\ & + \tau_d r_t d_{t-1} + \tau_k(r_t^k - \delta_k)k_{t-1}\end{aligned} \tag{2.6}$$

τ_w stands for the income tax, τ_p for property tax, τ_d and τ_k for tax on deposit and capital return, respectively. In addition, to remain consistent with the current US tax code, the patient household profits from a tax break equal to a fraction of the property tax[8] (the second and third term in the bracket). The last term in the budget constraint is the

[8]https://www.irs.gov/publications/p530/ar02.html

adjustment cost AC^P consistent with the literature[9].

The FOC with respect to residential and rental houses respectively are[10],

$$p_t^h = \beta_P \mathbf{E}_t[\frac{\varphi_h}{\lambda_t^P h_t^p} - \frac{\lambda_{t+1}^P}{\lambda_t^P}(\frac{\partial h_{t+1}^{Ph}}{\partial h_t^P} + \frac{\partial \tau_{t+1}^P}{\partial h_t^P})] \tag{2.7}$$

$$p_t^h = \beta_P \mathbf{E}_t[\frac{\lambda_{t+1}^P}{\lambda_t^P}(\frac{\partial \omega_{t+1}^P}{\partial h_t^R} - \frac{\partial h_{t+1}^{Ph}}{\partial h_t^R} - \frac{\partial \tau_{t+1}^P}{\partial h_t^R})] \tag{2.8}$$

where λ^P is the Lagrangian multiplier of the budget constraint. The FOCs with respect to deposit and capital respectively are

$$1 = \beta_P \mathbf{E}_t[\frac{\lambda_{t+1}^P}{\lambda_t^P}(1 - \frac{\partial \tau_{t+1}^P}{\partial d_t} + \frac{\partial \omega_{t+1}^P}{\partial d_t})] \tag{2.9}$$

$$1 = \beta_P \mathbf{E}_t[\frac{\lambda_{t+1}^P}{\lambda_t^P}(\frac{\partial \omega_{t+1}^P}{\partial k_t} - \frac{\partial i_{t+1}^P}{\partial k_t} - \frac{\partial \tau_{t+1}^P}{\partial k_t})] \tag{2.10}$$

2.1.2 Impatient households

The utility function of the representative impatient household is in the same fashion as the patient one but with a different discount factor,

$$E_t \sum_{\tau=t}^{\infty} \beta_I^{\tau-t} \{\log c_\tau^I + \varphi_h \log h_{\tau-1}^I - \varphi_l \frac{(l_\tau^I)^{1+\iota}}{1+\iota}\} \tag{2.11}$$

in order to have the impatient household as a net borrower and the patient one as a net saver in the equilibrium, I assume the impatient discount factor is less than the one for the patient household hence $\beta_I < \beta_P$. The impatient budget constraint is

$$(1+\tau_c)c_t^I + p_t^h h_t^{Ih} + (1+r_t^b)M_{t-1} - \varsigma_t^I \leq \omega_t^I + M_t - \tau_t^I - AC_t^I \tag{2.12}$$

Impatient households consume c^I. h^{Ih} is impatient housing investments

$$h^{Ih} = h_t^I - (1-\delta_h)h_{t-1}^I \tag{2.13}$$

[9]Patients' adjustment cost is $AC_t^P = AC_t^{Pk} + AC_t^{Pd}$ where $AC_t^{Pk} = \frac{\psi_k}{2}\frac{(k_t-k_{t-1})^2}{\bar{k}}, AC_t^{Pd} = \frac{\psi_{dh}}{2}\frac{(d_t-d_{t-1})^2}{\bar{d}}$ and it is consistent with Iacoviello (2015).

[10]Ignoring adjustment cost

where h^I is impatient houses. M is mortgages from the banking sector. ω^I is total impatient income

$$\omega_t^I = w_t^I l_t^I + \Gamma_t^I \tag{2.14}$$

where w presents wage and Γ^I is the transfer from the government. ς_t^I is the key point of the paper. It stands for a redistribution shock. When it is positive, it conducts wealth transfers from the asset side of bankers to the demand side of the impatient household. This shock provides more consumption resources by defaulting on loans and paying back less return to the banker. This is consistent with the fact that most of the damage incurred by the banking system during the Great Recession was caused by household defaults[11]. It is more intuitive to look at $[(1+r_t^b)M_{t-1} - \varsigma_t^b]$ as one term. Total tax related to the borrower is composed of income and property taxes,

$$\tau_t^I = \tau_w[w_t^I l_t^I - r_t^b M_{t-1} - \tau_p p_t^h h_{t-1}^I] + \tau_p p_t^h h_{t-1}^I \tag{2.15}$$

consistent with the current US tax code there is a tax exemption for mortgage holders that is equal to a fraction of the mortgage return with the interest rate r^b and a fraction of the property tax. AC^I is the adjustment cost on changing houses[12].

Collateral constraint restricts the impatient household to a fraction of the expected value of his house,

$$M_t \leq \rho_m M_{t-1} + (1-\rho_m)\theta[\mathbf{E}_t(\frac{p_{t+1}^h}{1+r_{t+1}^b} h_t^I)] \tag{2.16}$$

where θ is the loan-to-value ratio in housing and ρ_m captures the fact that only a fraction of borrowers change their loan every period. Because the mortgage will be backed next period, the value of collateralized houses is the expectation of its future real value and not the current one. This structure captures the role of the price expectation and in the other

[11] See Gabriel et al. (2016).
"The packaging of increasingly risky subprime loans, extended to people with poor credit by banks and other mortgage lenders, undermined the market, which was deeply interconnected through complex financial transactions.Increased demand for housing soon spurred a bubble, based on the widely shared assumption that housing prices would continue to go up. When they instead began to fall, borrowers began defaulting and lenders began foreclosing on mortgages at higher rates, which in turn shook the financial markets, mortgage giants Fannie Mae and Freddie Mac and the complex securities dependent on those underlying assets". Source: http://businessresearcher.sagepub.com/sbr-1863-101611-2765611/20170102/shadow-banking

[12] $AC_t^I = \frac{\psi_m}{2}\frac{(M_t - M_{t-1})^2}{\overline{M}}$

words, the role of a bubble in housing in increasing mortgage-backed securities (MBS) and collateralized debt obligations (CDO). This friction is one of the channels which connects the real and financial side of the economy. By defaulting on loans, the borrowing constraint becomes tighter. In addition, to guarantee a binding borrowing constraint in the steady state the impatient discount factor should be set to a lower value than a weighted average of the discount factors of patient households and bankers.

The first order conditions with respect to impatient houses and mortgage respectively are

$$(p_t^h - \frac{\lambda_t^m}{\lambda_t^I}(1-\rho_m)\theta \mathbf{E}_t \frac{p_{t+1}^h}{1+r_{t+1}^b}) = \beta_I \mathbf{E}_t[\frac{\varphi_h}{\lambda_t^I h_t^I} - \frac{\lambda_{t+1}^I}{\lambda_t^I}(\frac{\partial h_{t+1}^{Ih}}{\partial h_t^I} + \frac{\partial \tau_{t+1}^I}{\partial h_t^I})] \tag{2.17}$$

$$1 - \frac{\lambda_t^m}{\lambda_t^I} = \beta_I \mathbf{E}_t[\frac{\lambda_{t+1}^I}{\lambda_t^I}(1+(1-\tau_w)r_{t+1}^b - \frac{\lambda_{t+1}^m}{\lambda_t^I}\rho_m] \tag{2.18}$$

where λ^I is the Lagrangian multiplier of the budget constraint and λ^m is the Lagrangian multiplier of the collateral constraint.

2.1.3 Renter households

Renter households' utility function is similar to the impatient one with the same discount factor. The renter budget constraint is

$$(1+\tau_c)c_t^R + p_t^R h_{t-1}^R \leq (1-\tau_{wr})w_t^R l_t^R + \Gamma_t^R \tag{2.19}$$

that presents a hand-to-mouth household which consumes what it earns. The Renter consumes c^R and rents rental houses from the patient household. The renter provides the share labor l^R to the economy and earns wage w^R. Based on the US tax codes they pay less tax on their wages, $\tau_{wr} < \tau_w$. Their income is composed of the wage and government transfer Γ^R. I Assume that renters are neither able to buy houses nor borrow. Renters are added to the model to make it sensitive to data and therefore more realistic. The first order conditions with respect to rental housings is

$$p_t^R = \frac{\varphi_h}{\lambda_t^R h_{t-1}^R} \tag{2.20}$$

where λ^R is the Lagrangian multiplier of the budget constraint.

2.1.4 Bankers

A representative banker is a type of household which consumes and intermediates between other agents. The banker issues liabilities d and raises funds a to borrowers. The borrowers are either households (who borrow in the form of mortgages M) or government (the borrowings of which are termed government loan b_g). Banker's utility function and budget constraint are,

$$\max E_t \sum_{\tau=t}^{\infty} \beta_B^{\tau-t} \log c_\tau^B$$
$$(1+\tau_c)c_t^B + (1+r_t)d_{t-1} + a_t + AC_t^B = d_t + (1+r_t^b)a_{t-1} - \varsigma_t^b$$
$$a_t = b_t^g + M_t \tag{2.21}$$

r^b is the interest rate on loans that is the same for the impatient household and government. The banker receives new deposits and the return on last period loans at the same time. ς_t^b is the total shock on the banker's assets. It is equal to either ς^I which is explained in the impatient section or the government spending shock ς^g (it will be explained in section 5.) which has the same context as ς^I but is applied specifically to governmental problem. ς_t^b is the shock which makes the banker's asset side smaller and forces the banker to recapitalize in order to meet its financial constraint. AC^B is the adjustment cost of issuing liabilities and assets[13].

The financial friction applied on the banking sector is

$$a_t - d_t - \mathbf{E}_t\varsigma_{t-1}^b \geq \rho_b(a_{t-1} - d_{t-1} - \mathbf{E}_{t-1}\varsigma_t^b) + (1-\phi)(1-\rho_b)(a_t - \mathbf{E}_t\varsigma_{t+1}^b) \tag{2.22}$$

Parameter ϕ is the Liabilities-to-assets ratio with the same context as the capital-to-asset ratio which is the keyword of Basel I, II and III. This constraint is in accordance with real economy functioning, making it much more informative than classic non-stochastic capital constraint with $\rho_b = 0$ i.e. $d_t \leq \phi a_t$ [14]. Similar to the real economic patterns, with this constraint, the bank has the ability to deviate its liabilities-to-assets ratio in the short run to reach ϕ in the long run. The constraint is derived from the fact that in every period the banker should be able to provide a fraction of bank assets. With the first term in the right hand side the bank has the option of partial adjustment in bank capital beyond one period. The optimalilty condition with respect to liabilities and assets

[13] $AC_t^B = \frac{\psi_a}{2}\frac{(a_t - a_{t-1})^2}{\bar{a}} + \frac{\psi_{db}}{2}\frac{(d_t - d_{t-1})^2}{\bar{d}}$

[14] which restricts the bank's corrective action to one period.

are[15]

$$1 = \frac{\lambda_t^{\phi}}{\lambda_t^B} + \beta_B \mathbf{E}_t \frac{\lambda_{t+1}^B}{\lambda_t^B}(1 + r_{t+1} - \rho_b \frac{\lambda_{t+1}^{\phi}}{\lambda_{t+1}^B}) \tag{2.23}$$

$$1 = (\phi(1-\rho_b) + \rho_b)\frac{\lambda_t^{\phi}}{\lambda_t^B} + \beta_B \mathbf{E}_t \frac{\lambda_{t+1}^B}{\lambda_t^B}(1 + r_{t+1}^b - \rho_b \frac{\lambda_{t+1}^{\phi}}{\lambda_{t+1}^B}) \tag{2.24}$$

where $\lambda_t^B, \lambda^{\phi}$ are the Lagrangian multiplier of the constraints. By setting the Liabilities-to-assets ratio at less than one, deposits become more liquid than loans. This results in a higher interest rate on loans r^b than the interest rate on deposits r.

2.2 Firms and Housing producer

All households except bankers work for the representative firm and receive wages depending on different labor elasticities, $\iota_P, \iota_I, \iota_R$ so that $\iota_P + \iota_I + \iota_R = 1$. Firms are identical of measure one. The firm produces a homogeneous final good using the Cobb-Douglas technology as

$$Y_t^f = A_t k_{t-1}^{\alpha}((l_t^P)^{\iota_P}(l_t^I)^{\iota_I}(l_t^R)^{\iota_R})^{1-\alpha} \tag{2.25}$$

and maximizes its profit

$$\max Y_t^f - w_t^P l_t^P - w_t^I l_t^I - w_t^R l_t^R - r_t^k k_{t-1} \tag{2.26}$$

consequently the market prices are the familial terms

$$\alpha \frac{Y_t^f}{k_{t-1}} = r_t^k \tag{2.27}$$

$$(1-\alpha)\iota_i \frac{Y_t^f}{l_t^i} = w_t^i, \quad i = P, I, R \tag{2.28}$$

In the economy there are perfectly competitive housing producers which provide housing to households. Adding this kind of producers guaranties a single price for housing across agents[16]. Housing producers buy undepreciated part of houses from households at relative price p^h then produce new houses with investment i^h and sell new houses to

[15] Ignoring adjustment costs

[16] Similar to Roi et al. (2007)

patient and impatient households. Hence, they maximize the benefit as

$$E_t \sum_{\tau=t}^{\infty} \beta_P^{\tau-t} \frac{\lambda_\tau^P}{\lambda_t^P} [p_\tau^h (h_\tau - (1-\delta_h) h_{\tau-1}) - i_\tau^h] \tag{2.29}$$

where $h_t = h_t^P + h_t^I + h_t^R$ is total housing. The production is subject to an adjustment cost defining as[17]

$$[1 - \frac{\psi_h}{2} (\frac{i_t^h}{i_{t-1}^h} - 1)^2] i_t^h = h_t - (1-\delta_h) h_{t-1} \tag{2.30}$$

The optimal condition for housing producer reveals the house price,

$$p_t^h [1 - \psi_{hp} (\frac{i_t^h}{i_{t-1}^h} - 1) \frac{i_t^h}{i_{t-1}^h} - \frac{\psi_{hp}}{2} (\frac{i_t^h}{i_{t-1}^h} - 1)^2] + \beta_P \mathbf{E}_t p_{t+1}^h [\frac{\lambda_{t+1}^P}{\lambda_t^P} \psi_{hp} (\frac{i_{t+1}^h}{i_t^h} - 1) (\frac{i_{t+1}^h}{i_t^h})^2] = 1 \tag{2.31}$$

2.3 Government

Government collects all incoming and housing taxes from all households

$$\begin{aligned} T_t = {} & \tau_c C_t + \tau_w [w_t^P l_t^P + (p_t^R - \delta_h) h_{t-1}^R - \tau_p (h_{t-1}^P + h_{t-1}^R)] + \tau_d r_t d_{t-1} + \tau_p (h_{t-1}^P \\ & + h_{t-1}^R) + \tau_k (r_t^k - \delta_k) k_{t-1} + \tau_w [w_t^I l_t^I - r_{t-1}^m M_{t-1} - \tau_p h_{t-1}^I] + \tau_p h_{t-1}^I \\ & + \tau_{wr} w_t^R l_t^R \end{aligned} \tag{2.32}$$

where $C_t = c_t^P + c_t^I + c_t^R + c_t^B$ is total households' consumption. In each period government has access to the funds from the banker as loans, b_g and total tax, T, to pay its liabilities to the banker, lump-sum transfers depending on level parameters specific to the type of household $\vartheta_P, \vartheta_I, \vartheta_R$ and the government spending, g. The government's budget constraint is

$$(1 + r_t^b) b_{t-1}^g + g_t + \Gamma_t = b_t^g + T_t \tag{2.33}$$

where Γ is total transfers to each household which are

$$\Gamma_t = \Gamma_t^P + \Gamma_t^I + \Gamma_t^R \tag{2.34}$$

$$\Gamma_t^i = \vartheta_i Y_t^f - \rho_g b_{t-1}^g, \quad i = I, P, R. \tag{2.35}$$

[17] See Smets and Wouters (2007) and Alpanda and Zubairy (2016).

ρ_g determines the response of transfers to government debt to adjust transfers to government loans in order to avoid Ponzi game by government[18].

2.4 Market clearing and shocks

The non-housing good firms produce goods to cover total consumption, total housing investment, capital investment and government spending. Good market clearing after shocks is

$$Y_t^f = C_t + i_t^h + i_t^k + g_t \tag{2.36}$$

In this paper total GDP is defined as[19]

$$Y_t = (1 + \tau_c)C_t + p_t^R h_{t-1} + i_t^h + i_t^k + g_t \tag{2.37}$$

A set of prices (p^h, p^R, r, r^b, r^k) and allocations $(c^P, c^I, c^R, c^B, h^P, h^I, h^R, d, k, b_g, g, \Gamma^P, \Gamma^i, \Gamma^R)$ define an equilibrium so that maximize the household utility functions subject to all constraints of households and government, market factors and market clearings.

3 Estimation

3.1 Calibration

Table 1 presents the value of the parameters which are chosen to get the targets quarterly in the data and as initial values for the estimation of the model. The calibration here is closely based on the empirical estimation of Iacoviello (2015). Discount factors of patient, impatient and banker are set to $0.9925, 0.94, 0.945$, respectively. With this setting the annual interest rate on deposits is 0.3 and the interest rate on loans is 0.5 according to Iacoviello (2015). In order to have binding borrowing constraint in the steady state the impatient discount factor should be set less than the weighted average of two others. Housing preference is set to 0.27 to have housing value over GDP equal to 5.44 according to Iacoviello and Neri (2010). Depreciation rates are set to 0.96% for housing and 1.6% for capital to target 5% housing, 10% non-housing investment and total investment equal to 15% and capital over GDP equal to 6 according to National Income and Product Accounts (NIPA,Bureau of Economic Analysis) and the Flow of

[18]See (Alpanda and Zubairy, 2016).

[19]Which is consistent with NIPA's data

Table 1: Calibrated parameters

Parameters	Symbol	Value
Discount factors	$\beta_P, \beta_I, \beta_B$	$0.9925, 0.94, 0.945$
Housing preference	φ_h	0.27
Labor Supply parameter	φ_l	0.8
Depreciation rates	δ_h, δ_k	$0.0096, 0.016$
Transfer share	$\vartheta_P, \vartheta_I, \vartheta_R$	$0.040, 0.036, 0.030$
Income taxes	τ_w, τ_{wr}	$0.32, 0.22$
loan-to-value ratio	θ	0.90
Liabilities-to-assets ratio	ϕ	0.90
Labor shares in production	$\iota_P, \iota_I, \iota_R$	$0.13, 0.67, 0.20$
Capital share in production	α, A	$0.2047, 1.805$
Inverse labor supply elasticity	ι	1
Inertia in collateral constraint	ρ_m	0.70
Inertia in capital constraint	ρ_b	0.24
Response of transfers to gov. debt	ρ_g	0.003
Taxes	$\tau_k, \tau_c, \tau_p, \tau_d$	$0.4, 0.05, 0.14/4, 0.15$
deposit and capital adj. for Pat.	ψ_{dh}, ψ_k	$0.10, 1.73$
deposit and loan adj. for Bank	ψ_{db}, ψ_a	$0.14, 0.54$
Mortgage adj. for Imp.	ψ_m	0.37
Housing investment adj. for Producer	ψ_h	2.48
Parameters of AR(1)	$\rho_{\varsigma^I}, \rho_{\varsigma^g}$	0.9

Funds Accounts (FOF; Federal Reserve Board). With this setting government loans over GDP is set to 80% consistent to the average loan of the US According to OECD 2016 for twenty years and government spending over GDP equal to 18% as (Alpanda and Zubairy, 2016). Total Consumption over GDP in this settings is $C/Y = 52\%$ and $c^P/C = 26\%, c^I/C = 53\%, c^R/C = 18\%, c^B/C = 3\%$. The inverse of the Frisch elasticity of labor supply is set to 1 according to Smets and Wouters (2007). $\vartheta_P, \vartheta_I, \vartheta_R$ are set to $0.04, 0.036, 0.030$, respectively, to target total transfer over GDP, $tr/Y = 0.08$ according to NIPA. τ_w, τ_{wr} are calibrated to $0.32, 0.22$ to get total income tax, $T/Y = 0.27$ as Zubairy (2014). loan-to-value ratio and Liabilities-to-assets ratio are both calibrated to 0.9, Inertia in collateral constraint and Inertia in capital constraint to 0.70 and 0.24 and parameters of AR(1) shock to 0.9 all according to the estimations of Iacoviello (2015). According to the 2001 Residential Finance Survey (RFS; Census Bureau), $\iota_P, \iota_I, \iota_R$ are set to $0.13, 0.67, 0.20$ respectively to target $h_P/h = 0.37, h_I/h = 0.43, h_R/h = 0.20$. Response of transfers to government debts is calibrated to 0.003 to adjust transfers with government loans and to avoid Ponzi game by government. α, A are set to $0.2047, 1.805$ based on the optimal conditions and the relation between r_k, k and to insure $k/Y = 6$. All coefficients for adjustment cost are chosen from the estimations of Iacoviello (2015), except adjustment cost for housing producer that is set as Roi et al. (2007). Capital, consumption, property and deposit taxes,$\tau_k, \tau_c, \tau_p, \tau_d$, are set to $0.4, 0.05, 0.14/4, 0.15$ respectively based on the US tax codes as Zubairy (2014). Table 2 presents the steady state value of all variables over GDP for the baseline model.

Table 2: Steady state of the benchmark model

Variable	symbol	Steady State/GDP
Consumption	c^P, c^I, c^R, c^B	$0.13, 0.28, 0.10, 0.01$
Housing	h^P, h^I, h^R	$2, 2.3, 1.1$
Tax	T	0.27
Bankers' asset	a	2.87
Mortgage	M	2.07
Government loan	b_g	0.80
Deposit	d	2.5
non-housing output	Y^f	0.84
wages	w^P, w^I, w^R	$0.38, 1.2, 0.36$
Government Exp.	g	0.18
Transfers	tr^P, tr^I, tr^R	$0.031, 0.027, 0.022$
Investments	i^k, i^h	$0.10, 0.05$

3.2 Estimation results

In order to estimate the model, Dynare[20] and Bayesian methods[21] are used. The model is estimated based on the borrower household default, consistence with the situation of the Great Recession. The shock[22] presented in the model are in the form of autoregressive (AR) model which follow

$$\varsigma_t^I = \rho_{\varsigma^I} \varsigma_{t-1}^I + \epsilon_t^I \tag{3.1}$$

$$\varsigma_t^b = \varsigma_t^I \tag{3.2}$$

where $\epsilon^I \approx N(0, \sigma^2_{\varsigma^I})$. The optimizer for the mode computation is one introduced by Sims et al. (1999). There is one shock in the model so for estimating the parameters, there must only be one data set, otherwise, stochastic singularity arises[23]. On the other hand, estimating such a model on only one observable series is a bit of a stretch, hence I use measurement error technique[24] to estimate the model on 4 observable series. The applied series are U.S. quarterly data on real consumption, mortgage, losses from mortgage default

[20] http://www.dynare.org/manual/index_27.html

[21] SeeAn and Schorfheide (2007).

[22] Note, another shock will be defined to the model in the government default section.

[23] See Ruge-Murcia (2007).

[24] See Pfeifer (2014)

and real house prices (all in the form of deviation from steady state) between 1985$Q1$ and 2010$Q4$[25]. The 20 first observations are used as a training sample for the Kalman filter[26].

Number of replications for Metropolis-Hastings algorithm[27] (Markov chain Monte Carlo, MCMC) is set to 100000. Table 3 presents the estimated variables. Other variables are assumed to be fixed as Table 1, due to demeaned data and the fact that in the estimation procedure, when steady state is being updated for any draw, the non-estimated parameters are not able to conduct steady-state values in the procedure. Initial values for estimation are, in addition, set to the ones in the calibration (Table 1). Table 3 presents the comprehensive results of the estimation[28].

Table 3: Estimation results

Parameter	symbol	Pri. mean	Post. mean	90% HPD interval		De.	Pri sd	Post. sd
St. Dev., default shock	σ_{ς^I}	0.0025	0.0015	0.0013	0.0016	I.G	0.025	0.0001
Autocor., default shock	ρ_{ς^I}	0.80	0.9037	0.8804	0.9294	Be.	0.100	0.0150
Inertia in collateral cons.	ρ_m	0.70	0.7069	0.6904	0.7238	Be.	0.100	0.0102
Inertia in capital cons.	ρ_b	0.25	0.4221	0.1380	0.7148	Be.	0.100	0.1769
Adj. cost,P Deposit	ψ_{dh}	0.25	0.2169	0.0567	0.3810	Ga.	0.125	0.1086
Adj. cost,P capital	ψ_k	1.00	1.1750	0.2905	2.0514	Ga.	0.500	0.5782
Adj. cost,B Deposit	ψ_{db}	0.25	0.2532	0.0599	0.4523	Ga.	0.125	0.1330
Adj. cost,I Mortgage	ψ_m	0.25	0.1864	0.0449	0.3184	Ga.	0.125	0.0900
Adj. cost,B assets	ψ_a	0.25	0.2528	0.0538	0.4342	Ga.	0.125	0.1275
Adj. cost,HP	ψ_h	1.00	1.2129	0.3883	2.0726	Ga.	0.500	0.5685

P:Patient household, I:Impatient, B:banker, HP:Housing producer, I.G:Inverse Gamma, Be:Beta, Ga:Gamma, HPD:highest posterior density interval

90% highest posterior density interval shows the most probable interval of parameters. Posterior mean of inertia in collateral constraint is around 0.71. This coefficient presents what fraction of impatient household that changes its mortgage every period. Inertia in bankers' capital constraint is estimated around 0.42. This parameters shows that how flexible a banker can in order to deviate from the liabilities-to-loans ratio in short term after shock, before the recapitalization and meeting the fixed ratio set by regulator. The autocorrolation of the default shock is around 0.90 that presents a high persistent shock and its standard deviation is 0.0015. Estimated adjustment cost of deposit and loans for bankers make no noteworthy changes (in contrast to what preceded them) which shows the observed data are not very informative about these parameters. Household deposit

[25] As introduced in Iacoviello (2015)

[26] See Kalman et al. (1960).

[27] See Metropolis et al. (1953) and Chib and Greenberg (1995)

[28] The optimal acceptance rate in a DSGE estimation with Bayesian method should be between one third and one quarter. The best value for the acceptance rate is approximately 23.4%. See Roberts et al. (1997). In the present estimation, the acceptance rate is 23.5%.

adjustment cost is estimated at around 0.21. The difference between deposit adjustment cost of households and banks shows that changing deposits for households is cheaper and easier than bankers. Capital and producer adjustment costs are both estimated around 1.2 which confirm the existence of a high inertia and show that deviating capital and housing from steady state is a costly activity.

4 The Great Recession

Household defaults, as explained before, were the central cause of the Great Recession. This section shows the impact of the household default (a shock close to the real situation of the Great Recession) through the lens of the estimated model. During the Great Recession, intermediary agents lost their assets. The loss was slowly recovered after the shock. The Great Recession officially happened in 2007-2009 with the consequence of bankruptcies and bank runs. The most crucial one was the Bankruptcy of Lehman Brothers, the largest bankruptcy filing in U.S. history, with holding over 613 billion in assets on September 2008. This crisis was the consequence of distortions in the economy accumulated from the late 2000[29]. Mortgage underwriting standards declined gradually during the boom period, particularly from 2004 to 2007 and mortgage fraud by lenders and borrowers increased enormously[30]. In 2004, an important credit risk of non-prime mortgage lending and an epidemic in mortgage fraud were warned by the Federal Bureau of Investigation[31]. Figure 1 (top left) shows that the rate of default starts to increase from 2005 and it got almost doubled in 2006[32].

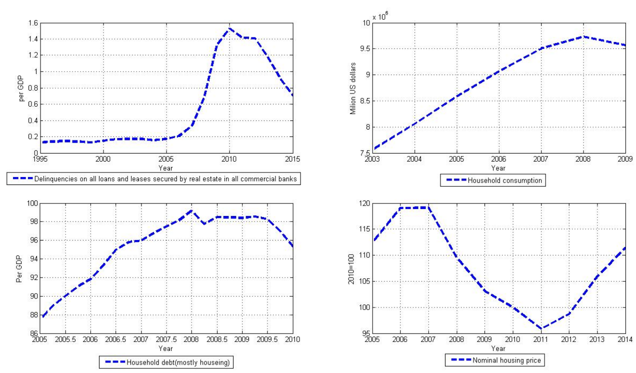

Figure 1: Household accounts.
Resource: (top left) Federal Reserve bank of st. Louis, (the rest) OECD Data

[29] See Vos et al. (2011).
[30] See Cowen (2008).
[31] See Black (2009).
[32] See Demyanyk and Van Hemert (2009) and an interesting discussion in Antoniades (2016).

To simulate the situation of the Great Recession, the unexpected impatient shock is fed by 0.38% of annual GDP for 12 quarters (3 consecutive years). It is done to set the maximum losses equal to 2.8% of GDP after three years and a cumulative losses equal to 9% of GDP after 5 years (20 quarters)[33]. It simulates the same situation of the Great Recession starting from 2005 and followed by the deadly point of the crisis with the bankruptcy of Lehman in 2008. After shock, losses gradually come back to zero. I use the posterior mean values of estimated parameters in Table 3 and the value of non-estimated parameters in Table 1 to calibrate the model and simulate the Great Recession. Figure 2 shows the impact of the described shock on the model's key variables. Note that in this model, the banks are not allowed to a run or to increase their interest as a response to the shock. As a result, the analysis of the fitness of the model and data should be focused in the period right before the runs in 2008.

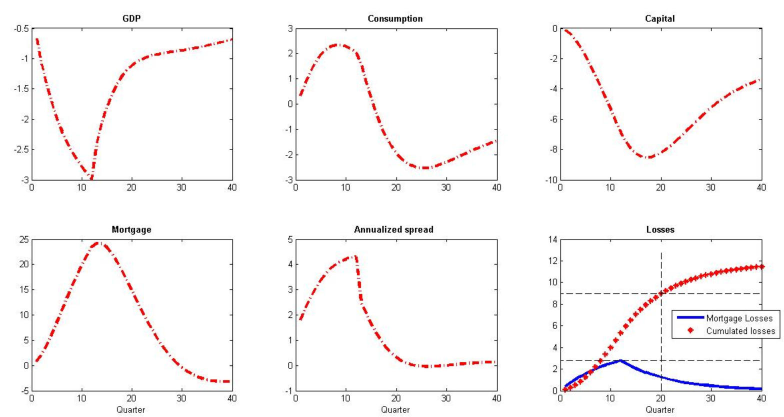

Figure 2: Simulation of the Great Recession, Key variables, (%) change from SS

The negative shock on bank's assets gradually declines GDP to about −3%. The decline comes from a drop in housing and capital investments by patient households due to more incentives for raising deposits in the banking sector. It is a consequence of the increase in the spread. Before the shock, the spread[34] is about 2%. It is followed by a raise to 4.2% until the end of the third year. Simultaneously, the raise in the spread motivates bankers to raise credits in the form of mortgage back securities for which they need more deposits. This accelerates raising deposits and connects the financial sector to the real side. In addition, household consumption raises due to the transferred wealth

[33] To ensure the comparability of the model, I aim the same target as Iacoviello (2015). This setting is driven in order to meet and target the evidence and estimations found in IMF (2009).

[34] Annualized spread is calculated as the annualized difference between the interest rate on baker's loans and the interest rate on deposits.

from bankers to impatient households and the wealth effect. The model well fits the data in 2005-2008 and shows the same behavior. Figure 1 at the top right and bottom left shows the increase in household consumption and debt (mostly mortgage) after starting mortgage defaults in 2005 until the crisis. The figures shares the same behavior as what the model simulates and with a good approximation, according to the evidence of the Great Recession.

Figure 3 presents the simulation of housing factors. This figure depicts an interesting feature which proves the reliability of the model. Figure 1 (bottom right) presents the nominal housing price between 2005-2014. After starting the default in 2005, the data shows an increase in the price, this increase is stopped in 2006 and declines until the early 2011. It is the evidence of the *home price double-dip* when, even after ending the crisis (in 2009) and starting the recovery, housing price continues on its downward spiral. This continuous negative effect was one of the reasons which lags the recovery after the Great Recession and makes it one of the long-lasting crisis. The data from FRED shows that it took almost 5 years for the the US economy to reach the same level as the 2007 level of output per capita. Historically, for an economy like the US, it takes shorter time to recovery and goes back to the pre-recession peak[35].

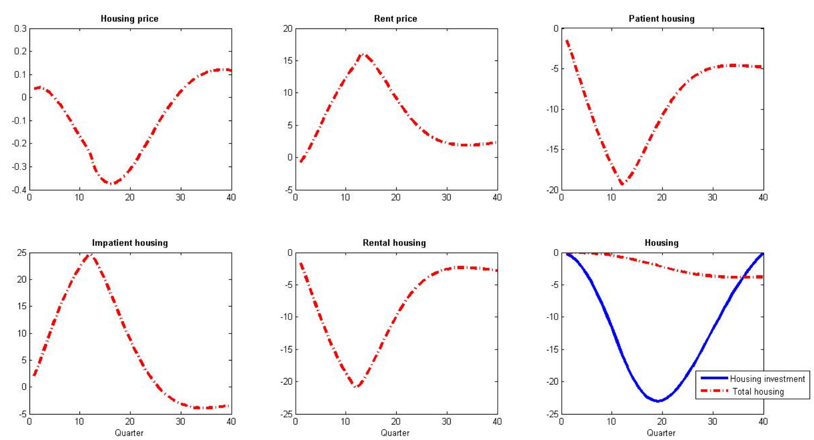

Figure 3: Simulation of the Great Recession, Housing factors, (%) change from SS

The response of the housing price to the shock in the model is exactly the same. In the beginning, the simulated housing price increases. It is mostly a response to the positive impact on the impatient-house demand supported by the increase in mortgages. Note that the amount of the current mortgage is realized by the previous mortgage and the expectation of the feature housing value (equ 2.16) that both are increasing. With a re-

[35]For more details, see Christiano (2016).

laxed constraint, the shadow price of the mortgage, λ^m decreases which makes more space for the price. Concentrating more on deposits, patient households decrease their housing investment which decreases the demand and decreases the housing price. Impatient households benefit more the low price and expand their consumption and investments. These expansions ends by the closure of the shock. Contrary, the drop of the housing price is not over by the shutdown of the shock and still continues for more periods after starting the recovery. This double-dip effects is resulted mostly due to the lack of the housing investment after the crisis, adjustment cost subject to investments, the lower price expectation which affects the amount of mortgages and the lower capacity of borrowers to buy houses.

Comparing with other models in the literature, the model behaves more closely to the climate of the Great recession. Figure 4 compares the path of the key variables of the present model and the model of Iacoviello (2015). The same shock hit the economy in both models. The GDP response is almost the same. On the other hand, contrary to the data shown in figure 1, after starting the shock, key variables like consumption, mortgage and deposit decline in his model. In addition, the model shows an immediate decline in the housing price and cannot capture the context of the double-dip in the housing price[36].

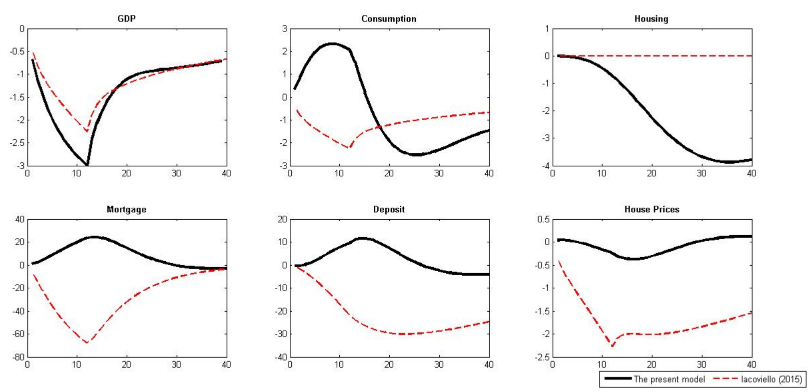

Figure 4: Simulation of the Great Recession, Housing factors, (%) change from SS

5 Private vs Government default

This section compares the household and government default. The impulse responses of the same size defaults (from the different sources) to the asset side of the bank balance sheet are used to assess the characteristics of different-source recessions. Welfare effects

[36] Iacoviello (2015) supposed the fixed housing supply. Total housing is normalized to one.

as the significant way to compare defaults are as well presented in this section.

In addition to the private default shock presented in section 3.2, another type of default explored in the literature is government default. It happens when the government does not fully return its promised loans to intermediary agents. This can be caused by a variety of circumstances, for example, a sudden raise in the government expenditure or raising public spending due to political or economical situations[37]. A famous example of this situation is 1998 Russian crisis in which the low productivity, a high fixed exchange rat, a chronic fiscal deficit and declines in demand and price of crude oil (following the Asian financial crisis) impacted Russian foreign exchange reserves and consequently leads the government to an internal default and as well the economy to collapse[38]. In the model, it is assumed that a government spending shock ς_t^g hit the government budget at time t, hence its new expenditure is defined as

$$g_t^n = g_t + \varsigma_t^g \tag{5.1}$$

the government tries to cover its need to more funds by defaulting on its obligations to the banking sector. It pays less back, equal to the loan minus the shock, $(1+r_t^b)b_{t-1}^g - \varsigma_t^g$. This default makes a shortage to the bankers' asset side and directly provides required funds to the raised government expenditure[39]. The government's budget constraint is

$$(1+r_t^b)b_{t-1}^g - \varsigma_t^g + g_t^n + \Gamma_t = b_t^g + T_t - AC_t^g \tag{5.2}$$

The shock is defined as the same fashion of the household default shock

$$\varsigma_t^g = \rho_{\varsigma^g}\varsigma_{t-1}^g + \epsilon_t^g \tag{5.3}$$

$$\varsigma_t^b = \varsigma_t^g \tag{5.4}$$

where $\epsilon^g \approx N(0, \sigma_{\varsigma^g}^2)$.

[37] See Roubini and Sachs (1989) and Ramey (2011).

[38] The IMF sources, http://www.imf.org/external/np/sta/ir/IRProcessWeb/data/rus/eng/currus.htm/#I

[39] Note in this paper I analyze the impact of the government default due to a raise in government expenditure. So the default value equates exactly to the shock. Impacts of government defaults in cases of other needs(i.e. with the fixed government expenditure) is still an open question that would make an interesting subject for future studies.

5.1 Impulse response analysis

The impulse response of the 1% of GDP idiosyncratic shocks are presented in Figure 5. These shocks hit the asset side of the bank balance sheet due to the household and government default.

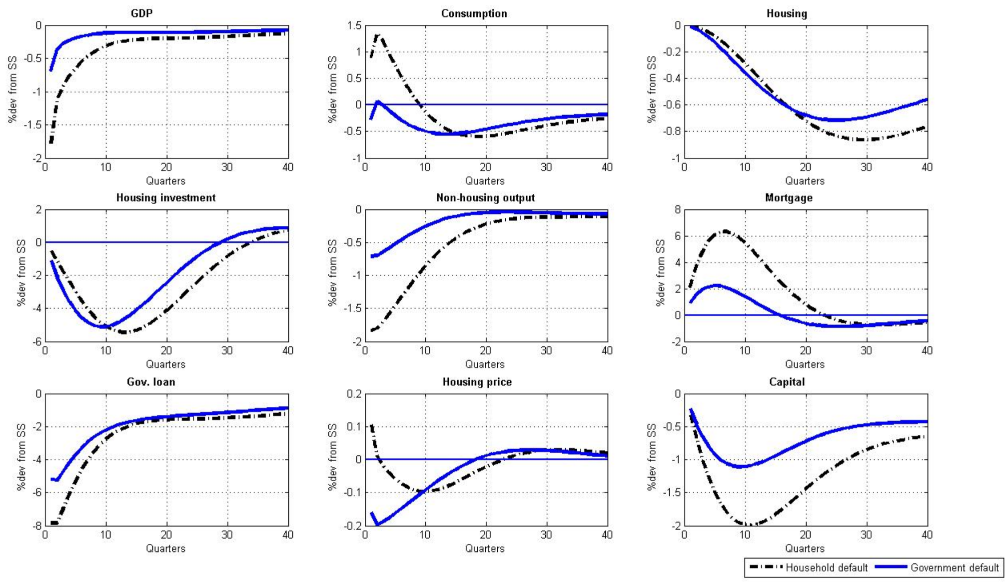

Figure 5: IRFs to households and government defaults, aggregate variables

The household default affects the economy through two different channels. Firstly, the shock directly raises the supply side of the impatient household and as a result, the household has more resources to consume. Increasing consumption decreases the marginal utility of consumption which in turn increases impatient housing demands and consequently increases the housing price and mortgage. Secondly, the impatient household default creates an asset deficit for the banker. The housing and mortgage are affected as well through this channel. The banker faced credit crunch (and a liabilities-to-loans below the target) is obliged to recapitalize its assets in order to meet the financial constraint. Hence, the banker decreases its consumption and as well credits to other agents i.e. a drop in government loans. This is the mechanism by which the credit crunch on capital constraint bankers propagates to the other agents and impacts all the economy. Borrowing-constrained bankers make a static and dynamic wedge which restricts the saving size of household into investment goods. When there is no capital constraint, all assets are directly invested in investment goods only with an adjustment cost.

Due to the capital constraint, the less assets, the tighter the constraint and the less deposits. The drop in deposits reduces the supply side of the patient household. In order to smoothen consumption, the patient household consumes less, and decreases its savings into housing and capital. The drop in patient housing demands decreases the housing price. With a lower housing price, due to the collateral constraint, the impatient household is motivated to increase its housing demands. Increasing impatient housing demand alongside the collateral constraint increases the impatient household's need for borrowing. This results in a raise in mortgages. Deposits will increase afterward as a response to the increase of the spread and more demand on mortgages. The less capital, the less non-housing output and as well the less GDP and transfers. The decline in household savings has repercussions for investments. It consequently impacts GDP and inflame a recession. In addition, the drop in output results in a negative income effect for households especially patient and renters. Hand-to-mouth renters are dependent on transfers and are therefore forced to decrease their consumption and housing which results in a drop in the rental price. At the beginning, the raise in impatient consumption makes a raise in total consumption, but in total consumption declines due to the decline in patient and renter households. Total housing as well declines due to less investments.

The government default does not change the government budget constraint[40], but it causes the credit crunch with the same size as the household default on the bankers' asset side. Similar to the previous shock, the banker is forced to recapitalize its assets. By the same mechanism as the previous shock, the government default negatively impacts government loans. Government default instigates a sharp decline in housing prices. Following Khan and Reza (2016) this drop is a general result of DSGE models (with housing features) and comes from the approximately constant shadow value of housing for patient households[41]. The deviation of the marginal utility of housing from its steady state is relatively zero due to the weak contribution of housing in the stock variation[42]. Impatient households benefit this lower price to increase their housings. The low price as well has a wealth effect which increases impatient consumption. A raise in government expenditure following the same size drop in banking assets causes a decline in deposits through the capital constraint. As explained before, the deposit drop is followed by a drop in patient consumption which results in an increase in the marginal rate of substitution. The declined consumption increases the marginal rate of substitution and marginal utility of

[40]Note, the government default is a response to an accidental raise in government expenditures. So the government defaults on its obligations in order to cover its accidental needs. Unlike impatient household, government is not constraint. The default is a response to an exogenous shock in expenditures or public spending.

[41]See Barsky et al. (2007)

[42]The marginal utility of housing is defined as $\lambda_t^p p_t^h$.

housing. These effects, thereafter, provoke a raise in housing price from the optimal condition of the housing producer and decrease the rental price from the optimal condition of rental houses. The raise in the housing price shows that the raise in the marginal rate of substitution is less than the raise in the marginal utility of housing. The raise in impatient consumption cannot counterbalance the decline in others' consumption so the total consumption declines after a few periods.

Comparing the two defaults declares the severity of the private default vs the government default. The default in the case of government spending shock does not change the government budget constraint and only creates a credit crunch on the bankers' asset side. Comparing this case with the household default which causes a shortage on banking sector, and in addition adds more credit to the impatient problem, demonstrates why the government default is less damaging for this economy. With a 1% of GDP negative shock in the case of the private default, GDP drops 1.8% which is almost twice of the same drop in the case of government default (0.8%). The economy will be recovered after 10 periods in the case of the latter default whereas the recovery time of the former is almost 20 periods. Furthermore, the house price declines more in the latter default. The fact that the impatient households do not face additional resources to consume or buy houses lowers housing flow demands, and consequently lowers the housing price more than the impact of the former default.

Another reason which generally makes private defaults more long-lasting is the frictions in housing and capital investments and consequently the Paradox of Thrift[43]. Investment frictions make saving more desirable than investing. In an efficient market the risk-adjusted real interest rate adjusts conventionally to clear the lending market. On the other hand, the zero lower band makes an obstacle for this clearing and as a result, the economy clears itself by lowering output. This chain of reasons makes this kind of crisis long-lasting.

5.2 Welfare effects

Another way to assess the impact of defaults in the model is through the analysis of welfare effects. This enables us to assess and compare defaults in the form of the change in the respective lifetime welfare in terms of annual consumption equivalents for each

[43] See Huo and Ríos-Rull (2013) and Christiano (2016).

household, $\Delta_i, i = P, I, R, B,$

$$\sum_{t=0}^{\infty} \beta_i^t U((1+\Delta_i)c_0^i, h_0^i, l_0^i) = \sum_{t=0}^{\infty} \beta_i^t U(c_t^i, h_t^i, l_t^i), \quad i = P, I, R, B \tag{5.5}$$

c_0^i, h_0^i, l_0^i are consumption, housing and labor of each agent at time zero i.e. at the steady state before any shock. Bankers only consume so housing and labor for them are zero. After related shock, the variables change. I observe the transition path for 1000 consecutive periods till the variables come back to the initial steady state. The negativity of Δ means the change results in a worse-off economy and otherwise for the positivity. Table 4 presents welfare effects of each default.

Table 4: welfare effects in %

Type of default	Δ_P	Δ_I	Δ_R	Δ_B
Private default	-4.2	15	-10	-50
Government default	-2.4	3.6	-3.2	-44

A 1% GDP default shock on the bankers' asset side results in a significant worse off for bankers. It is mostly because the bankers' utility function is only composed of consumption. So any decline in consumption has a direct effect on their welfare. After the defaults, both patients and renters are worse off, which is obvious, due to the negative impacts of the shocks on their consumption and housing and also an increase on their working hours. Impatient households are better off due to the positive impact on their consumption and housing as well as wealth effects. The welfare effects depict the severity of the private default rather than the government default. The former impoverished patient households twice more that the latter and it is triple for renters. The former default directly increase the supply side of the patient households so its welfare effects on the patients is almost triple more then the effect of the latter default.

6 Macroprudential regulation

In the aftermath of the global financial crisis, macroprudential policy tools have been proposed widely. The aim of these policies are to help financial stability and to prevent crises and recessions. In this section, two kinds of macroprodential policy, one on the the collateral constraint of the borrower and one on the capital constraint of the banker is proposed. Debt-to-income (DTI) focuses on borrowers and acts as a ceiling on credit growth. Liabilities-to-assets ratio (LTS) restricts the liabilities of financial institutions to a fraction of their assets. In order to apply the DTI into the model, Equ 2.16 is changed to

$$M_t \leq \rho_m M_{t-1} + [\theta_m(w_t^I l_t^I) + (1-\theta_m)(1-\rho_m)\theta(\mathbf{E}_t(\frac{p_{t+1}^h}{1+r_{t+1}^b} h_t^I))] \tag{6.1}$$

where θ_m is the weight assigned by the banker to the borrower's wage income.

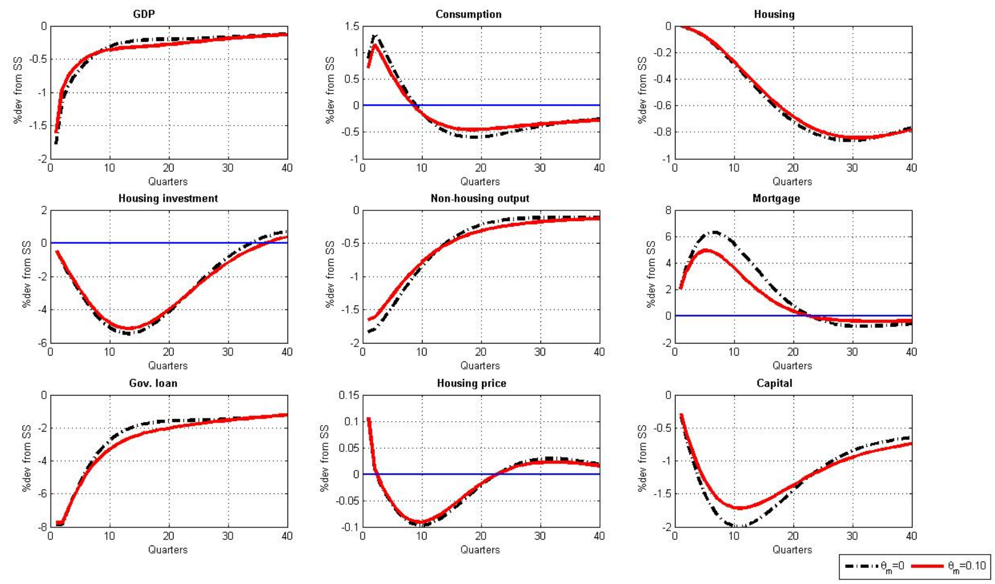

Figure 6: The impact of applying debt-to-income (DTI) into the model.

Figure 6 presents the impulse response to a negative 1% of GDP shock on the banker's asset side from the household default, without a DTI and with DTI=0.10. The debt-to-income ratio limits the borrower's debt service to 10% of his disposable income and 90% of the expectation of his house value. The DTI is quiet effective in reducing vulnerabilities and it is procyclical. Increasing the DTI by 10% reduces the damaging impact of the shock on GDP by 0.3%. This procyclity is mostly due to the policy's positive effect on the volatility of the housing price and reduces the house price appreciation. On the other hand, focusing on the effect of the DTI on output, one finds the DTI makes the economy difficult to recovery. With such policy on the collateral constraint, the economy wakes up faster but recovers slower. The reason is twofold. Firstly, GDP, capital and as well wages decline after the shock. The DTI restricts borrowers to their income so their accessibility to credits drops. Without the DTI, borrowers can raise more credit with lower income and buy more houses. This action can mitigate the economy and helps the recovery. However, the stricter regulation to prudent debt-to-income can control the housing boom and as a result, can cut down the harshness of the crisis. Secondly, a higher DTI and consequently a lower amount of mortgages are translated to a lower deposit issuance and credits. This affects the amount of government loans which therefore slows down the economy.

A higher liabilities-to-assets ratio (LTS) i.e. the liabilities-to-assets ratio ϕ, gives the banker the ability to further increase deposits. Raising more deposits, Bankers are able to reduce the bad impact of the sudden shock and commit their responsibilities, even if they are forced to recapitalize the assets. This is why the banker is no longer forced to sharply reduce government loans in the higher LTS. This helps the economy to recover more faster. The impact of 1% increase on the LTS is depicted in figures 7.

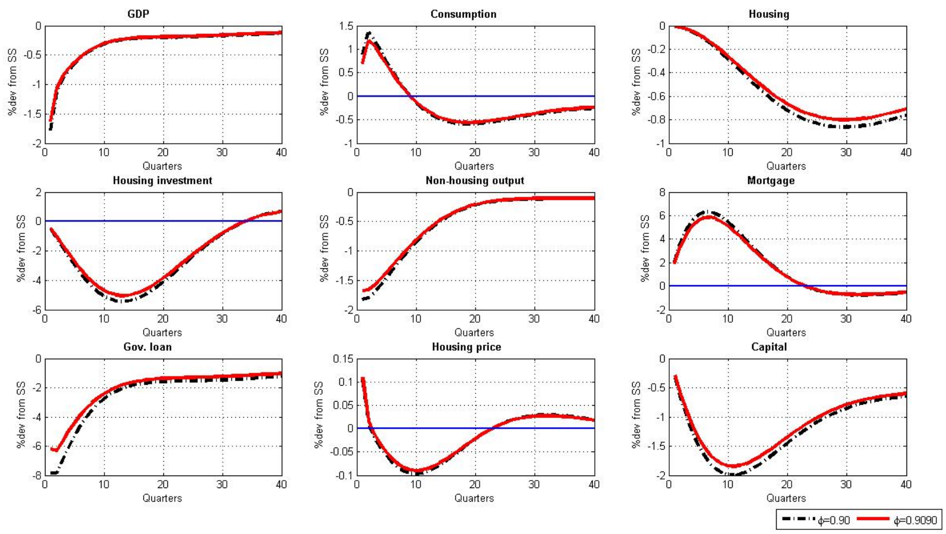

Figure 7: IRFs to households defaults, different liabilities-to assets ratio

As the ability of patient households to transmit their saving through the banker's safe assets increases, the appreciation of patient consumption and housing reduces. As a result, the drop in the house and rental price is adjusted. Furthermore, the impatient household cannot increase its consumption and housing as before (rather than another scenario with the lower LTS), due to a higher price and consequently lower income effects. This results in a lower volatility in mortgages. The policy has procyclicality features and reduces the bad impact on GDP about 0.2%.

7 Conclusion

In this paper, I use a DSGE model to study the impacts of defaults on the asset side of bank balance sheet. The model is made representative the real economy, through the introduction of four types of heterogeneous household: lenders, borrowers, renters and bankers. In addition, the model is equipped with government, firms and house producers as well as a tax system closed to the real tax code in the US. The key ingredients of the model are stochastic financial frictions in the form of collateral constraints for borrower households and lending constraint for intermediary agents. This paper simulates how a credit crunch on financial intermediaries similar to the 2007 financial shock impacts economy's key variables and welfare. On the other hand, the role of macroprudential policy tools in protecting financial stability is assessed.

A few essential points must be made regarding the role of intermediaries in financial shocks and these would be interesting departure points for future studies. In this model, banks are not able to run, though this is not the case in a real economy. For instance in 2007, financial companies which could not meet their obligations were forced to run. This chain began with bankruptcy of Lehman Brothers who had over 600 billion dollars in assets. The run was a result of having held on the large positions in subprime and other lower-rated mortgage tranches while securitizing the underlying mortgages[44]. Other reasons studied in the literature are illiquid aspects of bank's assets as well as variations of the maturity time for the projects. As a result, banks are incapable of responding to all request simultaneously. Different orientations like the one of Uhlig (2010), Calvo (2012) and Gertler and Kiyotaki (2015) would make an interesting addition to the model. In this model banker are not allowed to charge higher interest rates in response to the shcok, so the application of different policies would be interesting.
One could also study the impact of other shocks on the model such as technological shocks. The presented DSGE model has the ability to explore impacts of other scenarios of government default. However, it remains a significant challenge for further studies. If government default does not occur specifically in response to the government spending shock, the results might be different. One scenario could be government default in order to provide more transfers to households. This situation could happen in an exceptional social-political situation wherein governments might need political supports. This is the case of some third world countries which defaulted on their loans to increase public spending[45]. This model conduct the shocks in exogenous way. It would be favorable to improve the model to examine the interaction of primitive economic elements. The model proposed in this paper takes a significant stride towards generating a model which is perfectly sensitized to real economic trends.

[44] Alan and Bialeck (2015)

[45] See Dinç (2005).

References

Alan, R. and Bialeck, L. (2015). *American Pinocchios*. Lulu Press.

Alpanda, S. and Zubairy, S. (2016). Housing and tax policy. *Journal of Money, Credit and Banking*, 48(2-3):485–512.

An, S. and Schorfheide, F. (2007). Bayesian analysis of dsge models. *Econometric reviews*, 26(2-4):113–172.

Angelini, P., Clerc, L., Cúrdia, V., Gambacorta, L., Gerali, A., Locarno, A., Motto, R., Roeger, W., Van den Heuvel, S., and Vlček, J. (2015). Basel iii: Long-term impact on economic performance and fluctuations. *The Manchester School*, 83(2):217–251.

Angelini, P., Neri, S., and Panetta, F. (2014). The interaction between capital requirements and monetary policy. *Journal of Money, Credit and Banking*, 46(6):1073–1112.

Antoniades, A. (2016). Commercial bank failures during the great recession: The real (estate) story.

Bachmann, R. and Sims, E. R. (2012). Confidence and the transmission of government spending shocks. *Journal of Monetary Economics*, 59(3):235–249.

Barsky, R. B., House, C. L., and Kimball, M. S. (2007). Sticky-price models and durable goods. *The American economic review*, 97(3):984–998.

Bernanke, B. S. (2009a). The crisis and the policy response. *Stamp Lecture, London School of Economics, January*, 13:2009.

Bernanke, B. S. (2009b). Four questions about the financial crisis. *Chairman of the Board of Governors of the US Federal Reserve System, Speech at the Morehouse College, Atlanta, Georgia, April*, 14.

Black, W. (2009). The two documents everyone should read to better understand the crisis. *Huffington Post*, 28.

Blanchard, O. and Perotti, R. (2002). An empirical characterization of the dynamic effects of changes in government spending and taxes on output. *the Quarterly Journal of economics*, 117(4):1329–1368.

Borensztein, E. and Panizza, U. (2009). The costs of sovereign default. *IMF Staff Papers*, 56(4):683–741.

Brunnermeier, M. K. and Sannikov, Y. (2014). A macroeconomic model with a financial sector. *The American Economic Review*, 104(2):379–421.

Calvo, G. (2012). Financial crises and liquidity shocks a bank-run perspective. *European Economic Review*, 56(3):317–326.

Case, K. E., Quigley, J. M., and Shiller, R. J. (2003). Home-buyers, housing and the macroeconomy. *Berkeley Program on Housing and Urban Policy*.

Case, K. E. and Shiller, R. J. (2003). Is there a bubble in the housing market? *Brookings papers on economic activity*, 2003(2):299–342.

Chib, S. and Greenberg, E. (1995). Understanding the metropolis-hastings algorithm. *The american statistician*, 49(4):327–335.

Christiano, L. J. (2016). The great recession: Earthquake for macroeconomics. *Macroeconomic Review*, 15(1):87–96.

Claessens, S., Ghosh, S. R., and Mihet, R. (2013). Macro-prudential policies to mitigate financial system vulnerabilities. *Journal of International Money and Finance*, 39:153–185.

Cowen, T. (2008). So we thought. but then again. *New York Times*, 13.

Crockett, A. (2000). Marrying the micro-and macro-prudential dimensions of financial stability. *BIS speeches*, 21.

Demyanyk, Y. and Van Hemert, O. (2009). Understanding the subprime mortgage crisis. *The Review of Financial Studies*, 24(6):1848–1880.

Dinç, I. S. (2005). Politicians and banks: Political influences on government-owned banks in emerging markets. *Journal of financial economics*, 77(2):453–479.

Duffie, D., Pedersen, L. H., and Singleton, K. J. (2003). Modeling sovereign yield spreads: A case study of russian debt. *The Journal of Finance*, 58(1):119–159.

Forni, M. and Gambetti, L. (2016). Government spending shocks in open economy vars. *Journal of International Economics*, 99:68–84.

Gabriel, S. A., Iacoviello, M. M., and Lutz, C. (2016). A crisis of missed opportunities? foreclosure costs and mortgage modification during the great recession.

Gelain, P., Lansing, K. J., and Mendicino, C. (2013). House prices, credit growth, and excess volatility: Implications for monetary and macroprudential policy.

Gennaioli, N., Martin, A., and Rossi, S. (2014). Sovereign default, domestic banks, and financial institutions. *The Journal of Finance*, 69(2):819–866.

Gerali, A., Neri, S., Sessa, L., and Signoretti, F. M. (2010). Credit and banking in a dsge model of the euro area. *Journal of Money, Credit and Banking*, 42(s1):107–141.

Gersbach, H., Rochet, J.-C., and Scheffel, M. (2015). Financial intermediation, capital accumulation, and recovery.

Gertler, M. and Karadi, P. (2011). A model of unconventional monetary policy. *Journal of monetary Economics*, 58(1):17–34.

Gertler, M. and Kiyotaki, N. (2015). Banking, liquidity, and bank runs in an infinite horizon economy. *The American Economic Review*, 105(7):2011–2043.

Gorton, G. and Metrick, A. (2010). Regulating the shadow banking system. *Brookings papers on economic activity*, 2010(2):261–297.

Gorton, G. B. (2010). *Slapped by the invisible hand: The panic of 2007*. Oxford University Press.

Guerrieri, L., Iacoviello, M. M., Covas, F., Driscoll, J. C., Jahan-Parvar, M. R., Kiley, M. T., Queralto, A., and Sim, J. (2015). Macroeconomic effects of banking sector losses across structural models.

Huo, Z. and Ríos-Rull, J.-V. (2013). Paradox of thrift recessions. Technical report, National Bureau of Economic Research.

Iacoviello, M. (2015). Financial business cycles. *Review of Economic Dynamics*, 18(1):140–163.

Iacoviello, M. and Neri, S. (2010). Housing market spillovers: evidence from an estimated dsge model. *American Economic Journal: Macroeconomics*, 2(2):125–164.

Igan, D. and Kang, H. (2011). Do loan-to-value and debt-to-income limits work? evidence from korea.

IMF (2009). Global financial stability report–responding to the financial crisis and measuring systemic risk. *International Monetary Fund.*

Kalman, R. E. et al. (1960). A new approach to linear filtering and prediction problems. *Journal of basic Engineering*, 82(1):35–45.

Khan, H. and Reza, A. (2016). House prices and government spending shocks.

Lambertini, L., Nuguer, V., and Uysal, P. (2017). Mortgage default in an estimated model of the us housing market. *Journal of Economic Dynamics and Control*, 76:171–201.

Lim, C. H., Costa, A., Columba, F., Kongsamut, P., Otani, A., Saiyid, M., Wezel, T., and Wu, X. (2011). Macroprudential policy: what instruments and how to use them? lessons from country experiences.

Merz, M. (1995). Search in the labor market and the real business cycle. *Journal of monetary Economics*, 36(2):269–300.

Metropolis, N., Rosenbluth, A. W., Rosenbluth, M. N., Teller, A. H., and Teller, E. (1953). Equation of state calculations by fast computing machines. *The journal of chemical physics*, 21(6):1087–1092.

Mimir, Y. (2016). Financial intermediaries, credit shocks and business cycles. *Oxford Bulletin of Economics and Statistics*, 78(1):42–74.

Pfeifer, J. (2014). A guide to specifying observation equations for the estimation of dsge models. *Research series*, pages 1–150.

Ramey, V. A. (2011). Identifying government spending shocks: it's all in the timing. *The Quarterly Journal of Economics*, 126(1):1–50.

Roberts, G. O., Gelman, A., Gilks, W. R., et al. (1997). Weak convergence and optimal scaling of random walk metropolis algorithms. *The annals of applied probability*, 7(1):110–120.

Roi, M. B., Mendes, R. R., et al. (2007). *Should Central Banks Adjust Their Target Horizons in Response to House-Price Bubbles?* Bank of Canada.

Roubini, N. and Sachs, J. D. (1989). Political and economic determinants of budget deficits in the industrial democracies. *European Economic Review*, 33(5):903–933.

Ruge-Murcia, F. J. (2007). Methods to estimate dynamic stochastic general equilibrium models. *Journal of Economic Dynamics and Control*, 31(8):2599–2636.

Sims, C. et al. (1999). Matlab optimization software. *QM&RBC Codes*.

Sims, E. and Wolff, J. (2013). The output and welfare effects of government spending shocks over the business cycle. Technical report, National Bureau of Economic Research.

Smets, F. and Wouters, R. (2007). Shocks and frictions in us business cycles: A bayesian dsge approach. *The American Economic Review*, 97(3):586–606.

Sturzenegger, F. and Zettelmeyer, J. (2008). Haircuts: estimating investor losses in sovereign debt restructurings, 1998–2005. *Journal of international Money and Finance*, 27(5):780–805.

Summers, L. H. (2002). 16 some skeptical observations on real business cycle theory. *A Macroeconomics Reader*, page 389.

Supervision, B. (2011). Basel committee on banking supervision.

Tchana, F. T. (2012). The welfare cost of banking regulation. *Economic Modelling*, 29(2):217–232.

Uhlig, H. (2010). A model of a systemic bank run. *Journal of Monetary Economics*, 57(1):78–96.

Vos, R., Agabekian, G., Al Dardari, A., et al. (2011). World economic situation and prospects 2013.

Zubairy, S. (2014). On fiscal multipliers: Estimates from a medium scale dsge model. *International Economic Review*, 55(1):169–195.