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# Macroeconomic Consequences of Bank's Assets Reallocation After Mortgage Defaults

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**Abstract**

This paper proposes a DSGE model which uses Bayesian estimations to assess an economy under the strain of borrower's default on its obligation to intermediary agents, similar to the climate of the Great Recession. The paper finds that the treasury bond market plays an important role in such economy: the default increases the spread between the return of mortgages and deposits, as a result banks prefer to compensate their losses by making profit in the mortgage market and in turn, decreasing their treasury bond holdings. These changes transfer the shock to the real side of the economy through housing, credit, deposit and government loan channels and thereby instigate a business cycle. The model proposed in this paper accurately portrays the behaviour of key economic variables before the Great Recession; in particular housing prices, mortgages, deposits and treasury bond holdings by banks. Significantly, this model illustrates the home price downward spiral which succeeded the recession. The paper demonstrates that the specification of the credit constraint relying on house price expectations as well as frictions in housing and capital investments, which can give rise to the Paradox of Thrift, are the major delay factors in recovery. In addition, the findings argue that macroprudential policies help mitigate financial risks and reduce common exposures across markets. Such policies, however, may be inadequate for the post-crisis restoration of the economy.

*JEL classification*:E32, E44, E62 .

*Keywords*: Private default, Financial business cycle, Macroprudential policy, home-price downward spiral.

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# 1 Introduction

This paper outlines a DSGE model for the purpose of assessing the impacts of default on bank loans, in the presence of government, housing and credit markets. The key questions addressed by the paper are: *i*) What is the role of housing and credits in accelerating financial shocks? *ii*) what is the impact of frictions and expectations on recovery time? and *iii*) do *macroprudential regulation tools* always provide mechanisms to mitigate the adverse impact of shocks? To answer these questions, I build a model which incorporates a real sector, financially constrained intermediaries, government, housing and credit markets. The paper uses Bayesian methods to estimate and simulate the behaviour of the economy before and after the Great Recession. The model captures the important features of the recent crisis such as the home price downward spiral and the lengthy recovery period.

This paper is designed to incorporate the basic features of Iacoviello (2015). The banking structure, the context of default and the financial shock, as presented in this model, are closely comparable to Iacoviello (2015). In both models, the household default causes a wealth transfer from the banking system to borrower households. While Iacoviello (2015) successfully identifies the origin of the Great Recession[1], his simulation does not correctly match the data on house prices, mortgages or deposits. Iacoviello (2015)' simulation indicates that mortgages and deposits decrease in times of default, while the data from 2005 to 2008 indicates[2] an upswing in both variables. This upswing happened due to an increase in the return spread (between return on assets and liabilities) and the demand in the mortgage market. As a result, the intermediary agents ignored the defaults and heated the mortgage market by liquidating the sovereign bond holdings and increasing the liabilities[3].

Iacoviello (2015) neither incorporates unconstrained borrower[4] nor fluctuations in the total housing supply. Both borrows, entrepreneurs and households, are financially constrained: their loans are constrained by their assets. When a default happens, due to the raise in the asset price and the impact of the fixed housing supply, the entrepreneur's

[1] Interestingly, it shows that "financial shocks account for two-thirds of the decline in private GDP during the 2007–2009 recession"

[2]Source: The World bank 2017 and European Mortgage Federation (EMF) 2014.

[3]The process of reducing Sovereign Bond Holdings by bank from 2005 to 2008 is pointed in Bruegel database of sovereign bond holdings developed in Merler and Pisani-Ferry (2012).

[4]The unconstrained borrower points at government. Banks participate in general trading operations (open market) to buy and sell securities. The government securities mostly offer risk free returns and are generally the most liquid instrument a bank holds. Using these liquid assets, banks are able to immediately react to shocks. See Gennaioli et al. (2014).

credit constraint is relaxed. This increases the entrepreneur's ability to borrow from the financial sector. As a result, the mortgage supply reduces.

To deal with this problem, I improve on a rich macrofounded general equilibrium model which has been widely implemented in previous literature. This paper develops Alpanda and Zubairy (2016)'s model by introducing intermediary agents to the lender-borrower relationship. The model features lender, borrower and renter households, elastic housing supply, a financial intermediary sector, house producers and a government. Government collects taxes, distributes lump-sum transfers and issues bonds. Both borrower households and government are debtors of the financial sector. There is no friction in the bond market so the intermediary agents can freely hold or sell government bonds. On the other hand, there is a friction in the mortgage market in the form of collateral constraint. The main result of incorporating government, the bond market and an elastic housing supply is that the model of this paper accurately simulates the behaviour path of key economic variables especially deposits, mortgages and housing prices. The existence of both constrained and unconstrained borrowers provides a freedom for the financial sector to answer mortgage demands by adjusting its bond holdings. However, this liquidity-risk change[5] exposes the financial sector to shock[6].

This paper finds the crucial role of house price expectation in lengthy recovery[7]. The collateral constraint in this paper is based on the expectation of house value and not on the current price. House producers also take the house price and adjustment costs into account to produce houses. With these features, the model captures the role of the price expectation on the credit and investment growth: the mortgage market and housing investments move in the same direction of the house price expectation. The paper illustrates that the expectation of the economy for a lower house price as well as frictions in investments cause a gradual decline in house prices, even after the default is ended. This *home price downward spiral* is an economic setback which delays recovery.

Finally, the paper presents the application of macroprudential tools and their impact on recovery. These tools are applied to debt-to-income ratio on the borrower side and liabilities-to-assets ratio on the bank asset side. The paper reveals that by introducing a cap on debt-to-income ratio to the mortgage market, the economy is safeguarded against extreme drops but recovers more slowly. In addition, the paper shows that the application

[5] I used this term because in my model bonds act as a liquid asset which is traded without any friction and their return is risk-free.While in the mortgage market there is a constraint which should be satisfied, and borrower households can default.

[6] See Angeloni and Wolff (2012).

[7] See Case and Shiller (2003) and Case et al. (2003).

of a countercyclical liabilities-to-assets ratio policy helps reduce house price volatilities.

There is an expansive body of literature which studies banking sector, intermediary agents and capital constraints which incorporate 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) presents a banking regulation in an overlapping-generations model and analyses 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 the addition of a stochastic banking sector. Banks in these two models either act as zero profit organizations or accumulate net worth every period and consume all their net worth at the final period of their life. The model of this paper is more realistic as following Iacoviello (2015), it uses a stochastic representative banking sector which consumes every period. Households do not have the expertise required for direct investment and so they rely on bankers to invest under behalf. In other words, the banking sector facilitates transfers of assets between agents. In addition, the banking sector in this paper faces a capital adequacy constraint which is dynamically dependent on banker's expectations for future assets, defaults and liabilities-to-assets ratio set by an authority as a macroprudential policy tool.

Macroprudential policy tools[8] aim to provide a global model for the protection of banks and households against financial and real shocks. Following the recession, attention turned to the study of the effects of these tools i.e. Lim et al. (2011) and Igan and Kang (2011). This paper provides a theoretical background which sustains known empirical results on the procyclicality on macroprudential policies. By simulating the behaviour of the economy after the default shock, the paper confirms Claessens et al. (2013)'s empirical assertion that macroprudential tools are time inconsistent. The stylized facts, e.g. Gordy and Howells (2006), show that an efficient tool in boom periods could slow down the recovery of the economy during a recession. This procyclicality is evidenced in this paper for a cap on borrower credit which is based on debt-to-income ratio à la Gelain et al. (2013).

Macroprudential tools are all protecting, but should be carefully selected. Some policies are designed to mitigate the vulnerabilities and others are better suited to building up

[8]Macroprudential policy tools are proposed by regulators including the SEC, Federal Reserve, Basel Committee on Banking Supervision (BCBS), Financial Standards Board (FSB), Prudential Regulatory Authority (PRA) and the European Commission.

buffers. The liabilities-to-assets ratio pertains to the latter[9]. Both countrcyclical capital buffers and the prudential policies for mitigating vulnerabilities (especially in the form proposed by the Basel committee) 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. The impact of these buffers after the shock on recovery is neglected in the literature . This paper finds that a countercyclical liabilities-to-assets ratio reduces the volatility of house prices and protects the economy without slowing it down. The model used here highlights the supporting role of the macroprudential policy tools in mitigating financial system vulnerabilities. These policies address both the cross-sectional and temporal dimension of systemic risk and may assist monetary policy by counteracting financial imbalances.

This paper is organized as follows: Section 2 presents the model. Section 3 calibrates and estimates the parameters used as per the US data. Section 4 simulates the Great Recession using the estimated parameters and compares the accuracy of the model with previous literature. Section 5 outlines the effectiveness of different macroprudential policies and their protective mechanism. Section 6 offers a conclusion on the findings of this paper.

# 2 Model

The model is composed of four heterogeneous households: lenders (patient), borrowers (impatient), renters (hand to mouth) and bankers. Lenders are capital owners. Firms borrow this capital to produce non-housing goods. Lenders are, in addition, active in the housing market. They accumulate housing which are either for personal use or for rent to renter households. Lenders issue bank deposits. Bankers are expert investors and the owners of the banking sector. Bankers create credits for borrowers in the form of mortgages and trade government securities. Borrowers accumulate housing and because of their impatience, do not save. Stochastic financial frictions are applied on impatient households and bankers in the form of collateral and capital constraints, respectively. The government collects income and housing taxes and combines them with governmental

[9] The liabilities-to-assets ratio is controversial because it has the same context as the capital requirement ratio (CRR). 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. The required total capital increases up to 10.5% (Supervision, 2011).

liabilities to cover its expenditure and lump-sum transfers to patient, impatient and renter households.

## 2.1 Household

Superscribes $P, I, R, B$ stand for Patient, Impatient, Renter households and Bankers, respectively. There is a unit measure of every type of infinitely lived household.

### 2.1.1 Patient households

The patient households' problem is

$$\max E_t \sum_{\tau=t_0}^{\infty} \beta_P^{\tau-t_0} \{\log c_\tau^P + \varphi_h \log h_{\tau-1}^P - \varphi_l \frac{(l_\tau^P)^{1+\iota}}{1+\iota}\}$$

$$s.t.$$

$$(1+\tau_c)c_t^P + p_t^h h_t^{Ph} + i_t^k + d_t \leq \omega_t^P - \tau_t^P - AC_t^P \tag{2.1}$$

where $t$ presents time. $\beta_P < 1$ is the discount factor that is greater than the discount factor of other households. $\varphi_h$ and $\varphi_l$ present the relative importance of housing and labor in the utility function respectively, and $\iota$ is the inverse of the Frisch-elasticity of labor supply. $\tau_c$ is the tax on consumption.

A representative patient household consumes $c_t^P$, accumulates housing $h_t^{Ph}$ at relative price $p_t^h$. There are two types of houses: residential houses $h^P$, and rental houses $h^R$. $l_t^P$ is the labor supply of patient households. The patient household is the owner of capital which is borrowed by firms in order to produce non-housing goods. The patient housing variation $h_t^{Ph}$, and capital investments $i_t^k$ respectively are

$$h_t^{Ph} = [h_t^P - (1-\delta_h)h_{t-1}^P] + [h_t^R - (1-\delta_h)h_{t-1}^R] \tag{2.2}$$

$$i_t^k = k_t - (1-\delta_k)k_{t-1} \tag{2.3}$$

The depreciation rates on housing and capital are $\delta_h$ and $\delta_k$, respectively. Deposit $d_t$ is the saving of the patient household in the banking sector. In summary, the patient household has three saving tools, housing, capital and deposit. Total income $\omega_t^P$ is composed of wage $w_t^P$, rent from renters at price $p_t^R$ , return on deposit and capital with interest rate $r_t$ and $r_t^k$ respectively and the government transfer $\Gamma_t^P$,

$$\omega_t^P = w_t^P l_t^P + p_t^R h_{t-1}^R + (1+r_t)d_{t-1} + r_t^k k_{t-1} + \Gamma_t^P \tag{2.4}$$

Total tax paid by the patient household $\tau_t^P$ is composed of taxing on wage, rent, property, return on deposit and capital,

$$\tau_t^P = \tau_w[w_t^P l_t^P + p_t^R h_{t-1}^R - \delta_h h_{t-1}^R - \tau_p p_t^h (h_{t-1}^R + h_{t-1}^P)] + \tau_p p_t^h (h_{t-1}^P + h_{t-1}^R) \\ + \tau_d r_t d_{t-1} + \tau_k (r_t^k - \delta_k) k_{t-1} \tag{2.5}$$

$\tau_w$ stands for the income tax rate , $\tau_p$ for property tax rate, $\tau_d$ and $\tau_k$ for tax rate on deposit and capital return, respectively. In addition, to remain consistent with the US tax code, home owners profit from a tax break[10] on property taxes and depreciation allowances for housing. The last term in the budget constraint is the adjustment cost $AC^P$ consistent with the literature[11].

The FOC with respect to residential and rental houses respectively are

$$p_t^h = \beta_P \mathbf{E}_t[\frac{\varphi_h}{\lambda_t^P h_t^p} + \frac{\lambda_{t+1}^P}{\lambda_t^P}((1 - \delta_h - \tau_p(1 - \tau_w))p_{t+1}^h] \tag{2.6}$$

$$p_t^h = \beta_P \mathbf{E}_t[\frac{\lambda_{t+1}^P}{\lambda_t^P}((1 - \delta_h - \tau_p(1 - \tau_w)p_{t+1}^h + (1 - \tau_w)p_{t+1}^R + \tau_w \delta_h] \tag{2.7}$$

where $\lambda_t^P$ is the Lagrange multiplier of the budget constraint at time $t$. The FOCs with respect to deposit, capital and labor respectively are[12],

$$1 = \beta_P \mathbf{E}_t[\frac{\lambda_{t+1}^P}{\lambda_t^P}(1 + (1 - \tau_d)r_{t+1})] \tag{2.8}$$

$$1 = \beta_P \mathbf{E}_t[\frac{\lambda_{t+1}^P}{\lambda_t^P}(1 - \delta_k + (1 - \tau_k)r_{t+1}^k + \tau_k \delta_k)] \tag{2.9}$$

$$\varphi_l (l_t^P)^\iota = \lambda_t^P (1 - \tau_w) w_t^P \tag{2.10}$$

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

[11] 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 adopted from Iacoviello (2015).

[12] For simplicity in reading, the derivatives of adjustment costs are not written in the equations. They are, of course, considered in the coding.

### 2.1.2 Impatient households

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

$$\max E_t \sum_{\tau=t_0}^{\infty} \beta_I^{\tau-t_0}\{\log c_\tau^I + \varphi_h \log h_{\tau-1}^I - \varphi_l \frac{(l_\tau^I)^{1+\iota}}{1+\iota}\}$$

$$s.t.$$

$$(1+\tau_c)c_t^I + p_t^h h_t^{Ih} + (1+r_t^b)M_{t-1} - \varsigma_t^I \leq \omega_t^I + M_t - \tau_t^I - AC_t^I \tag{2.11}$$

in order to have the impatient household as a net borrower and the patient one as a net saver in equilibrium, it is assumed that $\beta_I < \beta_P$. Impatient households consume $c_t^I$. $h_t^{Ih}$ is impatient housing variation

$$h_t^{Ih} = h_t^I - (1-\delta_h)h_{t-1}^I \tag{2.12}$$

where $h_t^I$ is impatient houses. $M_t$ is mortgages from the banking sector. $\omega_t^I$ is total impatient income at time $t$

$$\omega_t^I = w_t^I l_t^I + \Gamma_t^I \tag{2.13}$$

where $w_t$ represents wage and $\Gamma_t^I$ is the transfer from the government. $\varsigma_t^I$ is the focal point of the paper. It stands for a default shock. Since it is positive, it induces wealth transfers from the bank to the impatient household. It is a redistribution shock. This is consistent with the fact that during The Great Recession most of the damage incurred by the banking system was due to household defaults[13]. Repayments to the banking system are $[(1+r_t^b)M_{t-1} - \varsigma_t^b]$. Total tax paid by the borrower is composed of income and property taxes,

$$\tau_t^I = \tau_w[w_t^I l_t^I - r_t^b M_{t-1} - \tau_p p_t^h h_{t-1}^I] + \tau_p p_t^h h_{t-1}^I \tag{2.14}$$

[13]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

To remain consistent with the current US tax code, there is a tax exemption on the mortgage return, with the interest rate $r^b$, and on the property tax. $AC^I$ is the adjustment cost on changing houses[14].

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

$$M_t \leq \rho_m M_{t-1} + (1-\rho_m)\theta[\mathbf{E}_t(\frac{p^h_{t+1}}{1+r^b_{t+1}} h^I_t)] \tag{2.15}$$

where $\theta$ is the loan-to-value ratio in housing and $\rho_m$ captures the fact that only a fraction of borrowers change their loan every period. Collateralized houses are valued by the expectation of their future real value and not their current value. This structure captures the role of the price expectation in the credit market. This friction is one of the channels which connects the real and financial side of the economy.
The first order conditions with respect to impatient houses, mortgage[15] and labor respectively are

$$p^h_t - \frac{\lambda^m_t}{\lambda^I_t}(1-\rho_m)\theta \mathbf{E}_t \frac{p^h_{t+1}}{1+r^b_{t+1}} = \beta_I \mathbf{E}_t[\frac{\varphi_h}{\lambda^I_t h^I_t} + \frac{\lambda^I_{t+1}}{\lambda^I_t}((1-\delta_h - \tau_p(1-\tau_w))p^h_{t+1})] \tag{2.16}$$

$$1 - \frac{\lambda^m_t}{\lambda^I_t} = \beta_I \mathbf{E}_t[\frac{\lambda^I_{t+1}}{\lambda^I_t}(1+(1-\tau_w))r^b_{t+1} - \frac{\lambda^m_{t+1}}{\lambda^I_t}\rho_m] \tag{2.17}$$

$$\varphi_l (l^I_t)^\iota = \lambda^I_t (1-\tau_w) w^I_t \tag{2.18}$$

where $\lambda^I_t$ is the Lagrange multiplier of the budget constraint and $\lambda^m_t$ is the Lagrange multiplier of the collateral constraint at time $t$.

### 2.1.3 Renter households

Renter households are hand-to-mouth and consume what they earn. The renters' problem is

$$\max E_t \sum_{\tau=t_0}^{\infty} \beta_I^{\tau - t_0} \{\log c^R_\tau + \varphi_h \log h^R_{\tau-1} - \varphi_l \frac{(l^R_\tau)^{1+\iota}}{1+\iota}\}$$
$$s.t.$$
$$(1+\tau_c)c^R_t + p^R_t h^R_{t-1} \leq (1-\tau_{wr}) w^R_t l^R_t + \Gamma^R_t \tag{2.19}$$

[14] $AC^I_t = \frac{\psi_m}{2}\frac{(M_t - M_{t-1})^2}{\overline{M}}$

[15] To keep the simplicity of reading, the derivations of the adjustment cost is not written in the equations.

where the discount factor of renters is the same as impatient one. The Renter consumes $c_t^R$ and rents rental houses from the patient household. They are are so poor so that they cannot borrow and lend. The renter provides the labor supply $l_t^R$ to the economy and earns wage $w_t^R$. Because their income level is low, the government drives a lower tax on their wages, $\tau_{wr} < \tau_w$ (based on the US tax codes). Their income is composed of the wage and government transfer $\Gamma_t^R$. The existence of three types of households is a convenient approximation to mimic the stylized fact of the presence of lenders, borrowers and renters without making it an endogenous decision. 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 $\lambda_t^R$ is the Lagrange multiplier of the budget constraint at time $t$.

### 2.1.4 Bankers

A representative banker is a type of household which consumes and intermediates between other agents. The banker issues liabilities $d_t$ and buys assets $a_t$. The borrowers are either households (who borrow in the form of mortgages $M_t$) or government (the borrowings of which are termed government bonds $b_t^g$). Banker's utility function and budget constraint are,

$$\begin{aligned}
&\max E_t \sum_{\tau=t_0}^{\infty} \beta_B^{\tau-t_0} \log c_\tau^B \\
&(1+\tau_c)c_t^B + (1+r_t)d_{t-1} + a_t + AC_t^B = d_t + (1+r_t^b)a_{t-1} - \varsigma_t^I \\
&a_t = b_t^g + M_t
\end{aligned} \tag{2.21}$$

$r^b$ is the interest rate on loans. It is the same for impatient households and the government. The banker receives new deposits and the return on last period loans. $\varsigma_t^I$ is the default shock to the banker's assets. $\varsigma_t^I$ is the shock which makes the banker's asset side smaller and forces the banker to recapitalize (i.e. change banker's portfolio) in order to meet its budget constraint. $AC^B$ is the adjustment cost of issuing liabilities and assets[16].

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

The financial friction on the banking sector is[17]

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

Parameter $\phi$ is the Liabilities-to-assets ratio (hence the capital-to-asset ratio is $1-\phi$). Basel $I, II$ and $III$ are based on this ratio. Similar to the real regulation patterns, with this constraint, the bank has the ability to deviate from its liabilities-to-assets ratio in the short run. In the long run bank should set its leverage ratio to $\phi$. 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 first order conditions with respect to liabilities,$d_t$, and assets, $a_t$, are

$$1 = \frac{\lambda^\phi_t}{\lambda^B_t} + \beta_B\mathbf{E}_t\frac{\lambda^B_{t+1}}{\lambda^B_t}(1 + r_{t+1} - \rho_b\frac{\lambda^\phi_{t+1}}{\lambda^B_{t+1}}) \tag{2.23}$$

$$1 = (\phi(1-\rho_b) + \rho_b)\frac{\lambda^\phi_t}{\lambda^B_t} + \beta_B\mathbf{E}_t\frac{\lambda^B_{t+1}}{\lambda^B_t}(1 + r^b_{t+1} - \rho_b\frac{\lambda^\phi_{t+1}}{\lambda^B_{t+1}}) \tag{2.24}$$

where $\lambda^B_t, \lambda^\phi_t$ are the Lagrange multiplier of the budget constraint and the collateral constraint at time $t$, respectively.

## 2.2 Firms and Housing producers

Patient, impatient and renter households work for the representative firm and receive wages depending on different labor elasticity, $\iota_P, \iota_I, \iota_R$. It is assumed that $\iota_P + \iota_I + \iota_R = 1$. There is a continuum of identical firms of measure one. The firm produces a homogeneous good using a Cobb-Douglas technology

$$Y^f_t = A_t k^\alpha_{t-1}((l^P_t)^{\iota_P}(l^I_t)^{\iota_I}(l^R_t)^{\iota_R})^{1-\alpha} \tag{2.25}$$

and maximizes its profit

$$\max Y^f_t - w^P_t l^P_t - w^I_t l^I_t - w^R_t l^R_t - r^k_t k_{t-1} \tag{2.26}$$

[17] This type of friction modeling is standard and used in Iacoviello (2015).

Since markets are perfectly competitive, the market prices are the usual 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 is a continuum of measure one and perfectly competitive housing producers which provide housing to households[18]. At every period, housing producers buy undepreciated part of houses from households at a relative price $p_t^h$, then invest then $i_t^h$ to produce new houses $h_t$. 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 patient households' stochastic discount factor is used to discount future profits[19]. The production is subject to an adjustment cost defined as a fraction of investment. As a result, the housing production follows the law of motion

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

The FOC with respect to housing 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

The government collects all taxes from all households

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

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

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

where $C_t = c_t^P + c_t^I + c_t^R + c_t^B$ is total households' consumption. In each period, the government has access to funds from the banker in the form of bonds, $b_t^g$ and total tax, $T_t$, to pay its liabilities to the banker, lump-sum transfers and the government spending, $g_t$. Hence, 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 $\Gamma_t$ is total transfers to each household, depending on level parameters specific to the type of household $\vartheta_P, \vartheta_I, \vartheta_R$

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

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

$\rho_g$ determines the response of transfers to government debt to adjust transfers to government loans in order to avoid Ponzi game by government[20].

## 2.4 Market clearing

The non-housing good firms produce goods to cover total consumption, total housing investment, capital investment and government spending. Good market clearing 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[21]

$$Y_t = Y_t^f + \tau_c C_t + p_t^R h_{t-1} \tag{2.37}$$

An equilibrium defines a set of prices $(p^h, p^R, r, r^b, r^k)$ and allocations $(c^P, c^I, c^R, c^B, h^P, h^I, h^R, d, k, b_g, g, \Gamma^I$ so that all agents and firms maximize their objective functions subject to all constraints while all markets clear (markets for good, housing, labor, deposit, mortgage, capital and government bonds).

[20]Making the adjustment through transfers is standard, for example see Alpanda and Zubairy (2016) and Alpanda and Zubairy (2017). The evidence could be find in Leeper et al. (2010).

[21]To be is consistent with the National Income and Product Accounts (NIPA) data which is used for the calibration. NIPA is choosen because it is the only data that includes imputed rental income from owner-occupied housing. In NIPA data, VAT is included in the relative price of consumption and housing provides consumption services.

# 3 Estimation

## 3.1 Calibration

Table 1: Calibrated parameters

| Parameters | Symbol | Value |
|---|---|---|
| Discount factors | $\beta_P, \beta_I, \beta_B$ | $0.9925, 0.94, 0.945$ |
| Housing preference | $\varphi_h$ | 0.27 |
| Labor Supply parameter | $\varphi_l$ | 0.8 |
| Depreciation rates | $\delta_h, \delta_k$ | $0.0096, 0.016$ |
| Transfer share | $\vartheta_P, \vartheta_I, \vartheta_R$ | $0.040, 0.036, 0.030$ |
| Income taxes | $\tau_w, \tau_{wr}$ | $0.32, 0.22$ |
| loan-to-value ratio | $\theta$ | 0.90 |
| Liabilities-to-assets ratio | $\phi$ | 0.90 |
| Labor shares in production | $\iota_P, \iota_I, \iota_R$ | $0.13, 0.67, 0.20$ |
| Capital share in production | $\alpha, A$ | $0.2047, 1.805$ |
| Inverse labor supply elasticity | $\iota$ | 1 |
| Inertia in collateral constraint | $\rho_m$ | 0.70 |
| Inertia in capital constraint | $\rho_b$ | 0.24 |
| Response of transfers to gov. debt | $\rho_g$ | 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. | $\psi_{dh}, \psi_k$ | $0.10, 1.73$ |
| deposit and loan adj. for Bank | $\psi_{db}, \psi_a$ | $0.14, 0.54$ |
| Mortgage adj. for Imp. | $\psi_m$ | 0.37 |
| Housing investment adj. for Producer | $\psi_h$ | 2.48 |
| Parameters of AR(1) | $\rho_{\varsigma^I}, \rho_{\varsigma^g}$ | 0.9 |

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). 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. Thus, 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). 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 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). 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 and based on their share of total income. $\tau_w, \tau_{wr}$ 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). This calibration also addresses deposit and mortgage to GDP equal to 65% and 52%, respectively, roughly consistent with the wold bank data 1980-2015. 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. Housing preference is set to 0.27 to have housing value over GDP equal to 5.44 according to Iacoviello and Neri (2010). Labor supply parameters calibrated in order to get total labor supply equal to one. Capital share in production $\alpha$, is set to 0.2047 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). Total Consumption over GDP in this settings is $C/Y = 52\%$ and $c^P/C = 26\%, c^I/C = 53\%, c^R/C = 18\%, c^B/C = 3\%$.

Table 2: Steady state of the benchmark model annually

| Variable | symbol | Steady State/GDP |
|---|---|---|
| Consumption | $c^P, c^I, c^R, c^B$ | $0.13, 0.28, 0.10, 0.01$ |
| Housing | $h^P, h^I, h^R$ | $0.50, 0.58, 0.27$ |
| Tax | $T$ | 0.27 |
| Bankers' asset | $a$ | 0.71 |
| Mortgage | $M$ | 0.51 |
| Government loan | $b_g$ | 0.80 |
| Deposit | $d$ | 0.65 |
| 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[22] and Bayesian methods[23] are used. The model is estimated based on the borrower household default, consistence with the situation of the Great Recession. The shocks[24] follow autoregressive (AR1) process

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

where $\epsilon^I \approx N(0, \sigma^2_{\varsigma^I})$. The optimizer for the mode computation is that 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[25]. 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[26] to estimate the model on 4 observable series. The applied series are U.S. quarterly data on real consumption, mortgage, losses from mortgage default and real house prices (all in the form of deviation from steady state) between $1985Q1$ and $2010Q4$[27]. The 20 first observations are used as a training sample for the Kalman filter[28].

Number of replications for Metropolis-Hastings algorithm[29] (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[30].

The 90% Highest Posterior Density interval shows the most probable interval of parameters. Posterior mean of inertia in collateral constraint is 0.71. This coefficient presents the fraction of impatient households which change mortgage every period. Inertia in bankers' capital constraint is estimated 0.42. This parameters shows how flexible a banker can be in deviating from the liabilities-to-loans ratio in short term after the shock. The autocor-

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

[23] SeeAn and Schorfheide (2007).

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

[25] See Ruge-Murcia (2007).

[26] See Pfeifer (2014)

[27] As introduced in Iacoviello (2015)

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

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

[30] 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%.

Table 3: Estimation results

| Parameter | symbol | Pri. mean | Post. mean | 90% HPD interval | | De. | Pri sd | Post. sd |
|---|---|---|---|---|---|---|---|---|
| St. Dev., default shock | $\sigma_{\varsigma^I}$ | 0.0025 | 0.0015 | 0.0013 | 0.0016 | I.G | 0.025 | 0.0001 |
| Autocor., default shock | $\rho_{\varsigma^I}$ | 0.80 | 0.9037 | 0.8804 | 0.9294 | Be. | 0.100 | 0.0150 |
| Inertia in collateral cons. | $\rho_m$ | 0.70 | 0.7069 | 0.6904 | 0.7238 | Be. | 0.100 | 0.0102 |
| Inertia in capital cons. | $\rho_b$ | 0.25 | 0.4221 | 0.1380 | 0.7148 | Be. | 0.100 | 0.1769 |
| Adj. cost,P Deposit | $\psi_{dh}$ | 0.25 | 0.2169 | 0.0567 | 0.3810 | Ga. | 0.125 | 0.1086 |
| Adj. cost,P capital | $\psi_k$ | 1.00 | 1.1750 | 0.2905 | 2.0514 | Ga. | 0.500 | 0.5782 |
| Adj. cost,B Deposit | $\psi_{db}$ | 0.25 | 0.2532 | 0.0599 | 0.4523 | Ga. | 0.125 | 0.1330 |
| Adj. cost,I Mortgage | $\psi_m$ | 0.25 | 0.1864 | 0.0449 | 0.3184 | Ga. | 0.125 | 0.0900 |
| Adj. cost,B assets | $\psi_a$ | 0.25 | 0.2528 | 0.0538 | 0.4342 | Ga. | 0.125 | 0.1275 |
| Adj. cost,HP | $\psi_h$ | 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

rolation of the default shock is 0.90, this constitutes a high persistent shock. It has the standard deviation of 0.0015. Prior and posterior estimated adjustment costs of deposits and loans for bankers are practically equal. This shows the observed data are not very informative about these parameters. Household deposit adjustment cost is estimated at 0.21. The difference between deposit adjustment cost of households and banks shows that changing deposits for households is cheaper and easier than for bankers. Capital and producer adjustment costs are both estimated around 1.2. This confirms 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 primary cause of the Great Recession. This section demonstrates the impact of household default similar to the the real situation of the Great Recession within 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 significant collapse was that of the Lehman Brothers. This was 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 late 2000[31]. Mortgage underwriting standards declined gradually during the boom period, particularly from 2004 to 2007 and mortgage fraud by lenders and bor-

[31]See Vos et al. (2011).

rowers increased enormously[32]. In 2004, an important credit risk of non-prime mortgage lending and an epidemic in mortgage fraud were foreseen by the Federal Bureau of Investigation[33]. Figure 1 (left) shows that the rate of default starts to increase from 2005 and it was almost doubled in 2006[34].

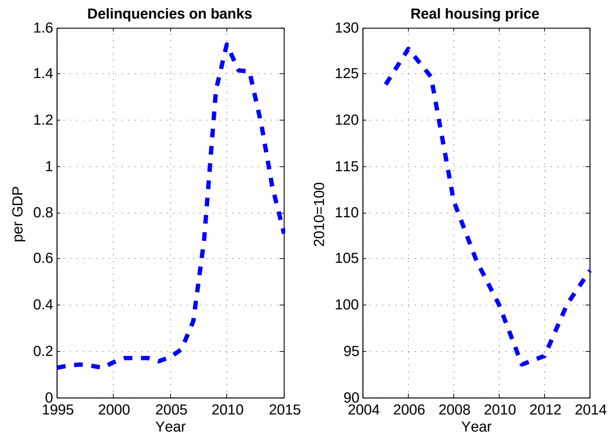


Figure 1: Delinquencies on all loans and leases secured by real estate in all commercial banks (left) and real house price (right). Resource: (left) Federal Reserve bank of st. Louis, (right) OECD Data 2017

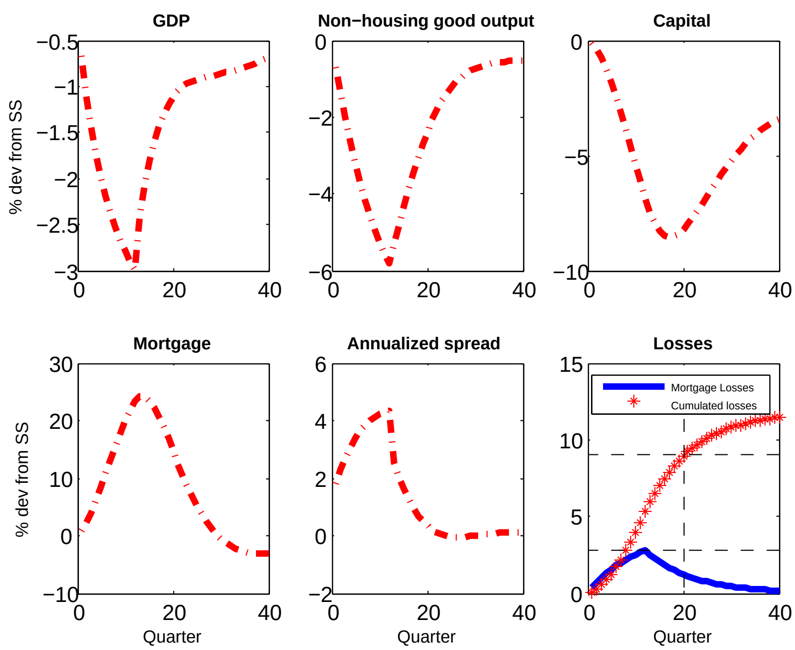


Figure 2: Simulation of the Great Recession, Key variables, Spread is in level.

To simulate the situation of the Great Recession, the unexpected impatient shock is

[32] See Cowen (2008).
[33] See Black (2009).
[34] See Demyanyk and Van Hemert (2009) and an interesting discussion in Antoniades (2016).

fed by 0.38% of annual GDP for 12 quarters (3 consecutive years). The maximum losses are set to equal 2.8% of GDP after three years and a cumulative losses are set to equal 9% of GDP after 5 years (20 quarters)[35]. This emulates the Great Recession starting in 2005 and culminating with the bankruptcy of Lehman in 2008. After the shock, there is no shock so losses gradually return to zero.

The posterior mean values of estimated parameters in Table 3 and the value of non-estimated parameters in Table 1 are inputted to the model to simulate the Great Recession. Figure 2 shows the impact of the described shock on the model's key variables.

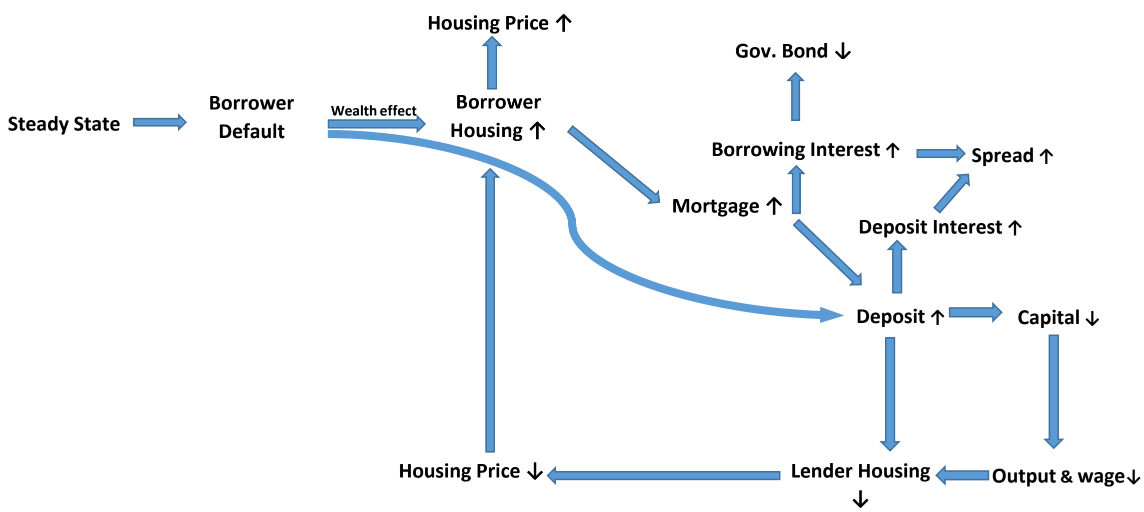


Figure 3: The mechanisms of the model

The negative shock on bank's assets is a wealth transfer from bankers to impatient households for 12 periods, corresponding to the 2005-2008 period in the data. The effect of the transfers in these 12 periods is summarized in Figure 3. The mechanisms are fourfold. First, The transfer increases the housing demand by impatient households and consequently, the mortgage demand increases. This raises the return on mortgages. Impatient households can afford a high return due to the wealth effect. Second, bank which both suffers a loss in its assets and faces a high mortgage demand increases deposits. The deposit increase helps bank finance mortgage demands and payoff its liabilities. This effect raises the return on deposits. The mixed effect of the raise in deposit and mortgage interest rate on the spread[36], as seen in figure 2, is positive. Before the shock, the spread

[35] 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).

[36] Annualized spread is calculated as the annualized difference between the interest rate on banker's

is about 2%. This raises to 4.2% by the end of the third year. Third, a higher interest rate on deposits changes the patient's portfolio. Patient households relocate their saving from capital and housing to deposits. The effect on the the housing market is further discussed below. The drop in capital investment gradually reduces GDP from 0.6% to $-3\%$ in 12 periods. Four, bank reduces its government bond holding in order to answer mortgage demands [37]. This mechanism reduces the size of the government's budget balance sheet and decreases the government expenditure. Figure 4 presents the data on government bond holdings of banking sector before 2009 and the simulation of the model.

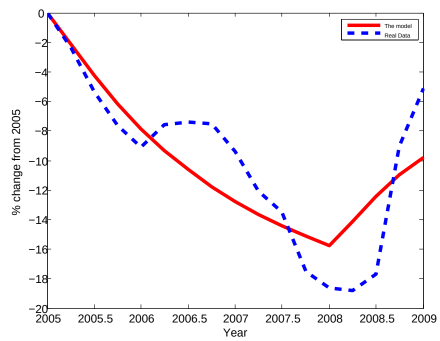


Figure 4: Treasury bonds at all commercial banks per GDP. . Index:2005 Sources: BEA, Board of Governors, FRED

The model imitated 2005-2008 economic behaviour and data. Figure 5 compares the data for deposit and mortgage to GDP alongside annualized spread between lending and borrowing rate in 2005-2010 with the path simulated by the model of this paper for the similar variables. The simulation demonstrates the same behaviour as the data.

After the shock (after period 12), the economy does not go back immidiately to the steady state. Capital and housing keep on falling for same periods before they recover. The explanation for this is as follows. The real housing price between 2005-2014 is presented in figure 1 (right). Following the beginning of the default in 2005, house prices increased. The increase picks in 2006 and then declines until early 2011. Noting the after crisis period, the figure 1 (right) evidences the *home price downward spiral* when, even after the crisis ends (in 2009) and recovery begins, housing price continue to fall. This continuous negative effect was a major contributing factor to the late recovery after the Great Recession. The data from FRED shows that it took almost 5 years for the the US economy to return to the 2007 level of output per capita. Normally for an economy like

loans and the interest rate on deposits.

[37] Merler and Pisani-Ferry (2012) illustrate the reduction in Sovereign Bond Holdings by banks from 2005 to 2008.

that of the US, it takes less time to return to the pre-recession peak[38].

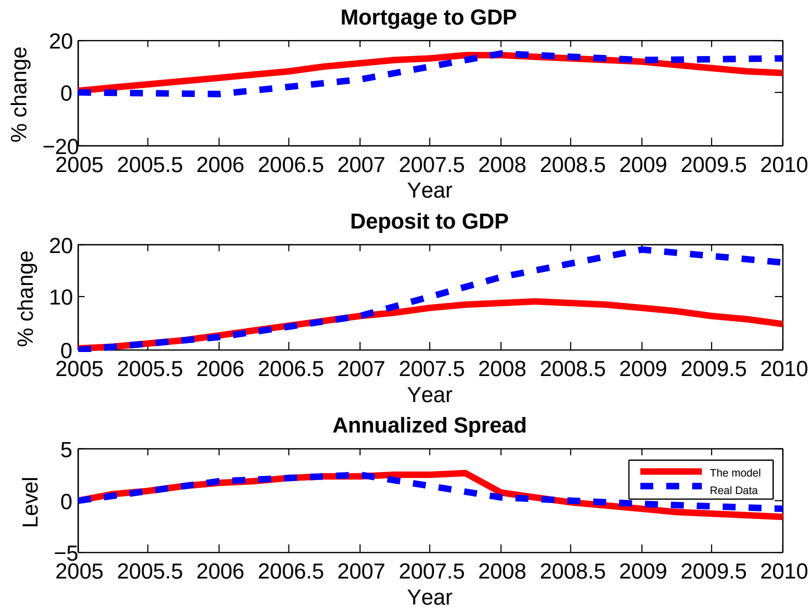


Figure 5: Deposit and Mortgage to GDP, Annual Spread (lending-borrowing rate). Index:2005 Resource: The World Bank and European Mortgage Federation (EMF) 2015

Figure 6 presents the simulation of housing factors. The figure at the top left indicates that the home price downward spiral is captured by the model. The mechanisms effective in the behaviour house price are as follows. First, the wealth transfer has a positive impact on the impatient-house demand. This increase in housing demand is the reason of the initial house price increase, right after the shock. The increase in housing demand supports an increase in mortgages prevision. Note that the amount of the current mortgage is contingent on the previous mortgage and the expectation of the future house value (equ 2.15), the latter of which is increasing. This clearly shows the crucial role of the expectation in mortgage fluctuations. Second, as discussed before, patient households prioritize deposits and decrease their housing investment. This, in turn, decreases the demand and consequently the housing price. Some period after the shock, this effect dominates the first mechanism. As a result, the house price decreases. Impatient households benefit from the impact on the housing price and expand their consumption and housing. When the shock comes to an end, so too do these expansions. Lastly, the rent price increases because lenders ask for a higher return rate on rental houses[39], so rental housing demands

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

[39]Because of the arbitrary condition. As seen before, the rate on deposits increases so the return on

decreases.

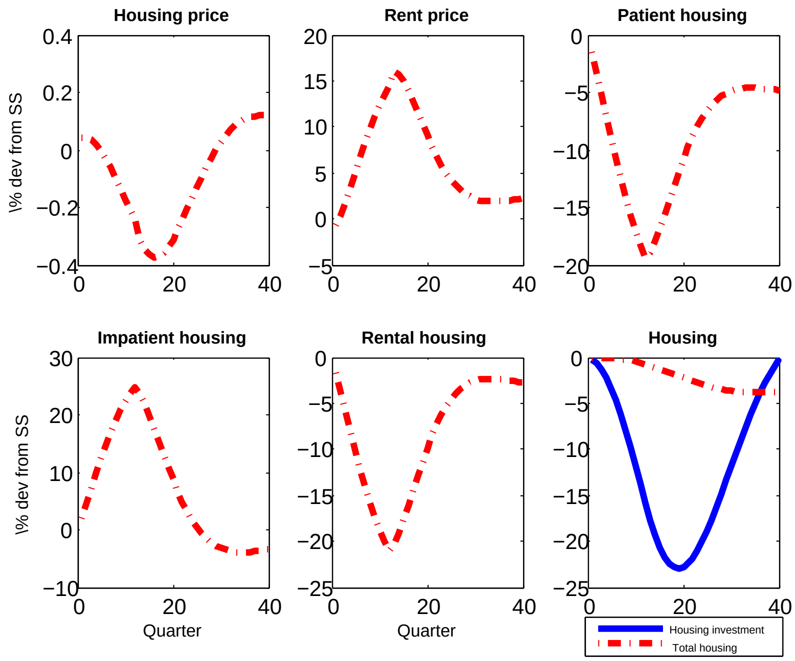


Figure 6: Simulation of the Great Recession, Housing factors, (%) change from SS

In contrast, the drop in housing prices does not end at the same time as the shock. As recovery begins, house prices continue to fall. The explanation is as follows. At the end of the shock, the economy is still below the steady state and there is a large marginal utility of housing. So the immediate increase in the house price is not consistent with the all other returns on saving tools being equal. As a result, the house prices continue to decrease. For impatient households, the housing is large. So the return on housing is small. This is not a problem because impatient households make no arbitrage with deposits. For patient households, the rate on deposits remains above the steady state for a long time. So the return on housing for patient households remains above the steady state as long as the effect of the shock on housing has not disappeared.

The lower investment in housing and capital which makes the crisis so long-lasting is similar to the context of the Paradox of Thrift[40]. Investment frictions make saving more desirable than investing. Hence, personal savings role as a net drag on the economy during a recession.

Figure 7 compares the path of the key variables in the present model and in Iacoviello

rental houses also increases.

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

(2015)'s model. The economy was hit by the same shock in both models. The GDP response is almost the same. However, contrary to the data shown in figure 1, after the unset of the shock, key variables such as house price, mortgage and deposit decline in Iacoviello (2015)'s model. In addition, his model does not capture the downward spiral in the housing price.

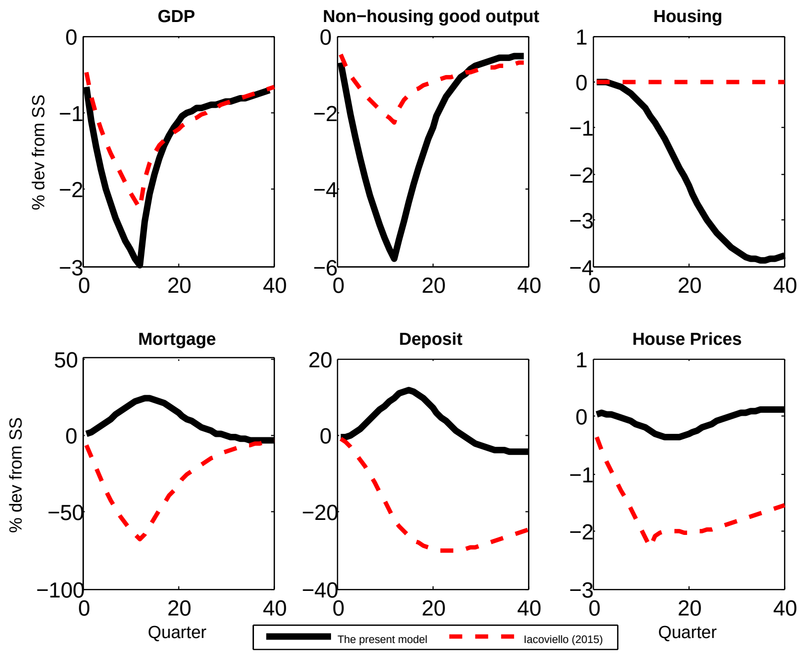


Figure 7: Simulation of the Great Recession for two models Iacoviello (2015) and the model of this paper , (%) change from SS

# 5 Macroprudential regulation

In the aftermath of the global financial crisis, macroprudential policy tools have been proposed to ensure financial stability. In this section, two types of macroprudential policy are proposed; One on the the collateral constraint of the borrower and the other on the capital constraint of the banker. The debt-to-income (DTI) ratio caps credit growth for borrowers. Liabilities-to-assets ratio (LTA) restricts the liabilities of financial institutions to a fraction of their assets. In order to apply the DTI to the model, Equ 2.15 is changed to

$$M_t \leq \rho_m M_{t-1} + [\theta_m(w_t^I l_t^I) + (1-\theta_m)(1-\rho_m)\theta(\mathbf{E}_t(\frac{p_{t+1}^h}{1+r_{t+1}^b} h_t^I))] \tag{5.1}$$

where $\theta_m$ is the weight assigned by the banker to the borrower's wage income.

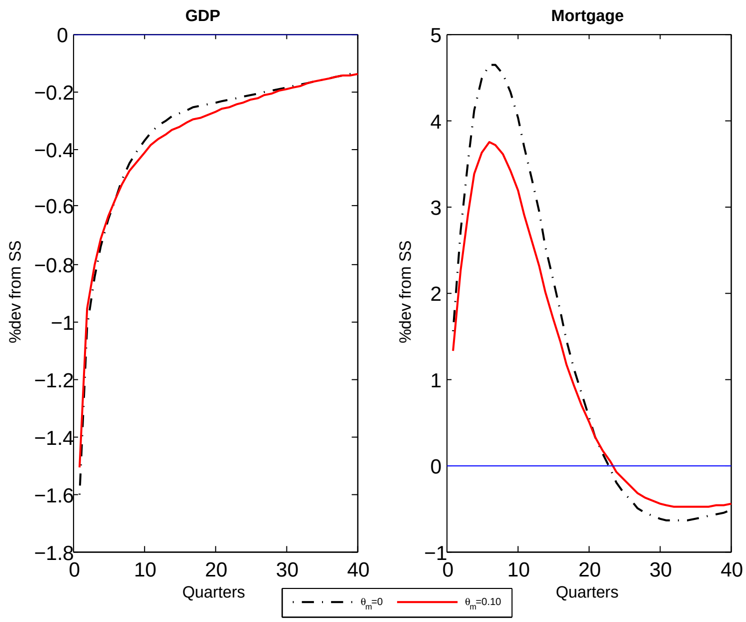


Figure 8: The impact of applying debt-to-income (DTI) into the model.

Figure 8 presents the impulse response to a negative 1% shock to the banker's asset without a DTI and with DTI=0.10. The DTI ratio limits the borrower's debt to 10% of disposable income and 90% of the expected house value. Increasing the DTI by 10% reduces the shock's negative impact on GDP by 0.4%. As explained in the previous section, GDP declines due to the higher demand of deposits by banks in response to the higher demand of mortgages. The DTI restricts mortgages. As a result, the patient household's portfolio change is moderated.

On the other hand, the DTI's effect on mortgages makes it difficult for the economy to recover. With such policy on the collateral constraint, the economy suffers less but recovers more slowly. The reasons are twofold. Firstly, GDP, capital and 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 ignites the economy and helps recovery. However, the strict regulation of a prudent debt-to-income ratio can regulate the housing boom and moderate the crisis. Secondly, a higher DTI and consequently a lower amount of mortgages result in less deposit issuance and credits. This reduces the amount of government loans and consequently government spending. The economy therefore slows down.

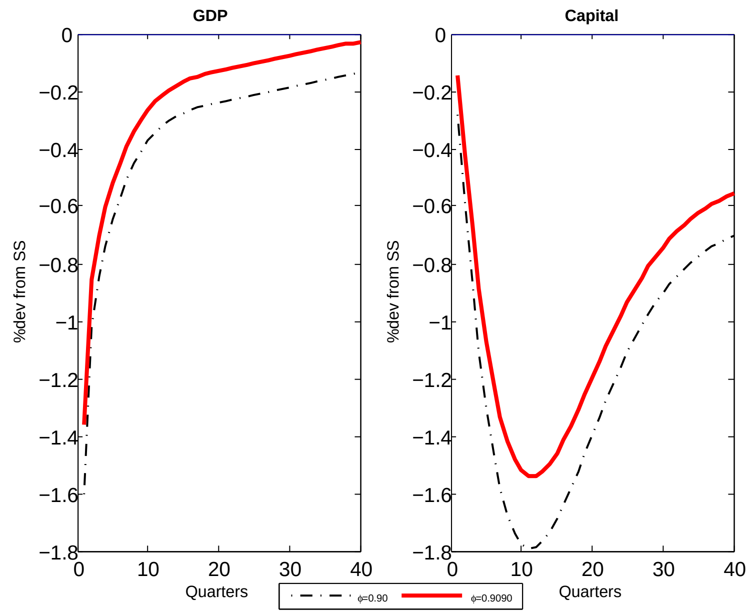


Figure 9: IRFs to households defaults, different liabilities-to assets ratio

A higher liabilities-to-assets ratio (LTA) $\phi$, influences the economy as follows. The rise gives the banker the ability to further increase deposits. Mortgages is regulated by the household collateral constraint which binds the mortgage to the expectation of the house value. The mortgage, therefore, is not affected immediately. By raising more deposits, bankers can pay off the liabilities with new deposits and reduce the negative impact of a sudden shock. This is why the banker is no longer forced to sharply reduce government loans in the higher LTA. This helps the economy to recover more quickly. The impact of a 1% increase to the LTA is depicted in figures 9.

# 6 Conclusion

In this paper, I use a DSGE model to study the impact of defaults on the asset side of the bank balance sheet. The model features four types of heterogeneous households: lenders, borrowers, renters and bankers. In addition, the model incorporates government, firms and house producers as well as a tax system closed to the real tax code in the US. The key elements of the model are stochastic financial frictions: first, collateral constraints for borrower households based on the expected house value and second, capital constraints on intermediary agents. This paper examines the impact of a credit crunch on financial intermediaries similar to that of 2005-2008 on the aggregate key variables. The lack of regulations allows the intermediary agents to heat the housing market by liquidating the sovereign bond holdings, increasing the liabilities and financing more mortgages. The findings of this paper reveal that the role played by expectations and friction in housing and capital investments, which give rise to the Paradox of Thrift, are the major delay factors in recovery. In addition, 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. 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. In 2007, financial companies which could not meet their obligations were forced to run. This trend began with the bankruptcy of Lehman Brothers who had over 600 billion dollars in assets. The run was a result of having high volumes of subprime and other lower-rated mortgage which were not sufficiently secured[41]. Other reasons outlined in literature are illiquid aspects of bank's assets and variations in the maturity time for the projects. As a result, banks are incapable of responding to all requests simultaneously. Different orientations such as those used by Uhlig (2010), Calvo (2012) and Gertler and Kiyotaki (2015) would make an interesting addition to the model. 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 the impacts of other scenarios of default e.g. government default[42]. The Government default may occur specifically in response to a government spending shock. 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[43]. This model conducts the shocks in an exogenous manner but It would be favorable to examine the interaction of primitive economic elements.

[41] Alan and Bialeck (2015)

[42] See Roubini and Sachs (1989) and Ramey (2011). 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. The IMF sources, http://www.imf.org/external/np/sta/ir/IRProcessWeb/data/rus/eng/currus.htm/#I. The shock in the model is not directly comparable with the Russian crisis, but it has the potential to be extended to meet the parameters of the Russian default.

[43] 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.

Alpanda, S. and Zubairy, S. (2017). Addressing household indebtedness: Monetary, fiscal or macroprudential policy? *European Economic Review*, 92:47–73.

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.

Angeloni, C. and Wolff, G. B. (2012). Are banks affected by their holdings of government debt? Technical report, Bruegel working paper.

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

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

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.

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.

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). Banks, government bonds, and default: what do the data say?

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.

Gordy, M. B. and Howells, B. (2006). Procyclicality in basel ii: Can we treat the disease without killing the patient? *Journal of Financial Intermediation*, 15(3):395–417.

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

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.

Leeper, E. M., Plante, M., and Traum, N. (2010). Dynamics of fiscal financing in the united states. *Journal of Econometrics*, 156(2):304–321.

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.

Merler, S. and Pisani-Ferry, J. (2012). Who's afraid of sovereign bonds? Technical report, Bruegel Policy Contribution.

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*.

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.

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.